

Original Research Article

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Assessment of Biostimulants on Availability and Uptake of Nutrients by Irrigated Transgenic Cotton

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ABSTRACT

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A field investigation was carried out to study the effect of biostimulants such as microbial consortia, L-aminoacid complex and chitin in different combinations on uptake of nutrients by crop and fertility status of the soil in irrigated transgenic cotton. The experiment was laid out in randomized block design with five treatments and four replications. The soil of the experimental site is non-saline, slightly alkaline in reaction, calcareous and clay loam belonging to Periyanaickenpalayam series. The analysis of plants and soils collected at flowering, boll formation and harvest stages revealed that the application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching with activation and foliar spray without activation significantly increased nutrient uptake by crop, favorably altered availability of nutrient status in soil.

Introduction

Cotton (*Gossypium hirsutum* L.) popularly known as “White Gold” is a premier cash crop playing a key role in economic and social status of the world. India is one of the largest producers of cotton in the world accounting for about 23% of the world cotton production. In India, it is grown in an area of 125.84 lakh hectares with a production of 360 lakh bales and productivity of 486 kg per hectare (Current Cotton Scenario, 2020). It is an important raw material supplying about 65

per cent requirement of the Indian textile industry and it provides a livelihood to more than 60 million people in India by way of support in agriculture, processing and use of cotton in textiles. It contributes 29.8 per cent of the Indian agricultural gross domestic product hence it plays a vital role in the economic development of the country. The projected cotton requirement for 2020 is estimated as 590 lakh bales (Sreenivasan and Ravindran, 2010). The potential productivity of the crop has not been fully exploited and needs important technological interventions

for increasing the productivity of cotton. Indian government is now looking forward to improve the production of cotton to boost the nation economy.

Complementarily to those naturally occurring interactions, agricultural biostimulants include diverse formulations of compounds, substances and microorganisms that are applied to plants or soils to regulate and enhance the crop's physiological processes, thus making them more productive (Calvo *et al.*, 2014). Biostimulants act on the plant through different pathways to improve crop vigour, yields, quality, stress tolerance and post-harvest shelf life/conservation.

The agrinos high yield technology products are biostimulants which consist of naturally occurring beneficial microbes, L-amino acid complex and micronized chitin. The use of integrated biostimulants enhances the vitality of the agricultural biosphere and thus inturn enables increased crop productivity, improved efficiency of conventional fertilizer use and decreased environmental footprint.

Materials and Methods

Field experiment was conducted with irrigated transgenic cotton at farmers holding in Dasampalayam village, Annur block, Coimbatore district, Tamil Nadu on an Inceptisol (Vertic Ustropept). The farm is located in the Western agro climatic zone of Tamil Nadu at 11°12' North latitude and 76° 58' East longitude at an altitude of 426.74 m above MSL. The soil type of the experimental field belonged (Table 2) to Periyanaickenpalayam series (Vertic Ustropept). The transgenic hybrid irrigated cotton Jackpot (KCH -15 K 39 BG II) selected for this experiment is an extra long stable, cotton hybrid. This hybrid is high yielding with good quality fibre. The experimental field was ploughed well, leveled and ridges and furrows were formed at a

distance of 120 cm. The field was divided into plots of 7.8 x 6 m². The design adopted was randomized block design (RBD). The number of treatments was 5 and they were replicated as four. The treatment details for field experiments were given in Table 1.

Among the treatments HYT indicates High yield Technology and HYT A, HYT B and HYT C consists of Microbial consortia, L-Aminoacid complex and Micronized chitin.

Good viable seeds of Jackpot BG II hybrid were dibbled on one side of the ridge with a spacing of 60 cm between plants.

The seed rate adopted was 3 kg of delinted seeds per hectare. The crop was raised under irrigated condition. Irrigation was given depending upon the need of the crop during the different phases. Proper plant protection measures were taken up toward off sucking pests as and when needed. All the intercultural operations were carried out as per the crop production guide of Tamil Nadu Agricultural University.

Based on soil test values, the fertilizer doses were calculated for macronutrients using Soil Test Crop Response (STCR) equation.

The calculated fertilizer dose applied uniformly for all the treatments, of this full dose of P and 50 percent of N and K was applied as basal dose at the time of sowing and the balance 50 percent of N and K was applied as top dressing at 45 and 60 DAS in equal split.

Collection of soil and plant samples for chemical analysis

Soil samples

The initial soil sample was collected from different sites of the experimental field and a composite sample was prepared. The initial

sample was analysed for various physical, chemical and biological properties.

Moreover, soil samples were collected at the critical growth stages of the two crops *viz.*, flowering (70 DAS), boll formation (110 DAS) and harvest (final picking) stages for cotton as well as vegetative (30 DAS), pegging (60 DAS) and harvest (105 DAS) stages for groundnut. The soil samples thus collected were air dried, sieved through 2 mm sieve and stored in polythene bags for analysis. These soil samples were analysed for available N, P, K, exchangeable Ca and Mg and available S.

Plant samples

Plant samples were collected at the same three stage of soil samples collection. Five plants selected at random from each plot were uprooted for estimating dry matter production.

The plant samples were washed thoroughly to remove the adhering soil particles. The samples were initially air dried and later in oven at 60-70°C to constant weight. The oven dry weight was recorded and computed to kg ha⁻¹. The oven dried samples were powdered in a wiley-mill and used for the chemical analysis. The plant samples were analysed for the nutrients content as per the procedures enlisted in Table 5. Uptake of different nutrients was calculated by multiplying the concentration of each nutrient with their dry matter yield.

Results and Discussion

Data on initial soil analysis of the experimental site of village Dasampalayam revealed that the soil was non-saline, slightly alkaline in reaction with a pH of 8.41 and calcareous in nature. N availability was low, P availability was medium and K availability was high.

Nutrient uptake

N uptake (Figure 1)

The various treatments exhibited significant influence on N uptake in cotton. At flowering stage, the N uptake ranged from 47.55 to 54.88 kg ha⁻¹. When comparing the effect of treatments on N uptake, the application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray had recorded the highest N uptake (54.88 kg ha⁻¹) than other treatments. The treatments T₄ and T₃, T₂ and T₁ were on par with each other.

At boll development stage, the N uptake ranged from 97.86 to 113.27 kg ha⁻¹ and the highest N uptake was obtained with the application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray which was on par with treatment T₃.

At harvest stage, the N uptake was ranged from 135.94 to 151.99 kg ha⁻¹. The N uptake at harvest was also higher in treatment T₄. The treatments T₃ (149.22 kg ha⁻¹) and T₂ (145.16 kg ha⁻¹), T₂ and T₁ (140.93 kg ha⁻¹) and T₅ (135.94 kg ha⁻¹) were on par with each other. The standard check recorded the lowest N uptake at all the critical growth stages.

P uptake (Figure 2)

The uptake of P in flowering, boll formation and harvest stages ranged from 10.83 to 12.70, 23.39 to 26.54 and 29.91 to 34.25 kg ha⁻¹.

Application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray (T₄) registered significantly higher uptake at all stages of crop growth and was comparable with HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹

as soil drenching and foliar spray (T₃). Irrespective of the stages, standard check recorded the lowest P uptake.

K uptake (Figure 3)

The K uptake in different stages of cotton was markedly influenced by the different treatments. The range in values was quite marked from 30.18 to 36.56, 85.21 to 95.97 and 116.21 to 138.40 kg ha⁻¹ at flowering, boll formation and harvest stage respectively.

During flowering, boll formation and harvest stage, the application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray and HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching and foliar spray were on par with each other and recorded highest K uptake than other HYT treatments. At flowering stage, the treatment T₃ (35.79 kg ha⁻¹) was followed by T₂ (32.63 kg ha⁻¹), T₁ (31.34 kg ha⁻¹) and T₅ (30.18 kg ha⁻¹). At boll formation stage, T₃ (94.62 kg ha⁻¹) was on par with T₂ (91.69 kg ha⁻¹). At harvest stage, T₂ (123.39 kg ha⁻¹) was on par with T₁ (119.04 kg ha⁻¹) and T₁ was on par with T₅ (116.21 kg ha⁻¹).

Ca uptake (Figure 4)

The Ca uptake in cotton at critical stages of crop growth differed significantly among the treatments. The Ca uptake values were in the range of 30.33 to 36.58 kg ha⁻¹ at flowering, 74.61 to 84.25 kg ha⁻¹ at boll formation and 80.79 to 97.43 kg ha⁻¹ at harvest stage.

In all the stages, application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray (T₄) recorded the highest Ca uptake and standard check (T₅) recorded the lowest Ca uptake.

At flowering stage, the treatment T₄ (36.58 kg ha⁻¹) was on par with T₃ (35.62 kg ha⁻¹). At boll formation stage, the treatments T₄ and T₃, T₃ and T₂, T₂ and T₁, T₁ and T₅ were on par with each other. In harvest stage, the treatment T₁ (84.24 kg ha⁻¹) was on par with T₅ (80.79 kg ha⁻¹).

Mg uptake (Figure 5)

The variation in Mg uptake was significant among the treatments. The Mg uptake values were found to range from 13.10 to 17.44, 27.20 to 33.20 and 34.18 to 41.79 kg ha⁻¹ at flowering, boll formation and harvest stage respectively.

Highest value of 17.44 kg ha⁻¹ at flowering, 33.20 kg ha⁻¹ at boll formation and 41.79 kg ha⁻¹ at harvest was observed with application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray (T₄). At flowering stage, the treatment T₄ was followed by T₃. But in boll formation and harvest stage, the treatment T₄ was on par with T₃.

S uptake (Figure 6)

The application of different treatments significantly altered the S uptake. The highest S uptake of 11.49, 15.62 and 28.68 kg ha⁻¹ in flowering, boll formation and harvest stage respectively has been accounted to T₄ - HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray and the lowest value of 8.80, 13.42 and 21.75 kg ha⁻¹ to standard check. At flowering and harvest stage, the treatment T₄ was followed by T₃, T₂, T₁ and T₅. In boll formation stage, the treatments T₄ (15.62 kg ha⁻¹), T₃ (15.43 kg ha⁻¹) and T₂ (15.05 kg ha⁻¹) showed equal effect and had significantly higher uptake than rest of the treatments.

Soil available nutrients

Available N (Table 3)

The variation in soil available N status at critical growth stages of cotton was significant for the treatments imposed and it varied from 273 to 311 kg ha⁻¹ at flowering, 232 to 263 kg ha⁻¹ at boll formation and 201 to 225 kg ha⁻¹ at harvest stage.

At all stages, the highest soil available N was observed with application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray. The treatment T₄ was followed by T₃, T₂, T₁ and T₅ at flowering and harvest stages. But, in boll formation stage T₄ was on par with T₃. At all stages, the lowest available nitrogen content was recorded in standard check. Irrespective of treatments, available nitrogen decreased with advancement of crop growth.

Available P (Table 3)

A marked variation was found to exist among treatments with available P status. The highest value of 55.5 kg ha⁻¹ at flowering, 44.8 kg ha⁻¹ at boll formation and 35.7 kg ha⁻¹ at harvest stages were recorded with application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray. At flowering and harvest stage, the treatment T₄ was followed by T₃, T₂, T₁ and T₅. In boll formation stage, the treatment T₄ was on par with T₃ (HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching and foliar spray). The lowest soil available P was associated with standard check (T₅).

Available K (Table 3)

Available K status varied from 868 to 897, 813 to 846 and 762 to 801 kg ha⁻¹ at

flowering, boll formation and harvest stage respectively.

At all stages, the highest available K was accounted by the application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray and lowest by standard check (T₅). Though the variation was significant, most of the treatments remained on par with each other.

Exchangeable Ca (Table 4)

The exchangeable Ca was ranged from 23.40 to 23.75 and 17.80 to 18.30 cmol (P⁺) kg⁻¹ at flowering, 23.25 to 23.50 and 17.55 to 18.10 cmol (P⁺) kg⁻¹ at boll formation, 22.90 to 23.30 and 17.40 to 17.80 cmol (P⁺) kg⁻¹ at harvest stage. The highest level of exchangeable Ca was found in treatment with application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray (23.75 cmol (P⁺) kg⁻¹ at flowering, 23.50 cmol (P⁺) kg⁻¹ at boll formation and 23.30 cmol (P⁺) kg⁻¹ at harvest stage) and lowest with standard check (T₅) at all the stages. Even though the treatments differed significantly with respect to exchangeable Ca level in soil, most of the treatments remained on par in all the three stages.

Exchangeable Mg (Table 4)

Though the exchangeable Mg level in soil was significantly influenced by the treatments, there was no marked enhancement in exchangeable Mg level. The exchangeable Mg in soil varied from 10.81 to 11.24 cmol (P⁺) kg⁻¹ at flowering stage, 10.78 to 11.15 cmol (P⁺) kg⁻¹ at boll formation stage and 10.76 to 11.13 cmol (P⁺) kg⁻¹ at harvest stage. It was found that the soil exchangeable Mg in the treatment T₄ - HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹

as soil drenching (with activation) and foliar spray was higher than other HYT treatments in all the stages.

Available S (Table 4)

The available S content of soil at flowering and boll formation stage of cotton was significantly influenced by the application of different treatments. The values ranged from 92.4 to 96.2 kg ha⁻¹ in flowering stage and

89.6 to 93.6 kg ha⁻¹ in boll formation stage. But the S availability in harvest stage was not influenced by the application of different treatments. The highest S availability at all the stages was observed with application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray. The other HYT treatments T₃, T₂ and T₁ showed their supremacy over standard check with respect to available S in soil.

Table.1 Treatment details

	Treatments	Method of application
T₁	HYT A @ one lit ha ⁻¹ + Molasses @ two lit ha ⁻¹ (Ready for application only after 12 hrs. activation)	Soil drenching in the stem base on 7-15 days after sowing
	HYT B @ one lit ha ⁻¹	Foliar spray on 30-35 and 60-65 days after sowing
T₂	HYT A @ one lit ha ⁻¹ + HYT B @ two lit ha ⁻¹ (Ready for application only after 72 hrs. activation)	Soil drenching in the stem base on 7-15 days after sowing
	HYT B @ 1lit ha ⁻¹	Foliar spray on 30-35 and 60-65 days after sowing
T₃	HYT A @ one lit ha ⁻¹ + HYT B @ one lit ha ⁻¹ + HYT C @ one kg ha ⁻¹	Soil drenching in the stem base on 7-15 days after sowing and foliar spray on 30-35 and 60-65 days after sowing
T₄	HYT A @ one lit ha ⁻¹ + HYT B @ one lit ha ⁻¹ + HYT C @ one kg ha ⁻¹ (Ready for application only after 72 hrs. activation)	Soil drenching in the stem base on 7-15 days after sowing
	HYT A @ one lit ha ⁻¹ + HYT B @ one lit ha ⁻¹ + HYT C @ one kg ha ⁻¹	Foliar spray on 30-35 and 60-65 days after sowing
T₅	Standard Check	

*In all the above treatments STCR (Soil Test Crop Response) based fertilizer recommendation was followed.

Table.2 Characteristics of cotton experimental soil

S.No.	Parameter	Details
1.	Soil series	Periyanaickenpalayam
2.	Taxonomic classification	Vertic Ustrocept
3.	Mechanical composition	
	Clay (%)	36.40
	Silt (%)	26.18
	Fine sand (%)	14.37
	Coarse sand (%)	21.29
	Texture	Clay loam
4.	Physical composition	
	Bulk density (Mg m ⁻³)	1.28
	Particle density (Mg m ⁻³)	2.24
5.	Chemical composition	
	pH	8.41
	EC (dSm ⁻¹)	0.23
	Organic carbon (g kg ⁻¹)	2.8
	Available nitrogen (kg ha ⁻¹)	143
	Available phosphorus (kg ha ⁻¹)	24.8
	Available potassium (kg ha ⁻¹)	697
	Exchangeable calcium (cmol (P ⁺) kg ⁻¹)	18.4
	Exchangeable magnesium (cmol (P ⁺) kg ⁻¹)	9.7
	Available sulphur (mg kg ⁻¹)	43.15
	DTPA-Fe	6.31
	DTPA-Mn	12.3
	DTPA-Zn	1.7
	DTPA-Cu	1.9
6.	Biological properties	
	Bacteria (x 10 ⁶ cfu g ⁻¹ of dry soil)	27.8
	Fungi (x 10 ⁴ cfu g ⁻¹ of dry soil)	10.1
	Actinomycetes (x 10 ³ cfu g ⁻¹ of dry soil)	8.9

Table.3 Effect of treatments on available NPK in soil (kg ha^{-1}) at different growth stages of transgenic cotton

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	Flowering	Boll formation	Harvest	Flowering	Boll formation	Harvest	Flowering	Boll formation	Harvest
T₁	291	244	210	41.6	32.2	25.2	659	602	556
T₂	298	251	216	47.8	35.8	28.3	668	611	567
T₃	308	259	224	51.2	39.6	30.4	678	623	583
T₄	317	267	231	53.8	41.7	32.5	686	634	598
T₅	279	235	204	37.3	29.4	21.8	651	592	545
SEd	5.38	2.28	2.54	0.59	0.39	0.22	4.62	7.05	4.43
CD (P=0.05)	11.25	4.77	5.31	1.25	0.82	0.47	9.65	14.72	7.25
T₁ - HYT A 1lit ha⁻¹ + Molasses 2lit ha⁻¹ (WA) + HYT B 1lit ha⁻¹ T₂ - HYT A 1lit ha⁻¹ + HYT B 2lit ha⁻¹ (WA) + HYT B 1lit ha⁻¹ T₃ - HYT A 1lit ha⁻¹ + HYT B 1lit ha⁻¹ + HYT C 1kg ha⁻¹ T₄ - HYT A 1lit ha⁻¹ + HYT B 1lit ha⁻¹ + HYT C 1kg ha⁻¹ (WA) + HYT A 1lit ha⁻¹ + HYT B 1lit ha⁻¹ + HYT C 1kg ha⁻¹ T₅ - Standard check									

Note: HYT – High yield technology; WA - With activation

Table.4 Effect of treatments on exchangeable Ca and Mg and available S in soil (kg ha⁻¹) at different growth stages of transgenic cotton

Treatments	Exchangeable Ca (kg ha ⁻¹)			Exchangeable Mg (kg ha ⁻¹)			Available S (kg ha ⁻¹)		
	Flowering	Boll formation	Harvest	Flowering	Boll formation	Harvest	Flowerin g	Boll formation	Harvest
T₁	17.95	17.65	17.45	9.21	9.00	8.93	76.4	72.4	69.0
T₂	18.15	17.80	17.55	9.43	9.20	9.01	77.2	73.0	69.6
T₃	18.20	18.05	17.70	9.56	9.30	9.17	78.6	74.2	70.0
T₄	18.30	18.10	17.80	9.57	9.36	9.32	78.8	75.6	70.2
T₅	17.80	17.55	17.40	9.20	8.91	8.80	75.4	70.6	68.4
SEd	0.09	0.07	0.06	0.08	0.05	0.05	0.99	0.90	0.92
CD (P=0.05)	0.19	0.15	0.14	0.16	0.11	0.10	2.06	1.89	NS
T₁ - HYT A 1lit ha⁻¹ + Molasses 2lit ha⁻¹ (WA) + HYT B 1lit ha⁻¹ T₂ - HYT A 1lit ha⁻¹ + HYT B 2lit ha⁻¹ (WA) + HYT B 1lit ha⁻¹ T₃ - HYT A 1lit ha⁻¹ + HYT B 1lit ha⁻¹ + HYT C 1kg ha⁻¹ T₄ - HYT A 1lit ha⁻¹ + HYT B 1lit ha⁻¹ + HYT C 1kg ha⁻¹ (WA) + HYT A 1lit ha⁻¹ + HYT B 1lit ha⁻¹ + HYT C 1kg ha⁻¹ T₅ - Standard check									

Note: HYT – High yield technology; WA - With activation

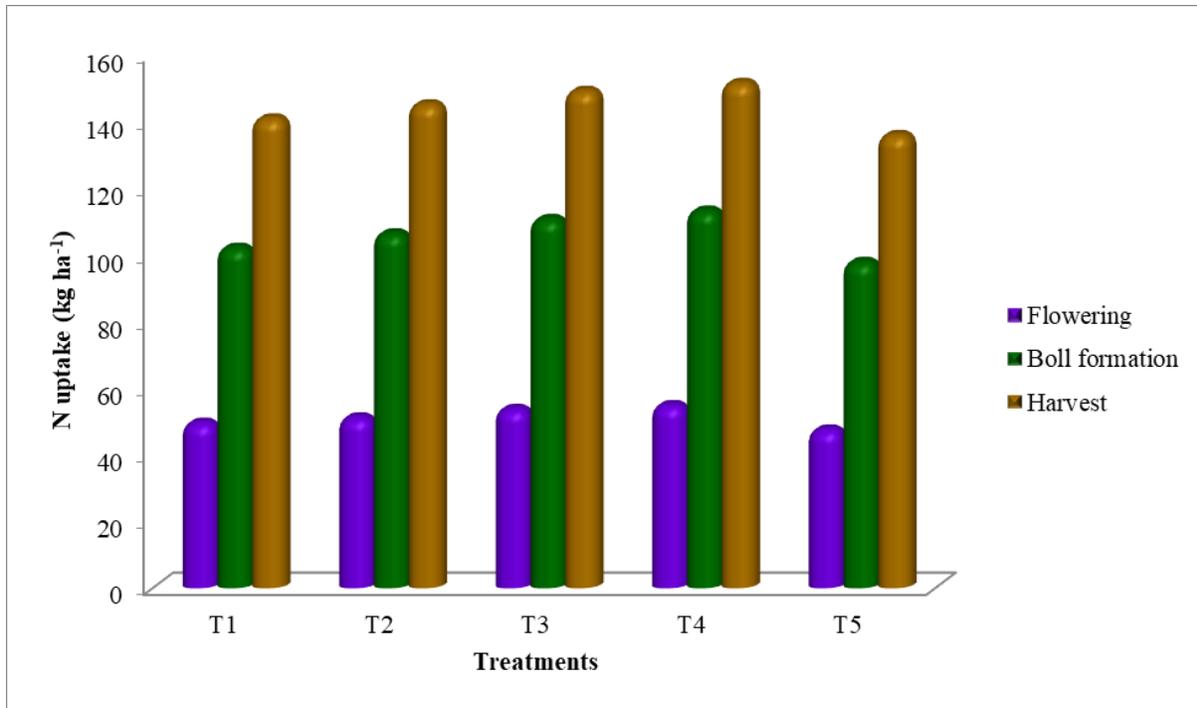


Figure.1 Effect of treatments on N uptake (kg ha⁻¹) at different growth stages of transgenic cotton

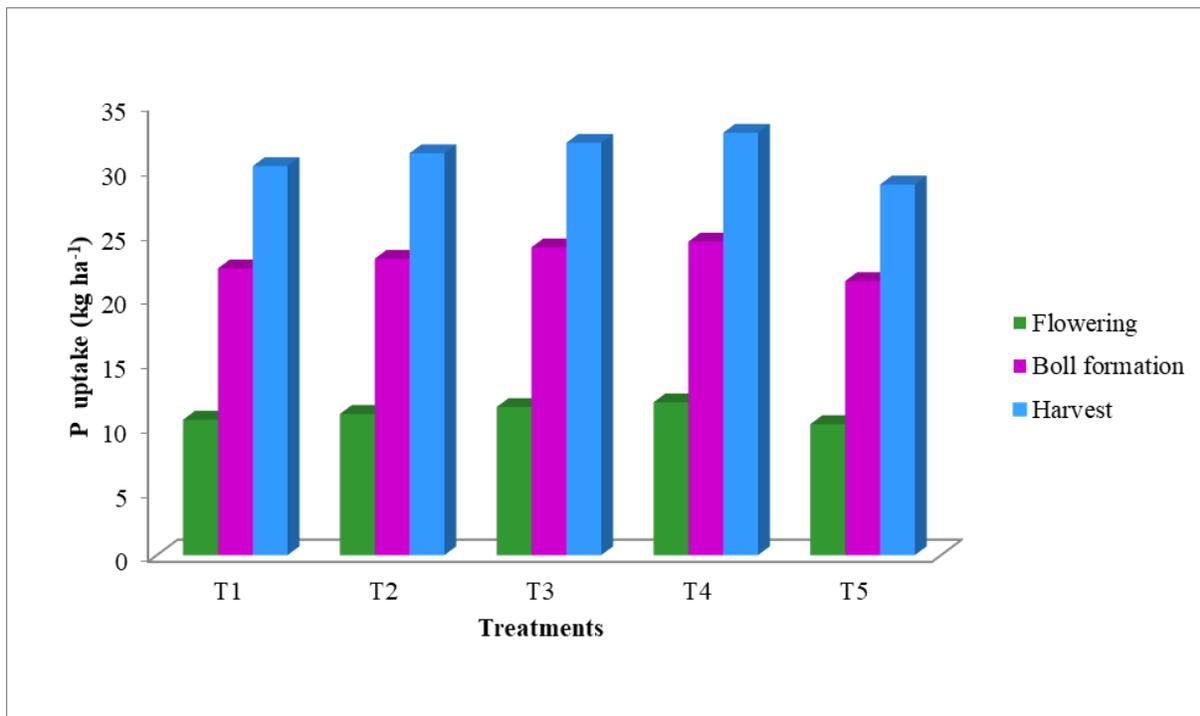


Figure.2 Effect of treatments on P uptake (kg ha⁻¹) at different growth stages of transgenic cotton

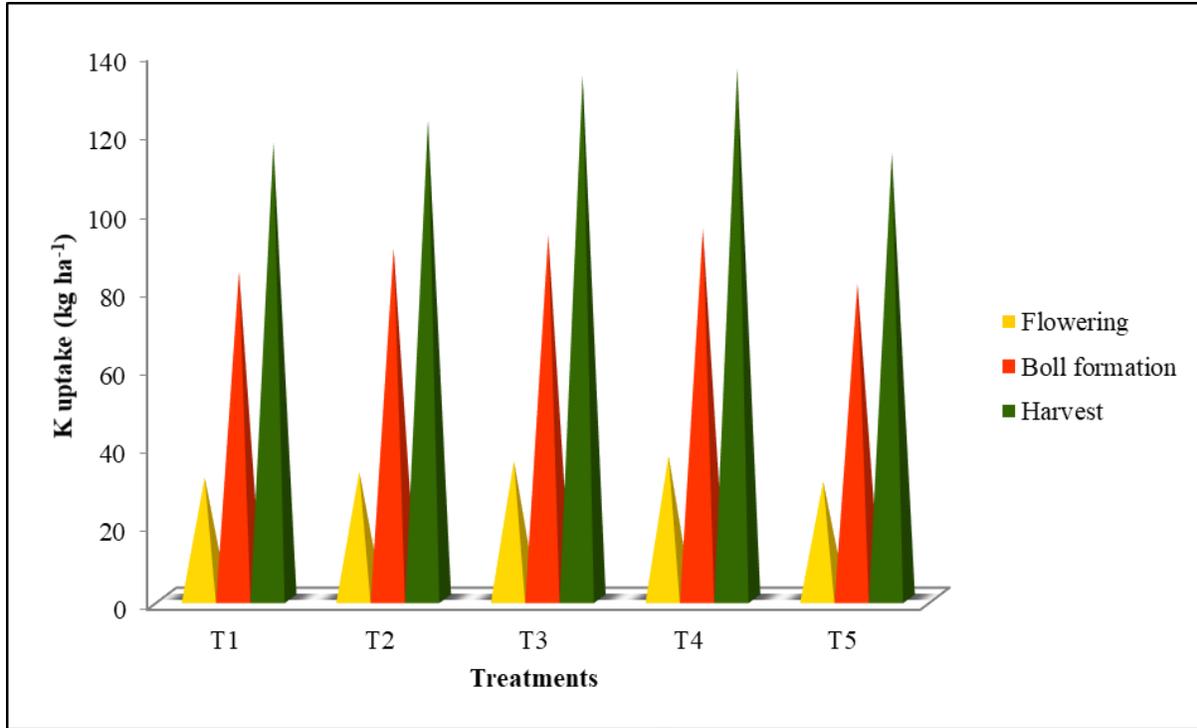


Figure.3 Effect of treatments on K uptake (kg ha⁻¹) at different growth stages of transgenic cotton

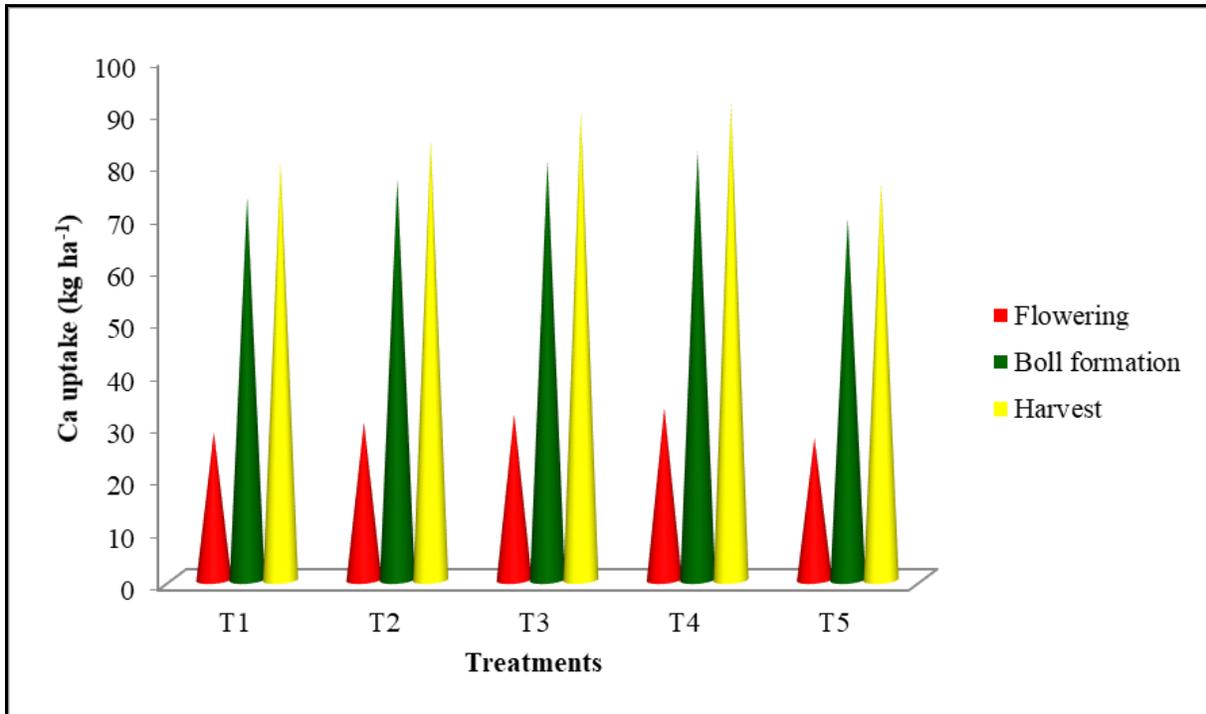


Figure.4 Effect of treatments on Ca uptake (kg ha⁻¹) at different growth stages of transgenic cotton

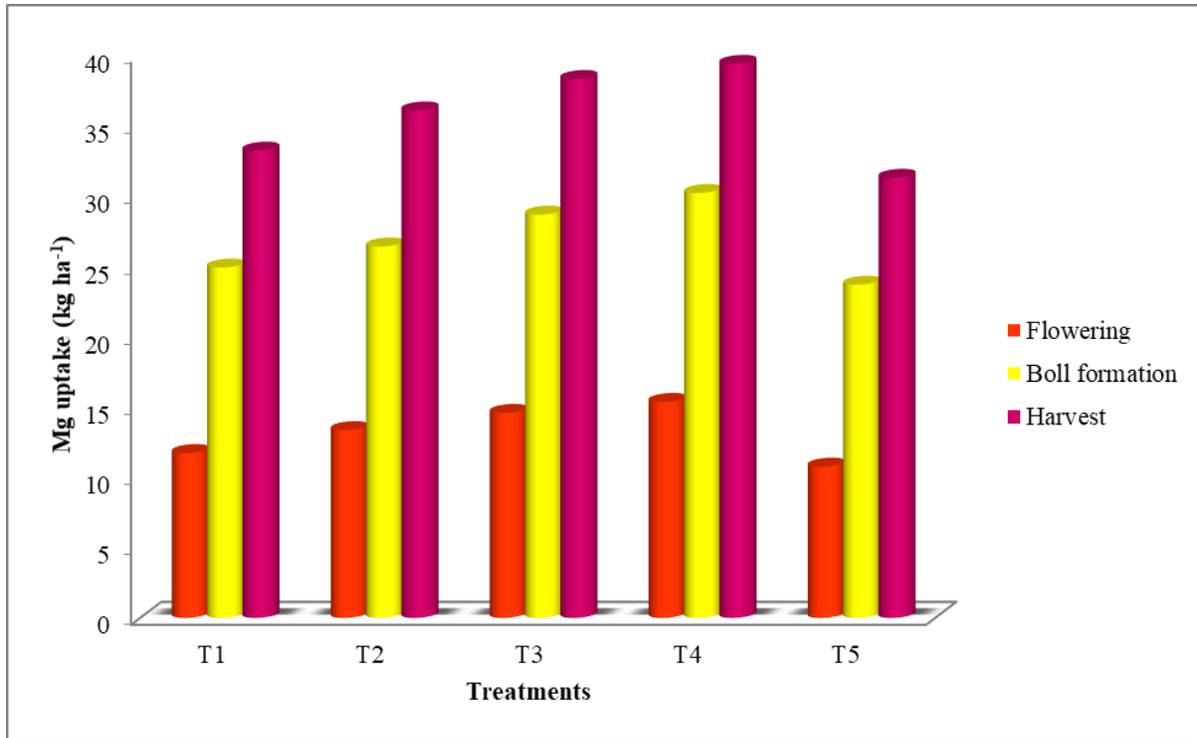


Figure.5 Effect of treatments on Mg uptake (kg ha⁻¹) at different growth stages of transgenic cotton

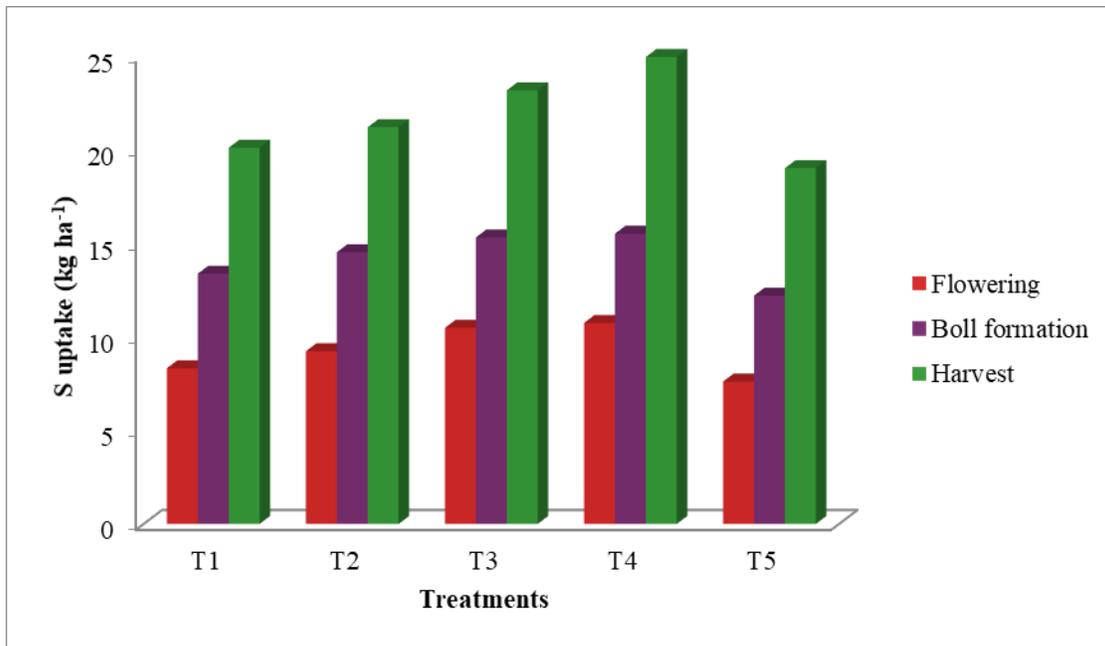


Figure.6 Effect of treatments on S uptake (kg ha⁻¹) at different growth stages of transgenic cotton

Uptake of macronutrients (N, P and K)

Enhancement in the uptake of N in all the growth stages due to application of HYT products was highly significant. Higher uptake value obtained with application of HYT A @ one lit per hectare + HYT B @ one lit per hectare + HYT C @ one kg per hectare as soil drenching (with activation) and foliar spray might be attributed to the increased yield of dry matter with enhancement in the absorption of N from the soil during the growth stages. The application of HYT A in soil ecosystem creates a synergistic microbial biosphere in the soil, fixing atmospheric nitrogen, solubilizing soil and mineral nutrients and forming symbiotic nutrient pathways with plant root stalk. Similar results were observed by Egamberdiyeva and Hoflich (2004) in cotton and pea. Amino acids application to the soil also activates the microbial population which causes an increase in biological activity with a greater process of humification and therefore considerable increase in soil fertility. Plants can also access the nitrogen in chitin *viz.*, microbial breakdown and the release of inorganic nitrogen or directly taking up monomers as organic nitrogen (Spiegel *et al.*, 1988; Roberts and Jones, 2012). These attributes enhanced uptake of N by the plant and enhances the efficiency of conventional crop inputs such as mineral fertilizer.

The results shown that the application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray had resulted in significantly higher P uptake. It could be mentioned that the staggered and steady supply of the nutrients from soil due to applied sources create a favourable atmosphere for better root growth and absorption of nutrients. Microorganisms play an important role in the soil phosphorus cycle and thus in mediating phosphorus availability

to plants, enhancing the capacity of plants to acquire phosphorus from the soil by directly solubilizing and mineralizing inorganic phosphorus or by facilitating the mobility of organic phosphorus through microbial turnover and increasing the root system (Richardson and Simpson, 2011) and also the soil application of amino acids, increase the population of phosphate solubilizing microorganisms in the rhizosphere, which in turn enhances the solubility of phosphates in soil (Teruo Higa, 1993).

The appreciable increase in the K uptake at harvest to the tune of 19.1 per cent was observed by application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray over standard check could be reasoned out for the increased dry matter production including seed cotton as aided by the constant supply of nutrients throughout the cropping period.

Uptake of secondary nutrients (Ca, Mg and S)

Significant uptake values for both Ca and Mg were recorded by soil and foliar application of HYT products. The influence was highest at application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray. This could probably because of increased availability of Ca and Mg as a result of HYT products application due to increased microbial activity or dissolution of minerals by root exudates, which enhanced higher uptake of these nutrients.

Perusal of the results with reference to the uptake of S indicated that sufficient quantity of S is being taken up by cotton during flowering, boll formation and harvest stage. This might be due to solubilizing soil and mineral nutrients by applied sources.

Soil available nutrients

Macronutrients

A marked decline in the soil available N content was observed with the advancement of crop growth which might be due to the continuous removal of N by the crop and losses due to transformation. The available N content was significantly influenced by the application of HYT products. At all the three stages, the treatment HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray had recorded the highest available N over the standard check. Higher N availability in soil could be attributed to the increased microbial activity and nitrogen fixation in soil. Also, the soil application of amino acids and chitin (Roberts and Jones, 2012) act as energy sources for microbes, which accelerates the amplified microbial flora in soil and therefore considerable increase in soil fertility and availability of N in soil.

In line with the trend observed for nitrogen, soil available phosphorus registered a conspicuous decline with the advancement of crop growth stages. The highest soil available phosphorus registered under the application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray might be ascribed to their solubilizing effect on applied and native soil phosphorus and consequent contribution to labile pool. This enhanced phosphorus availability could be attributed to the synthesis of low molecular weight organic acids by microbes. The organic acids bind phosphate with their hydroxyl and carboxyl groups thereby chelating cations and also inducing soil acidification, resulting in the release of soluble phosphate (Richardson and Simpson, 2011).

As in the case of soil available nitrogen and phosphorus, the application of HYT products

enhanced the available K status of the soil at all stages of growth. Variation in the K content of the soil was observed among stages, the vegetative stage recorded the highest while the harvest stage registered the lowest values. This might have been due to continuous absorption, assimilation and metabolism of K, causing a reduction in the availability of K as the crop ages. Among the different treatments, application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray recorded the highest soil available K. This might be the reason that the ammonium ions generated during mineralization of N could have caused the displacement of K ions from the lattice positions of clay by virtue of ion exchange.

Application of bacterial inoculants increases the nutrient availability of N, P and K in soil of maize crop as reported by Umesha *et al.*, (2014) supports these findings.

Secondary nutrients

Application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray enhanced the level of exchangeable Ca and Mg in soil at all the stages. Other treatments also showed slightly higher exchangeable Ca and Mg values in soil than standard check. Such enhancement could have been due to the dissolution of calcium carbonates and other insoluble forms of Ca and Mg by root exudates and also by various products of microbial activity which have been improved due to HYT products application.

Significant variation in S availability was observed at flowering and boll formation stage. Application of HYT A @ one lit ha⁻¹ + HYT B @ one lit ha⁻¹ + HYT C @ one kg ha⁻¹ as soil drenching (with activation) and foliar spray and other treatments showed slight

increase in S availability when compared to the standard check. But the S availability did not vary due to the applied sources at harvest stage of crop growth.

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