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Morphological Investigations on Putative indices of different Cotton Genotypes Regarding Leaf Reddening under different Irrigation Environments

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ABSTRACT: A research trail was planned to find out the abiotic cause of major disorder in cotton i.e., leaf reddening, during Kharif 2020, at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar (dist.), Maharashtra, India. The main objective of the trail was to study morphological parameters of cotton plants in three different genotypes (Phule Shwetambari, Phule Mahi and Rashi 659) under three different irrigation environments (June, July and August) and sown during three different intervals of time (rainfed environment, irrigated environment and waterlogged environment). Standardize the different irrigation environments were the great challenges in the present research. Maximum leaf area plant^{-1} at 50 % flowering, plant height and number of branches plant^{-1} were observed in normal sowing time i.e., June, under irrigated environment and in Bt hybrid i.e., Rashi 659 but, more number of leaves plant^{-1} at 50 % flowering were observed in Phule Shwetambari genotype. Leaf area affected plant^{-1}, plants affected with reddening plot^{-1} and per cent incidence of leaf reddening was more in extra late sowing time i.e., August, under waterlogged environment and in Bt hybrid i.e., Rashi 659 while, more number of affected leaves plant^{-1} were observed in Phule Mahi genotype of cotton.

Keywords: Cotton, Leaf reddening, Morphology, Sowing time, Genotype and Environment.

INTRODUCTION

Cotton is a well-known and well-loved natural fiber grown around the world (Sundar *et al.*, 2022*)*. It is sometimes referred to as "White Gold" and the "King of Fibers" (Kumar and Katageri 2017). The five main producers of cotton are China, India, United States, Pakistan, and Uzbekistan, with China having the highest production (Khan *et al.*, 2020). Cotton is grown on around 2.5% of the planet's crop land(Cotton Incorporated, 2009). 34.50 million hectares, 121.50 million bales and 791 kg ha^{-1} of cotton were produced globally in 2019–20 (Anonymous, 2020). Average cotton area, production and productivity in India were 134.77 lakh hectares, 365 lakh bales and 460 kg ha^{-1} in 2019–20 (Anonymous, 2021). In the 21st century, it is crucial to both the human economy as well as the global economy. Leaf reddening is one of the most common physiological disorders in cotton induced by different abiotic stresses (As and Bhoopal 2020). Any stage of the crop's growth is affected by it Permul and Hebba (2006; Blesseena *et al.* (2023). The formation and distribution of red pigments from the flavonoid group (C6-C3-C6), especially anthocyanin pigments, along with the degradation of chlorophyll, may be the cause of a leaf's reddening (Hosamani *et al*., 2017; Chen *et al.*, 2023). Seed cotton yield could be reduced to an extent of 30-60 per cent depending on variety, reddening intensity and time of occurrence (Pagare, 2011). The effects of availability of water on cotton plants growth are prominently reflected in the plant height, leaf area index and yield (Xiao *et al*., 2023). Cotton is damaged by drought in a variety of ways, according to related publications, and this causes a 34% decrease in cotton yield (Liu *et al.*, 2015; Ullah *et al.*, 2017). The morphological growth and nutrient uptake of cotton plants are also affected by waterlogging environment (Dodd *et al*., 2013; Zang *et al.*, 2021). In this regard, present investigation explored leaf reddening in cotton under different irrigation environments.

MATERIAL AND METHODS

During the *kharif* 2020 season, a research trail was conducted at the Cotton Improvement Project, MPKV, Rahuri. 27 treatment combinations of different irrigation environments (I), such as S1: Normal sowing (June), S2: Late sowing (July) and S3: Extra Late Sowing (August), sowing times (S), such as I0: Rainfed, I1: Irrigated, and I2: Water logging, and genotypes (V), such as V1: Phule Shwetambari, V2: Phule Mahi and V3: Rashi 659 were used in order to investigate the abiotic causes of leaf reddening in cotton. The morphological parameters of cotton plants were observed and noted down. Concerning data has been displayed in tables and graphs. Three replications were used in a double split plot design to set up the experiment with gross plot size of 7.20 × 4.50 m^2 and net plot size of 5.40 × 4.50 m^2.

Morphological parameters play significant role in leaf reddening, influenced by varying irrigation environments, sowing times and genotypes. The different observations *viz.*, number of leaves $plant^{-1}$ and leaf area $plant^{-1}$ (dm^2) were observed at 50 % flowering while, number of affected leaves $plant^{-1}$, leaf area affected $plant^{-1}$ (dm^2), plants affected with reddening $plot^{-1}$, per cent incidence of leaf reddening (%), plant height (cm) and number of branches $plant^{-1}$were critically observed at the time of harvest. Observed data were analyzed statistically as described by Gomez and Gomez (1984) using Split Plot Design technique, fed in computer and transformation of data was also made whenever required. Critical difference (CD) values at a 5% level of probability were calculated whenever results were found to be significant.

RESULTS AND DISCUSSION

A. Number of leaves $plant^{-1}$ at 50 % flowering

Irrigated environment (I1) was found superiorly significant (57.13) while, waterlogged environment (I2) recorded less (47.98) number of leaves shown in Table 1. Data on number of leaves $plant^{-1}$ at 50 % flowering stage in the context of different dates of sowing showed significant results revealing more (70.49) number of leaves in normal sowing time (S1) and less (34.99) number of leaves in extra late sowing time (S3).There were significant differences between different genotypes for number of leaves $plant^{-1}$ at 50 % flowering which showed that variety Phule Shwetambari (V1) (54.84) recorded maximum number of leaves $plant^{-1}$ followed by Phule Mahi (V2) (52.34). Rashi 659 (V3) showed less (49.80) number of leaves. Irrigated environment + normal sowing time (I1×S1) recorded significantly highest (74.98) number of leaves $plant^{-1}$ at 50 % flowering, whereas, waterlogged environment + extra late sowing time (I2×S3) recorded lowest (32.11) number of leaves. Interact combination of normal sowing time + Phule Shwetambari (S1×V1) was found to be more (72.36) significant for number of leaves $plant^{-1}$ at 50 % flowering whereas, interact combination of extra late sowing time + Rashi 659 (S3×V3) was found to be less (32.04). Irrigated environment + Phule Shwetambari (I1×V1) recorded significantly more (59.67) number of leaves $plant^{-1}$ whereas, less (45.07) number of leaves $plant^{-1}$ was observed in waterlogged environment + Rashi 659 (I2×V3). Irrigated environment + normal sowing time + Phule Shwetambari (I1×S1×V1) recorded significantly more (77) number of leaves $plant^{-1}$ while, less (28.13) number of leaves $plant^{-1}$ was observed in waterlogged environment + extra late sowing time + Rashi 659 (I2×S3×V3).

B. Leaf area $plant^{-1}$ at 50 % flowering (dm^2)

Irrigated environment (I1) was found superiorly significant (63.92) for leaf area $plant^{-1}$ at 50 % flowering, while rainfed environment (I0) was less (57.01) (Table 1). Among three different dates of sowing, normal sowing time (S1) showed significantly maximum (71.67) leaf area $plant^{-1}$ at 50 % flowering whereas, extra late sowing time (S3) exhibited minimum (50.20) leaf area. The resources of a cotton crop that was sown at the ideal moment accumulated more and were assimilated into reproductive growth. Compared to late-planted cotton, early-planted cotton was able to benefit from more favourable climatic conditions (Pettigrew and Adamczyk 2006). Significant differences were observed between different genotypes of cotton for leaf area $plant^{-1}$ at 50 % flowering which showed that Rashi 659 (V3) recorded maximum (62.49) leaf area $plant^{-1}$ followed by Phule Shwetambari (V1) (60.71). Phule Mahi (V2) showed minimum (59.40) leaf area. The Bt hybrid had fewer leaves than the other two hybrids, but it had larger leaf surfaces than non-Bt hybrids. Irrigated environment + normal sowing time (I1×S1) recorded significantly more (75.14) leaf area $plant^{-1}$ at 50 % flowering and irrigated environment + extra late sowing time (I1×S3) recorded minimum (50.98) leaf area. Normal sowing time + Rashi 659 (S1×V3) exhibited significantly maximum (73.03) leaf area $plant^{-1}$ at 50 % flowering and minimum (48.41) leaf area $plant^{-1}$ was observed in extra late sowing time + Phule Mahi (S3×V2). Irrigation environments and genotypes had no significant effect on leaf area $plant^{-1}$ at 50 % flowering. Irrigated environment + normal sowing time + Rashi 659 (I1×S1×V3) recorded significantly maximum (76.79) leaf area $plant^{-1}$ at 50 % flowering whereas, minimum (44.89) leaf area was observed in rainfed environment + extra late sowing time + Phule Mahi (I0×S3×V2). Guang *et al.* (2012) observed that cotton leaf area index was adversely affected by waterlogging condition.

C. Number of affected leaves $plant^{-1}$

Irrigation environments differ significantly for number of affected leaves $plant^{-1}$ where maximum number of affected leaves $plant^{-1}$ were found in waterlogged environment (I2) (12.76) and minimum in irrigated environment (I1) (9.66) (Table 1).Significantly maximum number of affected leaves $plant^{-1}$ were found in extra late sowing time (S3) (13.76) while, were found in normal sowing time (S1) (9.46).Among three genotypes studied, Phule Mahi (V2) recorded significantly maximum number of affected leaves $plant^{-1}$ (12.96 dm^2) followed by Phule Shwetambari (V1) (11.36 dm^2) and Rashi 659 (V3) (9.33 dm^2). Significantly maximum number of affected leaves $plant^{-1}$ were found in the interact combination of waterlogged environment + extra late sowing time (I2×S3) (15.67) while minimum were found in the interact combination of irrigated environment + normal sowing time (I1×S1) (7.16). Data pertaining to interaction effects of sowing times and genotypes regarding number of affected leaves $plant^{-1}$showed non-significant effect. Interaction of waterlogged environment + Phule Mahi (I2×V2) was found significantly superior (14.64) for number of affected leaves $plant^{-1}$ while, interaction of irrigated environment + Rashi 659 (I1×V3) was found to have minimum (7.76) number of affected leaves $plant^{-1}$.

Interaction of waterlogged environment + extra late sowing time + Phule Mahi (I2×S3×V2) was found to be significantly superior (18) for number of affected leaves plant^{-1} whereas minimum (5.13) number of affected leaves plant^{-1} were found in the interaction effect of irrigated environment + normal sowing time + Rashi 659 (I1×S1×V3). With hirsutum cotton types grown in rainfed conditions, more red leaves have been observed, according to reports by Akarte *et al.* (1985).

D. Leaf area affected plant^{-1} (dm^2)

Significantly maximum (23.97 dm^2) leaf area affected plant^{-1} was observed in waterlogged environment (I2) while, minimum (18.77 dm^2) was observed in irrigated environment (I1) (Table 1). Leaf area affected plant^{-1}was significantly highest (25.07 dm^2) during extra late sowing time (S3) and less (17.35 dm^2) during normal sowing time (S1). Leaf area affected plant^{-1} was significantly higher (22.35 dm^2) in variety Rashi 659 (V3) and lower (18.96 dm^2) in variety Phule Mahi (V2). Behera (2019) Murlidhar (2016); Govind (2008) made similar observations on cotton leaves having larger leaf area due to less intense reddening. Irrigation environments and sowing times had significant effect on leaf area affected plant^{-1}. Irrigated environment + extra late sowing time (I1×S3) showed significantly maximum (26.52 dm^2) leaf area affected plant^{-1} whereas, irrigated environment + normal sowing time (I1xS1) exhibited minimum (14.34 dm^2) leaf area affected plant^{-1}. Interaction effect of sowing times and genotypes had non-significant effect on leaf area affected plant^{-1}. Interaction effects of irrigation environments and genotypes, for leaf area affected plant^{-1} were noticed to be non-significant. Interact combination of waterlogged environment + extra late sowing time + Rashi 659 (I2×S3×V3) recorded significantly maximum (28.13 dm^2) leaf area affected plant^{-1} while, interact combination of rainfed environment + normal sowing time + Phule Mahi (I0×S1×V2) recorded minimum (13.61 dm^2) leaf area. Guang *et al.* (2012) observed that cotton leaf area index was adversely affected by waterlogging condition

E. Plants affected with reddening plot^{-1}

Irrigation environments differ significantly for number of plants affected with reddening plot^{-1} where, maximum (17.30) number of plants affected with reddening plot^{-1} were found in waterlogged environment (I2) and minimum (13.44) were found in irrigated environment (I1) (Table 2). Significantly maximum (20.04) number of plants affected with reddening plot^{-1} were found in extra late sowing time (S3) while, minimum (11.48) number of plants affected with reddening plot^{-1} were found in normal sowing time (S1). Among the three genotypes studied, Rashi 659 (V3) (16.67) recorded significantly maximum number of plants affected with reddening plot^{-1} followed by Phule Shwetambari (V1) (15.19) and Phule Mahi (V2) (13.48).

Waterlogged environment + extra late sowing time (I2×S3) was showed significantly more (22.78) number of plants affected with reddening plot^{-1} whereas, irrigated environment + normal sowing time (I1×S1) showed less (9.89) number of plants affected. Data regarding interaction effects for plants affected with reddening plot^{-1} were found to be non-significant. Irrigation environments and genotypes had non-significant effect regarding number of plants affected with reddening plot^{-1}.

Three factor interaction of irrigation environments, sowing times and genotypes for number of plants affected with reddening plot^{-1} was found to be non-significant.

F. Per cent incidence of leaf reddening (%)

Data on the % incidence of leaf reddening depicted in Table 2, which demonstrates that the % incidence of leaf reddening is higher under stressful circumstances compared to an irrigated environment and lower at regular sowing periods. Among different irrigation environments, waterlogged environment (I2) was observed to be significantly superior (33.23) whereas, irrigated environment (I1) showed less (27.21) per cent incidence of leaf reddening. Significantly maximum (36.51) per cent incidence of leaf reddening was found for extra late sowing time (S3) and normal sowing time (S1) exhibited minimum (24.45) per cent incidence of leaf reddening. Per cent incidence of leaf reddening was significantly highest (31.91) in Rashi 659 (V3) followed by Phule Shwetambari (V1) (30.17). Phule Mahi (V2) showed minimum (28.11) per cent incidence of leaf reddening. According to reports from Thakur and Bhale (2019), Bt cotton showed significantly higher reddening percent than non-Bt cotton among cotton hybrids, which was also corroborated by the results of Hosmath *et al*. (2012); Deshmukh (2013). The combination of waterlogged environment + extra late sowing time (I2×S3) showed significantly highest (41.66) per cent incidence of leaf reddening while, the combination of irrigated environment + normal sowing time (I1×S1) showed lowest (22.73) per cent incidence of leaf reddening. Data regarding the interaction of sowing times and genotypes regarding per cent incidence of leaf reddening were found to be non-significant. Interaction effect of irrigation environments and genotypes had non-significant effect for the per cent incidence of leaf reddening. Three factor interaction of irrigation environments, sowing times and genotypes had non-significant effect per cent incidence of leaf reddening.

G. Plant height (cm)

In Table 2, plant height information is displayed in cotton crop. It is clear from the data that significantly higher (144.79cm) plant height was obtained in irrigated environment (I1) whereas, waterlogged environment (I2) showed less (111.78cm) plant height. Significantly maximum (148.23 cm) plant height was found in normal sowing time (S1) whereas, extra late sowing time (S3) exhibited minimum (109.48 cm) plant height. Plant height was significantly highest (137.40cm) in Rashi 659 (V3) followed by Phule Shwetambari (V1) (128.45 cm). Phule Mahi (V2) showed less (119.17 cm) % plant height compared to other genotypes studied. Irrigated environment + normal sowing time (I1×S1) showed significantly higher (176.07cm) plant height whereas, waterlogged environment + extra late sowing time (I2×S3) showed less (93.07cm) plant height. Interaction between normal sowing time + Rashi 659 (S1×V3) showed significantly highest (158.65cm) plant height while, extra late sowing time + Phule Mahi (S3×V2) showed less (100.68cm) plant height. Irrigated environment + Rashi 659 (I1×V3) recorded significantly higher (154.10cm) plant height while, less (101.68cm) plant height was observed in waterlogged environment + Phule Mahi (I2×V2).

Considering the above results, similar results for plant heig in cotton were obtained by Ishag *et al*. (1987); Govind (2008); Namdeo (2012); Deshmukh (2013); Shivamurthy (2014); Deshpande *et al.* (2015); Murlidhar (2016); Honnali and Chittapur (2017); Behera (2019); Abbas *et al.* (2021).

H. Number of branches plant^{-1}

Number of monopodial branches plant^{-1}. Data regarding number of monopodial branches is depicted in Table 2. Significantly higher (1.84) number of monopodial branches were recorded in irrigated environment (I1) while, less (1.57) number of monopodial branches were recorded under waterlogged environment (I2). Among three different dates of sowing, normal sowing time (S1) showed significantly maximum (2.10) number of monopodial branches whereas, extra late sowing time (S3) exhibited minimum (1.38) number of monopodial branches. These results were in conformity with Koraddi *et al.* (1992) that plant height, number of sympodial and monopodial branches plant^{-1} decreased significantly with delay in planting of cotton. Rashi 659 (V3) recorded significantly maximum (1.75) number of monopodial branches followed by Phule Mahi (V2) (1.69) and Phule Shwetambari (V1) (1.64). Significantly maximum (2.37) number of monopodial branches were found in irrigated environment + normal sowing time (I1×S1) combination whereas, minimum (1.33) number of monopodial branches were found in waterlogged environment + extra late sowing time (I2×S3) combination. Normal sowing time + Rashi 659 (S1×V3) showed significantly maximum (2.19) number of monopodial branches whereas, minimum (1.34) number of monopodial branches were observed in extra late sowing time + Phule Shwetambari (S3×V1). Interaction effect of irrigation environments and genotypes had non-significant effect regarding the number of monopodial branches.Three factor interaction of irrigated environment + normal sowing time + Rashi 659 (I1×S1×V3) showed more (77) number of monopodial branches but, less (28.13) number of monopodial branches were observed in waterlogged environment + extra late sowing time + Phule Shwetambari (I2×S3×V1).Similar observations were recorded in cotton by Ishag *et al.* (1987); Namdeo (2012); Behera (2019).

Number of sympodial branches plant^{-1}. Sympodial branches arise from main stem as well as on monopodial branches exhibiting stop-grow-stop pattern of growth. They are numerous and produce flowers. In stressful circumstances and as a result of the delayed sowing time, the number of sympodial branches dropped. Table 2 shows information on the number of sympodial branches. More (24.95) number of sympodial branches were significantly recorded in irrigated environment (I1) whereas, less (18.39) number of sympodial branches were recorded in rainfed environment (I0) (31.44).

Among three different dates of sowing, normal sowing time (S1) showed significantly more (24.45) number of sympodial branches while, extra late sowing time (S3) exhibited less (18.19) number of sympodial branches. Rashi 659 (V3) (22.52) recorded significantly maximum number of sympodial branches followed by Phule Mahi (V2) (20.85). Phule Shwetambari (V1) showed less (19.17) number of sympodial branches. Interaction effect of irrigated environment + normal sowing time (I1×S1) was found to be significantly superior (28.93) results while, rainfed environment + extra late sowing time (I0×S3) showed less (16.22) number of sympodial branches. Data regarding the interaction effects of sowing times and genotypes for number of sympodial branches were found to be non-significant. Interaction of irrigation environments and genotypes had non-significant effect with reference to the number of sympodial branches. Interaction effect of three factors i.e., irrigated environment + normal sowing time + Rashi 659 (I1×S1×V3) recorded more (30.79) number of sympodial branches while, less (14.22) number of sympodial branches were observed in rainfed environment + extra late sowing time + Phule Shwetambari (I0×S3×V1).

According to the results shown above, early-sown cotton crops had more sympodial branches than late- or extra-late-sown cotton crops. Ishag *et al.* (1987); Govind (2008); Namdeo (2012); Shivamurthy (2014); Behera (2019) all provided support for the findings. This is also consistent with findings from Khan *et al.* (2017), who found that early access to resources led to 32% more fruiting branches being produced in the best cotton crop than in the late-sown fields.

Table 1: Effect of Environment, Sowing times and Genotypes on number of leaves plant^{-1}, leaf area plant^{-1} at 50% flowering, number of affected leaves plant^{-1} and leaf area affected plant^{-1} (dm^2) in cotton crop.

Treatments	Number of leaves plant^{-1} at 50% flowering	Leaf area plant^{-1} at 50% flowering	Number of affected leaves plant^{-1}	Leaf area affected plant^{-1} (dm^2)
Environment (I)				
I0	51.87	57.01	11.23	19.49
I1	57.13	63.92	9.66	18.77
I2	47.98	61.67	12.76	23.97
S. E (m)	0.093	0.045	0.122	0.090
C. D	0.278	0.135	0.366	0.271
Sowing times (S)				
S1	70.49	71.67	9.46	17.35
S2	51.50	60.72	10.43	19.81
S3	34.99	50.20	13.76	25.07
S. E (m)	0.093	0.045	0.122	0.090
C. D	0.278	0.135	0.366	0.271
Genotypes (V)				
V1	54.84	60.71	11.36	20.93
V2	52.34	59.40	12.96	18.96
V3	49.80	62.49	9.33	22.35
S. E (m)	0.081	0.088	0.151	0.113
C. D	0.234	0.252	0.434	0.324
Environment × Sowing times (I × S)				
I0 × S1	70.20	68.39	10.73	16.23
I0 × S2	50.69	56.10	10.07	18.74
I0 × S3	34.71	46.54	12.89	23.51
I1 × S1	74.98	75.14	7.16	14.34
I1 × S2	58.29	65.63	9.11	16.80
I1 × S3	38.13	50.98	12.71	25.16
I2 x S1	66.29	71.50	10.49	21.49
I2 × S2	45.53	60.43	12.11	23.91
I2 × S3	32.11	53.09	15.67	26.52
S. E (m)	0.161	0.078	0.212	0.157
C. D	0.482	0.234	0.634	0.469
Sowing times × Genotypes (S × V)				
S1 × V1	72.36	71.58	9.64	17.52
S1 × V2	70.80	70.41	11.27	15.45
S1 × V3	68.31	73.03	7.47	19.09
S2 × V1	54.09	60.49	10.64	19.96
S2 × V2	51.38	59.38	12.27	17.99
S2 × V3	49.04	62.29	8.38	21.49
S3 × V1	38.07	50.06	13.80	25.29
S3 × V2	34.84	48.41	15.33	23.44
S3 × V3	32.04	52.14	12.13	26.47
S. E (m)	0.141	0.152	0.262	0.195
C. D	0.405	0.437	NS	NS
Environment × Genotypes (I × V)				
I0 × V1	54.07	56.89	12.00	19.84
I0 × V2	51.78	55.53	12.71	17.42
I0 × V3	49.76	58.62	8.98	21.22
I1 × V1	59.67	63.81	9.71	18.85
I1 × V2	57.16	62.63	11.51	16.99
I1 × V3	54.58	65.30	7.76	20.46
I2 × V1	50.78	61.44	12.38	24.09
I2 × V2	48.09	60.04	14.64	22.46
I2 × V3	45.07	63.54	11.24	25.37
S. E (m)	0.141	0.152	0.262	0.195
C. D	0.405	NS	0.752	NS
Environment × Sowing times × Genotypes (I × S × V)				
I0 × S1 × V1	72.00	68.13	11.67	16.41
I0 × S1 × V2	70.40	67.35	12.87	13.61
I0 × S1 × V3	68.20	69.68	7.67	18.68
I0 × S2 x V1	52.67	56.04	10.93	19.06
I0 × S2 × V2	50.53	54.33	11.53	17.03

I0 × S2 × V3	48.87	57.93	7.73	20.12
I0 × S3 × V1	37.53	46.49	13.40	24.05
I0 × S3 × V2	34.40	44.89	13.73	21.62
I0 × S3 × V3	32.20	48.25	11.53	24.87
I1 × S1 × V1	77.00	74.89	7.40	14.36
I1 × S1 × V2	75.13	73.73	8.93	12.33
I1 × S1 × V3	72.80	76.79	5.13	16.33
I1 × S2 × V1	61.73	65.44	9.40	16.81
I1 × S2 × V2	58.00	64.75	11.33	14.95
I1 × S2 × V3	55.13	66.70	6.60	18.64
I1 × S3 × V1	40.27	51.12	12.33	25.37
I1 × S3 × V2	38.33	49.42	14.27	23.69
I1 × S3 × V3	35.80	52.40	11.53	26.42
I2 × S1 × V1	68.07	71.73	9.87	21.80
I2 × S1 × V2	66.87	70.15	12.00	20.40
I2 × S1 × V3	63.93	72.61	9.60	22.26
I2 × S2 × V1	47.87	60.01	11.60	24.01
I2 × S2 × V2	45.60	59.05	13.93	21.98
I2 × S2 × V3	43.13	62.25	10.80	25.72
I2 × S3 × V1	36.40	52.58	15.67	26.45
I2 × S3 × V2	31.80	50.91	18.00	24.99
I2 × S3 × V3	28.13	55.78	13.33	28.13
S. E (m)	0.244	0.264	0.454	0.338
C. D	0.701	0.757	1.302	0.971

Table 2: Effect of Environment, Sowing times and Genotypes on the number of plants affected with reddening plot^{-1}, incidence of leaf reddening (%), plant height (cm) and the number of branches plant^{-1} (monopodial branches and sympodial branches) in cotton crop.

Treatments	Plants affected with reddening plot^{-1}	Incidence of leaf reddening	Plant height (cm)	Number of monopodial branches plant^{-1}	Number of sympodial branches plant^{-1}
Environment (I)					
I0	14.59	29.75	128.46	1.67	18.39
I1	13.44	27.21	144.79	1.84	24.95
I2	17.30	33.23	111.78	1.57	19.21
S. E (m)	0.113	0.089	0.2080	0.0067	0.1195
C. D	0.338	0.266	0.6234	0.0201	0.3581
Sowing times (S)					
S1	11.48	24.45	148.23	2.10	24.45
S2	13.81	29.23	127.32	1.60	19.90
S3	20.04	36.51	109.48	1.38	18.19
S. E (m)	0.113	0.089	0.2080	0.0067	0.1195
C. D	0.338	0.266	0.6234	0.0201	0.3581
Genotypes (V)					
V1	15.19	30.17	128.45	1.64	19.17
V2	13.48	28.11	119.17	1.69	20.85
V3	16.67	31.91	137.40	1.75	22.52
S. E (m)	0.207	0.186	0.1431	0.0051	0.1077
C. D	0.593	0.534	0.4103	0.0146	0.3088
Environment × Sowing times (I × S)					
I0 × S1	11.11	24.54	144.12	2.07	21.34
I0 × S2	12.89	29.17	127.22	1.58	17.62
I0 × S3	19.78	35.53	114.04	1.34	16.22
I1 × S1	9.89	22.73	176.07	2.37	28.93
I1 × S2	12.89	26.55	136.98	1.70	24.35
I1 × S3	17.56	32.34	121.31	1.45	21.56
I2 × S1	13.44	26.08	124.50	1.86	23.08
I2 × S2	15.67	31.95	117.76	1.51	17.72
I2 × S3	22.78	41.66	93.07	1.33	16.81
S. E (m)	0.195	0.154	0.3602	0.0116	0.2069
C. D	0.585	0.460	1.0797	0.0348	0.6202
Sowing times × Genotypes (S × V)					
S1 × V1	11.56	24.77	147.60	2.02	22.86
S1 × V2	9.89	22.74	138.44	2.09	24.50

S1 × V3	13.00	25.84	158.65	2.19	26.00
S2 × V1	13.89	29.24	129.03	1.55	18.25
S2 × V2	12.56	27.07	118.39	1.60	19.89
S2 × V3	15.00	31.37	134.54	1.63	21.56
S3 × V1	20.11	36.50	108.72	1.34	16.40
S3 × V2	18.00	34.53	100.68	1.37	18.17
S3 × V3	22.00	38.51	119.03	1.41	20.01
S. E (m)	0.358	0.322	0.2478	0.0088	0.1865
C. D	NS	NS	0.7106	0.0252	NS
Environment × Genotypes (I × V)					
I0 × V1	14.56	30.03	128.33	1.60	16.83
I0 × V2	12.89	27.60	119.73	1.66	18.44
I0 × V3	16.33	31.61	137.33	1.74	19.91
I1 × V1	13.67	27.15	144.17	1.79	23.36
I1 × V2	11.44	25.52	136.10	1.84	24.97
I1 x V3	15.22	28.97	154.10	1.89	26.51
I2 × V1	17.33	33.33	112.86	1.53	17.32
I2 × V2	16.11	31.22	101.68	1.56	19.15
I2 × V3	18.44	35.14	120.79	1.61	21.15
S. E (m)	0.358	0.322	0.2478	0.0088	0.1865
C. D	NS	NS	0.7106	NS	NS
Environment × Sowing times x Genotypes (I × S × V)					
I0 × S1 × V1	11.00	25.08	142.12	1.94	20.00
I0 × S1 × V2	9.67	22.76	135.75	2.05	21.34
I0 × S1 × V3	12.67	25.78	154.49	2.23	22.68
I0 × S2 × V1	12.67	29.35	128.25	1.55	16.28
I0 × S2 × V2	11.67	26.28	118.86	1.58	17.77
I0 × S2 × V3	14.33	31.88	134.55	1.61	18.82
I0 × S3 × V1	20.00	35.66	114.61	1.32	14.22
I0 × S3 × V2	17.33	33.75	104.58	1.35	16.20
I0 × S3 × V3	22.00	37.17	122.93	1.37	18.24
I1 × S1 × V1	10.33	23.04	174.33	2.31	26.91
I1 × S1 × V2	7.67	21.10	167.19	2.37	29.09
I1 × S1 × V3	11.67	24.06	186.68	2.43	30.79
I1 × S2 × V1	13.00	26.24	138.91	1.64	22.89
I1 × S2 × V2	11.33	24.92	128.39	1.71	24.13
I1 × S2 × V3	14.33	28.50	143.65	1.74	26.03
I1 × S3 × V1	17.67	32.15	119.27	1.41	20.28
I1 × S3 × V2	15.33	30.53	112.71	1.44	21.68
I1 × S3 × V3	19.67	34.34	131.96	1.50	22.71
I2 × S1 × V1	13.33	26.18	126.37	1.82	21.67
I2 × S1 × V2	12.33	24.36	112.38	1.85	23.07
I2 × S1 × V3	14.67	27.69	134.77	1.91	24.52
I2 × S2 × V1	16.00	32.12	119.95	1.46	15.57
I2 × S2 × V2	14.67	30.01	107.93	1.51	17.76
I2 × S2 × V3	16.33	33.72	125.41	1.55	19.84
I2 × S3 × V1	22.67	41.68	92.27	1.30	14.71
I2 × S3 × V2	21.33	39.30	84.74	1.33	16.62
I2 × S3 × V3	24.33	44.02	102.20	1.37	19.09
S. E (m)	0.620	0.559	0.4292	0.0152	0.3230
C. D	NS	NS	1.2309	0.0437	0.9264

CONCLUSIONS

The study of morphological factors showed that an irrigation system produced better outcomes with the least amount of leaf reddening. Compared to the other two habitats, the waterlogged environment had a more noticeable influence on the reddening of cotton leaves. With the delay in sowing time in the cotton crop, the proportion of plants with reddening, the number of affected leaves per plant and the area of affected leaves per plant all increased. At practically all moisture circumstances, cotton sown at the normal sowing time experienced less leaf reddening than cotton sown at the delayed sowing time. Bt hybrid Rashi 659 recorded more percent incidence of leaf reddening and leaf area affected plant^{-1} compared to the other two genotypes studied.

FUTURE SCOPE

Thorough research on this topic at different stages of cotton growth would offer a helpful platform in reducing leaf reddening disease with minimal input costs, so more methodical research on this topic needs to be done in the future.

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