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Effect of Different Levels of Phosphorus, Phosphorus Solubilising Bacteria and Farmyard Manure on Nutrient Content and Uptake by *Bt*-Cotton

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To determine the effect of integrated use of inorganic phosphorus along with phosphorus solubilising bacteria and farmyard manure on nutrient Content and uptake 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, the 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. Plant samples were collected at 45, 90 DAS, and harvest. Plant samples were shade dried and kept in hot air oven at 75°C until a constant weight was obtained. Samples were powdered and then analysed using standard chemical procedures.
Results: The uptake of macronutrients *viz.*, N, P, and K was markedly influenced by the treatments with maximum values recorded by the treatment that received 60 kg P_2O_5 ha^{-1} + FYM + PSB. Their uptake significantly differed with increase in dose of phosphorus applied at all growth stages.

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Combined use of 60 kg P_2O_5 ha^{-1} + FYM + PSB resulted in a significant increase in uptake of all micronutrients (Zn, Cu, Mn, and Fe) at all stages except Cu at 90 DAS.

Conclusion: Application of phosphorus combined with FYM and PSB not only reduce inorganic phosphorus fertilization but also enhance the uptake of nutrients and plant nutrient content by providing favourable conditions for plant growth. Application of 30 kg P_2O_5 ha^{-1}+ PSB + FYM was found to be on a par with addition of only 60 kg $ha^{-1}$$P_2O_5$. Hence the P dose can be reduced to half by integrating with PSB and FYM.

Keywords: Phosphorus; PSB; FYM; Bt-Cotton.

1. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is globally considered as one of the most important commercial crops. Being a cash crop, it is grown worldwide. About 30 million hectares of fertile land are engaged in cotton cultivation in almost 70 different countries of the world. China is the world's largest cotton producer and consumer with an average lint yield of 14.38 g m^{-2} during 2013 followed by the US, India, and Pakistan. Due to its indeterminate growth habit, cotton exhibits morphological adaptation, such as modifying the canopy arrangement with phosphorus (P) application [1]. The utilization of mineral fertilizers is sought as an effective strategy to improve soil nutrient and boost cotton yield.

Phosphorus is very important in crop production after nitrogen (N); however, its resources are limited worldwide [2]. The P application improves root architecture by increasing the length, width, and diameter of root. Hence, P uptake by the plants is predominantly controlled by the availability and acquisition of P [3]. Therefore, the P deficiency inhibits cotton growth and development by declining biomass accumulation, leading to lower seed cotton yield [4].

The organic manures play an important role in crop production [5]. It acts on the soil physical properties, organic matter promotes the formation of soil crumbs, thus makes the soil friable and thereby facilitates the proper movement of air and water as well as infiltration of rain water. Organic matter decomposition acts on insoluble nutrient reserves in the soil and make them available biologically. Organic matter provides food for the beneficial microorganisms and also adds plant nutrients to the soil during [6].

Approximately 15-20 per cent of applied fertilizer phosphorus is utilized by the crops rest of the added phosphorus gets fixed in the soil and becoming unavailable to crop plants [7]. Thus, the availability of phosphorus is the major problem in productivity of crops concerning not only its actual deficiency in soil but also its availability to crop plants. Integrated phosphorus management (IPM) is the only viable strategy for increasing phosphorus availability. The IPM helps to restore and sustain soil fertility, crop productivity and also economically beneficial. In view of this, the present investigation was undertaken to determine the response of Bt-Cotton to different levels of phosphorus, FYM and microbial inoculation of PSB to study the effect of integrated use of phosphorus on yield and uptake of nutrients by *Bt*-cotton.

2. MATERIALS AND METHODS

The experiment was carried out at the Agricultural College Farm, Bapatla, Andhra pradesh, in *kharif* season with 10 treatments replicated thrice in a randomized block design. Tulasi-BG II hybrid of cotton was used as a test crop, with a spacing of 90 cm x 60 cm. The treatments comprised of T_1 = RDP (60 kg P_2O_5 ha^{-1}); T_2 = RDP+PSB; T_3 = 50% RDP+PSB; T_4 = PSB; T_5 = RDP+FYM; 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°C and 21.90°C, respectively with a total rainfall of 627.8 mm over 30 rainy days.

The initial composite sample collected from experimental field and analyzed for physical, physico-chemical properties, nutrient status, bacterial population and phosphatase activity. The results of the analyses indicated that the soil was clay loam in texture, with slightly alkaline in reaction (pH 7.8), nonsaline (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}). 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.

Plant samples were collected at 45, 90 DAS, and at harvest. Biomass at 45, 90 DAS, and harvest was calculated expressed as kg ha^{-1}. The plant samples were shade dried and then kept inoven at 75°C until constant weights were obtained. The samples were ground and analysed chemically to know the nitrogen, phosphorus, potassium and micronutrients (Zn, Cu, Mn, and Fe) in the plant. Uptake was calculated by multiplying the Nutrient content with biomass at different plant growth stages. Standard procedures were followed to analyze plant nutrient content and Fisher's method of analysis of variance was followed for analysis and interpretation of the data as suggested by Panse and Sukhatme [8]. Data analysis tool pack in MS-Excel software was used to analyze the data and the means were separated at a significance level of 0.05 (P).

3. RESULTS

3.1 Nitrogen

The nitrogen content in a cotton plant (Table 1 and Fig. 1) showed decreasing trend and the uptake of nitrogen increased from 45 DAS to harvest. The higher nitrogen uptake at harvest even with lower concentration of nitrogen is due to the substantial increase in biomass production. Among all the treatments more uptake of nitrogen was observed in the treatments receiving combined application of FYM and PSB over their individual applications with inorganic phosphorus. Irrespective of the treatment the uptake of nitrogen was low where no inorganic phosphorus was applied. Combined application of 60 kg P_2O_5 ha^{-1} + PSB + FYM (T_8) recorded significantly higher values over all other treatments at 45 DAS, 90 DAS, and at harvest (16.62, 104.37, 151.10 kg ha^{-1}, respectively). At all the stages lowest value was recorded in T_4.

The data also indicated that the increase in P level (0-60 kg P_2O_5 ha^{-1}) along with FYM and PSB resulted in an significant increase in the uptake of nitrogen ranging from 11.51 to 16.62 kg ha^{-1}, 72.91 to 104.37 kg ha^{-1} and 77.87 to 151.10 kg ha^{-1} at 45, 90 DAS, and at harvest respectively. A similar increase in N uptake at high levels of P with FYM or PSB was observed but with lower values.

Table 1. Effect of phosphorus levels, PSB and FYM on uptake of nitrogen by *Bt*-cotton

Treatments	Uptake of nitrogen (kg ha^{-1})		
	45 DAS	**90 DAS**	**Harvest**
T_1-60 kg P_2O_5 ha^{-1}	12.26 (2.27)*	75.59(1.96)	89.05(1.55)
T_2-60 kg P_2O_5 ha^{-1} +PSB	13.27(2.31)	79.65(2.02)	102.82(1.59)
T_3-30 kg P_2O_5 ha^{-1} +PSB	10.43(2.17)	64.93(1.88)	73.03(1.45)
T_4-PSB	9.02(2.09)	54.98(1.78)	64.31(1.33)
T_5-60 kg P_2O_5 ha^{-1} +FYM	14.98(2.45)	95.11(2.14)	126.01(1.72)
T_6-30 kg P_2O_5 ha^{-1} +FYM	12.51(2.32)	78.73(2.03)	83.66(1.59)
T_7-FYM	10.53(2.25)	67.77(1.95)	73.31(1.48)
T_8-60 kg P_2O_5 ha^{-1} +PSB+FYM	16.62(2.52)	104.37 (2.22)	151.10(1.81)
T_9-30 kg P_2O_5 ha^{-1} +PSB+FYM	13.40(2.39)	87.00(2.09)	91.80(1.69)
T_{10}-PSB+FYM	11.51(2.31)	72.91(2.00)	77.87(1.55)
SEM±	0.62	1.94	2.87
CD@0.05	1.86	5.77	8.53
CV (%)	8.68	4.31	5.33

**Data in paranthesis indicate concentration of nutrients in percent*

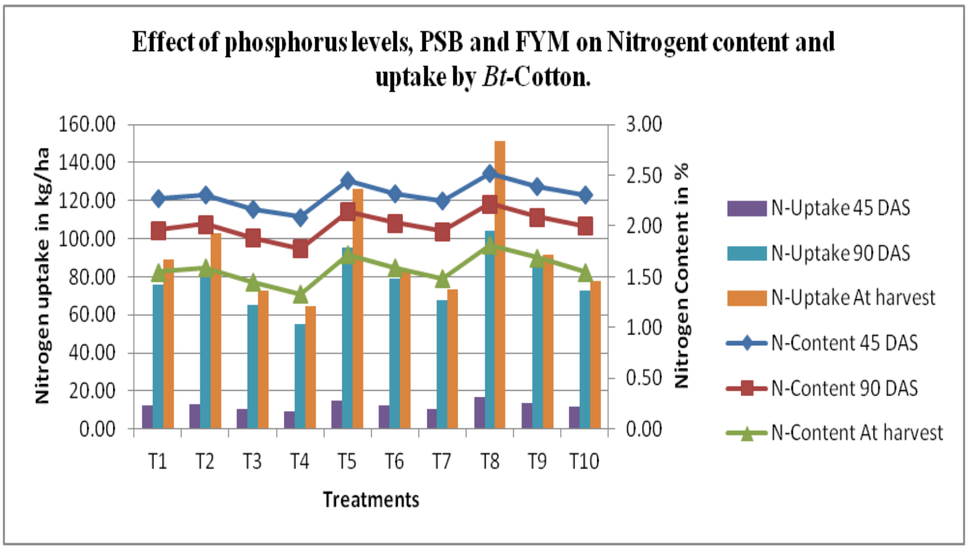

Fig. 1.

3.2 Phosphorus

With the advancement of the crop growth, phosphorus uptake (Table 2 and Fig. 2) was increased up to 90 DAS in all the treatments but at harvest higher values were recorded only in combined treatments, which received 60 kg P_2O_5 ha^{-1} + PSB (T_2-22.42 kg ha^{-1}), 60 kg P_2O_5 ha^{-1} + FYM (T_5-26.70 kg ha^{-1}) and 60 kg P_2O_5 ha^{-1} + PSB + FYM (T_8-32.10 kg ha^{-1}). Comparatively lower uptake at harvest at the same dose of phosphorus inferred that the phosphorus use efficiency was more when combined with both PSB and FYM than their individual application as indicated by significantly highest uptake in T_8 followed by T_5 and T_2.

3.3 Potassium

Uptake of potassium (Table 3 and Fig. 3) also followed the same increasing trend of nitrogen with advancement of growth. At all stages of crop growth, the highest potassium uptake was recorded by the T_8 treatment followed by T_5 and the lowest in T_4.

Potassium uptake by the crop was significantly increased due to the application of phosphorus up to 60 kg ha^{-1} P_2O_5 with PSB, FYM and their combination at all stages, which might be due to increased biomass. The results were in accordance with those of Pagaria et al. [9] and Muthuchamy and Subramanian [10].

Table 2. Effect of phosphorus levels, PSB and FYM on uptake of phosphorus by *Bt*-cotton

Treatments	Uptake of phosphorus (kg ha^{-1})		
	45 DAS	**90 DAS**	**Harvest**
T_1-60 kg P_2O_5 ha^{-1}	3.34 (0.62)*	20.07(0.52)	18.54(0.32)
T_2-60 kg P_2O_5 ha^{-1} +PSB	3.71(0.65)	21.53(0.55)	22.42(0.35)
T_3-30 kg P_2O_5 ha^{-1} +PSB	2.64(0.55)	15.76(0.46)	13.37(0.27)
T_4-PSB	1.95(0.45)	11.65(0.38)	9.54(0.20)
T_5-60 kg P_2O_5 ha^{-1} +FYM	4.09(0.67)	25.50(0.57)	26.70(0.36)
T_6-30 kg P_2O_5 ha^{-1} +FYM	2.98(0.56)	18.85(0.49)	15.17(0.29)
T_7-FYM	2.28(0.49)	14.19(0.41)	10.76(0.22)
T_8-60 kg P_2O_5 ha^{-1} +PSB+FYM	4.56(0.69)	27.55(0.59)	32.10(0.39)
T_9-30 kg P_2O_5 ha^{-1} +PSB+FYM	3.38(0.60)	21.14(0.51)	16.61(0.31)
T_{10}-PSB+FYM	2.60 (0.52)	15.89 (0.44)	11.82 (0.24)
SEM$\pm$	0.16	0.52	0.64
CD@0.05	0.48	1.54	1.90
CV	8.78	4.64	6.25

**Data in paranthesis indicate concentration of nutrients in per cent*

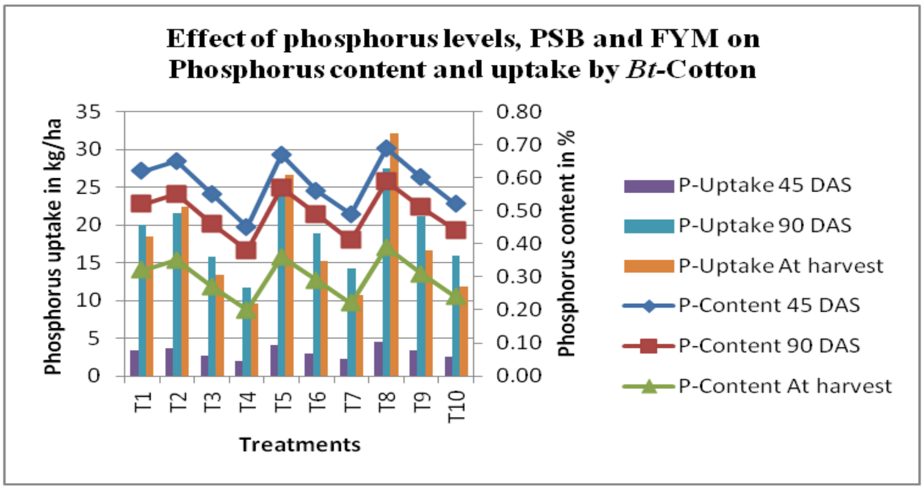

Fig. 2.

Table 3. Effect of phosphorus levels, PSB and FYM on uptake of potassium by *Bt*-cotton

Treatments	Uptake of potassium (kg ha^{-1})		
	45 DAS	90 DAS	Harvest
T_1-60 kg P_2O_5 ha^{-1}	16.56(3.07)*	104.78(2.72)	115.73(2.02)
T_2-60 kg P_2O_5 ha^{-1} +PSB	17.99(3.13)	111.28(2.82)	138.31(2.13)
T_3-30 kg P_2O_5 ha^{-1} +PSB	15.33(3.18)	97.54(2.82)	111.03(2.20)
T_4-PSB	13.46(3.12)	84.68(2.75)	102.76(2.13)
T_5-60 kg P_2O_5 ha^{-1} +FYM	19.76(3.23)	131.26(2.95)	167.53(2.28)
T_6-30 kg P_2O_5 ha^{-1} +FYM	17.27(3.22)	110.84(2.87)	118.51(2.25)
T_7-FYM	14.92(3.18)	99.58(2.87)	110.40(2.23)
T_8-60 kg P_2O_5 ha^{-1} +PSB+FYM	22.45(3.40)	143.37(3.05)	194.46(2.33)
T_9-30 kg P_2O_5 ha^{-1} +PSB+FYM	18.83(3.35)	123.47(2.97)	121.22(2.23)
T_{10}-PSB+FYM	16.56(3.32)	115.33(2.97)	119.82(2.38)
SEM±	0.89	2.79	3.28
CD@0.05	2.65	10.36	10.84
CV	8.93	4.48	4.57

**Data in paranthesis indicate concentration of nutrients in percent*

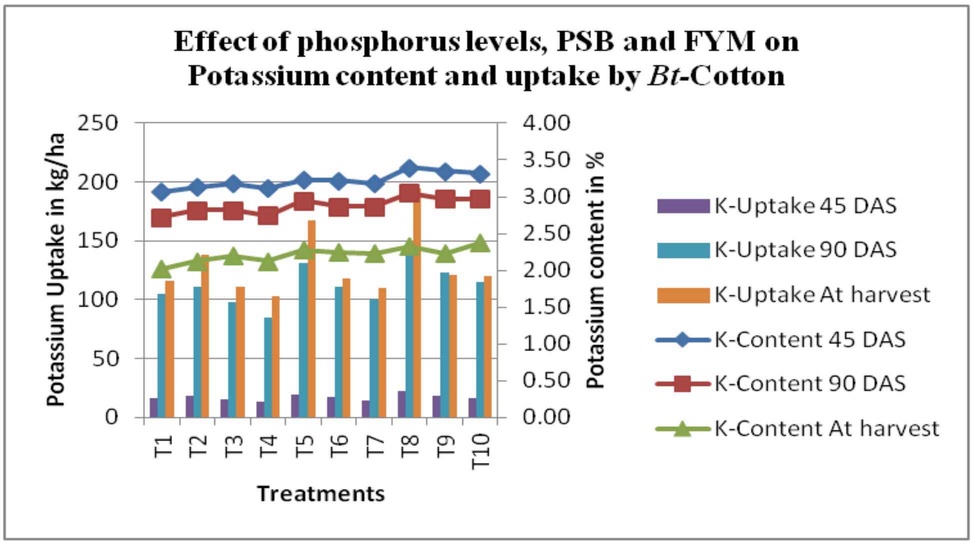

Fig. 3.

Critical observation of data revealed that the highest dose of phosphorus along with PSB and FYM resulted in maximum uptake of nitrogen, phosphorus and potassium followed by combination with only FYM or PSB. It was also observed that treatment receiving 30 kg P_2O_5 ha^{-1} + FYM + PSB (T_9- 18.83, 123.47, 121.22 kg ha^{-1}) recorded higher uptake than only 60 kg P_2O_5 ha^{-1} (T_1-16.56, 104.78, 115.73 kg ha^{-1}) but were on a par with each other at 45, 90 DAS, and at harvest. Among different levels of phosphorus, higher nutrient uptake was recorded at a maximum dose of phosphorus.

3.4 Micronutrients

The highest and lowest zinc uptake (Table 4 and Fig. 4) at 45, 90 DAS and at harvest were recorded in T_8 (22.45, 144, and 223 kg ha^{-1}) and T_4 (18.55, 106, and 133 kg ha^{-1}), respectively. However, the zinc uptake at 90 DAS was markedly influenced by integration of PSB + FYM at all levels of phosphorus (T_8, T_9, and T_{10}) while at harvest the treatments T_8 (60 kg P_2O_5 ha^{-1} + PSB + FYM) and T_5 (60 kg P_2O_5 ha^{-1} + FYM) were superior over only inorganic phosphorus application (T_1).

The copper uptake (Table 4 and Fig. 5) was significantly influenced by the treatment T_5 (60 kg P_2O_5 ha^{-1} + FYM-26.28 kg ha^{-1}) at 45 DAS and T_8 (60 kg P_2O_5 ha^{-1} + PSB + FYM-138 kg ha^{-1}) at harvest over T_1 (60 kg P_2O_5 ha^{-1}) while no marked influence was noticed at 90 DAS.

Manganese uptake (Table 5 and Fig. 6) was significantly influenced by the treatments at all stages. At 45 DAS higher uptakes were observed in the treatments T_8 and T_5 (60 kg P_2O_5 ha^{-1} + PSB + FYM and 60 kg P_2O_5 ha^{-1} + FYM i.e., 31.64, 28.75 kg ha^{-1}, respectively). At 90 DAS, the integrated PSB + FYM at different levels of phosphorus (T_8, T_9 and T_{10} i.e., 296, 280, and 228 kg ha^{-1}) and T_5 (60 kg P_2O_5 ha^{-1}+FYM-247 kg ha^{-1}) recorded marked superiority over only inorganic phosphorus. At harvest, the integrated treatments receiving the maximum dose of inorganic Phosphorus (T_8, T_5, and T_2) were superior over only inorganic phosphorus. The highest manganese was observed at 90 DAS later it decreased at harvest in all the treatments.

Table 4. Effect of phosphorus levels, PSB and FYM on uptake of zinc and copper by *Bt*-cotton

Treatments	Zinc			Copper		
	(g ha^{-1})					
	45 DAS	90 DAS	Harvest	45 DAS	90 DAS	Harvest
T_1-60 kg P_2O_5 ha^{-1}	18.55 (34.46)*	106 (27.47)	133 (23.21)	18.00 (33.47)	110 (28.46)	161 (27.00)
T_2-60 kg P_2O_5 ha^{-1} +PSB	19.22 (33.50)	106 (26.91)	153 (23.52)	18.16 (31.77)	125 (31.77)	166 (25.55)
T_3-30 kg P_2O_5 ha^{-1} +PSB	18.87 (38.99)	93 (26.86)	130 (25.71)	14.97 (31.30)	95 (27.58)	156 (30.95)
T_4-PSB	15.32 (35.49)	90 (29.18)	132 (27.55)	21.30 (34.87)	115 (37.50)	133 (27.60)
T_5-60 kg P_2O_5 ha^{-1} +FYM	20.03 (32.87)	126 (28.30)	186 (25.35)	26.28 (43.53)	126 (28.37)	210 (28.65)
T_6-30 kg P_2O_5 ha^{-1} +FYM	19.10 (35.35)	109 (28.09)	147 (27.95)	17.32 (32.53)	126 (32.47)	146 (27.60)
T_7-FYM	17.80 (37.74)	106 (30.67)	139 (28.11)	15.91 (33.83)	104 (29.95)	110 (22.25)
T_8-60 kg P_2O_5 ha^{-1} +PSB+FYM	22.45 (33.70)	144 (30.73)	223 (26.53)	20.06 (30.46)	138 (29.40)	218 (26.00)
T_9-30 kg P_2O_5 ha^{-1} +PSB+FYM	20.53 (36.20)	139 (33.29)	155 (28.59)	18.96 (33.90)	129 (30.93)	133 (24.50)
T_{10}-PSB+FYM	17.74 (35.45)	137 (35.29)	148 (29.31)	14.65 (29.23)	100 (27.28)	117 (23.30)
SEM$\pm$	2.08	8.9	18	1.40	9.59	11
CD@0.05	6.18	26	52	4.15	NS	24
CV	13.73	14	16	14.07	14	9

**Data in paranthesis indicate concentration of nutrients in ppm*

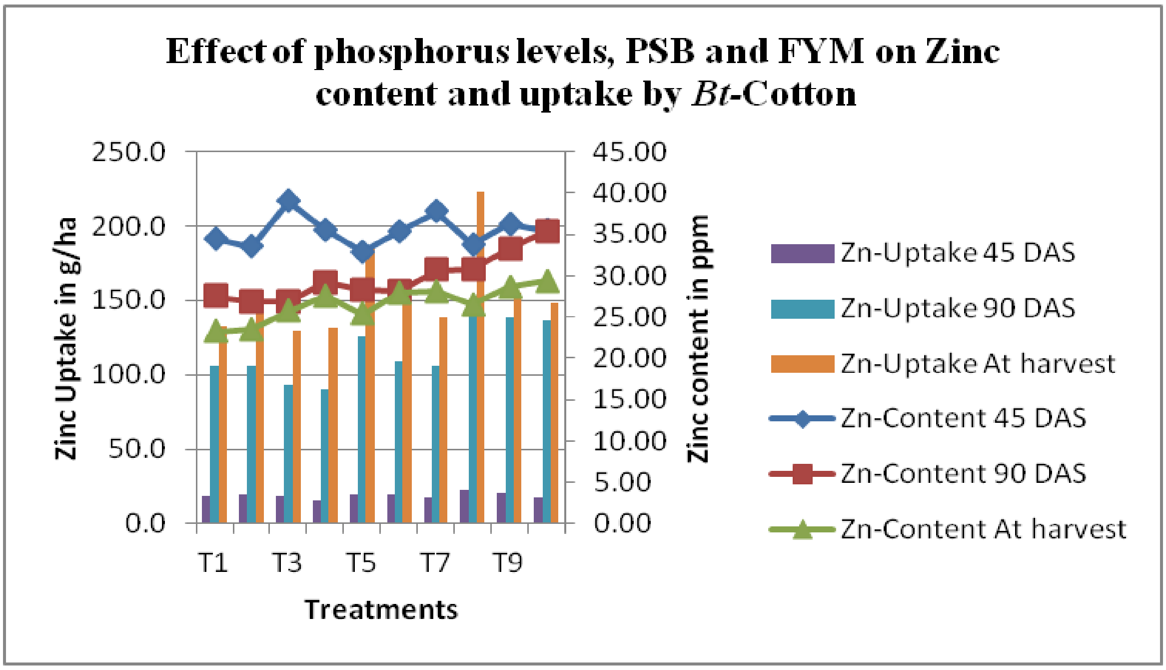

Fig. 4.

Table 5. Effect of phosphorus levels, PSB and FYM on uptake of manganese and iron by Bt-Cotton

Treatments	Manganese			Iron		
	(g ha^{-1})					
	45 DAS	90 DAS	Harvest	45 DAS	90 DAS	Harvest
T_1-60 kg P_2O_5 ha^{-1}	19.05 (33.93)	187 (48.60)	249 (43.23)	174 (321.63)	1043 (270.07)	1313 (229.17)
T_2-60 kg P_2O_5 ha^{-1} +PSB	24.20 (41.70)	197 (49.67)	303 (46.80)	191 (331.93)	1088 (275.47)	1510 (232.90)
T_3-30 kg P_2O_5 ha^{-1} +PSB	20.17 (41.90)	161 (46.63)	256 (50.60)	152 (316.07)	901 (260.33)	1131 (224.00)
T_4-PSB	17.08 (39.87)	149 (48.67)	219 (45.57)	133 (308.70)	759 (246.67)	1036 (215.07)
T_5-60 kg P_2O_5 ha^{-1} +FYM	28.75 (47.13)	247 (55.60)	359 (48.87)	208 (341.33)	1301 (292.27)	1795 (244.67)
T_6-30 kg P_2O_5 ha^{-1} +FYM	22.62 (43.27)	208 (53.63)	267 (50.77)	173 (325.30)	1029 (265.40)	1184 (223.77)
T_7-FYM	24.88 (54.30)	191 (55.03)	238 (48.23)	147 (313.50)	889 (255.73)	1087 (219.33)
T_8-60 kg P_2O_5 ha^{-1} +PSB+FYM	31.64 (48.43)	296 (63.00)	382 (45.73)	233 (351.87)	1412 (300.50)	2101 (250.97)
T_9-30 kg P_2O_5 ha^{-1} +PSB+FYM	25.83 (47.43)	280 (67.30)	268 (49.30)	183 (327.30)	1166 (280.03)	1274 (233.97)
T_{10}-PSB+FYM	21.55 (43.47)	228 (58.60)	231 (45.93)	160 (318.73)	1032 (264.77)	1113 (221.30)
SEM$\pm$	2.04	13	13	10	57	73
CD@0.05	6.09	40	40	29	169	217
CV	15.04	11	8	10	9	9

**Data in paranthesis indicate concentration of nutrients in pppm*

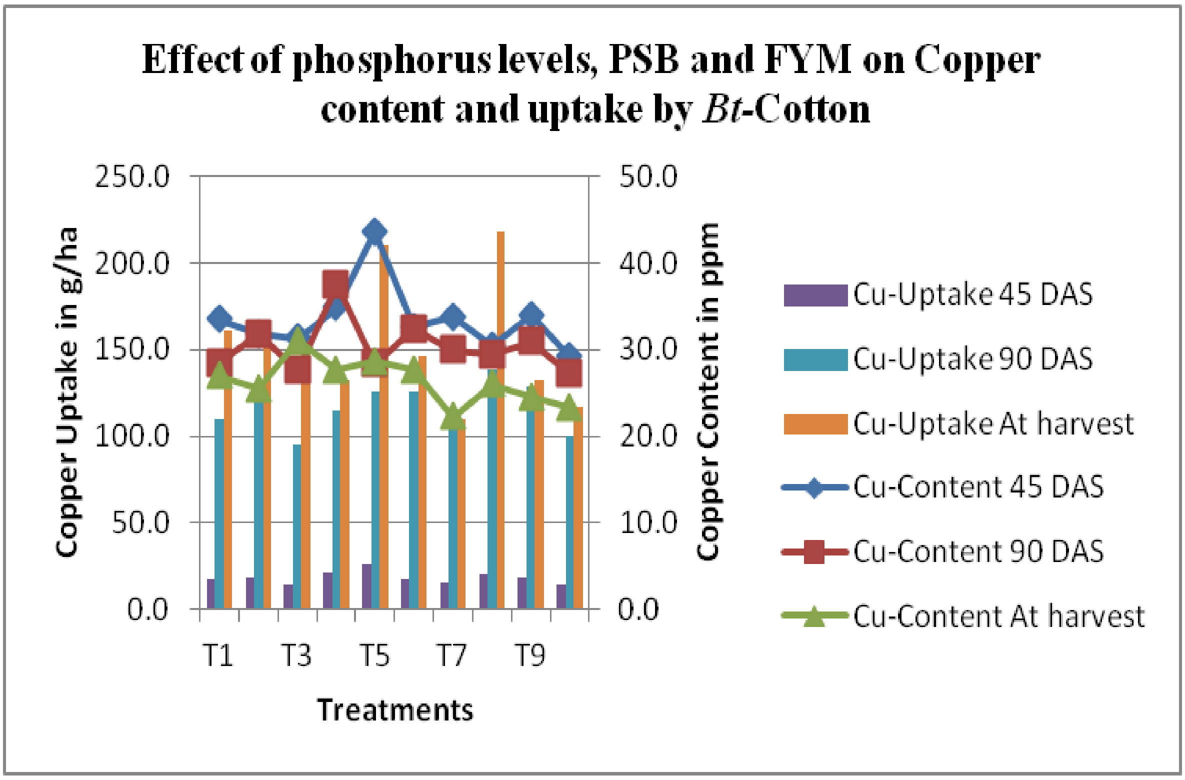
Effect of phosphorus levels, PSB and FYM on Copper content and uptake by *Bt*-Cotton
Copper Uptake in g/ha
Copper Content in ppm
250.0
200.0
150.0
100.0
50.0
0.0
50.0
40.0
30.0
20.0
10.0
0.0
T1
T3
T5
T7
T9
Treatments
Cu-Uptake 45 DAS
Cu-Uptake 90 DAS
Cu-Uptake At harvest
Cu-Content 45 DAS
Cu-Content 90 DAS
Cu-Content At harvest

Fig. 5.

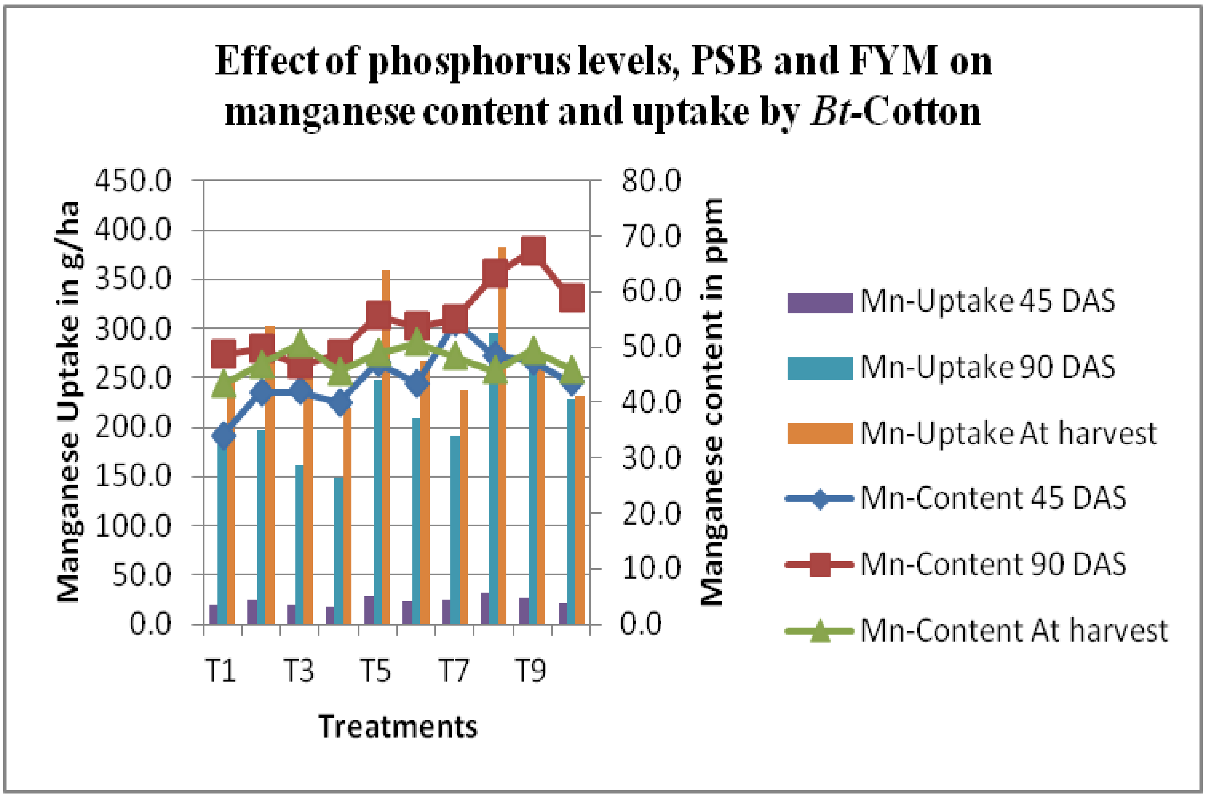
Effect of phosphorus levels, PSB and FYM on manganese content and uptake by *Bt*-Cotton
Manganese Uptake in g/ha
Manganese content in ppm
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
T1
T3
T5
T7
T9
Treatments
Mn-Uptake 45 DAS
Mn-Uptake 90 DAS
Mn-Uptake At harvest
Mn-Content 45 DAS
Mn-Content 90 DAS
Mn-Content At harvest

Fig. 6.

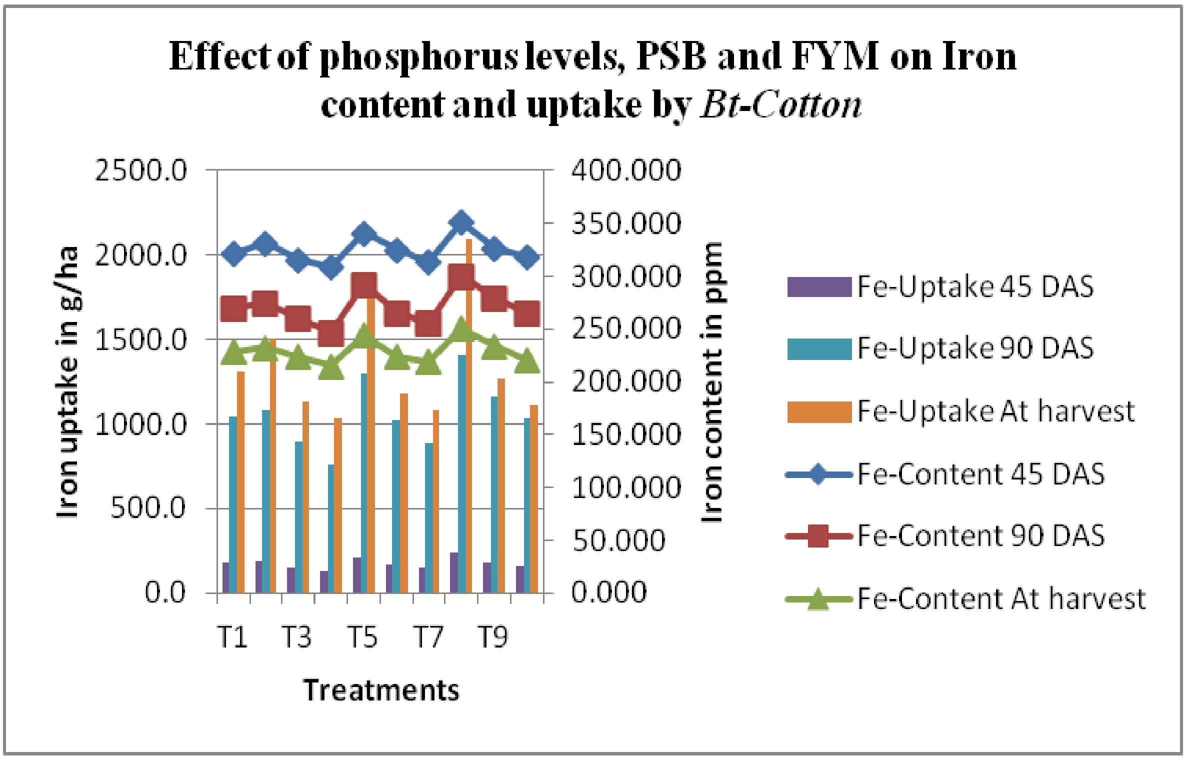

Fig. 7.

Iron uptake (Table 5 and Fig. 7) was markedly influenced by the treatments receiving maximum phosphorus (60 kg P_2O_5 ha^{-1}) with FYM (T_5) and PSB+FYM (T_8) at all growth stages and harvest. The uptake of all the micronutrient cations (Zn, Cu, Mn, and Fe) followed a increasing trend with advancement of crop growth.

4. DISCUSSION

Higher values of nitrogen uptake were recorded at a maximum dose of phosphorus that may be due to the increased volume of the root system which absorbs more amounts of nitrogen. The synergistic relationship between the two primary nutrients also might have favoured the higher nitrogen uptake. Application of FYM either alone or in combination with PSB increased the availability of nitrogen due to direct addition of nitrogen by the organic sources to the soil pool, enhanced fixation of nitrogen in the presence of readily available water-soluble P, and also increased mineralization with an increase in microbial population by the addition of organic matter and PSB. Similar results of a significant increase in nitrogen uptake due to phosphorus and FYM application were reported by Waghmare [11] and Baskar [12].

The marked influence of the application of FYM and PSB in combination with 60 kg ha^{-1} phosphorus on its uptake by cotton could be due to increased biomass obtained as a result of high availability of nutrients released during the decomposition of FYM and also solubilisation of native phosphorus by phosphate solubilizing microbes. The results were coinciding with Ravankar [13] and Patidar and Mali [14].

The increase in uptake of potassium in organic treated plots and PSB inoculated plots may be due to solubilisation and release of native and fixed forms of potassium, charging the soil solution with K^+ ions. The increase in uptake with time may be ascribed to split application of potassic fertilizers and the role of organics and PSB in increasing the use efficiency of applied fertilizers. The results are coinciding with those of Mahavishnan and Bhanurekha, [15].

An increase in uptake of micronutrients with phosphorus application could be due to the proliferation of roots, which might have helped in increased uptake of all the micronutrients. Application of FYM increased uptake of micronutrients (Zn, Cu, Mn, and Fe) by the crop, which might be due to chelation of Zn, Cu, Mn, and Fe by organic compounds formed on decomposition of FYM making them more available, on the other hand, FYM itself acts as a source of all micronutrients rendering them more available through mineralization.

5. CONCLUSION

It can be concluded that integration of inorganic phosphorus (60 kg ha^{-1} P_2O_5), PSB and FYM resulted in the highest uptakes of N, P and K. Highest uptakes were recorded by the integrated treatment that received 60 kg P_2O_5 ha^{-1} + PSB + FYM, followed by 60 kg P_2O_5 ha^{-1} + FYM. The uptake of all macronutrients was significantly influenced by levels of phosphorus applied. Uptake of all the micronutrients was markedly influenced by the treatments and FYM treated plots recorded superior values than other treatments. Application of 30 kg P_2O_5 ha^{-1}+ PSB + FYM was found to be on a par with addition of only 60 kg $ha^{-1}P_2O_5$. Hence the 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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