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Research Paper

Influence of time of planting and genotypes on leaf reddening, seed-cotton yield and productivity efficiency in *Bt* cotton (*Gossypium hirsutum*)

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ABSTRACT

A field experiment was conducted during 2014–15 and 2015–16 at College of Agriculture, University of Agricultural Sciences, Raichur, Karnataka, India, to study the interaction between cultivars ('Bindas', 'Bunny-Bt', 'ATM' and 'Dr. Brent') and planting time (II fortnight of June, and I and II first fortnights of July and August) on leaf reddening, seed-cotton yield and productivity efficiency, and a new measure to assess reddening tolerance in *Bt* cotton (*Gossypium hirsutum* L.). Early sowing during June II fortnight particularly with cv. 'Bindas' showed lower leaf-reddening indices [0, 0, 0.62 and 0.86 at 90, 105, 120 and 135 days after sowing (DAS), respectively], higher seed-cotton yield (4.17 t/ha) and consequently higher productivity efficiency (0.48). However, higher leaf reddening (1.55, 1.99, 2.00 and 2.60, 1.67, 1.97, 1.99 and 2.56 at 90, 105, 120 and 135 DAS respectively) and lower seed-cotton yield (0.86 and 0.84 t/ha respectively) resulting in lower productivity efficiency (0.13 and 0.13 respectively) were registered with delayed sowing during II fortnight of August, particularly with reddening susceptible cultivars 'Bunny-*Bt*' and 'Dr Brent'. In all, productivity efficiency emerged as effective inclusive tool in assessing leaf-reddening tolerance over leaf-reddening index alone in *Bt* cotton cultivars.

Key words: *Bt* cotton genotypes, Leaf-reddening index, Planting time, Productivity Efficiency, Seed-cotton yield

Cotton (*Gossypium hirsutum* L.), is one of the most important commercial cash crops of semi-arid Indian region. Four out of the 50 recognized *Gossypium* species, viz. tree (*G. arboreum* L.), levant cotton *(G. herbaceum* L.), upland cotton *(G. hirsutum* L.), and sea island cotton *(G. barbadense* L.), are cultivated for natural fibre in the world. India is the only country in the world where all the 4 species and some of their intra-species derivatives are commercially grown. Today, over hundreds of *Bt* (*Bacillus thuringiensis*) cultivars of varied potential and leaf-reddening tolerance are cultivated and the production has increased from a meagre 2.79 million bales (170 kg lint/bale) in 1947–48 to an all-time record of 36.0 million bales during 2019–20 (*https://cotcorp.org.in/statistics.aspx*). However, leaf-reddening malady is the major handicap in achieving potential crop yields, particularly in *hirsutum* in majority of the locations in spite of following best production practices. Leaf reddening could reduce the seed-cotton yield to the extent of 30–60%, depending on variety and reddening intensity (Pagare, 2011) and time of occurrence. The red colour becomes apparent when the green chlorophyll decomposes with the approaching winter (www.britannic.com 2007) and, therefore, early planting or use of cultivars suitable for late planting to escape hardships of winter assumes significance. Intense light and low temperatures of winter favour the development of anthocyanin pigments. In this context, the present investigation was carried out to study interaction effect of genotypes and time of sowing on seed-cotton leaf reddening incidence, yield and productivity efficiency of *Bt.* cotton.

MATERIALS AND METHODS

An experiment was conducted during 2014–15 and 2015–16 at the College of Agriculture, University of Agricultural Sciences, Raichur, Karnataka. Investigations were carried out in semiarid tropics in Tunga Bhadra Project (TBP) irrigation command area in deep black soil under irrigation. The experiment was laid out using split-plot design, consisting of 5 sowing dates, viz. D_1, second fortnight of June; D_2, first fortnight of July; D_3, second fortnight of July; D_4, first fortnight of August; and D_5, second fortnight of August as main plots and four cotton cultivars,

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viz. G_1, 'Bindas'; G_2, 'Bunny-*Bt*'; 'G_3, ATM; and G_4, 'Dr Brent' as subplot treatments. The recommended dose of fertilizers 150, 75 and 75 kg/ha N, P_2O_5 and K_2O were applied during both the years. Data recorded on growth and development and seed-cotton yield were subjected to statistical analysis and the means were compared using Duncan's Multiple Range Test (DMRT) using SPSS 16.0 version at P = 0.05.

The productivity efficiency (kg/ha-dm^2/day) was conceived as an effective measure for screening cultivars/ leaf reddening management (LRM) techniques or any other production interventions to evaluate performance, resilience or susceptibility to leaf reddening in cotton under any agro-climatic condition. Higher the productivity efficiency, higher the seed-cotton yield and/or lower the leaf reddening during the crop life-cycle. It is new and inclusive ratio developed and used in the study to evaluate productivity as related to photosynthetically active green surface as:

$$\text{Productivity efficiency (PE)} = \frac{\text{Yield (kg/ha)}}{LA\ (\mathrm{dm}^2) \times LRI \times duration\,(days)}$$

where LA, leaf area/(dm) and LRI, leaf-reddening index

Leaf-reddening index was recorded at 90, 105, 120 and 135 DAS for quantitative estimation of degree of leaf reddening as outlined by Dastur *et al*. (1952). The number of leaves showing signs of reddening, partly or wholly, were divided into 5 categories on the visual observations. At 60 DAS, *Bt* cotton plants did not exhibit the symptoms of leaf reddening, hence not recorded.

RESULTS AND DISCUSSION

The effect on leaf-reddening indices (LRI) was rather low initially and increased with the advancement in age up to 135 DAS, and different date of sowing and genotypes and their interactions differed significantly in LRI at all the growth stages during both the years and on pooled basis (Table 1). The indices were low rather zero up to 105 DAS with first sowing (D_1) and later revealed the minimum reddening (0.0, 0.0, 0.62 and 1.01 at 90, 105, 120 and 135 DAS respectively); however, with delayed sowing the reddening was steadily and significantly enhanced and August sowing showed higher LRI (1.49, 1.88, 1.93 and 2.32 with D_5 at 90, 105, 120 and 135 DAS, respectively). Among the cultivars, 'Bunny *Bt'* (G_2) (0.99, 1.31, 1.49 and 1.81 at 90, 105, 120 and 135 DAS, respectively) and 'Dr Brent' (G_4) had significantly higher and comparable LRI (0.94, 1.27, 1.50 and 1.79 at 90, 105, 120 and 135 DAS respectively), while cv. 'Bindas' (G_1) had lower LRI throughout (0.71, 0.98, 1.19 and 1.42 at 90, 105, 120 and 135 DAS, respectively), followed by cv. ATM. Similar trends of sowing dates and cultivars were visible in their interactions except that the former was more dominant and the differences due to cultivars opened up with late sowings. In fact, no reddening was observed up to 105 DAS with the first sowing in any of the cultivars and thereafter mild reddening occurred and the cultivars were at par. From second sowing onwards, LRI increased and cultivars also revealed variations with higher LRI with 'Bunny *Bt*' followed by 'Dr Brent' which during the II fortnight of August had 1.55, 1.99, 2.00 and 2.60 and 1.67, 1.97, 1.99 and 2.56, LRI respectively, at 90, 105, 120 and 135 DAS, LRI respectively, while cvs 'Bindas' and 'ATM' had relatively lower indices.

Production interventions in the form of planting time, cultivars and their interactions resulted in significant variations in seed-cotton yield during both the years and on pooled basis (Table 2). Among the different dates of sowing, significantly higher seed- cotton yield (3.84 t/ha) was recorded with the earliest sowing during II fortnight of June (D_1), followed by I fortnight of July (D_2). Further delay in sowing linearly and significantly decreased the seed-cotton yield and the last sowing, had almost one-fourth of the first sown crop (0.98 t/ha). Among the different genotypes, cv. 'Bindas' (G_1) gave significantly higher seed-cotton yield (2.87 t/ha), followed by 'ATM' (G_3) (2.67 t/ha) and 'Dr Brent' (G_3), while cv. Bunny *Bt* (G_2) had lower seed-cotton yield among all the cultivars.

Seed-cotton yield ranged from 0.84 to 4.17 t/ha due to different treatment combinations and revealed significant differences. Average of the last-sown crop was less than one-quarter of the first-sown crop. Overall, II fortnight of June with cv. 'Bindas' (D_1G_1) resulted in the maximum seed-cotton yield (4.17 t/ha); cv. 'ATM' sown simultaneously (D_1G_3) was the next best (3.78 t/ha), while the other cultivars (G_2 and G_4) were at par. Cultivar 'Bindas' sown during I fortnight of July (D_2G_1) was also on a par with the latter cultivars, whereas significantly lower seed-cotton yield (0.84, 0.86 and 0.95 t/ha, respectively) was observed with the second fortnight of August with cvs. 'Dr Brent', 'Bunny *Bt*' and 'ATM' ($D_5G_{2\text{-}4}$). Cultivar 'Bindas' was found superior to others even during the last sowing (D_5G_1) (1.29 t/ha).

Further, productivity efficiency as a consequence of green leaf surface varied significantly due to dates of sowing and genotypes (Table 2). Among the dates of sowing, significantly higher productivity efficiency was recorded consistently with early sowing during the II fortnight of June (D_1) (0.45 kg/ha/dm^2/day on pooled basis), followed by I fortnight of July (D_2), and the values decreased with further delay in the sowing and recorded the lowest productivity efficiency (0.15 kg/ha/dm^2/day on pooled basis) with the last sowing during the II fortnight of August (D_5). Among the genotypes, cv. 'Bindas' (G_1) consistently recorded higher productivity efficiency (0.35 kg/ha/dm^2/day on pooled basis), followed by 'ATM' (0.32 kg/ha/dm^2/day), while 'Bunny *Bt'* fared poorly (0.28 kg/ha/dm^2/day on

Table 1. Leaf-reddening index of *Bt.* cotton at various stages as influenced by time of planting and genotypes

Treatment	2014–15				2015–16				Pooled			
	90 DAS	105 DAS	120 DAS	135 DAS	90 DAS	105 DAS	120 DAS	135 DAS	90 DAS	105 DAS	120 DAS	135 DAS
Plant time												
D_1	0.00^{d}	0.00^{d}	0.58^{d}	1.08^{e}	0.00^{d}	0.00^{d}	0.66^{d}	0.93^{d}	0.00^{d}	0.00^{d}	0.62^{d}	1.01^{e}
D_2	0.43^{c}	0.70^{c}	1.03^{c}	1.33^{d}	0.51^{c}	0.70^{c}	1.00^{c}	1.41^{c}	0.47^{c}	0.70^{c}	1.02^{c}	1.37^{d}
D_3	0.95^{b}	1.87^{b}	1.55^{b}	1.66^{c}	0.94^{b}	1.13^{b}	1.43^{b}	1.22^{bc}	0.95^{b}	1.50^{b}	1.49^{b}	1.67^{c}
D_4	1.32^{a}	1.97^{a}	1.90^{a}	2.00^{b}	1.31^{a}	1.74^{a}	1.86^{a}	1.99^{ba}	1.32^{a}	1.85^{a}	1.88^{a}	1.99^{b}
D_5	1.45^{a}	1.93^{a}	0.93^{a}	2.32^{a}	1.52^{a}	1.83^{a}	1.94^{a}	2.32^{a}	1.49^{a}	1.88^{a}	1.93^{a}	2.32^{a}
SEm±	0.07	0.06	0.03	0.06	0.08	0.12	0.07	0.12	0.10	0.08	0.04	0.05
CD (P=0.05)	0.22	0.20	0.11	0.19	0.27	0.39	0.23	0.38	0.33	0.26	0.14	0.18
Genotypes												
G_1	0.71^{b}	1.07^{b}	1.19^{c}	1.40^{c}	0.70^{b}	0.89^{c}	1.19^{b}	1.35^{b}	0.71^{b}	0.98^{c}	1.19^{c}	1.42^{c}
G_2	1.01^{a}	1.40^{a}	1.49^{ba}	1.83^{a}	0.96^{a}	1.22^{a}	1.48^{a}	1.67^{a}	0.99^{a}	1.31^{a}	1.49^{a}	1.81^{a}
G_3	0.69^{b}	1.16^{b}	1.39^{b}	1.65^{b}	0.82^{ba}	1.04^{b}	1.38^{a}	1.58^{a}	0.76^{b}	1.10^{b}	1.38^{b}	1.67^{b}
G_4	0.91^{a}	1.36^{a}	1.53^{a}	1.79^{a}	0.96^{a}	1.18^{a}	1.47^{a}	1.69^{a}	0.94^{a}	1.27^{a}	1.50^{a}	1.79^{a}
SEm±	0.05	0.03	0.04	0.05	0.06	0.04	0.04	0.05	0.04	0.03	0.04	0.04
CD (P=0.05)	0.16	0.09	0.12	0.14	0.17	0.12	0.11	0.13	0.11	0.10	0.11	0.13
Interaction of D × G												
D_1G_1	0.00^{g}	0.00^{g}	0.60^{f}	0.93^{i}	0.00^{g}	0.00^{e}	0.64^{f}	0.78^{g}	0.00^{i}	0.00^{h}	0.62^{f}	0.86^{j}
D_1G_2	0.00^{g}	0.00^{g}	0.60^{f}	1.13^{ih}	0.00^{g}	0.00^{e}	0.75^{fe}	0.94^{g}	0.00^{i}	0.00^{h}	0.67^{f}	1.04^{ji}
D_1G_3	0.00^{g}	0.00^{g}	0.53^{f}	1.20^{igh}	0.00^{g}	0.00^{e}	0.58^{f}	1.06^{fg}	0.00^{i}	0.00^{h}	0.56^{f}	1.13^{hi}
D_1G_4	0.00^{g}	0.00^{i}	0.60^{f}	1.07^{ih}	0.00^{g}	0.00^{e}	0.70^{f}	0.93^{g}	0.00^{i}	0.00^{h}	0.65^{f}	1.00^{ji}
D_2G_1	0.33^{fg}	0.80^{i}	1.00^{e}	1.33^{fgh}	0.40^{gf}	0.68^{d}	0.97^{de}	1.40^{e}	0.37^{h}	0.74^{gf}	0.99^{e}	1.37^{hgf}
D_2G_2	0.53^{fe}	0.80^{i}	1.00^{e}	1.27^{igh}	0.56^{ef}	0.78^{d}	1.00^{de}	1.34^{fe}	0.55^{gh}	0.79^{gf}	1.00^{e}	1.30^{hj}
D_2G_3	0.47^{fe}	0.67^{i}	1.07^{e}	1.33^{fgh}	0.61^{ef}	0.62^{d}	1.05^{de}	1.43^{e}	0.54^{gh}	0.65^{g}	1.06^{ed}	1.38^{hfg}
D_2G_4	0.40^{fe}	0.80^{i}	1.07^{e}	1.40^{fgh}	0.48^{ef}	0.70^{d}	1.00^{de}	1.45^{e}	0.44^{gh}	0.75^{gf}	1.03^{ed}	1.43^{fg}
D_3G_1	0.60^{fe}	1.13^{h}	1.20^{ed}	1.33^{fgh}	0.65^{ef}	0.81^{d}	1.16^{dc}	1.07^{e}	0.63^{gf}	0.97^{f}	1.18^{d}	1.42^{fg}
D_3G_2	1.27^{bc}	1.80^{fed}	1.80^{bc}	1.93^{de}	1.12^{dc}	1.31^{c}	1.62^{b}	1.33^{cbd}	1.20^{ed}	1.55^{d}	1.71^{b}	1.95^{cd}
D_3G_3	0.73^{de}	1.47^{g}	1.40^{d}	1.50^{fg}	0.88^{ed}	1.09^{c}	1.32^{c}	1.17^{ed}	0.81^{f}	1.28^{e}	1.36^{c}	1.58^{ef}
D_3G_4	1.20^{bc}	1.87^{fecd}	1.80^{bc}	1.63^{fe}	1.13^{bdc}	1.31^{c}	1.61^{b}	1.31^{cd}	1.17^{ed}	1.59^{d}	1.70^{b}	1.74^{ed}
D_4G_1	1.13^{dc}	1.67^{fg}	1.40^{d}	1.50^{fg}	1.11^{dc}	1.31^{c}	1.36^{c}	1.48^{e}	1.12^{e}	1.49^{de}	1.38^{c}	1.49^{efg}
D_4G_2	1.73^{a}	2.33^{a}	2.07^{ba}	2.17^{dc}	1.54^{bac}	2.09^{a}	2.02^{a}	2.17^{cb}	1.64^{ba}	2.21^{a}	2.04^{a}	2.17^{cb}
D_4G_3	1.00^{dc}	1.73fe	1.93^{bac}	2.03^{dc}	1.22^{bdc}	1.62^{b}	1.98a	2.10^{cb}	1.11^{e}	1.68^{de}	1.96^{a}	2.07^{cb}
D_4G_4	1.40^{ba}	2.13^{ba}	2.20^{a}	2.30^{bc}	1.37^{bac}	1.94^{a}	2.07^{a}	2.21^{be}	1.39^{bdc}	2.04^{ba}	2.14^{a}	2.25^{b}
D_5G_1	1.47^{ba}	1.73^{fe}	1.73^{c}	1.90^{de}	1.34^{bc}	1.64^{b}	1.80^{ba}	2.00^{cb}	1.41^{bdc}	1.69^{dc}	1.77^{b}	1.95^{cd}
D_5G_2	1.53^{ba}	2.07^{bc}	2.0^{ac}	2.63^{a}	1.57^{ba}	1.90^{ba}	2.00^{a}	2.57^{a}	1.55^{bac}	1.99^{bc}	2.00^{a}	2.60^{a}
D_5G_3	1.27^{bc}	1.93^{becd}	2.0^{bac}	2.17^{dc}	1.37^{bac}	1.85^{ba}	1.96^{a}	2.17^{cb}	1.32^{cdc}	1.89^{bc}	1.98^{a}	2.17^{cb}
D_5G_4	1.53^{ba}	2.0^{bcd}	2.0^{bac}	2.57^{da}	1.80^{a}	1.95^{a}	1.98^{a}	2.55^{a}	1.67^{a}	1.97^{ba}	1.99^{a}	2.56^{a}
SEm±	0.13	0.09	0.08	0.11	0.14	0.14	0.10	0.15	0.12	0.10	0.08	0.10
CD (P=0.05)	0.38	0.26	0.24	0.32	0.41	0.42	0.30	0.42	0.31	0.30	0.24	0.29

*Means with same letters do not differ significantly under DMRT

DAS, Days of sowing; Main plot treatments; Time of planting (D); Subplot treatments: Genotypes (G)

D_1, Second fortnight of June; G_1, 'Bindas'; D_2, first fortnight of July; G_2, 'Bunny *Bt*'; D_3, second fortnight of July; G_3, 'ATM'; D_4, first fortnight of August; G_4, 'Dr Brent'; D_5, second fortnight of August

pooled basis). Among the treatment combinations, cv 'Bindas' sown first during the II fortnight of June (D_1G_1) showed significantly higher productivity efficiency (0.48 kg/ha/dm^2/day on pooled basis), while other cultivars were at par and were next in the order and so was 'Bindas' sown during the I fortnight of July. The trend was almost similar at other dates but the values decreased. Last sowing during the II fortnight of August, and cv. 'Bunny *Bt*' (D_5G_2) recorded the lowest productivity efficiency (0.13 kg/ha/dm^2/day) among all.

Interaction of genotypes and date of sowing is an important strategy to analyse crop yield and quality in a given environment and, therefore, genotype selection and sowing date management are important factors that can have a large impact on yield and quality of cotton crop (Delo, 2012). Optimum sowing time for different genotypes varies with regions, depending on the environmental conditions of the area. In the present study, seed cotton and productivity efficiency were the highest and leaf reddening was the lowest, and was almost nil across the cultivars with the earliest sowing during the II fortnight of June (D_1) followed by the I fortnight of July (Table 1). This may be primarily ascribed to *hirsutum* response to the drop in temperature occurring during winter and the crop sown late was more exposed to growth-limiting environment. Shanmugham (1992) reported that, drop in temperature below 21°C stimulates the formation of anthocyanin pigment, particularly the sudden fall in night temperature below 15°C stimulates the formation of anthocyanin pigment. Therefore, with further delay in sowing, yield and productivity efficiency decreased and leaf reddening increased linearly and significantly. The reduction in yield and productivity efficiency with further fortnightly delay in sowing was to the extent of 29.3, 47.4 and 74.4% with the II fortnight of July to the II fortnight of August (D_{2-5}) compared to early sowing during the II fortnight of June, and the yield with the last date with 1 ½ month difference resulted in almost quarter of the first-sown crop. Results are corroborating well with that of Pyati (2016), who observed yield decrement of 11.22 to 29% due to delay in sowing.

Table 2. Influence of time of planting and genotypes on seed-cotton yield (kg/ha) and productivity efficiency (kg/ha/dm²/day) of cotton

Treatment	Seed-cotton yield (t/ha)			Productivity efficiency (kg/ha/dm²/day)		
	2014–15	2015–16	Pooled	2014–15	2015–16	Pooled
Planting time (D)						
D_1	3.81^{a}	3.86^{a}	3.84^{a}	0.46^{a}	0.43^{a}	0.45^{a}
D_2	3.36^{b}	3.43^{b}	3.39^{b}	0.41^{b}	0.38^{b}	0.40^{b}
D_3	2.66^{c}	2.76^{c}	2.71^{c}	0.33^{c}	0.31^{c}	0.32^{c}
D_4	1.96^{d}	2.07^{d}	2.02^{d}	0.26^{d}	0.25^{d}	0.25^{d}
D_5	0.92^{e}	1.05^{e}	0.98^{e}	0.15^{e}	0.15^{e}	0.15^{e}
SEm±	0.07	0.06	0.01	0.01	0.01	0.01
CD (P=0.05)	0.245	0.20	0.04	0.05	0.05	0.05
Genotypes (G)						
G_1	2.83^{a}	2.92^{a}	2.87^{a}	0.36^{a}	0.34^{a}	0.35^{a}
G_2	2.24^{d}	2.32^{d}	2.28^{d}	0.28^{d}	0.27^{d}	0.28^{d}
G_3	2.63^{b}	2.72^{b}	2.67^{c}	0.33^{b}	0.31^{b}	0.32^{b}
G_4	2.47^{c}	2.56^{c}	2.52^{b}	0.31^{c}	0.30^{c}	0.31^{c}
SEm±	0.04	0.05	0.04	0.01	0.01	0.005
CD (P=0.05)	0.131	0.15	0.12	0.03	0.03	0.016
Interaction of (D × G)						
D_1G_1	4.15^{a}	4.20^{a}	4.17^{a}	0.50^{a}	0.47^{a}	0.48^{a}
D_1G_2	3.67^{b}	3.71^{b}	3.69^{cb}	0.45^{b}	0.42^{b}	0.43^{b}
D_1G_3	3.76^{b}	3.81^{b}	3.78^{b}	0.46^{b}	0.43^{b}	0.44^{b}
D_1G_4	3.68^{b}	3.71^{b}	3.69^{cb}	0.46^{b}	0.43^{b}	0.44^{b}
D_2G_1	3.56^{cb}	3.63^{b}	3.59^{c}	0.42^{cb}	0.39^{cb}	0.41^{cb}
D_2G_2	3.30^{dc}	3.37^{c}	3.33^{d}	0.41^{dc}	0.38^{dc}	0.40^{dc}
D_2G_3	3.33^{dc}	3.40^{c}	3.36^{d}	0.41^{dc}	0.38^{dc}	0.39^{dc}
D_2G_4	3.24^{d}	3.31^{dc}	3.27^{d}	0.40^{d}	0.37^{d}	0.39^{dc}
D_3G_1	3.06^{d}	3.16^{d}	3.11^{e}	0.39^{d}	0.37^{d}	0.38^{d}
D_3G_2	1.76^{gh}	1.85^{g}	1.81^{h}	0.21^{gh}	0.21^{gh}	0.21^{gh}
D_3G_3	3.16^{d}	3.25^{dc}	3.21^{ed}	0.39^{d}	0.37^{d}	0.38^{d}
D_3G_4	2.67^{e}	2.76^{e}	2.71^{f}	0.32^{e}	0.31^{e}	0.31^{e}
D_4G_1	2.15^{f}	2.25^{f}	2.20^{g}	0.29^{f}	0.29^{f}	0.29^{f}
D_4G_2	1.68^{h}	1.78^{g}	1.73^{h}	0.22^{h}	0.21^{h}	0.21^{h}
D_4G_3	2.02^{fg}	2.13^{f}	2.07^{g}	0.27^{fg}	0.25f^{g}	0.26^{fg}
D_4G_4	2.01^{fg}	2.11^{f}	2.06^{g}	0.26^{fg}	0.25^{fg}	0.25^{fg}
D_5G_1	1.22^{i}	1.35^{h}	1.29^{i}	0.20^{i}	0.20^{i}	0.20^{i}
D_5G_2	0.79^{j}	0.92^{i}	0.86^{j}	0.13^{j}	0.14^{j}	0.13^{j}
D_5G_3	0.88^{j}	1.01^{i}	0.95^{j}	0.15^{j}	0.15^{j}	0.15^{j}
D_5G_4	0.77^{j}	0.91^{i}	0.84^{j}	0.13^{j}	0.13^{j}	0.13^{j}
SEm±	0.12	0.11	0.11	0.02	0.01	0.01
CD (P=0.05)	0.36	0.34	0.33	0.06	0.03	0.03

*Means with same letters do not differ significantly under DMRT

DAS, Days of sowing; Main plot treatments; Time of planting (D); Subplot treatments: Genotypes (G)

D_1, Second fortnight of June; G_1, 'Bindas'; D_2, first fortnight of July; G_2, 'Bunny *Bt*'; D_3, second fortnight of July; G_3, 'ATM'; D_4, first fortnight of August; G_4, 'Dr Brent'; D_5, second fortnight of August

Overall, cv 'Bindas' sown during the II fortnight of June (D_1G_1) with lowest leaf reddening resulted in the maximum seed-cotton yield (4,173 kg/ha on pooled basis) and productivity efficiency, followed by cv 'ATM' sown simultaneously and cv 'Bindas' sown during the I fortnight of July (M_2G_1 – 3,695 kg/ha on pooled basis) was at par. Significantly lower seed-cotton yield was recorded with the last sowing during the II fortnight of August (D_5) wherein 'ATM', 'Bunny *Bt*' and 'Dr Brent' cultivars fared at par. Similarly, in Pakistan Khalid Usman *et al*. (2016) reported higher yield with cv. 'CRR' when sown early on 19 April. Sukbir Singh (2010) from Punjab, India, observed superior performance of cv 'RCH 134' with 20 April sowing among 3 cultivars and 5 dates of sowing studied. Thus, delayed planting would lead to yield reduction which could not be compensated by any other production practices (Pyati, 2016). Lower lint yield with late sowing could be probably due to shortened fruiting period and delayed maturity compared to early sowing (Bauer *et al*., 2000; Bangee *et al*., 2004). In case of late sowing, flowering initiates late in the season when temperature is low that probably affected radiation-use efficiency which might have limited crop growth, while early sowing provided favourable temperature and water supply contributing towards boll development and filling that probably resulted in higher yield (Yeates *et al*., 2010).

Thus, the study revealed that, in addition to leaf-reddening index (LRI measured at pre-scheduled stages), productivity efficiency or yield per photosynthetically active leaf surface over crop period is a more pragmatic inclusive index of overall crop response to agronomic practices and production environment in the assessment of leaf reddening in cotton.

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