The Pharma Innovation Journal 2023; 12(1): 2609-2613

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(1): 2609-2613

www.thepharmajournal.com
Received: 16-10-2022
Accepted: 19-11-2022

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Phenological impact in cotton crop affected by leaf reddening due to abiotic stress

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Abstract
A field experiment was conducted during *kharif* 2020, at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar (dist.), Maharashtra, India to evaluate the abiotic cause of major disorder i.e., leaf reddening in cotton plants. The main objective of study was on phenological responses of cotton plants studied using three different genotypes in three different irrigation environments and sown during three different intervals of time. Phenological parameters such as days for first square formation, days to 50% flowering and days for first boll opening were critically observed. The experiment was carried out in double split plot design, replicated thrice. Extra late sowing time, waterlogged environment and Bt hybrid i.e., Rashi 659 have taken more number of days for first square formation, days to 50% flowering and days for first boll opening.

Keywords: Cotton, leaf reddening, irrigation environments, sowing times, genotypes

Introduction
The word cotton (noun) is originated from an Arabic word “quton.” This was the usual word for cotton in medieval Arabic. In 15th century, cotton attained a verb use meaning “to form a nap on (cloth).” Cotton is a very ancient commodity. Archaeologists found cotton fabric fragments in the indus valley of India (Pakistan), where the ancient harappan civilization flourished. In 1500 B.C. cotton was referred in a hindu rigveda hymn mentioning as “threads in the loom.” It is generally believed that the first cultivation of cotton has taken place in India. In 1920s Mohandas Karamchand Gandhi thought that cotton was closely tied to Indian self-determination and launched the Khadi Movement, a massive boycott of British goods as the end of dependency on foreign materials. He urged Indians to use simple homespun cotton textiles, khadi and thus the cotton became an important symbol in Indian independence. Cotton is one of the oldest and most important commercial crop in the world. It has been used as fabric in India from times immemorial. Cotton is referred as “King of Fibres” and also known as “White Gold”. It has indeterminate growth and deep rooted crop.

Most of the Cotton production in India comes from the states of Maharashtra, Gujarat, Andhra Pradesh and Telangana. These states are collectively known as Cotton Basket of India. Gujarat and Maharashtra are the leading producers of Cotton because of the ideal moist temperature for cotton cultivation. Area, production and productivity of cotton in Maharashtra for the year 2019-20 were 43.69 Lakh hectares, 82 Lakh bales and 319 Kg ha^{-1} respectively (Anonymous 2020) [2].

Leaf reddening is one of the most common physiological disorder in cotton induced by different abiotic stresses. It may occur at any growth stage of the crop. This disorder occurs due to interaction of location, variety and environmental condition. In grand growth phase i.e., at flowering and boll development any hindrance in the assimilate production, translocation and distribution increases the leaf reddening effect. Late planting causes crop to flower later (Gormus and Yucel 2002) [5], that may push the critical development phase of cotton to unfavorable conditions leading to leaf reddening.

Material and Methods
Present field experiment was conducted at Cotton Improvement Project, MPKV, Rahuri during *kharif* 2020 season, to find out causes for leaf reddening in cotton besides biotic stress. For the experiment 27 treatment combinations of different irrigation environments (I) viz., S_1: Normal sowing (June), S_2: Late sowing (July) and S_3: Extra Late Sowing (August), sowing times (S) viz., I_0: Rainfed, I_1: Irrigated and I_2: Water logging and genotypes (V) viz., V_1: Phule Shwetambari (H x H hybrid), V_2: Phule Mahi (H x B hybrid) and V_3: Rashi 659 (H x H Bt

hybrid) were used to investigate the abiotic causes of leaf reddening in cotton crop. The observations on phenological parameters were recorded, statistically analyzed and presented in tables and graphs. The experiment was laid out in double split plot design using three replications.

Seasonal timing of life cycle and physiological development stages of plant are observed and recorded. The whole experimental unit is investigated on a regular basis to find out the changes of biological events in crop and following observations are noted down. Number of days required for the first square appearance from each plot of the experimental unit was recorded to note down days for first square formation. Total number of days from the date of sowing to the date on which the 50 per cent of plants initiated flowering in each plot of the experimental unit was recorded to note down day to 50% flowering. The date on which the first boll opened was recorded from the plants selected for observation in all the treatment plots of the experimental unit and number of days required were calculated to note down days for first boll opening.

Results and Discussion

a. Days for first square formation

The data on days for first square formation as influenced by irrigation environments, sowing times and varieties was recorded as and when the first square was appeared on each plot of the experimental unit, demonstrated in table 1.

Effect of irrigation environments

From the data in table 1, it was revealed that different irrigation environments have significant effect on days for first square formation, where more (34.22) number of days were significantly recorded in waterlogged conditions (I2) and less (31.44) number of days were recorded in rain fed environment (I0).

Effect of sowing times

In table 1, significant variation in sowing dates was reported in case of days for first square formation. Among three different dates of sowing, extra late sowing time (S3) showed more (35.37) number of days for first square formation whereas, normal sowing time (S1) exhibited less (29.11) number of days for first square formation.

Effect of varieties

Number of days for first square formation showed significant difference among different varieties. Data from table 1 revealed that, Phule Mahi (V2) (33.11) recorded maximum number of days for first square formation followed by Phule shwetambari (V1) (32.70) and Rashi 659 (V3) (31.52).

A similar finding was reported by Chen *et al.*, 2002 [3] that reddening in Bt cotton might be associated with changes in their phenological, morphological and physiological characteristics.

Interaction effect of irrigation environments and sowing times

The result for interaction effect of irrigation environments and sowing times was presented in table 1 from which it is clear that, the irrigation environments and sowing times had significant effect on number of days for first square formation. Waterlogged environment + extra late sowing time (I2xS3) recorded significantly more (37.67) number of days for first square formation and rainfed environment + normal sowing time (I0xS1) recorded less (27.78) number of days for first square formation.

Interaction effect of sowing times and varieties

From data obtained from table 1 it is revealed that sowing times and varieties had significant effect over number of days for first square formation. Extra late sowing time + Phule mahi (S3xV2) exhibited significantly more (36) number of days for first square formation while, normal sowing time + Rashi 659 (S1xV3) recorded less (27.67) number of days for first square formation.

Interaction effect of irrigation environments and varieties

It is revealed from table 1 that, irrigation environments and varieties interact significantly in case of number of days for first square formation. Waterlogged environment + Phule shwetambari (I2xV1) recorded significantly more (34.67) number of days for first square formation whereas, lower (30.33) number of days for first square formation was observed in rainfed environment + Rashi 659 (I0xV3).

Interaction effect of irrigation environments, sowing times and varieties

Three factor interaction presented in table 1 showed that, irrigation environments, sowing times and varieties had significant effect on number of days for first square formation. Waterlogged environment + extra late sowing time + Phule shwetambari (I2xS3xV1) recorded more (38.33) number of days for first square formation being at par with waterlogged environment + extra late sowing time + Phule mahi (I2xS3xV2) (38). Whereas, lower (26.33) number of days for first square formation was observed in rainfed environment + normal sowing time + Rashi 659 (I0xS1xV3).

b. Days to 50% flowering

Flowering is an essential part if reproductive stage which is also a critical developmental phase that can be vulnerable to environmental stresses (Kazan and Lyons, 2015). The data on days to 50% flowering as influenced by irrigation environments, sowing times and varieties is presented in table 1, which showed that as the sowing time got delayed, more number of days were required for 50% flowering in cotton.

Effect of irrigation environments

Data in table 1 revealed that, different irrigation environments have significant effect on number of days to 50% flowering. Significantly more (64.41) number of days were recorded in waterlogged conditions (I2) and lower (61.30) number of days were recorded in rainfed environment (I0).

Effect of sowing times

Different sowing times reported significant variation in number of days to 50% flowering in table 1. Among three different dates of sowing, extra late sowing time (S3) showed more (64.41) number of days to 50% flowering whereas, normal sowing time (S1) exhibited less (61.30) number of days to 50% flowering.

Effect of varieties

Significant difference in number of days to 50% flowering was observed among different varieties and recorded in table 1, which revealed that, Phule Mahi (V2) (63.52) recorded

maximum number of days to 50% flowering followed by Phule shwetambari (V1) (63) and Rashi 659 (V3) (61.96).
Findings were supported by Deshmukh, 2013 regarding increase in number of cotton leaves at 50% flowering due to low intensity of leaf reddening.

Interaction effect of irrigation environments and sowing times
The data in table 1 showed that, irrigation environments and sowing times had non-significant effect on number of days to 50% flowering.

Interaction effect of sowing times and varieties
The result obtained from table 1 revealed that, sowing times and varieties had significant effect over number of days for first square formation. Extra late sowing time + Phule mahi (S3xV2) exhibited significantly more (66.11) number of days to 50% flowering and less number of days to 50% flowering were observed in normal sowing time + Rashi 659 (S1xV3) (58).

Interaction effect of irrigation environments and varieties
It is clear from table 1 that, irrigation environments and varieties had non-significant effect for the number of days to 50% flowering.

Interaction effect of irrigation environments, sowing times and varieties
Three factor interaction effect presented in table 1 showed that, irrigation environments, sowing times and varieties had non-significant effect on number of days to 50% flowering.

c. Days for first boll opening
Data regarding days to first boll opening influenced by irrigation environments, sowing times and varieties is depicted in table 1, which showed that hybrid required less time for boll opening in normal sowing time. It is also observed that waterlogged environment in hybrid, delayed the number of days for first boll opening. Delay in sowing time may reduce the number of bursted bolls due to delayed physiological maturity and carbohydrate deficiency (Gwathmey and Clement, 2010) [6].

Effect of irrigation environments
It is revealed from data in table 1 that, irrigation environments differ significantly regarding number of days to first boll opening, where more (103.04) number of days were significantly recorded in waterlogged conditions (I2) and less (97.11) number of days were recorded in rainfed environment (I0).

Effect of sowing times
From table 1 it is clear that different sowing times reported significant variation in number of days to first boll opening while, extra late sowing time (S3) showed more (108.85) number of days to first boll opening and normal sowing time (S1) exhibited less (91.70) number of days to first boll opening.
Reduction in number of days to first boll opening induced by optimum normal sowing time could be explained by the fact that delay in sowing time lengthens the period between sowing to boll opening (Gormus and Yucel. 2002) [5].

Effect of varieties
Significant difference in number of days to first boll opening was observed among different varieties and recorded in table 1, which revealed that, Phule Mahi (V2) (101.04) recorded maximum number of days to first boll opening followed by Phule shwetambari (V1) (1000.15) and Rashi 659 (V3) (98.78).

Interaction effect of irrigation environments and sowing times
Interaction effect of irrigation environments and sowing times were presented in table 1, from which it is clear that, the irrigation environments and sowing times had significant effect on number of days to first boll opening. Waterlogged environment + extra late sowing time (I2xS3) recorded significantly more (111.89) number of days to first boll opening whereas, rainfed environment + normal sowing time (I0xS1) recorded less (90.11) number of days to first boll opening.

Interaction effect of sowing times and varieties
The result obtained from table 1 revealed that, sowing times and varieties had significant effect over number of days for first square formation. Extra late sowing time + Phule mahi (S3xV2) exhibited significantly more (110) number of days to first boll opening and less (90.89) number of days to first boll opening were observed in normal sowing time + Rashi 659 (S1xV3).

Interaction effect of irrigation environments and varieties
Data from table 1 revealed that, irrigation environments and varieties had non-significant effect on number of days to first boll opening.

Interaction effect of irrigation environments, sowing times and varieties
Interaction effect of three factors presented in table 1 showed that, irrigation environments, sowing times and varieties had significant effect on number of days to first boll opening. Waterlogged environment + extra late sowing time + Phule mahi (I2xS3xV2) recorded more (112.67) number of days to first boll opening whereas, lower (89.33) number of days to first boll opening were observed in rainfed environment + normal sowing time + Rashi 659 (I0xS1xV3).
Considering the data above regarding phenological observations in cotton, irrigated environment along with normal sowing time took less time regarding days for first square formation, days to 50% flowering and days for first boll opening. In case of genotypes, Bt hybrid took less time compared to other two hybrids. Even though all these parameters differed marginally, yield differences were significant only due to physiological efficiency of genotypes. Vijaykumar and Choudary, 1986 indicated the importance of earliness in cotton by reporting a positive correlation between days to first flowering and seed cotton yield. Such type of observations were also found by Adarsh *et al*., 2002 [1].

Table 1: Effect of irrigation, sowing time and varieties on days for first square formation, days to 50% flowering and days for first boll open in cotton crop

Treatments	Days for first square formation	Days to 50% flowering	Days for first boll opening
Irrigation (I)			
I0	31.44	61.30	97.11
I1	31.67	62.78	99.81
I2	34.22	64.41	103.04
S.E(m)	0.174	0.156	0.207
C. D	0.521	0.469	0.621
Sowing time (S)			
S1	29.11	59.11	91.70
S2	32.85	63.74	99.41
S3	35.37	65.63	108.85
S.E(m)	0.174	0.156	0.207
C. D	0.521	0.469	0.621
Varieties (V)			
V1	32.70	63.00	100.15
V2	33.11	63.52	101.04
V3	31.52	61.96	98.78
S.E(m)	0.111	0.077	0.106
C. D	0.319	0.221	0.304
Irrigation x Sowing time (I x S)			
I0 x S1	27.78	57.78	90.11
I0 x S2	33.00	62.00	95.33
I0 x S3	33.56	64.11	105.89
I1 x S1	28.67	58.78	91.67
I1 x S2	31.44	64.00	99.00
I1 x S3	34.89	65.56	108.78
I2 x S1	30.89	60.78	93.33
I2 x S2	34.11	65.22	103.89
I2 x S3	37.67	67.22	111.89
S.E(m)	0.301	0.271	0.359
C. D	0.902	NS	1.076
Sowing time x Varieties (S x V)			
S1 x V1	29.44	59.33	91.89
S1 x V2	30.22	60.00	92.33
S1 x V3	27.67	58.00	90.89
S2 x V1	33.00	63.78	99.67
S2 x V2	33.11	64.44	100.78
S2 x V3	32.44	63.00	97.78
S3 x V1	35.67	65.89	108.89
S3 x V2	36.00	66.11	110.00
S3 x V3	34.44	64.89	107.67
S.E(m)	0.192	0.134	0.183
C. D	0.552	0.383	0.526
Irrigation x Varieties (I x V)0.134			
I0 x V1	31.67	61.44	97.33
I0 x V2	32.33	62.00	98.00
I0 x V3	30.33	60.44	96.00
I1 x V1	31.78	63.00	99.78
I1 x V2	32.56	63.44	101.11
I1 x V3	30.67	61.89	98.56
I2 x V1	34.67	64.56	103.33
I2 x V2	34.44	65.11	104.00
I2 x V3	33.56	63.56	101.78
S.E(m)	0.192	0.134	0.183
C. D	0.552	NS	NS
Irrigation x Sowing time x Varieties (I x S x V)			
I0 x S1 x V1	27.67	58.00	90.33
I0 x S1 x V2	29.33	58.67	90.67
I0 x S1 x V3	26.33	56.67	89.33
I0 x S2 x V1	33.33	62.00	95.33
I0 x S2 x V2	33.33	62.67	96.00
I0 x S2 x V3	32.33	61.33	94.67
I0 x S3 x V1	34.00	64.33	106.33
I0 x S3 x V2	34.33	64.67	107.33
I0 x S3 x V3	32.33	63.33	104.00

I1 x S1 x V1	28.67	59.00	91.67
I1 x S1 x V2	30.00	59.67	92.33
I1 x S1 x V3	27.33	57.67	91.00
I1 x S2 x V1	32.00	64.00	99.00
I1 x S2 x V2	32.00	64.67	101.00
I1 x S2 x V3	30.33	63.33	97.00
I1 x S3 x V1	34.67	66.00	108.67
I1 x S3 x V2	35.67	66.00	110.00
I1 x S3 x V3	34.33	64.67	107.67
I2 x S1 x V1	32.00	61.00	93.67
I2 x S1 x V2	31.33	61.67	94.00
I2 x S1 x V3	29.33	59.67	92.33
I2 x S2 x V1	33.67	65.33	104.67
I2 x S2 x V2	34.00	66.00	105.33
I2 x S2 x V3	34.67	64.33	101.67
I2 x S3 x V1	38.33	67.33	111.67
I2 x S3 x V2	38.00	67.67	112.67
I2 x S3 x V3	36.67	66.67	111.33
S.E(m)	0.333	0.231	0.318
C. D	0.956	NS	0.911

Conclusion

According to the experiment mentioned above, it can be concluded that adjustment of sowing time, proper environmental conditions and suitable genotypes lower the reddening intensity in cotton leaves. Normal sowing time of cotton showed less leaf reddening effect in cotton compared to the delayed sowing times in almost all moisture conditions. Optimum sowing time of June, irrigated environment and Bt hybrid of cotton serves better chances for decreasing number of days for first square formation, days to 50% flowering and days for first boll opening.

Acknowledgement

Heartfelt gratitude to Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra for funding and guidance to carry out P.G. research study.

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