



## Effect of fertilizer levels on nutrient availability and yield of cotton on Vertisol at Rahuri, District Ahemadnagar, India

A. N. Deshpande, R. S. Masram and B. M. Kamble\*

Department of Soil Science and Agricultural Chemistry, Mahatma Phule Agricultural University, Rahuri, Ahemadnagar- 413722 (Maharashtra), INDIA

Present address: Agricultural Research Station, K. Digraj, Sangli- 416 305 (Maharashtra), INDIA

\*Corresponding author: E-mail: bmkamble2007@rediffmail.com

Received: May 23, 2014 Revised received: August 16, 2014 ; Accepted: October 23, 2014

**Abstract** The field experiment on effect of fertilizer levels on nutrient availability and yield of cotton on Vertisol was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri during May to September, 2008. The experiment was laid out in factorial randomized block design with three replications and two main treatments i.e. hybrid Bt RCH-2 and Non-Bt RCH-2 and nine sub treatments with different fertilizer doses i.e. F<sub>1</sub> - No recommended doses of fertilizer (RDF), F<sub>2</sub> -50 % RDF, F<sub>3</sub> - 75 % RDF, F<sub>4</sub> - 100 % RDF, F<sub>5</sub> -125 % RDF, F<sub>6</sub> - 150 % RDF, F<sub>7</sub> - 100 % RDF + 2% DAP spray, F<sub>8</sub> -100 % RDF + 1 % MgSO<sub>4</sub> and F<sub>9</sub> -100 % RDF + 1% KNO<sub>3</sub>. The results revealed that the non-Bt hybrid recorded maximum nitrogen (435.67 kg ha<sup>-1</sup>) and potassium (565.45 kg ha<sup>-1</sup>) content in 100 % RDF + 1% KNO<sub>3</sub> treatment at boll development stage as compared to Bt hybrid. However, magnesium (0.09 kg ha<sup>-1</sup>) and iron (3.66 ppm) were maximum in 100 % RDF + 1 % MgSO<sub>4</sub> treatment in non-Bt as compared to Bt hybrid and phosphorus content (17.58 kg ha<sup>-1</sup>) was maximum in 100 % RDF + 2 % DAP treatment in Bt as compared to non-Bt hybrid at boll development stage. The application of 100 % RDF + 1 % MgSO<sub>4</sub> sprays were recorded highest yield of Bt (33.53 q ha<sup>-1</sup>) and non-Bt cotton hybrids (31.27 q ha<sup>-1</sup>).

**Keywords:** Cotton, Fertilizer, Nutrient availability, Yield

### INTRODUCTION

Cotton is known as white gold and queen of fibers. It is an important cash crop of global significance which plays a dominant role in world agriculture and industrial economy. India is important grower of cotton on a global scale. It is one of the important cash crop for Indian farmer and contributes around 30 per cent to gross domestic product of Indian agriculture. The acreage under cotton in 2012-13, was decreased by around 3% to 117.73 lakh hectares as against 121.78 lakh hectares in previous year and acreage under Bt cultivation has also declined to 88% of the total acreage of around 117.73 lakh hectares as against 91% in last year. The cotton productivity in 2012-13 has been at 518 kg ha<sup>-1</sup> as against 512 kg ha<sup>-1</sup> in the previous season (Anonymous, 2013). Cotton plays an important role in the Indian economy as the country's textile industry is predominantly cotton based. India is one of the largest producers as well as exporters of cotton yarn and the Indian textile industry contributes about 11 percent to industrial production, 14 per cent to the manufacturing sector, 4 percent to the GDP and 12 per cent to the country's total export earnings (Anonymous, 2014). Cotton is one of the important industrial crop playing a vital role in the

history of mankind and civilization by providing the basic fibres of typical nature for clothing cellulose from it's lint and oil. Considering this importance of cotton crop different attempts have been made to boost up it's production. To grow the Bt cotton is one of the major attempt which is now a days following everywhere in India, as well as specially in Vidharbha. The commercial cultivation of Bt cotton in the world first began in 1996. Development of transgenic Bt cotton hybrids were approved in India for commercial cultivation in March 2002. Bt cotton has been developed by transferring crystal protein gene (Cry 1AC) from a soil bacterium *Bacillus thuringiensis* var. *Kurstaki* into cotton. The hybrids with Cry 1AC gene are known as Boll guard-I which is resistance to bollworms and the hybrids with Cry 1AC gene and Cry 2Ab gene called Boll guard-II. Twenty Bt hybrids have been approved for commercial cultivation in different agro-climatic areas of the country. These hybrids are fast becoming popular with the cotton farmers (Singh and Kaushik, 2007). Though the area under the Bt cotton is substantial but productivity is not of its full potential and considerable reduction in yield of cotton is due to several reasons of abiotic and biotic stresses. The present investigation was undertaken to study the effect of fertilizer levels on

nutrient availability and yield of cotton.

## MATERIALS AND METHODS

The field experiment was conducted at Cotton Improvement Project Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri during May to September, 2008. The soil of experiment plot was montomorillonitic Typic Haplusterts, deep black with slightly alkaline in reaction pH (1:2.5) 7.8, electrical conductivity (dS m<sup>-1</sup>) 0.36, organic carbon (%) 0.58, CaCO<sub>3</sub>(%) 11.20, available nutrients (kg ha<sup>-1</sup>) N - 244.50, P - 12.90, K - 526.40 and Fe - 4.9, Mn - 8.0, Zn - 0.4, Cu - 2.20 (ppm). Seeds of Bt and non Bt (RCH-2) variety were obtained from private Mahyco seed company. The experiment was laid out in factorial randomized block design with three replications and two main treatments *i.e.* hybrid Bt RCH-2 and Non-Bt RCH-2 and nine sub treatments with different fertilizer doses *i.e.* F<sub>1</sub> - No RDF, F<sub>2</sub> -50 % RDF, F<sub>3</sub> - 75 % RDF, F<sub>4</sub> - 100 % RDF, F<sub>5</sub> -125 % RDF, F<sub>6</sub> - 150 % RDF, F<sub>7</sub> - 100 % RDF + 2 % DAP spray, F<sub>8</sub> -100 % RDF + 1 % MgSO<sub>4</sub> and F<sub>9</sub> -100 % RDF + 1 % KNO<sub>3</sub>. The common RDF for Bt as well as non Bt was 100 N, 50 P<sub>2</sub>O<sub>5</sub> and 50 K<sub>2</sub>O kg ha<sup>-1</sup>. Uniform 10 Mg ha<sup>-1</sup> FYM dose was applied to all 9 treatments including control. Total 3 sprays were given in treatment F<sub>7</sub>, F<sub>8</sub> and F<sub>9</sub>, 1<sup>st</sup> at boll development stage and further two sprays at 15 days interval thereafter. The common packages of practices were followed for both cotton hybrids. The nitrogen, phosphorus and potassium were applied through urea, single super phosphate and muriate of potash respectively as per recommended dose 50 per cent of nitrogen and full dose of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O (50:50:50 N:P<sub>2</sub>O<sub>5</sub> :K<sub>2</sub>O kg ha<sup>-1</sup>) was applied at the time of

sowing and the remaining nitrogen was applied in two doses. The composite soil sample before sowing was taken and the soil samples were collected from each plot at square formation, boll formation and boll development stages and dried in shade and prepared for laboratory analysis after grinding and passing through 2 mm sieve. The seed cotton from each net plot was picked and the same weighed separately at each picking. The total yield (q ha<sup>-1</sup>) was work out by summation of quantity of seed cotton picked in all pickings. Plot wise data on soil nutrient content and yield etc. was subjected to statistical analysis by statistical method for factorial randomized block design and accordingly interpretations of results were given (Panse and Sukhatme, 1985).

## RESULTS AND DISCUSSION

### Effect of fertilizer levels and nutrient sprays on soil parameters at different growth stages :

**Available nitrogen:** The nitrogen content in the soil progressively decreased from square formation to boll formation stage (Table 1). Non Bt hybrid recorded maximum content of soil nitrogen (236.54 kg ha<sup>-1</sup>), (230.46 kg ha<sup>-1</sup>) and (312.37 kg ha<sup>-1</sup>) as compared to Bt hybrid (230.36 kg ha<sup>-1</sup>), (226.1 kg ha<sup>-1</sup>) and (294.86 kg ha<sup>-1</sup>) from square formation to boll development stages. The treatment F<sub>9</sub> recorded maximum nitrogen content in the soil at square formation (245.87 kg ha<sup>-1</sup>), boll formation (239.87 kg ha<sup>-1</sup>) and at boll development stage (428.90 kg ha<sup>-1</sup>) and this was significantly superior over all treatments at square formation and at par with F<sub>8</sub> (238.89 kg ha<sup>-1</sup>) at boll formation and with F<sub>7</sub> (428.38 kg ha<sup>-1</sup>) at boll development stage. Nitrogen supply through foliar spray also stated that nitrogen

**Table 1.** Effect of levels of N, P, K and foliar sprays of nutrients on soil available nitrogen of Bt and non- Bt Cotton.

Treatment	Square formation			Boll formation			Boll development		
	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non - Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean
	<b>Available nitrogen (kg ha<sup>-1</sup>)</b>								
F <sub>1</sub> : Control	199.80	114.73	207.26	196.30	200.01	198.15	160.00	193.06	177.53
F <sub>2</sub> : 50 % RDF	219.33	227.88	223.60	217.99	224.25	221.10	295.97	208.03	202.00
F <sub>3</sub> : 75 % RDF	225.37	235.63	230.50	221.65	226.12	233.88	298.67	218.60	208.7
F <sub>4</sub> : 100 % RDF	239.70	239.30	239.50	234.03	237.87	235.95	410.97	429.37	420.17
F <sub>5</sub> : 125 % RDF	227.26	239.03	233.14	225.83	231.77	228.79	207.58	227.67	217.62
F <sub>6</sub> : 150 % RDF	235.10	241.68	238.39	228.92	235.45	232.19	218.71	231.37	225.04
F <sub>7</sub> : RDF+ 2 % DAP spray	240.97	242.90	241.43	235.21	240.47	237.84	421.47	435.30	428.38
F <sub>8</sub> : RDF + 1 % MgSO <sub>4</sub> spray	240.67	241.09	241.36	237.18	240.50	238.89	418.26	430.27	424.27
F <sub>9</sub> : RDF + 1 % KNO <sub>3</sub> spray	245.05	246.69	245.87	238.43	241.31	239.87	242.13	435.67	428.90
Mean	230.36	236.54	233.45	226.11	230.46	228.51	294.86	312.37	303.62
	H	F	H X F	H	F	H X F	H	F	H X F
SEM <sub>±</sub>	0.56	1.19	1.69	0.20	0.43	0.61	0.12	0.26	0.36
CD at 5 %	1.62	3.44	4.86	0.58	1.24	1.75	0.35	0.75	1.05

**Table 2.** Effect of levels of N, P, K and foliar sprays of nutrients on soil available phosphorus of Bt and non- Bt Cotton.

Treatment	Square formation			Boll formation			Boll development		
	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non - Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean
<b>Available phosphorus (kg ha<sup>-1</sup>)</b>									
F <sub>1</sub> : Control	14.10	14.00	14.05	15.01	14.82	14.91	16.81	16.50	16.66
F <sub>2</sub> : 50 % RDF	14.51	14.26	14.38	15.37	15.01	15.19	17.06	16.96	17.01
F <sub>3</sub> : 75 % RDF	14.57	14.46	14.51	15.48	15.26	15.37	17.17	17.05	17.11
F <sub>4</sub> : 100 % RDF	14.80	14.63	14.71	15.65	15.60	15.62	17.77	17.62	17.69
F <sub>5</sub> : 125 % RDF	14.66	14.55	14.61	15.54	15.37	15.46	17.30	17.23	17.26
F <sub>6</sub> : 150 % RDF	14.77	14.61	14.69	15.60	15.43	15.52	17.58	17.43	17.50
F <sub>7</sub> : RDF+ 2 % DAP spray	14.87	14.72	14.79	15.66	15.61	15.63	18.10	18.09	18.09
F <sub>8</sub> : RDF + 1 % MgSO <sub>4</sub> spray	14.82	14.65	14.73	15.66	15.62	15.64	17.89	17.69	17.79
F <sub>9</sub> : RDF + 1 % KNO <sub>3</sub> spray	14.83	14.67	14.75	15.66	15.65	15.65	18.15	18.02	18.09
Mean	14.66	14.50	15.68	15.52	15.37	15.44	17.54	17.40	17.47
	H	F	H X F	H	F	H X F	H	F	H X F
SEM <sup>+</sup>	0.003	0.007	0.010	0.003	0.007	0.010	0.010	0.022	0.31
CD at 5 %	0.010	0.021	0.029	0.009	0.020	0.028	0.030	0.063	0.089

**Table 3.** Effect of levels of N,P,K and foliar sprays of nutrients on soil available potassium of Bt and non- Bt cotton

Treatment	Square formation			Boll formation			Boll development		
	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean
<b>Available potassium (kg ha<sup>-1</sup>)</b>									
F <sub>1</sub> : Control	515.07	521.80	518.43	490.09	505.70	497.89	440.90	496.37	468.63
F <sub>2</sub> : 50 % RDF	526.93	544.30	535.62	552.14	526.21	599.17	482.27	508.43	496.85
F <sub>3</sub> : 75 % RDF	538.33	550.08	544.21	528.27	531.00	529.63	503.40	515.14	509.27
F <sub>4</sub> : 100 % RDF	559.73	562.03	560.88	550.49	554.27	552.38	534.33	542.14	538.24
F <sub>5</sub> : 125 % RDF	545.28	556.37	550.82	535.77	537.78	537.78	515.53	524.33	520.43
F <sub>6</sub> : 150 % RDF	558.27	560.70	559.48	548.33	548.24	548.28	528.00	535.33	531.66
F <sub>7</sub> : RDF+ 2 % DAP spray	561.33	564.05	562.69	558.24	557.90	558.07	550.00	552.16	551.08
F <sub>8</sub> : RDF + 1 % MgSO <sub>4</sub> spray	560.10	565.23	562.67	545.77	553.77	554.21	542.27	550.54	546.40
F <sub>9</sub> : RDF + 1 % KNO <sub>3</sub> spray	566.20	567.77	566.98	558.27	561.63	559.95	561.93	565.45	563.69
Mean	547.92	554.70	551.31	537.37	541.83	539.60	517.96	532.32	525.14
	H	F	H X F	H	F	H X F	H	F	H X F
SEM <sup>+</sup>	0.19	0.39	0.56	0.23	0.49	0.69	0.21	0.45	0.64
CD at 5 %	0.54	1.14	1.61	0.66	1.41	1.99	0.61	1.31	1.84

acts as promoter of vegetative growth of leaf, stem and other vegetative organs (Jadhao *et al.*, 2004). Ravankar *et al.* (2001) also observed that lower doses of nutrients decreased the yields as well as nutrient uptake by the crops. The interaction between Bt/ non Bt with different fertilizer dose was found significant at all growth stages. Treatment combination of H<sub>2</sub>F<sub>9</sub> recorded maximum soil nitrogen content at square formation (246.69 kg ha<sup>-1</sup>),

boll formation (241.31 kg ha<sup>-1</sup>) and boll development (435.67 kg ha<sup>-1</sup>) stages, however it was at par with H<sub>2</sub>F<sub>7</sub> (242.90 kg ha<sup>-1</sup>) at square formation H<sub>2</sub>F<sub>8</sub> (240.50 kg ha<sup>-1</sup>) and H<sub>2</sub>F<sub>7</sub> (240.47 kg ha<sup>-1</sup>) at boll formation. This clearly indicated that, the residual effect of soil nitrogen was more in non-Bt cotton hybrids than Bt cotton hybrids.

**Available phosphorus:** The phosphorus content in the

**Table 4.** Effect of levels of N,P,K and foliar sprays of nutrients on soil exchangeable magnesium of Bt and non- Bt cotton hybrid cotton.

Treatment	Square formation			Boll formation			Boll development		
	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean
<b>Exchangeable magnesium (kg ha<sup>-1</sup>)</b>									
F <sub>1</sub> : Control	1.03	1.11	1.07	0.01	0.007	0.04	0.01	0.07	0.04
F <sub>2</sub> : 50 % RDF	1.11	1.15	1.13	0.05	0.12	0.09	0.04	0.08	0.06
F <sub>3</sub> : 75 % RDF	1.14	1.19	1.16	0.09	0.12	0.11	0.06	0.08	0.07
F <sub>4</sub> : 100 % RDF	1.24	1.25	1.24	0.15	0.16	0.16	0.07	0.09	0.08
F <sub>5</sub> : 125 % RDF	1.16	1.21	1.18	0.11	0.13	0.12	0.06	0.09	0.07
F <sub>6</sub> : 150 % RDF	1.21	1.24	1.23	0.13	0.14	0.13	0.07	0.09	0.08
F <sub>7</sub> : RDF+ 2 % DAP spray	1.28	1.30	1.29	0.16	0.18	0.17	0.07	0.09	0.08
F <sub>8</sub> : RDF + 1 % MgSO <sub>4</sub> spray	1.30	1.31	1.30	0.17	0.19	0.18	0.08	0.09	0.09
F <sub>9</sub> : RDF + 1 % KNO <sub>3</sub> spray	1.28	1.29	1.28	0.17	0.18	0.18	0.07	0.09	0.08
Mean	1.19	1.23	1.21	0.12	0.14	0.13	0.06	0.08	0.07
	H	F	H X F	H	F	H X F	H	F	H X F
SEM <sup>±</sup>	0.004	0.008	0.011	0.002	0.004	0.005	0.000	0.001	0.001
CD at 5 %	0.01	0.02	0.03	0.005	0.010	0.014	0.001	0.002	0.002

**Table 5.** Effect of levels of N,P,K and foliar sprays of nutrients on DTPA extractable iron of Bt and non- Bt cotton.

Treatment	Square formation			Boll formation			Boll development		
	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean	H <sub>1</sub> : Bt	H <sub>2</sub> : Non-Bt	Mean
<b>DTPA Iron (ppm)</b>									
F <sub>1</sub> : Control	4.00	4.06	4.03	3.38	3.51	3.45	2.52	3.00	2.76
F <sub>2</sub> : 50 % RDF	4.29	4.61	4.30	3.68	4.20	3.94	3.01	3.24	3.12
F <sub>3</sub> : 75 % RDF	4.39	4.47	4.43	3.73	4.25	3.99	3.08	3.28	3.18
F <sub>4</sub> : 100 % RDF	4.59	4.61	4.60	4.52	4.62	4.57	3.32	3.46	3.39
F <sub>5</sub> : 125 % RDF	4.46	4.49	4.47	4.36	4.38	4.37	3.16	3.39	3.27
F <sub>6</sub> : 150 % RDF	4.54	4.61	4.57	4.44	4.43	4.44	3.24	3.41	3.32
F <sub>7</sub> : RDF+ 2 % DAP spray	4.80	4.84	4.82	4.76	4.80	4.78	3.43	3.59	3.51
F <sub>8</sub> : RDF + 1 % MgSO <sub>4</sub> spray	4.70	4.71	4.71	4.72	4.71	4.71	3.46	3.66	3.56
F <sub>9</sub> : RDF + 1 % KNO <sub>3</sub> spray	4.75	4.76	4.75	4.60	4.70	4.65	3.39	3.57	3.48
Mean	4.50	4.54	4.52	4.24	4.40	4.32	3.18	3.40	3.29
	H	F	H X F	H	F	H X F	H	F	H X F
SEM <sup>±</sup>	0.003	0.007	0.009	0.006	0.013	0.018	0.004	0.009	0.012
CD at 5 %	0.009	0.019	0.027	0.017	0.036	0.051	0.012	0.025	0.035

soil was slightly increased from square formation to boll development stage (Table 2). Bt hybrid was recorded maximum content of phosphorus (14.66 kg ha<sup>-1</sup>), (15.52 kg ha<sup>-1</sup>) and (17.54 kg ha<sup>-1</sup>) as compared to non Bt hybrid (14.50 kg ha<sup>-1</sup>), (15.37 kg ha<sup>-1</sup>) and (17.40 kg ha<sup>-1</sup>) at square formation, boll formation and development stage, respectively. The treatment F<sub>7</sub>

recorded maximum content of phosphorus (14.79 kg ha<sup>-1</sup>), however, there was not so much difference among the other treatments except F<sub>1</sub> (14.05 kg ha<sup>-1</sup>), F<sub>2</sub> (14.38 kg ha<sup>-1</sup>) and F<sub>3</sub> (14.51 kg ha<sup>-1</sup>) at square formation. Similar observations were recorded at boll formation and boll development stage. Phosphorus availability in soil increased with each

**Table 6.** Effect of levels of N, P, K and foliar sprays of nutrients on seed cotton yield of Bt and non- Bt cotton.

Treatment	H <sub>1</sub> : Bt	Yield (q ha <sup>-1</sup> )	
		H <sub>2</sub> : Non – Bt	Mean
F <sub>1</sub> : Control	15.89	14.40	15.14
F <sub>2</sub> : 50 % RDF	27.82	25.25	26.54
F <sub>3</sub> : 75 % RDF	29.11	27.16	28.16
F <sub>4</sub> : 100 % RDF	30.86	28.39	29.62
F <sub>5</sub> : 125 % RDF	29.93	27.72	28.83
F <sub>6</sub> : 150 % RDF	30.45	27.82	29.14
F <sub>7</sub> : RDF+ 2 % DAP spray	31.68	29.16	30.42
F <sub>8</sub> : RDF + 1 % MgSO <sub>4</sub> spray	33.53	31.27	32.40
F <sub>9</sub> : RDF + 1 % KNO <sub>3</sub> spray	32.35	29.98	31.17
Mean	29.07	26.80	27.83
	H	F	H X F
SEM <sub>±</sub>	0.56	1.23	1.69
CD at 5 %	1.68	3.69	N.S.

increment of fertilizer dose. However, increase in availability was not proportionate to added amount. Phosphorus availability in soil also increased with advancement in crop age. This could be ascribed to increase in root activity in soil. Plant roots excrete organic acids and chelating organic compounds in rhizosphere. These compounds form multiple complex compounds with Ca, Mg and/or Fe and thereby increased phosphorus availability in soil (Tinker, 1980). As regards the interaction effect between Bt/non Bt with different fertilizer levels was found to be significant at all growth stages. Treatment combination H<sub>1</sub>F<sub>7</sub> (14.87) recorded maximum soil available phosphorus content as compared to the other treatment combinations at square formation. More or less same trend was observed at boll formation and boll development stage. This clearly indicated that, more soil available phosphorus residue was under Bt cotton hybrid than non Bt cotton hybrid, which showed the greater absorption of soil phosphorus by non Bt than Bt as reflected in phosphorus leaf content of Bt and non Bt cotton. Jayakumar *et al.* (2014) showed the highest NPK of post harvest soil values were noticed with 150 per cent recommended dose of NPK and biofertilization. Higher availability of nutrients in the soil and thereby increased the nutrient uptake by the crop.

**Available potassium:** The available potassium content in the soil was decreased from square formation to boll development stage. Non Bt hybrid recorded maximum content of soil available potassium (554.70 kg ha<sup>-1</sup>), (541.83 kg ha<sup>-1</sup>) and (532.32 kg ha<sup>-1</sup>) as compared to Bt hybrid (547.92 kg ha<sup>-1</sup>), (537.37 kg ha<sup>-1</sup>) and (517.96 kg ha<sup>-1</sup>) at square formation, boll formation and boll development stage, respectively (Table 3). The soil available potassium content was more under treatment F<sub>9</sub> at square and boll formation stages (566.98 and 559.95 kg ha<sup>-1</sup>) as well as at boll development stage (563.69 kg ha<sup>-1</sup>). Similarly, Islamov

and Ishmukhame (1967) observed that reddening due to potassium deficiency can be reduced 50 per cent if 200 kg K ha<sup>-1</sup> was applied to soil before planting. As regards, the interaction between Bt/non Bt with different fertilizer levels was found to be significant at all growth stages. Treatment combination H<sub>2</sub>F<sub>9</sub> (567.77 kg ha<sup>-1</sup>) recorded maximum soil available potassium content as compared to H<sub>1</sub>F<sub>9</sub> (566.20 kg ha<sup>-1</sup>) and it was statistically superior over all other treatment combinations at square formation. Similar observations also recorded at boll formation and boll development stage H<sub>2</sub>F<sub>9</sub> (561.63 and 565.45 kg ha<sup>-1</sup>) was significantly superior over all other treatments tested. Soil application of potassium as well as foliar spray of fertilizers containing both these nutrients helps to maintain sufficient level of both N and K during boll development (Sekhon and Singh, 2013).

**Exchangeable magnesium:** The magnesium content in the soil was decreased from square formation to boll development stages. Non Bt hybrid was recorded maximum content of magnesium in the soil (1.23 kg ha<sup>-1</sup>), (0.14 kg ha<sup>-1</sup>) and (0.08 kg ha<sup>-1</sup>) as compared to Bt cotton (1.19 kg ha<sup>-1</sup>), (0.12 kg ha<sup>-1</sup>) and (0.06 kg ha<sup>-1</sup>) at square formation, boll formation and boll development stage, respectively (Table 4). The treatment F<sub>8</sub> recorded maximum magnesium content in the soil (1.30 kg ha<sup>-1</sup>) and it remained at par with F<sub>7</sub> and F<sub>9</sub> and treatment F<sub>8</sub> was statistically superior over the control F<sub>1</sub> (1.07 kg ha<sup>-1</sup>) at square formation. Concentration of Mg strongly responded N fertilization suggesting that cotton Mg nutrition depends on nitrogen fertilization more than the level of the Mg application (Tewolde *et al.*, 2010). Magnesium content in the soil was decreased as the growth stages increased. Similar observation recorded at boll formation stage. The H<sub>2</sub>F<sub>8</sub> was recorded maximum magnesium content in the soil at square formation (1.31 kg ha<sup>-1</sup>), boll formation (0.19 kg ha<sup>-1</sup>) and boll development stage (0.09 kg ha<sup>-1</sup>), however, it was at

par with H<sub>2</sub>F<sub>7</sub>, H<sub>2</sub>F<sub>9</sub>, H<sub>1</sub>F<sub>7</sub>, H<sub>1</sub>F<sub>8</sub> and H<sub>1</sub>F<sub>9</sub> at square formation, H<sub>2</sub>F<sub>7</sub>, H<sub>2</sub>F<sub>9</sub>, H<sub>1</sub>F<sub>8</sub> and H<sub>1</sub>F<sub>9</sub> at boll formation and H<sub>2</sub>F<sub>4</sub>, H<sub>2</sub>F<sub>5</sub>, H<sub>2</sub>F<sub>6</sub>, H<sub>2</sub>F<sub>7</sub> and H<sub>2</sub>F<sub>9</sub> at boll development stage.

**DTPA iron:** The iron content in the soil was decreased from square formation to boll development stages (Table 5). Non-Bt hybrid recorded maximum content in the soil (4.54 ppm), (4.40 ppm) and (3.40 ppm) as compared to Bt cotton (4.50 ppm), (4.24 ppm) and (3.18 ppm) at square formation, boll formation and boll development stage, respectively. The treatment F<sub>7</sub> recorded maximum iron content in the soil (4.82 and 4.78 ppm, respectively) which was significantly superior over all the treatments tested at square and boll formation. At boll formation stage, F<sub>8</sub> showed maximum DTPA extractable soil iron (3.56 ppm), which was significantly superior over all the tested treatments. As regards the interaction between Bt/non-Bt with different fertilizer doses was found to be significant at all growth stages. At square and boll formation stages, H<sub>2</sub>F<sub>7</sub> showed significantly higher DTPA extractable soil iron (4.84 and 4.80 ppm, respectively), however it was at par with H<sub>1</sub>F<sub>7</sub> (4.76 ppm) at boll formation stage. However, at boll development H<sub>2</sub>F<sub>8</sub> showed significantly higher DTPA soil iron than other tested treatments. Mimmo *et al.*, (2014) reported that an enhanced release of inorganic (such as protons) and organic (organic acids, carbohydrates, amino acids, phytosiderophores, siderophores, phenolics and enzymes) compounds to increase the solubility of poorly available Fe pools.

**Seed cotton yield:** The Bt hybrid recorded maximum seed cotton yield (29.07 q ha<sup>-1</sup>) as compared to non-Bt hybrid (26.80 q ha<sup>-1</sup>) (Table 6). The treatment F<sub>8</sub> (100 % RDF + 1 % MgSO<sub>4</sub>) had given higher seed cotton yield (32.40 q ha<sup>-1</sup>) which was at par with F<sub>9</sub> (100 % RDF + 1 % KNO<sub>3</sub>), F<sub>7</sub> (100 % RDF + 2 % DAP) and F<sub>6</sub> (150 % RDF) (31.17, 30.42 and 29.14 q ha<sup>-1</sup>, respectively). The application of 100 % RDF along with foliar spray of 1 % MgSO<sub>4</sub>/1 % KNO<sub>3</sub>/2 % DAP helped in reducing reddening of leaves in cotton, which was ultimately resulted in increasing the yield of cotton. The soil application of MgSO<sub>4</sub> 25 kg ha<sup>-1</sup> + 3 foliar sprays of 1% MgSO<sub>4</sub> and 1% 19:19:19 water soluble fertilizer along with RDF 100: 50: 50 kg NPK ha<sup>-1</sup> + FYM 10 t ha<sup>-1</sup> recorded significantly higher seed cotton yield (2781 kg ha<sup>-1</sup>) as compared to other nutritional treatments and it was on par with the soil application of MgSO<sub>4</sub> 25 kg ha<sup>-1</sup> + 3 foliar sprays of 1% MgSO<sub>4</sub> and 2% KNO<sub>3</sub> water soluble fertilizer along with RDF + FYM (Shivamurthy and Biradar, 2014). Nehra *et al.*, (2004) indicated that the application of 50% NPK+10 t FYM ha<sup>-1</sup>+foliar nutrition was recorded the highest seed cotton yield (1940 kg ha<sup>-1</sup>) and remained statistically on par with 100% NPK+5 t FYM ha<sup>-1</sup>, 50% NPK+10 t FYM ha<sup>-1</sup> and 100% NPK+10 t FYM ha<sup>-1</sup>. Singh *et al.* (2004) reported that the highest seed cotton yield was

obtained with KNO<sub>3</sub>, followed by 2% urea and these two treatments were at par with each other. Similarly, Prabhakar (1981) reported that leaf reddening has been found to be a serious physiological problem in cotton resulting in reduced yield to an extent of 50 per cent depending on the extent of incidence. The interaction between Bt/non-Bt with different fertilizer doses was found non-significant. On the basis of this trial it was concluded that the application of two foliar spray of 1 % MgSO<sub>4</sub> at boll development and 15 days thereafter first spray along with 100 % RDF + FYM or two foliar spray of 1% KNO<sub>3</sub> at boll development and 15 days thereafter first spray along with 100 % RDF + FYM or two foliar spray of 2 % DAP at boll development and 15 days thereafter first spray along with 100 % RDF + FYM appears to be better for increasing nutrient availability and yield of Bt cotton.

## REFERENCES

- Anonmyous (2013). The Cotton Corporation of India Ltd. 43<sup>rd</sup> Annual Report 2012-2013. pp-7.
- Anonmyous (2014). Cotton Industry India, Ministry of Textiles, Government of India.
- Islamov, I.I. and Ishmakhamedova, S.G. (1967). Application of potassium to cotton. *Khlop Kovodstvo*. 10 : 30 (Quoted from F.C.A. 1968 No. 1128).
- Jadhao, J.G., Jadhao, S.D., Ghodpage, R.M. and Ingole, A.S. (2004). Effect of different chemical sprays on reddening and morphological characters in cotton. *PKV Research Journal*, 28(2):225-228.
- Jayakumar, M. Surendran, U. and Manickasundaram, P. (2014). Drip fertigation effects on yield, nutrient uptake and soil fertility of Bt Cotton in semi arid tropics. *International Journal of Plant Production*, 8 (3):375 -390.
- Mimmo, T., Del Buono, D., Terzano, R., Tomasi, N., Vignani, G., Crecchio, C., Pinton, R., Zocchi, G. and Cesco, S. (2014). Rhizospheric organic compounds in the soil microorganism plant system: their role in iron availability. *European Journal of Soil Science*. doi: 10.1111/ejss.12158.
- Nehra, P. L. Kumawat P. D. and Nehara, K. C. (2004). Integrated nutrient management in hirsutum cotton. *Journal of Cotton Research Development*, 18(2): 177-179.
- Panse, V.G. and Sukhatme, P.V. (1985). Statistical methods for agricultural workers, ICAR Publication, New Delhi.
- Prabhakar, A. S. (1981). Agronomic investigation on irrigated cotton Ph.D. Thesis, University of Agricultural Sciences, Bangalore.
- Ravankar, H. N., Sujata, P. A. and Hadole, S. S. (2001). Distribution of organic matter in vertisols under long term fertilization to sorghum-wheat cropping sequence. *PKV Research Journal*, 25(1): 16-19.
- Sekhon, N. K and Singh, C. B. (2013). Plant nutrient status during boll development and seed cotton yield as affected by foliar application of different sources of potassium. *American Journal of Plant Sciences*, 4:1409-1417.
- Shivamurthy, D. and Biradar, D. P. (2014). Effect of foliar nutrition on growth, yield attributes and seed cotton yield of Bt cotton. *Karnataka Journal of Agricultural*

- Sciences*, 27 (1): 5-8.
- Singh, A., Rathore, P. and Pathak, D. (2004). Effect of foliar application of inorganic nutrients on yield of American cotton. *Journal of Cotton Research Development*, 18 (2): 169-171.
- Singh, J. and Kaushik, S. K. (2007). Bt cotton in India. Present - scenario and future prospects. *Indian Farming*, 56(11): 26-28.
- Tewolde, H., Adeli, A. Sistani, K.R. and Rowe, D. E. (2010). Potassium and magnesium nutrition of cotton fertilized with broiler litter. *The Journal of Cotton Science*, 14:1-12.
- Tinker, P. B. (1980). Role of rhizosphere microorganisms in phosphorus uptake by plants, In: R.C. Dinauer (Ed.), *The Role of Phosphorus in Agriculture*, ASA-CSSA-SSSA, Madison, WI, USA.