The Bioscan 10(4): 1499-1504, 2015
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

SOIL ENZYME ACTIVITY, SOIL MICROBIAL COMMUNITIES, MICROBIAL BIOMASS CARBON CHANGES AND SEED COTTON YIELD UNDER DIFFERENT NUTRIENT MANAGEMENT PRACTICES IN *Bt* COTTON

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KEYWORDS
Bt cotton
Nutrient management
Soil enzyme activity
Microbial population
Yield

Received on :
15.07.2015

Accepted on :
24.10.2015

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ABSTRACT
Nutrient supply and availability during crop growth influences various microbial mediated biochemical reactions and nutrient transformations. Studies were conducted on a sandy clay loam during *kharif*, 2013-14 to understand the effect of different fertilizer doses on soil microbial activity and yield of *Bt* cotton. Dehydrogenase activity, a key biochemical indicator, was higher under soil test based fertilizer application with 3.43 μg of TPF g^{-1} day^{-1}. Farmers' practice of excessive fertilizer application had negative impact on DHA (2.57 μg TPF g^{-1} day^{-1}). Urease activity decreased by 24 to 27% with 150% RDF with and without sulphur @ 30 kg ha^{-1} when compared to 100% RDF. Increasing fertilizers from 100 to 150% caused inhibitory effect on the activity of acid and alkaline phosphatases. Soil microbial population and microbial biomass carbon did not show significant variations with treatments. Although higher seed cotton yield of 3847 kg ha^{-1} was realized by increasing fertilizer dose to 150%, it was on par with the yield realized in 100% NPK (3616 kg ha^{-1}) and soil test based fertilizer application (3688 kg ha^{-1}). Farmers' practice of application of very high doses of fertilizers resulted in slightly lower yield (3582 kg ha^{-1}) than 100% RDF.

INTRODUCTION

India has the world's largest hectarage of cotton (11.6 mha) and accounts for almost 1/3 of total global cotton plantings (34 mha).It plays important role in the Indian economy involving about 60 million people in cotton cultivation, textile industries and trade (Ameta *et al*., 2015). Due to commercialization, 95% of area is occupied by *Bt* cotton with a 220-fold increase by 2013 at 11 mha from 50,000 hectares in 2002. Cotton, particularly hybrid cotton being exhaustive, draw plenty of soil nutrients and thus under continuous cropping pattern nutrient management assumes importance. Response of cotton to fertilizer is more critical than other crops. The yield potential of the crop can be exploited to the maximum only when the nutrient requirements are fully met.Nutrient deficiencies, as a consequence of nutrient depletion over the years, have decreased seed cotton yields due to imbalance and inadequate fertilization that not only affect the fiber quality of cotton, but also cause deleterious effect on physico-chemical and biological properties of soil. It is also important to study the interaction of appropriate fertility levels with judicious selection of hybrid. The potential growth and developmental rates for a particular genotype may be decreased by stress factors (Shukla *et al*., 2013). On the other hand, excess application of fertilizer has its own limitation in promoting vegetative growth. The haphazard fertilization results in increasing the amount of nutrients not needed by the plant and increases the fertilizer costs of the farmer unnecessarily (Rajan *et al*., 2005). The optimal dose of nutrients builds up a favorable condition in increasing cotton productivity and improves the quality. Response of cotton to nutrients varies significantly among varieties and locations and therefore, region specific recommendation of nutrients are essential.

Further, nutrient supply and availability during the crop growth drives various microbial mediated biochemical reactions and nutrient transformations. Under low nutrient availability/ supply, inputs of energy rich carbon compounds from roots may be used by microbes for the production of extra-cellular enzymes that can release nutrients locked in SOM through rhizopriming (Brzostek *et al*., 2012) and referred as microbial mining (Fontaine *et al*., 2011). A negative priming effect may occur in soils of high nutrient availability (Dijkstra *et al*., 2013). The magnitude and direction of the rhizosphere priming effect may strongly depend on the relative availability of N and P in the soil (Sullivan and Hart, 2013). Hence, in the current investigation an attempt has been made to examine the influence of different nutrient management practices on the activity of soil enzymes, microbial population, microbial

biomass carbon (MBC) and yield of *Bt* cotton.

MATERIALS AND METHODS

A field experiment with hybrid *Bt* cotton was conducted on the research farm of Krishi Vignana Kendra (KVK), Malyal, Warangal district during *kharif* 2013-14. The farm is geographically situated at 79º57' 89" East longitudes and 17º33' 31" North latitudes and at an altitude of 212.44 m above mean sea level and falls under Central Telangana agro climatic zone of Telangana state, India. The soil was sandy clay loam in texture with 67% sand, 13% silt and 20% clay content. The soil was neutral in reaction (7.04) with low electrical conductivity (0.17 dSm^{-1}), medium in organic carbon content (0.57%), low in available N (156.8 kg ha^{-1}), low in available P (9.98 kg ha^{-1}) and medium in available K (190.4 kg ha^{-1}), deficient in available S (5.2 ppm), low in available Zn (0.22 ppm) and high in Cu, Mn and Fe (3.7, 30.8 and 16.3 ppm respectively).

In Farmers practice treatment (T2) fertilizer doses were arrived by conducting a survey in the study area, covering 11 mandals of the district. The outcome of the survey revealed that very excessive and high doses of nutrients/fertilizers are being used as against the state recommendation. Soil samples were collected at flowering and harvesting stages and were processed for enzyme assay following the standard procedures viz., dehydrogenase enzyme activity (Casida *et al*., 1964), urease enzyme activity (Tabatabai and Bremner, 1972), phosphatase (acid and alkaline) enzyme activity (Tabatabai and Bremner, 1969). Colony forming units (CFU) of *Azotobacter* (glucose medium), PSB (Pikovaskya agar medium) and Total microbial population (Plate count agar) were determined by serial dilution and spread plating on selective media. Replicates of the inoculated agar plates were incubated for 2 days at 37ºC for PSB, 5 days for PCA and 7 days for *Azotobacter* after which the counts were taken. The enumerated microbial population was expressed as $\log_{10}$ CFU g^{-1} of soil. Microbial biomass carbon was estimated by the method of Nunan *et al*. (1998), using aliquots of K_2SO_4 extracts through dichromate digestion. Available nutrients were estimated by using the standard extractants and procedures viz., nitrogen by 0.32% Alkaline $KMnO_4$ (Subbaiah and Asija, 1956), phosphorus by Olsens method with 0.5M $NaHCO_3$ (Olsen *et al*., 1954), potassium with 1 N Neutral Normal Ammonium Acetate method (Jackson, M. L. 1973) and Sulphur by Turbidimetric method with 0.15% $CaCl_2$ (Williams and Steinberg, 1959).

The experiment was laid out in RBD with three replications and nine treatments as detailed below

Treatment	Nutrient management practice
T1 :	Control
T2 :	Farmers' Practice (333:97:142:17 kg NPKS ha^{-1})
T3 :	RDF: 150:60:60 Kg ha^{-1} ($N:P_2O_5:K_2O$)
T4 :	RDF + S @ 30 kg ha^{-1}
T5 :	Soil test based fertilizer application for an yield target of 25 q ha^{-1} (114:104:28 kg NPK ha^{-1})
T6 :	125% RDF
T7 :	125% RDF + S @ 30 kg ha^{-1}
T8 :	150% RDF
T9 :	150% RDF + S @ 30 kg ha^{-1}

The seed cotton was harvested three times when the bolls were fully burst at 135, 155 and 170 days after sowing. The total seed cotton yield was obtained by adding the weight from each of these pickings and expressed as kg ha^{-1}. The data recorded on various parameters during the investigation were statistically analyzed duly following the analysis of variance technique for randomized block design as suggested by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Effect of nutrient management practices on soil enzyme activity (Table 1)

The biochemical properties of soil have often been proposed as early and sensitive indicators of soil ecosystem health (Oliveira and Pampulha, 2006). Activities of soil enzymes indicate the direction and strength of all kinds of biochemical processes in soil and act as key biological indicator of soil. Soil enzymes play an essential role in energy transfer, environmental quality, organic matter decomposition, nutrient cycling and crop productivity (Tabatabai, 1969; Kumar *et al*., 1992). Measurement of enzymes activity in combination with count of number of key microorganisms provides sensitive information of the changes occurring in soil (Brookees, 1995). Fertilizer doses tested in *Bt* cotton showed remarkable influence on soil enzyme activity both at flowering and harvesting stages and activity of different enzymes is discussed in the following sections.

Dehydrogenase activity (DHA) (Table 1)

Dehydrogenase activity is an indicator of overall soil microbial activity and reflects the total scope of activity of soil microflora (Nannipieri *et al*., 2003). The activity of dehydrogenase was high at flowering stage when compared to harvest. Lowest DHA was recorded in control, with 2.22 μg TPF g^{-1} day^{-1} at flowering and 1.86 μg TPF g^{-1} day^{-1} at harvest. DHA increased with application of fertilizers. Higher dehydrogenase activity was recorded in soil test based fertilizer treatment both at flowering (3.43 μg TPF produced g^{-1} day^{-1}) and harvest stages (3.0 μg TPF produced g^{-1} day^{-1}) and this was on par with the DHA recorded in 100% RDF with and without sulphur treatments. Increase in dehydrogenase activity with application of the macro elements was presumably due to increased rhizosphere development and activity (Bednarz and Krzepilko, 2009). But, excessively high doses of fertilizers showed a negative impact on activity of dehydrogenase as evidenced by the significantly lower DHA in farmers' practice (2.57 μg TPF g^{-1} day^{-1} at flowering stage and 2.0 μg TPF g^{-1} day^{-1} at harvesting). Application of 125% (2.90 μg TPF g^{-1} day^{-1} at flowering stage and 2.70 μg TPF g^{-1} day^{-1} at harvest) and 150% RDF (2.84 μg TPF g^{-1} day^{-1} at flowering stage and 2.28 μg TPF g^{-1} day^{-1} at harvest) also recorded significantly lower DHA when compared to application of recommended doses of fertilizers. Inhibition of dehydrogenase activity with higher doses of mineral fertilizers was reported by Zakarauskaite *et al*. (2008) in sandy and silty loams.

Urease activity (Table 1)

Urease is an extracellular enzyme involved in the hydrolysis

of urea-type substrates to carbon dioxide and ammonia and its activity is important in the transformation of urea fertilizer. In this study, activity of urease at flowering and harvest stages showed variations with fertilizer doses. Lowest urease activity was registered in control both at flowering (85.5 μg NH^+_4 N released g^{-1} 2 h^{-1}) and harvest stages of crop growth (72.3 μg NH^+_4 N released g^{-1} 2 h^{-1}). Urease activity increased with application of fertilizers. At both flowering and harvest stages, urease activity was significantly higher in 100% RDF (143.5 and 130.3 μg NH^+_4 N released g^{-1} $2h^{-1}$) followed by 100% RDF + S @ 30 kg ha^{-1} (140.1 and 126.9 μg NH^+_4 N released g^{-1} $2h^{-1}$) and soil test based fertilizer application (138.8 and 125.6 μg NH^+_4 N released g^{-1} $2h^{-1}$). Juan *et al*. (2008) reported lowest urease activity in the untreated soils which increased by 62.5% with the application of mineral fertilizers. Increased the activity of urease activity with application of N and P fertilizers over control was also reported by Akmal *et al*. (2012). Increasing recommended doses of fertilizers from 100 to 150% with and without sulphur@ 30 kg ha^{-1} resulted in significant decrease in urease activity at flowering and harvest stages. The urease activity was less by 22 to 24% with 150% RDF (112.1 and 100 μg NH^+_4 N released g^{-1} $2h^{-1}$) and by 24 to 27% with 150% RDF + S @ 30 kg ha^{-1} (109.2 and 96.0 μg NH^+_4 N released g^{-1} $2h^{-1}$). This might be due to inhibition of urease activity under elevated levels of N availability. Studies of Yanyu *et al*. (2011) also indicate negative correlation between urease activity and soil N concentration. The results of Ajwa *et al*.(1999) also indicated inhibitory effect of mineral fertlizers and 15% decreased urease activity with application of excess doses of mineral fertilizers.

Acid and alkaline phophatases activity (Table 1)

Phosphatase activity is important as is related to phosphorus cycle in the soil (Bhadoria *et al*., 2011). Phosphatase enzymes are believed to be involved in mineralizing organic phosphorus to inorganic phosphorus. Activities of acid and alkaline phosphatases in the present study were significantly influenced by various treatments. Activity of these enzymes was high at flowering and decreased at harvest. Owing to very low status of available phosphorus of the experimental soil, the activity of these enzymes was highest in control both at flowering (212 μg PNP released $g^{-1}h^{-1}$ of acid phosphatase and 125.6 μg PNP released $g^{-1}h^{-1}$ of alkaline phosphatase) and at harvest (174.3 μg PNP released g^{-1} h^{-1} of acid phosphatase and 85.2 μg PNP released $g^{-1}h^{-1}$ of alkaline phosphatase). Singh and Walker (2006) also reported that under phosphorus deficiency conditions, both plants and microorganisms release phosphatase enzymes into the soil which have the potential to mobilize the P reserve. Addition of fertilizers in increased doses from 100 to 150% significantly reduced the activity of these enzymes. Application of sulphur also showed inhibitory effect on acid phosphatase activity. Baligar *et al*. (2005) and Haynes and Swift (1998) also reported a significant linear and inverse relationships between phophatase activities and soil inorganic P content. Further, activity of these enzymes in soil test based fertilizer treatment was also significantly lower than fertilizer treatments with 130 μg PNP released $g^{-1}h^{-1}$ of acid phosphatase and 50.4 μg PNP released $g^{-1}h^{-1}$ of alkaline phosphatase at flowering stage and 107.8 μg PNP released $g^{-1}h^{-1}$ of acid phosphatase and 33.2 μg PNP released $g^{-1}h^{-1}$ of alkalne phosphatase at harvest stage. This might be due to the reason that large quantity of phosphorus fertilizer was applied to soil to meet the crop demand because of low status of initial soil phosphorus. Activity of phosphatases in farmers' practice was also low and on par with that recorded in soil test based fertilizer treatment.

Effect of nutrient management practices on soil microbial population and microbial biomass carbon (Table 2)

Microbial populations (log_{10}CFUg^{-1}soil) viz., total beneficial microbes, *Azotobacter* and *Psuedomonas* (PSB) count was recorded at flowering and harvest stages. Microbial population was high at flowering stage and decreased by harvest stage. Among the treatments, control recorded lower total microbes (4.99 and 4.73 log_{10} CFU g^{-1} soil), *Psuedomonas* (4.64 and 4.03 log_{10} CFU g^{-1} soil) and *Azotobater* (4.84 and 4.12 log_{10} CFU g^{-1} soil) population at flowering and harvest stages. Further, increased and higher doses of fertilizers resulted in lower microbial population. Higher total beneficial microbial population (log_{10}CFU g^{-1} soil) was recorded in 125% RDF + S @ 30 kg ha^{-1} both at flowering stages. Population of *Psuedomonas* and *Azotobacter* was higher with 100% RDF. However, all the treatments with respect to total microbes, *Pseudomonas* and *Azotobactor* were statistically on par. Results of Bharathi *et al*. (2011) also clearly indicated that all the fertilization reduced the *Azospirillum,* P solubilising

Table 1: Soil enzymes activity (dehydrogenase, urease, acid phosphatase and alkaline phosphatase) in soil under *Bt* cotton as influenced by different fertilizer practices at flowering and harvest

Treatments	Dehydrogenase (μg TPF g^{-1} day^{-1})		Urease (μg NH_4^+ g^{-1} 2 h^{-1})		Acid phosphatase (μg PNP release $dg^{-1}h^{-1}$)		Alkaline phosphatase (μg PNP release $dg^{-1}h^{-1}$)	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
Control (No fertilizer)	2.22	1.86	85.5	72.3	212	174.3	125.6	85.2
Farmers practice (333:97:142:17 kg NPKS ha^{-1})	2.57	2.00	105.5	92.3	133	111.3	54.3	37.1
Recommended dose of fertilizers (RDF) (150:60:60 kg NPK ha^{-1})	3.31	2.80	143.5	130.3	196	162.6	108.0	68.0
RDF + S (150:60:60:30 kg NPKS ha^{-1})	3.40	2.92	140.1	126.9	184	155.3	95.2	60.7
STB fertilizer application(114:104:28 kg NPK ha^{-1})	3.43	3.00	138.8	125.6	130	107.8	50.4	33.2
125% RDF(188:75:75 kg NPK ha^{-1})	2.90	2.70	120.5	110.4	167	138.6	84.8	57.5
125% RDF + S (188:75:75:30 kg NPKS ha^{-1})	2.87	2.51	115.2	103.4	157	130.0	73.3	50.0
150% RDF (225:90:90 kg NPK ha^{-1})	2.84	2.28	112.1	100.0	146	118.4	66.5	41.5
150% RDF + S (225:90:90:30 kg NPKS ha^{-1})	2.65	2.20	109.2	96.0	139	115.6	57.2	38.0
SEm ±	0.18	0.13	3.7	3.5	6.7	5.0	4.8	3.4
CD (p=0.05)	0.55	0.41	11.2	10.7	20.4	15.2	14.6	10.3

bacteria and total diazotrophs population in maize rhizosphere.

The estimates of soil microbial biomass for the different treatments (Table 2) also followed a similar trend as that of microbial population. Higher MBC was recorded in RDF (133.9 mg kg^{-1}) and Biomass C was even suppressed in the experimental soil with the application of very high doses fertilizers as in farmers' practice (109.2 mg kg^{-1}). These results are in consistent with findings of Šimek *et al*. (1999).

Effect of nutrient management practices on nutrient availability (Table 3)

Availability of nutrients at flowering and harvest stages recorded significant changes with reference to treatments. Nitrogen availability was lowest in control (134.7 and 123.7 kg ha^{-1}) and was highest in farmers' practice (187.5 and 170.8 kg ha^{1}) at flowering and harvest stages respectively and these were significantly different from nitrogen status in 100% RDF treatment (150.5 and 141.3 kg ha^{-1}). Other treatments with higher doses of fertilizers as in 150% RDF + S @ 30 kg ha^{-1} (173.5 and 165.4 kg ha^{-1}) also maintained higher nutrient availability compared to 100% RDF, soil test based fertilizer application (143.8 and 135.2 kg ha^{-1}) and control. Gadhiya *et al*. (2009) also reported increased available N content in soil after harvest of *Bt* cotton crop with higher dose of N application.

Phosphorus availability was lowest in control (8.5 and 7.9 kg ha^{-1}) and highest in soil test based fertilizer application treatment (40.0 and 34.2 kg ha^{-1}) at flowering and harvest respectively. Farmers' practice treatment also recorded high (37.3 and 32.5 kg ha^{-1}) and on par available P as that of soil test based fertilizer treatment. In all other treatments, phosphorus status was low and treatment variations were significant.

Available potassium content in soil decreased from flowering to harvest. Availability of potassium was lowest in control (174.5 and 162.0 kg ha^{-1}) and was highest in farmers' practice treatment (267.5 and 235.3 kg ha^{-1}) at flowering and harvest stages respectively. In soil test based fertilizer treatment also the available potassium was significantly low and on par with control. Available potassium status was significantly higher in farmers' practice (267.5 and 235.3 kg ha^{-1}) and 150% RDF (with and without sulphur) over 100% RDF. However the treatments soil test based fertilizer application (196.8 and 183.9 kg ha^{-1}) and control (174.5 and 162.0 kg ha^{-1}) registered lower available potassium than 100% RDF (211.5 and 196.9 kg ha^{-1}). But Kalaichelvi (2008) reported that the application of higher levels of nutrients at the rate of 200:100:100 kg NPK ha^{-1} had

Table 2: Microbial population (log_{10} CFU g^{-1} soil) and Microbial biomass carbon and seed cotton yield as influenced by different fertilizer practices

Treatments	Total microbial population		*Pseudomonas*		*Azotobacter*		MBC (mg kg^{-1})	Seed cotton yield (kg ha^{-1})
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	at harvest	
Control (No fertilizer)	4.99	4.73	4.64	4.03	4.84	4.12	127.8	1249
Farmers practice(333:97:142:17 kg NPKS ha^{-1})	5.84	5.27	4.78	4.06	5.35	4.09	109.2	3582
Recommended dose of fertilizers (RDF) (150: 60:60 kg NPK ha^{-1})	6.28	5.37	5.69	4.61	5.67	4.26	133.9	3616
RDF + S(150:60:60:30 kg NPKS ha^{-1})	6.46	5.30	5.25	3.88	4.81	4.00	130.0	3665
STB fertilizer application(114:104:28 kg NPK ha^{-1})	6.34	5.12	5.10	4.08	5.20	4.00	129.1	3688
125% RDF (188:75:75 kg NPK ha^{-1})	5.65	5.25	5.48	3.99	4.44	3.37	124.2	3717
125% RDF + S(188:75:75:30 kg NPKS ha^{-1})	6.61	5.74	5.22	4.29	5.28	3.34	123.6	3747
150% RDF (225:90:90 kg NPK ha^{-1})	5.97	5.11	4.90	4.09	5.07	3.67	122.6	3837
150% RDF + S (225:90:90:30 kg NPKS ha^{-1})	6.12	5.17	4.75	4.13	4.63	3.70	118.6	3845
SEm ±	0.40	0.23	0.34	0.29	0.27	0.22	7.4	202
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	612

Table 3: Available nitrogen, phosphorus, potassium and sulphur status in soil at flowering and harvest of *Bt* cotton as influenced by different fertilizer practices

Treatments	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Sulphur (ppm)	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
Control (No fertilizer)	134.7	123.7	8.5	7.9	174.5	162.0	3.4	2.4
Farmers practice(333-97-142-17 kg NPKS ha^{-1})	187.5	170.8	37.3	32.5	267.5	235.3	13.6	10.7
Recommended dose of fertilizers (RDF) (150-60-60 kg NPK ha^{-1})	150.5	141.3	21.0	17.7	211.5	196.9	7.7	6.1
RDF + S (150-60-60-30 kg NPKS ha^{-1})	163.2	145.8	22.5	19.7	215.3	198.2	8.6	7.8
Soil Test based fertilizer application (114-104-28 kg NPK ha^{-1})	143.8	135.2	40.0	34.2	196.8	183.9	8.7	7.4
125% RDF(188-75-75 kg NPK ha^{-1})	156.1	145.2	25.5	19.6	225.2	209.0	8.1	6.5
125% RDF + S (188-75-75 -30 kg NPKS ha^{-1})	168.8	158.2	28.5	23.3	230.9	217.3	9.3	8.5
150% RDF(225-90-90 kg NPK ha^{-1})	165.3	150.3	32.0	27.2	239.7	223.7	8.6	7.1
150% RDF + S (225-90-90 -30 kg NPKS ha^{-1})	173.5	165.4	34.2	30.0	245.1	228.8	14.8	12.1
SEm ±	6.4	7.8	1.3	1.7	8.2	11.6	0.7	0.5
CD (p = 0.05)	19.3	23.5	4.0	5.1	24.8	35.0	2.1	1.6

resulted in significantly higher nitrogen and phosphorus availability but no significant influence on potassium availability at a 60 DAS, 80 DAS and post harvest stage of the *Bt* cotton crop.

Addition of sulphur along with fertilizers resulted in higher sulphur status in soil. Available sulphur content in soil was lowest in control (3.4 and 2.4 mg kg^{-1}) and highest in 150% RDF +S @ 30 kg ha^{-1} treatment (14.8 and 12.1 mg kg^{-1}) at flowering and harvest stages respectively. Farmer's practice (13.6 and 10.7 mg kg^{-1}) also recorded high and on par available sulphur as that of 150% RDF +S @ 30 kg ha^{-1} treatment. In all other treatments, sulphur status was low and treatment variations were nonsignificant at flowering stage but the treatments involving sulphur maintained significantly higher sulphur staus than the similar treatment without sulphur.

Effect of nutrient management practices on seed cotton (kapas) yield (Table 2)

The yield potential of the crop can be exploited to the maximum only when the nutrient requirements are fully met. On the other hand, excess application of fertilizer has its own limitations. In the present study, kapas yield was significantly influenced by the fertilizer doses. Lowest yield (1249 kg ha^{-1}) was recorded in unfertilized plots. Increasing fertilizer dose from 100 to 150% increased the kapas yield but it was on par with the yield realized in 100% NPK (3616 kg ha^{-1}) and soil test based fertilizer application treatments (3688 kg ha^{-1}). Further, in farmers' practice the yield (3582 kg ha^{-1}) was even less and on par with that of 100% NPK. This might be due to imbalance of nutrients caused by excessive application of fertilizers. Fertilizer response studies in *Bt cotton* hybrid carried out by Reddy and Kumar, (2010) indicated that response to nitrogen was observed up to 150 kg ha^{-1}only, and with further increase in nitrogen level cotton yield was reduced and response to phosphorus and potassium was observed up 60 kg ha^{-1} each.

Though the experimental soil was deficient in sulphur, response was not observed to applied sulphur. Inclusion of 30 kg sulphur along with 100% RDF or other levels of fertilizers (125 and 150%) did not result in any additional yield increment in this study. A seed cotton yield of 3665, 3747 and 3845 kg ha^{-1} was realized with addition of 30 kg S ha^{-1} along with 100%, 125% and 150% recommended doses of NPK respectively. This might be due to the fact that sulphur received through SSP was sufficient to meet the requirement of crop. Thus use of straight fertilizers like SSP to supply phosphorus not only reduced the cost of production but also helped in meeting the sulphur demand of crop. At higher levels of phosphorus (125 and 150%) inclusion of sulphur resulted in very little increment in yields. Further, kapas yield in soil test based fertilizer treatment (3688 kg ha^{-1}) was higher than the targeted yield of 25 q ha^{-1}. The reason was that, since no STCR equations were available for *Bt* cotton in Warangal region, equations developed for red soils of Kadapa region of Andhra Pradesh were used in this study. The result suggests the need for development and validation of new STCR equations for use in Warangal district, especially in the context of very high yield potential of recent *Bt* cotton hybrids as indicated by the yield in control (1249 kg ha^{-1}). These higher yields also indicate the nutrient mining ability of cotton hybrids to meet their nutrient requirements even under low nutrient supply.

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