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Full Research Article

Effect of Fertilizer Levels and Foilar Application on Morphological Characters, Nutrient Content and Yield of Cotton

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Abstract

A field experiment on effect of fertilizer levels and foliar application on morpho-physiological, nutrient content, reddening and yield of cotton on Vertisol" was conducted at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India during May to September, 2008-09. The experiment was laid out in a 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. 50% recommended dose of fertilizer (RDF), 75% RDF, 100% RDF, 125% RDF, 150% RDF, 100% RDF+2% DAP spray, 100% RDF+1% $MgSO_4$ and 100% RDF+1% KNO_3. The non-Bt cotton hybrid showed pronounced effect on growth parameters than Bt cotton hybrid. The treatment 100% RDF at square and flowering recorded significant effects on biochemical parameters (Chlorophyll N, P, K, Mg and Fe content), which was maximum in non-Bt hybrid as compared to Bt cotton hybrid. At boll development stage, treatment 100% RDF+1% $MgSO_4$ was found to be the best for highest chlorophyll content in non-Bt than Bt cotton. The nutrient concentration in leaf was higher at square formation and goes on reducing as plant growth proceeded. The application 100% RDF along with three foliar sprays of 1% KNO_3 or 1% $MgSO_4$ or 2% DAP was found minimum intensity of reddening of leaves and increased yield of cotton.

1. Introduction

Cotton is an immensely important crop for the sustainable economy of India and livelihood of the Indian farming community. It is cultivated in about 33.9 mha across the world and in about 11.9 mha in the country (CICR, 2014). India accounts for about 32% of the global cotton area and currently ranking second after China. The production increased from a meager 2.3 m bales (170 kg lint bale^{-1}) in 1947-48 to a previous record production of 17.6 m bales in 1996-97 and an all time highest record of 37.5 m bales during 2013-14 (CICR,2014). 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. 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 decreasing soil fertility especially micronutrients, imbalanced use of fertilizer application and decreasing soil quality could be one of the reasons for the yield decline. Usually, a balanced optimum nutrient supply ensures optimum growth and ensures plant resistance which leads to depletion of nutrient and minimizing long term mining (Prasad et al., 2005). The nutrients are more important because in Bt cotton synchronized boll development altered the source-sink relationship due to rapid translocation of saccharides and nutrients from leaves to the developing bolls (Hebbar et al., 2007). To overcome these constraints, additional nutrition through foliar feeding is required over and above the normal fertilizer recommendation. Brar et al. (2008) opined that foliar application of water soluble complex fertilizers will act as a source of all major and micro nutrients, which helps in increasing the seed cotton yield. Foliar application of nutrients is highly beneficial, as crop benefits are achieved when the roots are unable to meet the nutrient requirement of the crop at a critical stage Foliar applications of K, especially late in the season when soil application may not be feasible or

effective, correct the deficiency quickly and efficiently. Brar et al. (2008) reported improvement in seed cotton yield with foliar application of potassium nitrate, irrespective of the soil status and soil applied K fertilizers. Various foliar fertilizers are available that vary in the concentration of nutrients, but the studies on their comparative usefulness for cotton are lacking. In view to above, the present investigation was undertaken to study the effect of fertilizer levels and foliar application on morpho physiological, nutrient content, leaf reddening and yield in Bt and non-Bt cotton.

2. Materials and Methods

The field experiment was conducted at Cotton Improvement Project Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India during May to September, 2008-09. 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^{-1}) 0.36 , Organic carbon (%) 0.58, $CaCO_3$ (%) 11.20 , Available nutrients (kg ha^{-1}) N 244.50, P 12.90,K 526.40, Fe 4.9, Mn 8.0, Zn 0.4 and Cu 2.2 (ppm). The experiment was laid out in a 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. control (F_1) O% recommended dose of fertilizer (RDF) 50% RDF(F_2), 75% RDF (F_3), 100% RDF (F_4), 125% RDF(F_5), 150% RDF (F_6), 100% RDF+2% DAP spray (F_7), 100% RDF+1% $MgSO_4$ (F_8), and 100% RDF+1% KNO_3 (F_9). The common RDF for Bt as well as non-Bt was 100 N, 50 P_2O_5 and 50 K_2O kg ha^{-1}. Uniform 10 t ha^{-1} FYM dose was applied to all nine treatments including control. Total three sprays of nutrients were given in treatments F_7, F_8 and F_9, 1st at boll development stage and further two sprays at 15 days interval thereafter. The recommended packages of practices were carried out. The nitrogen, phosphorus and potassium were applied through urea, single super phosphate and muriate of potash respectively as per recommended dose 50% of nitrogen and full dose of P_2O_5 and K_2O (50:50:50 N:P_2O_5:K_2O kg ha^{-1}) was applied at the time of sowing and the remaining nitrogen was applied in two split doses. The morphological observations viz.; plant height, percentage of leaf area affected with leaf reddening (%) and total dry matter per plant were recorded at square formation (45 days after sowing), flowering (65 days after sowing) and boll development stages (105 days after sowing). The seed cotton from each net plot was picked by hand in three time and weighed separately at each picking and total yield (kg ha^{-1}) was work out. Plot wise data on plant, nutrient content and yield etc. was subjected to statistical analysis by statistical method (Panse and Sukhatme, 1985). The plant samples also collected at square formation, flowering and boll development stages and prepared for laboratory analysis after drying in an oven at 70 °C and plant extract was prepared and analyzed for total N by micro-Kjeldahl method in H_2SO_4:H_2O_2 (1:1) digestion (Parkinson and Allen, 1975), total P by vanadomolybdate yellow color method in nitric acid H_2SO_4:$HClO_4$:HNO_3 (1:4:10) digestion (Jackson, 1973), total K on flame photometer in H_2SO_4:$HClO_4$:HNO_3 (1:4:10) (Chapman and Pratt, 1961) and Mg (Zoroski and Bureau, 1977). The chlorophyll content in leaves was estimated by colorimetric method extraction with 80% acetone (Sadasivam and Manickam,1992)

3. Results and Discussion

3.1. Effect of fertilizer levels and nutrient sprays on morphological parameters

3.1.1. Plant height (cm) and total dry matter per plant

The non-Bt hybrid recorded significantly higher plant height and as compared to Bt hybrid and at square formation, boll formation and boll development stages, respectively (Table 1 and 2). This might be due to that Bt cotton contain Cry 1Ac gene and non-Bt cotton has more vegetative growth as compared to Bt. The application of 100% RDF+2% DAP spray recorded significantly maximum plant height (35.90 cm) and which was at par with 100% RDF+1% KNO_3 (35.80 cm) and it was significantly superior over all other treatments at square formation stage. Similar trend was observed at flowering. At boll development stage, the treatment 100% RDF+2% DAP spray showed significant increase in plant height (104.74 cm) over all other treatments tested. The reason for increase in growth components might be due to additional application of macro nutrients (N, P and K) which might have increased the photosynthetic activity, enzyme activity and other biochemical process. The application of 100% RDF+1% KNO_3 spray recorded maximum dry matter plant^{-1} at all the three growth stages viz., square formation, flowering and boll development stages, however, it was at par with 100% RDF+1% $MgSO_4$ (19.08 g) at square formation stage, 100% RDF+1% $MgSO_4$ (73.52 and 277.22 g), 100% RDF+2% DAP spray (72.47 and 272.57 g) and 150% RDF (70.53 and 271.75 g) at flowering and boll development stages. Similar effects and observations were found by Pagare (2007). The soil application of $MgSO_4$ (25 kg ha^{-1})+3 foliar sprays of 1% $MgSO_4$ and 1% 19:19:19 water soluble fertilizer at 70, 90 and 110 DAS along with RDF (100: 50: 50 kg NPK ha^{-1})+FYM (10 t ha^{-1}) recorded significantly higher plant height and total dry matter production of cotton as compared to other nutritional treatments (Shivamurthy and Biradar, 2014). Pettigrew (2008) reported that potassium deficiency can lead to a reduction in both number of leaves and area of individual leaves. The interaction between Bt/non-Bt cotton hybrid and fertilizers doses was found statistically significant at boll formation and boll development stages

for plant height and at boll development stage.

3.2. Effect of fertilizer levels and nutrient sprays on biochemical parameters

3.2.1. Total chlorophyll content of affected (red) leaf

The chlorophyll content of leaves decreased from square formation to boll development stages. Chlorophyll content in case of affected (red) leaves in non-Bt cotton was recorded maximum as compared to Bt cotton and it was progressively decreased from square formation to boll development stages (Table 3). Further, it was also observed that chlorophyll content of non-Bt hybrid was maximum as compared to Bt hybrid at all the growth stages. The 100% RDF was recorded maximum chlorophyll content (1.27 mg g^{-1}) and 100% RDF+1% $MgSO_4$ (1.26), 100% RDF+1% KNO_3 (1.25) and 100% RDF+2% DAP spray (1.25) remained at par with 100% RDF and it was significantly superior over the all other treatments tested at square formation in affected leaves (Table 3). The treatments 100% RDF+2% DAP spray ,100% RDF+1% $MgSO_4$ and 100% RDF+1% KNO_3 were at par with each other

Table 1: Effect of levels of NPK and foliar sprays of nutrients on plant height (cm) of Bt and non-Bt Cotton

Treatments	Square formation (45 Days after sowing)			Flowering (65 Days after sowing)			Boll development (105 Days after sowing)		
	H_1: Bt	H_2: Non-Bt	Mean	H_1: Bt	H_2: Non-Bt	Mean	H_1: Bt	H_2: Non-Bt	Mean
F_1: Control	20.33	22.40	21.37	28.00	34.29	31.15	59.67	68.07	63.87
F_2: 50% RDF	28.81	30.89	29.85	47.12	55.17	51.14	90.32	91.37	90.84
F_3: 75% RDF	30.77	32.08	31.42	48.41	56.22	52.32	91.09	94.08	92.58
F_4: 100% RDF	33.23	36.12	34.67	55.81	66.47	61.14	95.64	97.74	96.69
F_5: 125% RDF	30.88	32.38	31.63	50.57	63.03	59.22	94.73	96.97	95.85
F_6: 150% RDF	33.03	36.03	34.53	55.40	63.03	59.22	94.73	93.97	95.85
F_7: RDF+2% DAP spray	34.17	37.63	35.90	59.27	75.26	67.26	100.96	108.52	104.74
F_8: RDF+1% $MgSO_4$ spray	33.07	35.80	34.43	58.65	67.37	63.00	99.93	101.40	100.66
F_9: RDF+1% KNO_3 spray	37.07	37.53	35.80	72.93	66.18	100.37	104.79	102.58	102.58
Mean	30.93	33.43	32.18	51.41	61.08	56.24	91.71	95.38	93.54
	H	F	HX F	H	F	HX F	H	F	HX F
SEm±	0.19	0.41	0.59	0.46	0.97	1.37	0.24	0.51	0.72
CD (p=0.05)	0.56	1.19	NS	1.31	2.78	3.93	0.69	1.46	2.6

H: Hybrid; F: Fertilizer; RDF: Recommended dose of fertilizer

Table 2: Effect of levels of NPK and foliar sprays of nutrients on total dry matter $plant^{-1}$ (g) of Bt and non-Bt Cotton hybrid cotton

Treatments	Square formation (45 Days after sowing)			Flowering (65 Days after sowing)			Boll development (105 Days after sowing)		
	H_1: Bt	H_2: Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2: Non-Bt	Mean
F_1: Control	8.73	12.17	10.45	29.13	48.70	38.92	107.97	172.03	140.00
F_2: 50% RDF	13.30	16.71	15.00	58.92	65.88	62.40	155.78	192.89	174.33
F_3: 75% RDF	14.33	16.33	15.33	60.58	71.56	66.07	205.50	222.12	213.81
F_4: 100% RDF	16.86	19.51	18.19	66.93	77.50	72.22	301.02	282.84	292.02
F_5: 125% RDF	15.30	17.83	16.56	63.04	72.09	67.58	209.80	229.50	219.65
F_6: 150% RDF	16.33	19.33	17.83	65.87	75.20	70.53	263.70	279.80	271.75
F_7: RDF+2% DAP spray	17.97	20.20	19.08	67.13	79.90	73.52	273.70	280.73	277.22
F_8: RDF+1% $MgSO_4$ spray	18.80	21.37	20.08	79.60	80.73	75.17	296.63	303.65	286.64
F_9: RDF+1% KNO_3 spray	15.46	18.12	16.79	60.71	72.37	66.54	288.07	249.27	238.67
Mean	15.46	18.12	16.79	60.71	72.37	66.54	218.07	249.26	238.67
	H	F	H×F	H	F	H×F	H	F	H×F
SEm±	0.19	0.39	0.56	0.82	1.74	2.47	3.01	6.39	6.04
CD (p=0.05)	0.53	1.13	NS	2.36	5.01	NS	8.66	18.38	25.99

H:Hybrid; F: Fertilizer; RDF: Recommended dose of fertilizer

at flowering and boll development stage. Chlorophyll content was higher in plants sprayed by foliar potassium fertilizers (Chapagain and Wiesma , 2004). In respect to interaction effect between Bt/ non-Bt with fertilizer levels found significant at boll formation stage and boll development stage. The treatments 100% RDF+2% DAP spray and 100% RDF+1% $MgSO_4$ to Bt and non-Bt cotton showed higher chlorophyll content of leaves at boll formation and boll development stage. The increase in chlorophyll content of affected leaves due to application of foliar nutrients at boll development stage indicated high requirement of nutrients by Bt cotton hybrid at boll development stage, which can be met through nutrient sprays. The total chlorophyll content was significantly higher with recommended dose of fertilizer based on soil test value with 10 t FYM ha^{-1} with one spray of each of 1% and 2% Urea and 1% $MgSO_4$ during flowering to boll development stage (Patel et al., 2011)

3.3. Effect of fertilizer levels and nutrient sprays on nutrient content in leaves

3.3.1. Nitrogen and magnesium content of affected leaves

The leaf nitrogen and magnesium content of the Bt and non-Bt hybrid decreased progressively from square formation to boll development stages. Nitrogen and magnesium content in the affected leaves in non-Bt cotton was recorded higher as compared to Bt hybrid and it was decreased from square formation to boll development stages (Table 4 and 5). The application of 100% RDF+1% KNO_3 recorded maximum nitrogen content (1.72%) which was at par with 100% RDF+2% DAP spray (1.68%) at square formation. The application of 100% RDF+1% KNO_3 showed statistically higher nitrogen content (1.63 and 1.21%) at flowering and boll development stage, respectively. The application of 100% RDF+1% $MgSO_4$ recorded highest magnesium content of leaves (1.05%) at square formation and it remained at par with 100% RDF+2% DAP spray (1.04%) and it was significantly superior over the all other treatments tested. The application of 100% RDF+1% $MgSO_4$ showed highest magnesium content (1.04%) at boll formation stage and boll development and it remained at par with 100% RDF+2% DAP spray (0.77%), 100% RDF+1% KNO_3 (0.77%), 150% RDF (0.77%) and 100% RDF (0.76%). In respect to interaction between Bt/non-Bt with fertilizer levels found non significant at boll development stage and significant results were found at flowering. Sekhon and Singh (2013) reported that the only N and K contents of premature senesced leaves were below the sufficiency range for cotton sufficient levels of P, Fe, Mn, Zn and Cu were observed. Though the concentrations of N and K in both the petiole and leaf blade initially improved with foliar spray, N content declined below the unsprayed control at later stages.

3.3.2. Phosphorus content of leaves

The phosphorus content of leaves was slightly increased from square formation to flowering stage, but at boll development stage it was slightly declined. Bt hybrid contain maximum percentage of phosphorus as compared to non-Bt hybrid at square formation, flowering and boll development stage, respectively. The application of 100% RDF+2% DAP spray recorded significantly maximum phosphorus content in the leaves at all three growth stages and which was at par with

Table 3: Effect of levels of NPK and foliar sprays of nutrients on total chlorophyll content of affected (mg g^{-1}) of Bt and non-Bt Cotton hybrid cotton

Treatments	Square formation (45 Days after sowing)			Flowering (65 Days after sowing)			Boll development (105 Days after sowing)		
	H_1: Bt	H_2: Non-Bt	Mean	H_1: Bt	H_2: Non-Bt	Mean	H_1: Bt	H_2: Non-Bt	Mean
F_1: Control	1.10	1.18	1.14	0.57	0.80	0.68	0.41	0.52	0.46
F_2: 50% RDF	1.16	1.19	1.18	0.93	1.00	0.97	0.58	0.65	0.62
F_3: 75% RDF	1.16	1.20	1.18	0.97	1.02	0.99	0.68	0.74	0.71
F_4: 100% RDF	1.26	1.26	1.27	1.03	1.06	1.05	0.85	0.91	0.88
F_5: 125% RDF	1.17	1.21	1.19	0.97	1.02	0.99	0.79	0.75	0.70
F_6: 150% RDF	1.19	1.24	1.22	1.00	1.06	1.04	0.67	0.86	0.67
F_7: RDF+2% DAP spray	1.24	1.26	1.25	1.01	1.08	1.05	1.15	1.13	1.14
F_8: RDF+1% $MgSO_4$ spray	1.25	1.27	1.26	1.01	1.08	1.05	1.17	1.15	1.17
F_9: RDF+1% KNO_3 spray	1.23	1.27	1.25	1.00	1.06	1.03	1.17	1.16	1.16
Mean	1.19	1.23	1.22	0.95	1.02	0.98	0.83	0.85	0.84
	H	F	HX F	H	F	HX F	H	F	HX F
SEm±	0.005	0.011	0.016	0.005	0.011	0.015	0.004	0.009	0.013
CD (p=0.05)	0.01	0.03	N.S	0.01	0.03	0.04	0.01	0.03	0.04

H: Hybrid; F: Fertilizer; RDF: Recommended dose of fertilizer

100% RDF+1% $MgSO_4$ at square and flowering stage, however application of 100% RDF+2% DAP spray was at par with 100% RDF (0.87%) and statistically significant over all other treatments at boll development. The treatment 100% RDF+2% DAP spray to Bt and non-Bt cotton (0.89%) were recorded higher phosphorus content.

3.3.4. Potassium and iron content of leaves

The potassium and iron content of leaves progressively decreases from square formation to boll development stages. Non-Bt hybrid recorded maximum potassium and iron content in leaves and as compared to Bt hybrid at square formation, flowering and boll development stage, respectively (Table 6 and 7). The application of 100% RDF+1% KNO_3 recorded significantly higher potassium content in leaves at all three stages which was at par with 100% RDF+2% DAP spray and it was significantly superior over the control (2.93%). Similar observation was also recorded by Jadhao et al. (2004). Hussein et al. (2006) found that N and K concentrations in shoots of barley plants were increased as a result of K application. The interaction effect between Bt cotton hybrids and fertilizer treatments were significant at boll formation and boll development stages (Table 6). The application of 100% RDF+1% KNO_3 to non-Bt cotton exhibited significantly superior potassium content at flowering and at boll development stages; however, it was at par with 100% RDF+2% DAP spray at both the stages. The application of 100% RDF recorded maximum iron content in the leaves (12.13 ppm) and 100% RDF+1% $MgSO_4$ (12.11 ppm) and 100% RDF+1% KNO_3 (12.09 ppm) remained at par with each other and it was significantly superior over all other treatments tested at square formation (Table 7). The application of 100% RDF+1% $MgSO_4$ showed statistically significant higher Fe content at flowering (9.04 ppm) and boll development (11.59 ppm) stages over all other treatments tested. In respect to interaction between Bt/ non-Bt with fertilizer doses was found significant at all growth stages.

Table 4: Effect of levels of NPK and foliar sprays of nutrients on nitrogen content of affected (red) Bt leaves (%) of Bt and non-Bt Cotton

Treatments	Square formation (45 Days after sowing)			Flowering (65 Days after sowing)			Boll development (105 Days after sowing)		
	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean
F_1: Control	1.01 (5.74)	1.24 (6.38)	1.13 (6.06)	1.01 (5.79)	1.14 (6.11)	1.07 (5.92)	0.09 (1.81)	0.17 (2.25)	0.13 (2.03)
F_2: 50% RDF	1.24 (6.38)	1.52 (7.03)	1.38 (6.70)	1.02 (5.83)	1.38 (6.79)	1.19 (6.31)	0.62 (4.44)	0.78 (5.12)	0.69 (4.78)
F_3: 75% RDF	1.44 (6.95)	1.68 (7.42)	1.56 (7.18)	1.25 (6.46)	1.45 (6.87)	1.35 (6.66)	0.87 (5.44)	1.01 (5.73)	0.94 (5.59)
F_4: 100% RDF	1.23 (6.38)	1.51 (7.03)	1.37 (6.70)	1.29 (6.53)	1.69 (7.42)	1.49 (6.97)	0.99 (5.72)	1.24 (6.38)	1.11 (6.05)
F_5: 125% RDF	1.18 (6.20)	1.69 (7.42)	1.53 (6.80)	1.27 (6.38)	1.51 (7.03)	1.39 (6.70)	0.87 (5.54)	1.03 (5.74)	0.95 (5.64)
F_6: 150% RDF	1.41 (6.80)	1.52 (7.03)	1.47 (6.91)	1.44 (6.88)	1.51 (7.03)	1.47 (6.95)	0.96 (5.54)	1.26 (6.38)	1.11 (5.96)
F_7: RDF+2% DAP spray	1.55 (7.17)	1.82 (7.71)	1.68 (7.41)	1.52 (7.03)	1.51 (7.03)	1.52 (7.03)	1.05 (5.93)	1.18 (6.20)	1.72 (6.06)
F_8: RDF+1% $MgSO_4$ spray	1.51 (7.03)	1.79 (7.71)	1.65 (7.37)	1.51 (7.03)	1.52 (7.03)	1.51 (7.03)	1.01 (5.83)	1.08 (5.83)	1.05 (5.83)
F_9: RDF+1% KNO_3 spray	1.52 (7.03)	1.92 (7.92)	1.72 (7.47)	1.58 (7.11)	1.69 (7.26)	1.63 (7.19)	1.14 (5.93)	1.28 (6.46)	1.21 (6.19)
Mean	1.34 (6.62)	1.63 (7.29)	1.49 (6.96)	1.32 (6.55)	1.49 (6.95)	1.40 (6.75)	0.84 (5.13)	1.00 (5.57)	0.92 (5.35)
	H	F	HX F	H	F	HX F	H	F	HX F
SEm±	0.008 (0.02)	0.017 (0.04)	0.025 (0.05)	0.01 (0.04)	0.03 (0.08)	0.04 (0.011)	0.01 (0.05)	0.03 (0.10)	0.04 (0.14)
CD (p=0.05)	0.024 (0.05)	0.05 (0.10)	0.071 (0.15)	0.042 (0.11)	0.089 (0.23)	0.13 (0.33)	0.04 (0.014)	0.08 (0.029)	N.S (N.S)

H:Hybrid; F: Fertilizer; RDF: Recommended dose of fertilizer; Figures in parenthesis indicates arcsine values

The application of 100% RDF+2% DAP spray to non-Bt cotton showed higher iron content of leaves at square formation, which was at par with 100% RDF, 100% RDF+1% $MgSO_4$ and 100% RDF+1% KNO_3, however, the iron content of leaves at flowering and boll development stage was significantly higher in 100% RDF+1% $MgSO_4$.

3.4. Effect of fertilizer levels and nutrient sprays on percentage of plant affected with reddening of leaves

The percentage of plants affected with reddening was observed maximum in Bt hybrid as compared to non-Bt hybrid and it was increased from square formation to boll development stage in both the hybrids (Table 8). The highest percentage of reddening in Bt hybrid was observed at boll development stage (26.25%). Bt hybrid recorded maximum reddening percentage of as compared to non-Bt hybrid at square formation, flowering and boll development stage. The higher dose of nitrogen along with phosphorus and potash may be beneficial for the control of reddening of leaves. Such type of observations also recorded by Bell et al. (2006). The percentage of plant affected with reddening of leaves was progressively increased from square formation to boll development stage. The application of 100% RDF recorded minimum percentage of plant affected with reddening at square formation and flowering stage, respectively. However, it was at par with 150% RDF, 100% RDF+2% DAP spray, 100% RDF+1% $MgSO_4$ and 100% RDF+1% KNO_3 at both the development stages. Similar trend was also observed at boll development stage. The evidence of the highest reddening in control treatment than the treatments of 100% RDF and 100% RDF+foliar sprays at all the growth stages. The application of recommended dose of fertilizer based on soil test value along with one spray of each of 1% and 2% urea and 1% $MgSO_4$ during flowering to boll development stage significantly reduced incidence of leaf reddening in Bt cotton (Patel et al.2011). The interaction effect with fertilizer

Table 5: Effect of levels of NPK and foliar sprays of nutrients on magnesium content of affected (red) leaves (%) of Bt and non-Bt Cotton

Treatments	Square formation (45 Days after sowing)			Flowering (65 Days after sowing)			Boll development (105 Days after sowing)		
	H_1: Bt	H_2: Non-Bt	Mean	H_1: Bt	H_2: Non-Bt	Mean	H_1: Bt	H_2: Non-Bt	Mean
F_1: Control	0.79 (5.13)	0.85 (5.13)	0.82 (5.43)	0.72 (4.80)	0.81 (5.13)	0.77 (4.96)	0.42 (3.63)	0.53 (4.05)	0.48 (3.84)
F_2: 50% RDF	0.82 (5.13)	0.87 (5.44)	0.84 (5.28)	0.79 (5.13)	0.88 (5.34)	0.84 (5.23)	0.66 (4.68)	0.72 (4.91)	0.69 (4.79)
F_3: 75% RDF	0.89 (5.34)	0.95 (5.54)	0.92 (5.44)	0.82 (5.13)	0.92 (5.44)	0.87 (5.28)	0.69 (4.68)	0.77 (5.13)	0.73 (4.90)
F_4: 100% RDF	0.91 (5.44)	1.00 (5.74)	0.96 (5.59)	0.84 (5.23)	0.95 (5.54)	0.89 (5.39)	0.72 (4.91)	0.79 (5.13)	0.76 (5.02)
F_5: 125% RDF	0.86 (5.34)	0.95 (5.54)	0.91 (5.44)	0.84 (5.13)	0.94 (5.44)	0.89 (5.28)	0.71 (4.80)	0.75 (4.91)	0.73 (4.85)
F_6: 150% RDF	0.89 (5.44)	0.99 (5.64)	0.94 (5.54)	0.87 (5.34)	0.99 (5.74)	0.93 (5.54)	0.75 (4.91)	0.79 (5.13)	0.77 (5.02)
F_7: RDF+2% DAP spray	1.00 (5.74)	1.07 (5.83)	1.04 (5.79)	1.00 (5.74)	1.03 (5.74)	1.01 (5.74)	0.73 (4.80)	0.83 (5.13)	0.77 (4.96)
F_8: RDF+1% $MgSO_4$ spray	1.01 5.74)	1.08 (5.93)	1.05 (5.83)	1.01 (5.74)	1.07 (5.92)	1.04 (5.83)	0.78 (5.13)	0.86 (5.23)	0.78 (4.96)
F_9: RDF+1% KNO_3 spray	1.00 (5.64)	1.01 (5.92)	1.00 (5.78)	0.99 (5.74)	1.01 (5.74)	1.00 (5.74)	0.73 (4.80)	0.82 (5.13)	0.77 (4.96)
Mean	0.91 (5.44)	0.98 (5.67)	0.94 (5.55)	0.88 (5.33)	0.96 (5.55)	0.92 (5.44)	0.69 (4.70)	0.76 (4.97)	0.73 (4.84)
	H	F	HX F	H	F	HX F	H	F	HX F
SEm±	0.004 (0.030)	0.009 (0.064)	0.013 (0.090)	0.003 (0.017)	0.006 (0.036)	0.008 (0.051)	0.004 (0.022)	0.010 (0.047)	0.013 (0.066)
CD (p=0.05)	0.01 (0.08)	0.03 (0.18)	N.S (N.S)	0.008 (0.049)	0.016 (0.10)	0.023 (0.15)	0.013 (0.06)	0.03 (0.13)	N.S (N.S)

H: Hybrid; F: Fertilizer; RDF: Recommended dose of fertilizer; Figures in parenthesis indicates arcsine values

levels and Bt and non-Bt cotton was non-significant at square formation and boll development stage, but it was significant at flowering stage. Among the fertilizer treatments of Bt cotton, the minimum percentage of plants affected with reddening at flowering stage was in the treatment 100% RDF+2% DAP spray, however, it was at par with 100% RDF+1% $MgSO_4$ and 100% RDF+1% KNO_3. In case of non-Bt varieties, 100% RDF+1% $MgSO_4$ showed minimum plant^{-1} reddening at flowering stage (3.67%), however it was at par with all other treatments tested except control. It is concluded from the study that, Bt hybrids were more susceptible to reddening than non-Bt. The reddening was increased from square formation to flowering stage. Application of higher doses of NPK and foliar sprays of 2% DAP,1% $MgSO_4$ and 1% KNO_3 helped in reducing reddening of plants.

3.5. Seed cotton yield

The Bt hybrid recorded maximum seed cotton yield (2907 kg ha^{-1}) as compared to non-Bt hybrid (2680 kg ha^{-1}) (Table 9). The application of 100% RDF+1% $MgSO_4$ had given higher seed cotton yield (3240 kg ha^{-1}) which was at par with 100% RDF+1% KNO_3, 100% RDF+2% DAP and 150% RDF (3117, 3042 and 2914 kg ha^{-1}, respectively). The application of 100% RDF along with three foliar sprays of 1% $MgSO_4$ or 1% KNO_3 or 2% DAP helped in reducing reddening of leaves in cotton, which was ultimately resulted in increasing the yield of cotton, however, this effect was more pronounced under Bt cotton hybrids than non-Bt cotton hybrids. Basal application of murieta of potash (MOP) increased seed cotton yield by 19%. Four foliar sprays of KNO_3, NPK, MOP and MOP+urea recorded yield increase in seed cotton yield of 22.8%, 22.4%, 18.5% and 24.5%, respectively over unsprayed control (Sekhon and Singh, 2013). The soil application of $MgSO_4$ (25 kg ha^{-1})+3 foliar sprays of 1% $MgSO_4$ and 1% 19:19:19 water soluble fertilizer at 70, 90 and 110 DAS along with RDF (100: 50:50 kg NPK ha^{-1})+FYM (10 t ha^{-1}) recorded significantly higher seed cotton yield (2781 kg ha^{-1}) as compared to other

Table 6: Effect of levels of NPK and foliar sprays of nutrients on potassium content of (%) of leaves of Bt and non-Bt Cotton

Treatments	Square formation (45 Days after sowing)			Flowering (65 Days after sowing)			Boll development (105 Days after sowing)		
	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean
F_1: Control	2.88 (9.74)	2.98 (9.91)	2.93 (9.84)	2.00 (8.13)	2.32 (8.72)	2.16 (8.42)	1.08 (5.93)	1.48 (7.03)	1.28 (6.48)
F_2: 50% RDF	2.99 (9.97)	3.07 (10.08)	3.03 (10.03)	2.22 (8.53)	2.44 (8.97)	2.33 (8.75)	1.32 (6.55)	1.59 (7.27)	1.46 (6.91)
F_3: 75% RDF	3.06 (10.02)	3.12 (10.14)	3.09 (10.08)	2.33 (8.72)	2.54 (9.16)	2.44 (8.94)	1.42 (6.80)	1.66 (7.34)	1.54 (7.07)
F_4: 100% RDF	2.13 (10.14)	3.28 (10.41)	3.20 (10.28)	2.45 (8.97)	2.83 (9.63)	2.64 (9.30)	1.58 (7.19)	1.48 (7.85)	1.73 (7.72)
F_5: 125% RDF	3.08 (10.14)	3.17 (10.25)	3.12 (10.19)	2.40 (8.91)	2.61 (9.28)	2.50 (9.09)	1.46 (6.95)	1.76 (7.56)	1.61 (7.26)
F_6: 150% RDF	3.09 (10.14)	3.22 (10.30)	3.16 (10.22)	2.44 (8.97)	2.75 (9.52)	2.59 (9.24)	1.50 (7.03)	1.82 (7.71)	1.66 (7.37)
F_7: RDF+2% DAP spray	3.16 (10.19)	3.31 (10.47)	3.23 (10.33)	2.51 (9.10)	2.94 (9.86)	2.73 (9.48)	1.79 (7.71)	1.93 (7.92)	1.86 (7.81)
F_8: RDF+1% $MgSO_4$ spray	3.07 (10.0)	3.24 (10.36)	3.16 (10.22)	2.44 (8.97)	2.87 (9.69)	2.65 (9.33)	1.71 (7.49)	1.90 (7.92)	1.81 (7.70)
F_9: RDF+1% KNO_3 spray	3.18 (10.25)	3.33 (10.47)	2.25 (10.36)	2.53 (9.10)	2.96 (9.86)	2.47 (9.88)	1.82 (7.71)	1.95 (7.92)	1.81 (7.70)
Mean	3.07 (10.07)	3.19 (10.27)	3.13 (10.17)	2.37 (8.82)	2.69 (9.41)	2.53 (9.12)	1.52 (7.04)	1.77 (7.62)	1.65 (7.33)
	H	F	HX F	H	F	HX F	H	F	HX F
SEm±	0.004 (0.014)	0.009 (0.29)	0.013 (0.041)	0.007 (0.01)	0.015 (0.013)	0.021 (0.04)	0.005 (0.002)	0.010 (0.03)	0.014 (0.05)
CD (p=0.05)	0.012 (0.04)	0.026 (0.08)	0.037 (N.S)	0.020 (0.04)	0.04 (0.09)	0.06 (0.012)	0.013 (0.05)	0.028 (0.09)	0.039 (0.14)

H: Hybrid; F: Fertilizer; RDF: Recommended dose of fertilizer; Figures in parenthesis indicates arcsine values

Table 7: Effect of levels of NPK and foliar sprays of nutrients on Iron content (ppm) of Bt and non-Bt cotton

Treatments	Square formation (45 Days after sowing)			Flowering (65 Days after sowing)			Boll development (105 Days after sowing)		
	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean
F_1: Control	11.45	11.62	11.53	15.72	6.01	5.87	4.82	5.26	5.04
F_2: 50% RDF	11.59	11.83	11.71	7.87	8.24	8.04	5.31	5.81	5.65
F_3: 75% RDF	11.64	11.97	11.81	8.11	8.41	8.26	5.54	6.17	5.85
F_4: 100% RDF	12.07	12.19	12.13	8.60	8.74	8.67	8.01	10.22	9.11
F_5: 125% RDF	11.70	12.05	11.88	8.26	8.41	8.33	5.82	6.64	6.23
F_6: 150% RDF	11.87	12.11	11.19	8.54	8.62	8.58	6.01	6.94	6.48
F_7: RDF+2% DAP spray	12.00	12.19	12.00	8.89	9.11	9.00	8.44	10.72	9.58
F_8: RDF+1% $MgSO_4$ spray	12.07	12.16	12.11	8.92	19.16	9.04	10.37	12.81	11.59
F_9: RDF+1% KNO_3 spray	12.03	12.15	12.09	8.81	9.03	8.92	7.41	9.51	8.46
Mean	11.83	72.03	11.93	8.19	8.41	8.30	6.86	8.23	7.55
	H	F	H X F	H	F	H X F	H	F	H X F
SEm±	0.01	0.02	0.03	0.005	0.010	0.015	0.004	0.009	0.013
CD (p=0.05)	0.03	0.06	0.08	0.01	0.03	0.004	0.01	0.03	0.04

H:Hybrid F: Fertilizer RDF: Recommended dose of fertilizer

Table 8: Effect of levels of NPK and foliar sprays of nutrients on percentage of plant affected with reddening of leaves of Bt and non-Bt Cotton

Treatments	Square formation (45 Days after sowing)			Flowering (65 Days after sowing)			Boll development (105 Days after sowing)		
	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean	H_1: Bt	H_2 : Non-Bt	Mean
F_1: Control	6.97 (15.34)	4.45 (12.11)	5.71 (13.81)	25.14 (30.07)	6.52 (14.77)	15.83 (23.42)	35.52 (36.59)	16.35 (23.85)	25.94 (30.22)
F_2: 50% RDF	5.24 (13.18)	1.88 (7.92)	3.56 (10.94)	17.79 (24.95)	4.77 (12.66)	11.28 (19.64)	28.27 (22.00)	9.99 (18.39)	19.13 (25.19)
F_3: 75% RDF	4.80 (12.66)	1.47 (7.03)	3.13 (10.14)	17.17 (24.50)	4.66 (12.52)	10.91 (19.18)	27.93 31.89)	9.05 (17.49)	18.49 (24.69)
F_4: 100% RDF	3.73 (11.09)	1.30 (6.50)	2.52 (9.10)	15.53 (23.18)	3.76 (11.24)	9.65 (18.05)	26.10 (30.64)	7.28 (15.63)	16.69 (23.14)
F_5: 125% RDF	4.68 (12.52)	0.07 (8.33)	3.37 (10.63)	16.83 (24.20)	4.65 (12.38)	10.74 (19.09)	27.72 (31.71)	8.47 (16.92)	18.09 (24.31)
F_6: 150% RDF	3.70 (11.09)	1.42 (6.80)	2.56 (9.28)	16.13 (23.66)	4.42 (12.11)	10.27 (18.72)	27.13 (31.35)	8.01 (16.43)	17.57 (23.89)
F_7: RDF+2% DAP spray	3.87 (11.39)	1.36 (6.80)	2.61 (9.28)	13.00 (21.13)	3.77 (11.24)	8.38 (16.85)	22.30 (27.98)	7.13 (15.44)	14.72 (21.71)
F_8: RDF+1% $MgSO_4$ spray	3.80 (11.24)	1.30 (6.55)	2.55 (9.10)	13.50 (21.56)	3.67 (11.09)	8.58 (17.05)	21.10 (27.31)	6.90 (15.21)	14.00 (21.26)
F_9: RDF+1% KNO_3 spray	3.90 (11.39)	1.26 (1.55)	2.58 (9.28)	14.00 (21.97)	3.83 (11.24)	8.92 (17.36)	20.20 (26.51)	6.37 (14.61)	13.29 (20.56)
Mean	4.52 (12.25)	1.83 (7.71)	3.18 (10.30)	15.57 (23.26)	4.45 (12.11)	10.51 (18.91)	26.25 (30.66)	8.84 (17.11)	17.55 (23.89)
	H	F	HX F	H	F	HX F	H	F	HX F
SEm±	0.09 (0.14)	0.19 (0.29)	0.27 (0.41)	0.37 (0.29)	0.78 (0.62)	1.10 (0.88)	0.69 (0.47)	1.47 (1.00)	2.07 (1.41)
CD (p=0.05)	0.26 (0.39)	0.55 (0.84)	N.S (N.S)	1.06 (0.84)	2.24 (1.79)	3.17 (N.S)	1.99 (1.35)	4.22 (2.87)	N.S (N.S)

H: Hybrid; F: Fertilizer; RDF: Recommended dose of fertilizer; Figures in parenthesis indicates arcsine values

Table 9: Effect of levels of N,P.K and foliar sprays of nutrients on seed cotton yield (kg ha^{-1}) of Bt and non-Bt cotton

Treatments	H_1: Bt	H_2 : Non-Bt	Mean
F_1: Control	1589	1440	1514
F_2: 50% RDF	2782	2525	2654
F_3: 75% RDF	2911	2716	2816
F_4: 100% RDF	3086	2839	2962
F_5: 125% RDF	2993	2772	2883
F_6: 150% RDF	3045	2782	2914
F_7: RDF+2% DAP spray	3168	2916	3042
F_8: RDF+1% $MgSO_4$ spray	3353	3127	3240
F_9: RDF+1% KNO_3 spray	3235	2998	3117
Mean	2907	2680	2783
	H	F	H X F
SEm±	56	123	169
CD (p=0.05)	168	369	NS

H:Hybrid F: Fertilizer RDF: Recommended dose of fertilizer

nutritional treatments (Shivamurthy and Biradar, 2014). The application of recommended dose of fertilizer based on soil test value along with one spray of each of 1% and 2% urea and 1% $MgSO_4$ during flowering to boll development stage significantly reduced incidence of leaf reddening in Bt cotton and also increased cotton yield and monetary return (Patel et al.2011).The interaction between Bt/non-Bt with different fertilizer doses was found non-significant.

3.6. Correlation studies

Leaf concentration of N, K, Fe, Mg and chlorophyll has significant negative correlation with the intensity of reddening (Table 10). Among these, potassium was the most significant superior factor for reddening (-0.785**) followed by magnesium (-0.731**), iron (-0.705**), nitrogen (-0.699**) and chlorophyll (-0.674**). The leaf nitrogen content had positive correlation with Mg (+0.924**), K (+0.807**), chlorophyll (+0.758**) and Fe (+0.654**). The leaf nitrogen content showed significant negative correlation with reddening of leaves (-0.699**). This indicated that the increased in leaf nitrogen reduced the reddening in cotton leaves. This might be associated with enhanced vegetative growth of plant, which can accelerate the nutrient uptake by cotton and maintained the proper ratios of nutrients in cotton plant system. The ratio of nitrogen to potassium in cotton leaves also governs the reddening phenomenon. Similarly, the Fe and Mg showed the significantly negative correlation with reddening of leaves (-0.705** and -0.731**). The leaf potassium content was significantly and positively correlated with Fe (+0.808**) and Mg (+0.825**). The leaf Fe content was also positively correlated with Mg (+0.667**). Potassium deficiency is predominant factor for reddening. Probably potash is a co-factor of enzymes involved in biosynthesis of chlorophyll alongwith Fe and Mg the deficiency of all these nutrients may result into low biosynthesis of chlorophyll and high synthesis of anthocyanin which impart red colour to cotton leaves. The increased synthesis of chlorophyll might be suppressed the synthesis of anthocyanin pigment (-0.674**) in cotton. Anthocyanin imparts the reddening to cotton leaves.

Table 10: Correlation coefficient between per cent as plant affected with reddening and mineral nutrient content in the leaves

	Leaf reddening (%)	N (%)	P (%)	K (%)	Fe (%)	Mg (%)	Chlorophyll (mg g^{-1})
Leaf reddening (%)	1						
N (%)	-0.699**	1					
P (%)	0.044	0.085	1				
K (%)	-0.785**	0.807**	0.084	1			
Fe (%)	-0.705**	0.654**	-0.027	0.808**	1		
Mg (%)	-0.731**	0.924**	0.050	0.825**	0.667**	1	
Chlorophyll (mg g^{-1})	-0.674**	0.755**	-0.020	0.800**	0.902**	0.748**	1

4. Conclusion

Application of recommended dose of fertilizer i.e. 100:50:50 kg N:P_2O_5:K_2O ha^{-1}and the three foliar sprays of mineral nutrients (N, P, K and Mg) through 1% $MgSO_4$, KNO_3 and 2% DAP had reduced the risk of leaf reddening as well as helped in increasing seed cotton yield in Bt and non-Bt cotton hybrids. As per correlation studies potassium deficiency was the most predominant factor for reddening followed by Mg, Fe, N and chlorophyll.

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