Leaf Reddening Index as an Indicator of Leaf Reddening Malady in Bt Cotton Hybrids: Causes And Remedies

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Cotton Area, Production, Productivity

	Area (Mha)		Production (Mbales)		Productivity(Kg/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Karnataka	0.594	0.760	2.3	2.8	658	628
India	11.72	12.65	39.80	40.00	577	537
World	44.12	34.27	118.95	119.37	759	758

Causes for Leaf Reddening

- In the recent past, leaf reddening has been a major problem in Bt-cotton which is an outcome of interaction of location, variety, environmental condition and nutrients.
- Drop in day temp.(< 20° C) and night temp.(<15^0 C)
- Both deficit and excess moisture stress
- Hindrances in assimilate production, translocation and distribution.
- In general, inter and intra specific tetraploid Bt hybrids are more sensitive and vulnerable to this malady may be due to Bt gene interaction.
- Leaf reddening may occur at any growth stage of the crop (flowering and boll development) and yield reduction may be up to 20 to 50%.

Objectives

- To find out the cause and curative measures of leaf reddening malady in Bt-cotton hybrids.
- To workout leaf reddening Index as an indicator to initiate curative majors.
- To find out effective nutrient supplementation for controlling leaf reddening in Bt. Cotton

Methodology

- Experiment was laid out during *Kharif* 2014-15 in a split plot design with following treatments
- Main plot treatments
- G_1: Bunny NCS 145 BGII
- G_2: Jaadoo KCH-14K59 BGII
- G_3: Bindaas BGII 7213-2
- Sub plot treatments
- T_1 : 100 % RDF
- T_2 : 125 % RDF + $MgSO_4$ soil application @ 25kg ha^{-1} + foliar spray of 1 per cent $MgSO_4$ + 1 per cent 19:19:19
- T_3 : 125 % RDF + $MgSO_4$ soil application @ 25kg ha^{-1} + foliar spray of 1 per cent $MgSO_4$ + 2 per cent KNO_3
- T_4 : 125 % RDF + soil application of $MgSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 15kg ha^{-1} + foliar spray of 0.5 per cent humic acid + 1 per cent $MgSO_4$ + 1 per cent 19:19:19 at 70, 85 and 100 DAS

Observations Made

- Morphological: Plant height, Leaf area index (LAI) & Total dry matter (TDM)
- Physiological: Photosynthesis, stomatal resistance, membrane injury index, leaf reddening index(LRI) & Specific leaf weight(SLW)
- Biochemical: Chlorophyll, anthocyanin, carotenoid & proline content, nitrate reductase activity and nutrient analysis
- Yield and Yield Attributes: Number of bolls per plant, boll weight, seed cotton yield and ginning percentage

Leaf reddening index (LRI) scale

- **Grades**

Zero – When all the leaves are green or less than three leaves per plant show the signs of reddening

One – When three leaves show the reddening

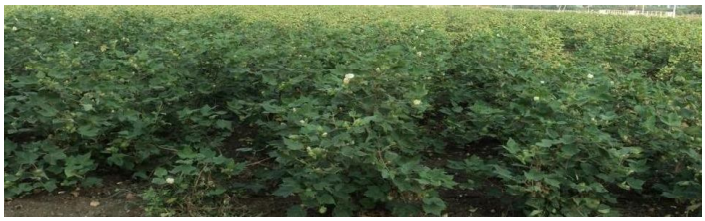
Two – When more than three leaves show the signs of reddening but young leaves are green.

Three – When all the leaves show reddening in patches

Four – When the whole plant turn red

45 DAS

View of experiment



90 DAS

Effect of nutrients and genotypes on SLA (mg dm^{-2})

Treatments	Days after sowing			
	45	90	135	At harvest
Main plots				
G_1	586.06	801.69	751.24	692.70
G_2	658.53	828.60	771.49	712.11
G_3	683.69	845.23	799.65	742.70
Mean	642.76	825.18	774.13	715.84
S.Em±	10.40	5.44	6.97	5.12
C.D. at 5%	31.84	16.64	21.19	15.98
Sub plots				
T_1	586.91	799.38	744.41	697.80
T_2	669.89	842.43	789.68	735.59
T_3	658.31	833.58	783.04	716.92
T_4	655.93	825.31	779.38	713.03
Mean	642.76	825.18	774.13	715.84
S.Em±	17.46	5.56	5.02	5.96
C.D. at 5%	52.87	16.51	14.92	17.71
T at the same G level				
S.Em±	30.24	9.63	8.70	10.32
C.D. at 5%	NS	NS	NS	NS
G at the same or different T levels				

Effect of nutrients and Bt-cotton genotypes on LRI

Treatments	Days after sowing		
	60	90	120
Main plots (Bt cotton genotypes)			
G_1	0.43	1.56	2.60
G_2	0.28	1.11	1.90
G_3	0.19	0.96	1.48
Mean	0.30	1.21	1.99
S.Em±	0.03	0.05	0.05
C.D. at 5%	0.10	0.16	0.16
Sub plots (Treatments)			
T_1	0.38	1.60	2.33
T_2	0.26	0.91	1.67
T_3	0.27	1.12	1.96
T_4	0.29	1.19	2.02
Mean	0.30	1.21	1.99
S.Em±	0.03	0.05	0.05
C.D. at 5%	0.08	0.16	0.15
T at the same G level			
S.Em±	0.05	0.09	0.09
C.D. at 5%	NS	NS	0.26
G at the same or different T levels			

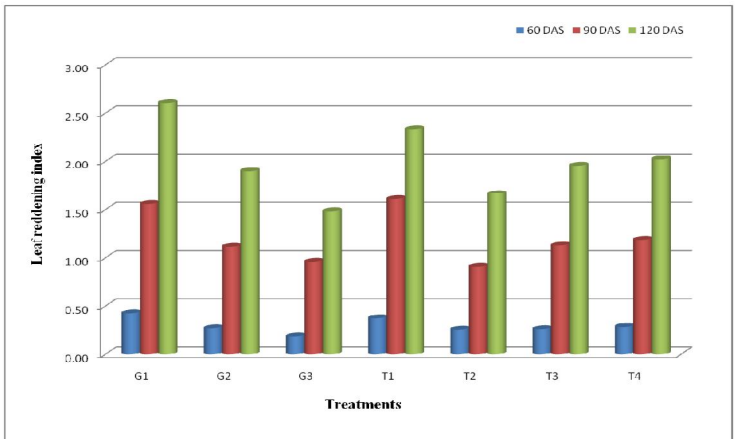
Effect of nutrients and genotypes on LRI

Sub plots	120 DAS				
	T_1	T_2	T_3	T_4	Mean
Main plots					
G_1	3.00	2.13	2.47	2.80	2.60
G_2	2.13	1.60	1.87	2.00	1.90
G_3	1.87	1.27	1.53	1.26	1.48
Mean	2.33	1.67	1.96	2.02	1.99
	S.Em±			C.D. at 5%	
Bt-cotton genotypes (G)	0.05			0.16	
Fertility levels (F)	0.05			0.15	
F at the same G	0.09			0.26	
G at the same or different F	0.10			0.30	

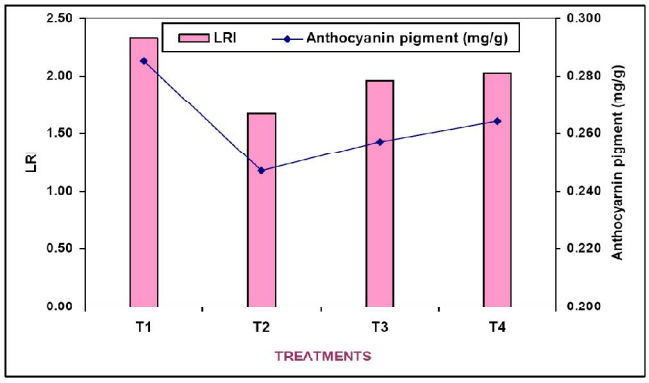
G_1: Bunny NCS 145 BGII
G_2: Jaadoo KCH-14K59 BGII
G_3: Bindaas BGII 7213-2

T_1: 100% RDF
T_2: 125% RDF + $MgSO_4$ soil application @ 25 kg ha^{-1} + foliar spray of 1 per cent $MgSO_4$ + 1 per cent 19:19:19
T_3: 125% RDF + $MgSO_4$ soil application @ 25kg ha^{-1} + foliar spray of 1 per cent $MgSO_4$ + 2 per cent KNO_3
T_4: 125% RDF + soil application of $MgSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 15kg ha^{-1} + foliar spray of 0.5 per cent humic acid + 1 per cent $MgSO_4$ + 1 per cent 19:19:19

Effect of different nutrients and Bt cotton genotypes on leaf reddening index at different growth stages



Relationship between LRI and anthocynin pigment (mg g^{-1} fresh weight) as influenced by different treatments at120 DAS



Effect of Nutrients and Genotypes on NRA Activity (µg NO_2 g^{-1} fr. wt.)

Treatments	Days after sowing		
	60	90	120
Main plots (Bt cotton genotypes)			
G_1	29.74	44.88	77.29
G_2	31.67	46.63	82.03
G_3	33.58	47.55	84.77
Mean	31.67	46.35	81.36
S.Em±	0.32	0.36	1.25
C.D. at 5%	1.24	1.43	4.92
Sub plots (Treatments)			
T_1	29.90	44.63	78.57
T_2	33.24	48.04	83.53
T_3	31.99	46.59	81.98
T_4	31.53	46.15	81.38
Mean	31.67	46.35	81.36
S.Em±	0.75	0.75	1.14
C.D. at 5%	2.22	2.22	3.38
T at the same G level			
S.Em±	1.30	1.30	1.97
C.D. at 5%	NS	NS	NS
G at the same or different T levels			

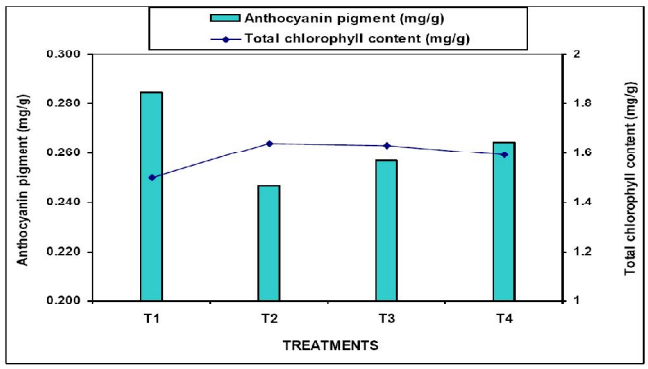
Proline (µg g^{-1} fr. wt.) & Chlorophyll (mg g^{-1} fr. wt)

Treatments	Proline content			Chlorophyll content			
	Days after sowing			Days after sowing			
	60	90	120	45	60	90	120
Main plots							
G_1	0.0517	0.066	0.080	0.668	1.50	2.37	1.49
G_2	0.0613	0.075	0.089	0.725	1.58	2.43	1.60
G_3	0.0648	0.079	0.095	0.740	1.61	2.47	1.68
Mean	0.06	0.07	0.09	0.71	1.56	2.42	1.59
S.Em±	0.0024	0.002	0.003	0.004	0.02	0.02	0.03
C.D. at 5%	0.0095	0.007	0.010	0.016	0.06	0.06	0.13
Sub plots							
T_1	0.0511	0.068	0.082	0.630	1.50	2.35	1.50
T_2	0.0662	0.082	0.093	0.768	1.61	2.51	1.64
T_3	0.0613	0.072	0.090	0.734	1.57	2.43	1.63
T_4	0.0586	0.071	0.089	0.712	1.57	2.39	1.59
Mean	0.06	0.07	0.09	0.71	1.56	2.42	1.59
S.Em±	0.0032	0.003	0.003	0.014	0.01	0.02	0.02
C.D. at 5%	0.0096	0.009	0.008	0.040	0.04	0.05	0.07
T at the same G levl							
S.Em±	0.0056	0.005	0.005	0.023	0.03	0.03	0.04
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
G at the same or different T levels							
S.Em±	0.0061	0.006	0.005	0.024	0.03	0.03	0.05

Membrane Injury Index (%) & Anthocyanin pigment (mg g^{-1} fresh weight)

Treatments	Membrane Injury Index (%)			Anthocyanin pigment		
	Days after sowing			Days after sowing		
	60	90	120	60	90	120
Main plots						
G_1	30.03	59.08	80.12	0.026	0.205	0.294
G_2	29.86	58.57	79.53	0.024	0.168	0.259
G_3	28.09	56.27	77.76	0.023	0.149	0.236
Mean	29.33	57.97	79.13	0.02	0.17	0.26
S.Em±	0.37	0.27	0.40	0.0006	0.001	0.002
C.D. at 5%	1.21	0.91	1.32	0.0019	0.004	0.006
Sub plots						
T_1	29.83	59.18	80.31	0.026	0.195	0.285
T_2	28.81	56.50	77.78	0.023	0.164	0.247
T_3	29.14	58.04	78.96	0.024	0.165	0.257
T_4	29.52	58.17	79.49	0.024	0.173	0.264
Mean	29.33	57.97	79.13	0.02	0.17	0.26
S.Em±	0.25	0.59	0.35	0.0004	0.002	0.003
C.D. at 5%	0.74	1.74	1.03	0.0013	0.006	0.008
T at the same G level						
S.Em±	0.43	1.01	0.60	0.0008	0.003	0.004
C.D. at 5%	NS	NS	NS	NS	0.010	0.013
G at the same or different T levels						
S.Em±	0.57	1.05	0.72	0.0010	0.004	0.005

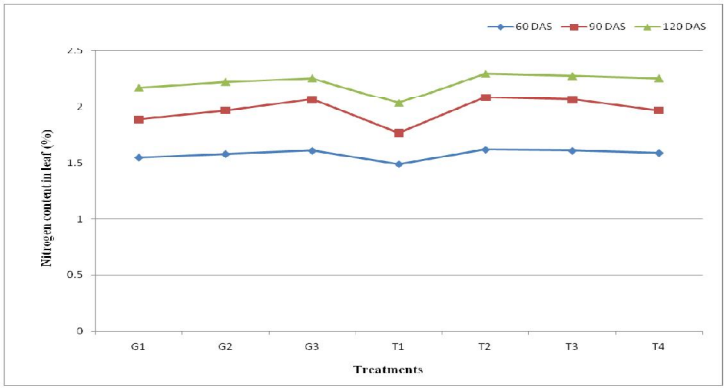
Relationship between Anthocyanin pigment and Chlorophyll as influenced by nutrients in Bt-cotton genotypes at 120 DAS



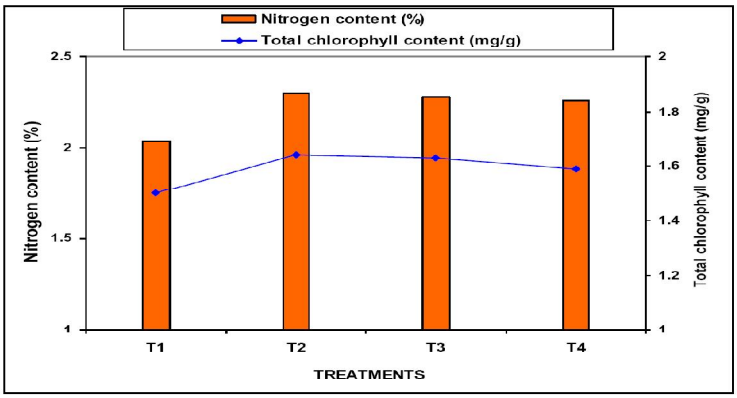
Nitrogen content in leaf (%) & Anthocyanin pigment (mg g^{-1} fresh weight)

Treatments	Nitrogen content in leaf (%) Days after sowing			Anthocyanin pigment Days after sowing		
	60	90	120	60	90	120
Main plots (Bt cotton genotypes)						
G_1	1.55	1.89	2.18	0.026	0.205	0.294
G_2	1.58	1.97	2.23	0.024	0.168	0.259
G_3	1.61	2.07	2.26	0.023	0.149	0.236
Mean	1.58	1.97	2.22	0.02	0.17	0.26
S.Em±	0.01	0.01	0.01	0.0006	0.001	0.002
C.D. at 5%	0.03	0.04	0.02	0.0019	0.004	0.006
Sub plots (Treatments)						
T_1	1.49	1.77	2.04	0.026	0.195	0.285
T_2	1.62	2.09	2.30	0.023	0.164	0.247
T_3	1.61	2.07	2.28	0.024	0.165	0.257
T_4	1.59	1.97	2.26	0.024	0.173	0.264
Mean	1.58	1.97	2.22	0.02	0.17	0.26
S.Em±	0.01	0.01	0.01	0.0004	0.002	0.003
C.D. at 5%	0.04	0.03	0.03	0.0013	0.006	0.008
T at the same G level						
S.Em±	0.02	0.02	0.02	0.0008	0.003	0.004
C.D. at 5%	NS	NS	NS	NS	0.010	0.013
G at the same or different T levels						
S.Em±	0.02	0.02	0.02	0.0010	0.004	0.005
C.D. at 5%	NS	NS	NS	NS	0.011	0.015

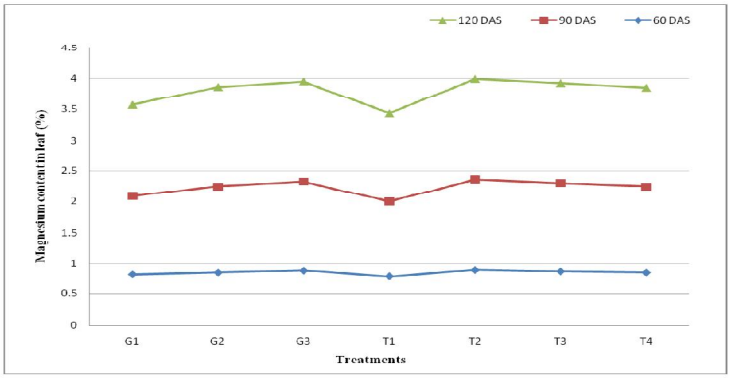
Effect of Nutrients and Genotypes on nitrogen content in leaf (%) at different growth stages



Relationship between Nitrogen content (%)and total Chlorophyll content (mg g^{-1} fr. wt) in leaf as influenced by Nutrients in Cotton genotypes at 120 DAS



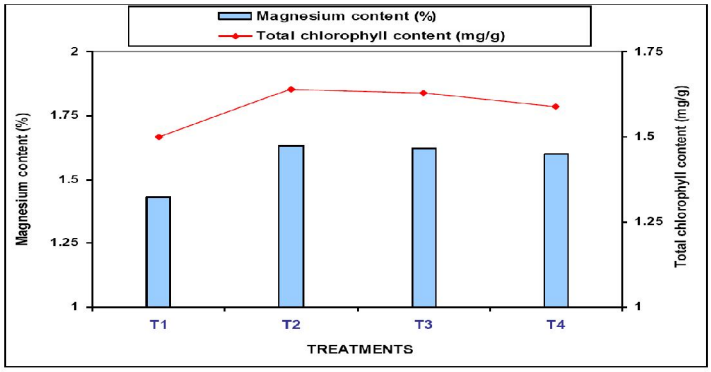
Effect of different nutrients and Bt cotton genotypes on magnesium content in leaf (%) at different growth stages



Zinc content in leaf (PPM) & Magnesium content in leaf (%)

Treatments	Zinc content Days after sowing			Magnesium content Days after sowing		
	60	90	120	60	90	120
Main plots						
G_1	17.30	21.72	22.64	0.83	1.26	1.48
G_2	21.82	24.46	26.46	0.86	1.39	1.61
G_3	22.84	25.65	26.66	0.89	1.44	1.62
Mean	20.65	23.95	25.25	0.86	1.37	1.57
S.Em±	1.36	0.43	0.83	0.01	0.01	0.01
C.D. at 5%	NS	1.69	3.26	0.02	0.04	0.03
Sub plots						
T_1	17.29	21.66	21.69	0.80	1.20	1.43
T_2	22.10	26.00	28.05	0.90	1.46	1.63
T_3	20.82	24.56	26.04	0.88	1.42	1.62
T_4	22.40	23.56	25.22	0.86	1.39	1.60
Mean	20.65	23.95	25.25	0.86	1.37	1.57
S.Em±	1.35	0.56	0.78	0.01	0.01	0.01
C.D. at 5%	NS	1.66	2.31	0.02	0.04	0.03
T at same G level						
S.Em±	2.34	0.97	1.35	0.01	0.2	0.02
C.D. at 5%	NS	NS	NS	NS	NS	NS
G at the same or different T levels						

Relationship between Magnesium and Chlorophyll in leaf as influenced by nutrients in Bt-cotton genotypes at 120 DAS



Effect of Nutrients and Genotypes on Iron content in leaf (PPM) & Copper content in leaf (PPM) at different growth stages

Treatments	Iron content in leaf (PPM)			Copper content in leaf (PPM)		
	Days after sowing			Days after sowing		
	60	90	120	60	90	120
Main plots (Bt cotton genotypes)						
G_1	728.58	695.75	722.36	13.52	8.35	14.30
G_2	728.83	710.17	741.86	13.62	8.87	14.82
G_3	734.83	733.83	755.11	13.91	9.08	15.11
Mean	730.74	713.25	739.77	13.69	8.77	14.75
S.Em±	11.96	7.28	4.97	0.10	0.13	0.14
C.D. at 5%	NS	22.59	15.53	NS	0.52	0.54
Sub plots						
T_1	729.11	699.67	727.03	13.41	8.52	14.44
T_2	733.50	726.22	750.13	14.07	9.11	15.22
T_3	730.26	720.44	746.02	13.64	8.74	14.68
T_4	730.11	706.67	735.92	13.62	8.69	14.65
Mean	730.74	713.25	739.77	13.69	8.77	14.75
S.Em±	4.98	6.01	3.59	0.17	0.14	0.18
C.D. at 5%	NS	17.85	10.66	NS	0.41	0.54
T at the same G level						
S.Em±	8.63	10.41	6.21	0.29	0.24	0.31
C.D. at 5%	NS	NS	NS	NS	NS	NS
G at the same or different T levels						
S.Em±	14.75	12.70	7.96	0.31	0.27	0.34
C.D. at 5%	NS	NS	NS	NS	NS	NS

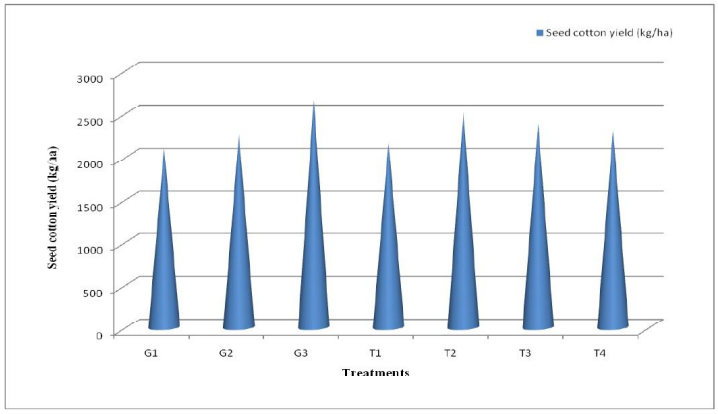
Photosynthetic rate (μ mol CO_2 m^{-1} s^{-1} fresh weight) & Stomatal resistance (m^2 s mol^{-1})

Treatments	Photosynthetic rate			Stomatal resistance		
	Days after sowing			Days after sowing		
	60	90	120	60	90	120
Main plots (Bt cotton genotypes)						
G_1	33.72	38.23	28.03	2.55	3.53	3.93
G_2	37.33	39.24	29.79	2.40	3.32	3.79
G_3	38.26	41.98	30.78	2.22	3.10	3.27
Mean	36.44	39.82	29.54	2.39	3.31	3.66
S.Em±	0.84	0.45	0.51	0.02	0.02	0.02
C.D. at 5%	3.32	1.48	1.64	0.07	0.10	0.09
Sub plots						
T_1	33.66	37.17	28.84	2.43	3.40	3.70
T_2	37.82	41.13	29.73	2.35	3.26	3.56
T_3	37.21	40.72	30.58	2.38	3.28	3.67
T_4	37.06	40.24	28.99	2.40	3.32	3.71
Mean	36.44	39.82	29.54	2.39	3.31	3.66
S.Em±	0.69	0.80	0.33	0.02	0.03	0.04
C.D. at 5%	2.05	2.38	0.98	0.05	0.10	0.10
T at the same G level						
S.Em±	1.20	1.39	0.57	0.03	0.06	0.06
C.D. at 5%	NS	NS	NS	NS	NS	NS
G at the same or different T levels						
S.Em±	1.46	1.46	0.76	0.03	0.06	0.06
C.D. at 5%	NS	NS	NS	NS	NS	NS

Effect of Nutrients and Genotypes on yield and yield components

Treatments	Bolls/ plant	Boll wt . (g $plant^{-1}$)	Yield (g $plant^{-1}$)	Yield (kg ha^{-1})	Ginning percent
Main plot					
G_1	26.77	3.81	115.52	2097.50	32.34
G_2	28.90	4.07	123.78	2265.17	34.47
G_3	30.14	4.52	144.43	2658.33	37.32
Mean	28.60	4.13	127.91	2340.33	34.71
S.Em±	0.18	0.05	2.39	40.16	0.84
C.D. at 5%	0.70	0.19	9.40	157.71	3.30
Sub plots					
T_1	27.22	3.85	118.20	2159.22	32.96
T_2	30.68	4.52	139.10	2518.89	35.92
T_3	28.50	4.16	129.16	2382.67	35.26
T_4	28.01	4.00	125.19	2300.56	34.70
Mean	28.60	4.13	127.91	2340.33	34.71
S.Em±	0.73	0.10	3.15	55.06	0.63
C.D. at 5%	2.16	0.30	9.37	163.59	1.87
T at the same G lev.					
S.Em±	1.26	0.17	5.46	95.37	1.09
C.D. at 5%	NS	NS	NS	NS	NS
G at the same or different T levels					

Effect of different nutrients and Bt-cotton genotypes on seed cotton yield (kgha^{-1}) at harvest different growth stages



Cost of cultivation, gross returns , net returns and benefit cost ratio

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BC ratio
Main plots (Bt cotton genotypes)				
G_1	30833	88095	57261	1.86
G_2	30833	95137	64303	2.08
G_3	30833	111650	80816	2.62
Mean	30833	98294	67460	2.19
S.Em±	--	1686	1686	0.06
C.D. at 5%	--	5223	5223	0.20
Sub plots (Treatments)				
T_1	28433	90687	62254	2.19
T_2	31723	105793	74070	2.33
T_3	30943	100072	69129	2.23
T_4	32234	96623	64389	2.00
Mean	30833	98294	67460	2.19
S.Em±	--	2312	2312	0.08
C.D. at 5%	--	6870	6870	0.24
T at the same G level				
S.Em±	--	4005	4005	0.14
C.D. at 5%	--	NS	NS	NS
G at the same or different T levels				
S.Em±	--	4346	4346	0.15
C.D. at 5%	--	NS	NS	NS

Plate 7: Bunny NCS 145 BGII

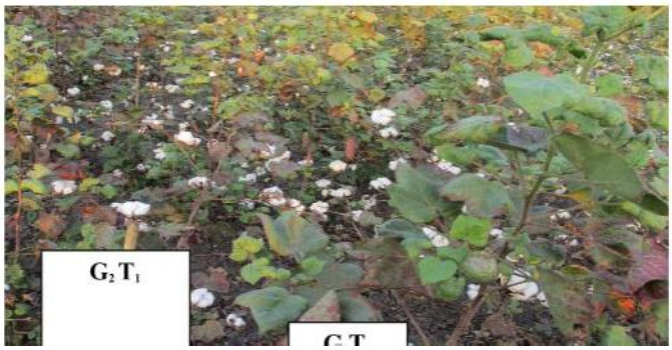


Plate 8: Jaadoo KCH-14 K59 BGII

Plate 9: Bindaas BGII 7213-2

Discussion

- Biochemical content in Bt-cotton leaf varied due to various treatments and genotypes. Among the different treatments and genotypes, application of 125% RDF and soil application of $MgSO_4$ @ 25 kg ha^{-1} along with foliar application of $MgSO_4$ @ 1% and 19:19:19 @ 1% and Bindaas BGII 7213-2 recorded significantly higher chlorophyll a, chlorophyll b, total chlorophyll content, carotenoid content, nitrate reductase activity and proline content.
- In addition higher photosynthesis was noticed

- While it recorded significantly lower content of anthocyanin, membrane injury index and stomatal resistance as compared to all other treatments and genotypes, respectively.
- **Significantly reduced LRI was observed with the application of 125% RDF and soil application of $MgSO_4$ @ 25 kg ha^{-1} along with foliar application of $MgSO_4$ @ 1% and 19:19:19 @ 1% (0.91 and 1.67 at 90 DAS and 120 DAS, respectively) whereas, higher LRI was recorded in 100% RDF (1.60 and 2.33 at 90 and 120 DAS, respectively).**
- Foliar application of macro nutrients played a important role in enzymatic reactions and plant metabolic activities which enhance total chlorophyll content, carotenoid content and nitrate reductase activity and reduced anthocyanin content and LRI.

Yield and Yield Components

- Among Bt-cotton genotypes, Bindaas BGII 7213-2 (G_3) recorded higher morphological parameters *viz.,* specific leaf weight (SLW) leaf area index (LAI), total dry matter (TDM), and yield attributes *viz.,* total number of bolls per plant, boll weight and seed cotton yield (2658.33 kg ha^{-1})
- Among different nutrients, application of 125% RDF and soil application of $MgSO_4$ @ 25 kg ha^{-1} along with foliar sprays of 1% $MgSO_4$ and 1% 19:19:19 (T_2) recorded significantly higher SLW, LAI, TDM, and yield attributes *viz.,* total number of bolls per plant, boll weight, seed cotton yield (2518.89 kg ha^{-1}).

Conclusion

- Based on the above experimental results, it could be concluded that, even with susceptible genotype Bunny NCS 145 BGII, T_2 showed significant reduction in LRI and anthocyanin pigment as compared to other treatments.
- Hence, the treatment T_2: 125% RDF and soil application of $MgSO_4$ @ 25 kg ha^{-1} along with foliar application of $MgSO_4$ @ 1% and 19:19:19 @ 1% is effective in controlling leaf reddening in Bt-cotton.
- While, the genotype, Bindaas BGII 7213-2 considered as tolerant to leaf reddening malady.

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