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Growth, phenology and yield response of cotton varieties under drought stress

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Abstract
Cotton is one of the most important economic crops and the fiber produced is the raw material for the textile industry. Drought affects cotton productivity and fibre growth, resulting in poor quality of fibre. It is essential to experiment and study the response of cotton varieties to changing water deficit scenarios. Present investigation was conducted in the Rain out shelter (ROS) and the varieties taken are compact Cotton Co 17 and a check variety KC3 (Kovilpatti Cotton 3). Drought stress (55% moisture reduction from control (T_1)) was imposed on squaring (T_2) and flowering stages (T_3) of cotton varieties. Results showed that the percentage reduction was higher in growth traits and nutrients in Co 17 (N: 16 %, P: 35%, K: 22%) than KC3 (N: 10%, P: 17%, K: 16%) under flowering stress. Under drought stress, varieties showed earlier flowering phase. Drought stress reduced the yield by 37% in Co 17 and 22% in KC3.

Keywords: drought, compact cotton, early flowering, nutrients and yield

Introduction

Cotton is grown as a leading commercial crop in many countries of world with major shares from China, India United States and predominantly cultivated in warmer regions. As a glycophyte, cotton shows higher tolerance to abiotic stresses than other major crops. However, extreme environmental conditions leading to drought affects growth, productivity, and fibre quality of cotton (Parida *et al.* (2007) [14] and Riaz *et al.* (2013)) [18]. Due to climate change, the occurrence of drought has been increasing in the cotton zones of India, which caused severe loss of the cotton yield. Drought has become the most extensive stress in the cotton growing period for past decade. Episodic drought events can cause severe lint yield penalty and may become a significant challenge for sustainable crop production.

The effects of water stress on plants depend on the severity and duration of the stress, the growth stage at which plants are subjected to stress and the genotype of the plant. There is a considerable diversity observed in cotton for its growth and physiological parameters *viz.,* plant height, number of leaves, specific leaf area, plant dry weight, leaf dry weight and productivity traits *viz.,* number of bolls per plant, boll diameter, staple length, fiber strength, ginning out percentage in relation to varying moisture deficit periods (Feg *et al.* (2011)). Genetically equivalent cotton plant populations, when subjected to water deficits, show reductions in yield up to 50 per cent compared to those that have been irrigated, especially when the stress is imposed during the period between flowering and fructification (Du and Huang, 2011) [3]. The quantity and quality of the fiber produced in cotton plant crops are directly related to water availability during the different phenological phases of development. Thus, the tolerance of cotton genotypes to water deficits has been the target of various studies on both the physiological and the molecular levels (Shi *et al.* (2013) [19]. Therefore, it is of considerable significance to study the drought resistant characteristics of cotton, to evaluate the drought resistance mechanism of new varieties reasonably, and screen for drought resistance identification indices, which provide a reference for assessing drought tolerance in future.

2. Materials and methods

The present work was carried out during April – September, 2019 in the Rain out shelter (ROS) at Department of Forage Crops, TNAU Coimbatore. The ROS was situated in Western agro-climatic zone of Tamil Nadu at 11°N latitude and 77°E longitude at an altitude of 426.7 m above mean sea level. The study comprised of compact Cotton Co 17 and check variety KC3 (Kovilpatti Cotton 3). The experiment had three treatments *viz.,* T_1: Control (Well watered), T_2: Drought at squaring stage, T_3: Drought at flowering stage (level of stress - 55% moisture reduction from control) and monitored the soil moisture content by using sensors (SMT 150 with temperature measurer). Soil water properties like Field Capacity and Permanent Wilting Point were measured using Pressure Plate Apparatus to study the soil water properties in the field and compared the soil properties range with sensor range to fix the drought treatments (55% moisture). A Factorial randomized block design (FRBD) was used to set up the experiment with four replicates in 16 plots (3 m × 3 m each). Data loggers were set in such a way to record the soil moisture content and temperature range for every second and averaged to an hourly interval. During the initiation of squaring stage and flowering stage irrigation was withheld until the soil moisture content reduced to 55 % from the control soil moisture content. Observations were recorded in well watered and drought affected plants on the last day of water stress (20 days after stress - DAS). Stress imposed plots were irrigated the next day to regain the soil moisture content same as control plots. Observations on the recovery of plants from stress were recorded later 10 days after rewatering (10-DARW). Observations and laboratory analyses for various physiological, biochemical and yield parameters were carried out at the Department of Crop Physiology, Tamil Nadu Agricultural University Coimbatore.

2.1. Growth traits

2.1.1. Specific leaf weight (SLW)

Specific leaf weight was calculated by using the formula of Pearce *et al.* (1968) and expressed in mg cm^{-2}.

$$SLW = \frac{\text{Leaf dry weight (mg)}}{\text{Leaf area (cm}^2\text{)}}$$

$$LAI = \frac{\text{Leaf area per plant}}{\text{Ground area occupied by the plant}}$$

2.1.2. Earliness traits

2.1.2.1. Number of days to 50 per cent flowering

Number of days from sowing to appearance of 50 per cent flowers was noted from the ten selected plants and average number of days taken for the appearance of 50 per cent flowers was calculated and expressed.

2.1.2.2. Number of days to first opening bolls (DFOB)

Number of days from sowing to first opening of bolls was noted from the ten selected plants and average number of days taken for opening of first bolls was calculated and expressed.

2.1.3. Nutrient uptake by plants

The samples collected for the estimation of dry matter production were used for the estimation of nutrient uptake. The plant analysis was done at squaring, flowering, boll development and maturity stages. The oven dried plant samples were ground using Willey-mill and analyzed for total NPK. The uptake values were computed to kg/ha by multiplying the nutrient content with corresponding dry matter production. Total nitrogen content was done as per Microkjeldahl digestion and distillation Humphries (1956). Total phosphorus content was done as per Alkaline $KMnO_4$ method triacid digestion colorimeter Jackson (1973) [10], Total potassium content was done as per Triacid digestion by flame photometer Jackson (1973) [10].

2.1.4. Yield traits

2.1.4.1. Boll weight

The weight of fully opened and matured bolls picked from five plants was recorded and expressed as mean boll weight in g/boll.

2.1.4.2. Seed Cotton yield

The seed cotton yield obtained from the net plot area was recorded and expressed in kg/ha.

2.1.5. Statistical analysis

The experimental design was factorial experiment under randomized block design (FBRD) with four replications under two different stages and two varieties. Graphs were designed using Origin Pro 8 software. Regression analyses were carried out between traits. The data were statistically analysed using Statistical Tool SPSS and value of $P \leq 0.05$ was considered statistically significant. Standard error was shown as an estimate of variability.

3. Results and Discussion

3.1. Soil water properties

Under drought treatments there was a gradual decline in the soil moisture content. Also there was a gradual increase in the soil temperature range. At the end of the stress, there was an obvious difference among soil moisture and temperature ranges at both the stages. Soil moisture content and soil temperature range recorded during the experiment period is given in Table 1a, b. After re-watering, the soil moisture content in water deficit plots begun to regain the moisture slowly. At the same time, the soil temperature begun to decrease gradually. The weather parameters like temperature and rainfall prevailed during the cropping period are recorded (Fig.1).

Table 1: Soil moisture content (%) and soil temperature (ºC) range recorded under water deficit, a. at squaring stage, b. at flowering stage A At Squaring stage

Irrigation schedule (5 days once)	Soil Moisture - Control (%)	Soil Moisture - Stress (%)	Soil Temperature - control (°C)	Soil Temperature - stress (°C)
10-May	40.16	40.34	28.98	29.30
15-May	39.90	35.64	29.64	30.88
20-May	40.01	27.78	29.74	31.64
25-May	40.20	21.93	29.70	32.06
30-May	40.70	19.74	30.20	33.00
04-Jun	39.25	25.96	30.08	30.72
09-Jun	40.47	38.14	28.86	29.96
14-Jun	41.01	40.30	29.60	28.58

Table 2: B At Flowering stage

Irrigation schedule (5 days once)	Soil Moisture - Control (%)	Soil Moisture - Stress (%)	Soil Temperature - control (°C)	Soil Temperature - stress (°C)
30-May	41.986	41.28	28.02	28.46
04-Jun	40.30	36.85	28.34	30.48
09-Jun	40.51	32.50	27.80	31.82
14-Jun	40.56	26.57	28.68	32.58
19-Jun	41.02	20.96	28.16	33.98
24-Jun	41.44	25.67	28.26	34.28
29-Jun	40.52	37.62	27.96	31.52
04-Jul	40.46	40.90	28.34	29.88

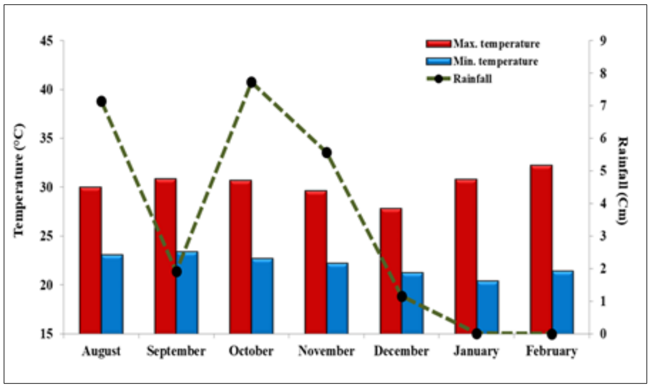

Fig 1: Details of weather data prevailed during the experimental period

3.2. Growth traits

3.2.1. Specific leaf weight

Specific leaf weight is the one of the important traits of plants as leaf is the major metabolically active organ of the plant involved in gas exchange process. The specific leaf weight (SLW) is also the key indicator of the thickness of the leaves of the plant. There were significant differences between the treatments and varieties under stress. Under drought stress, SLW got decreased in compact cotton Co 17 and KC3. Co 17 recorded a specific leaf weight of 4.28 mg cm^{-2} (T_1: Control) and 3.46 mg cm^{-2} (T_2: squaring stress) and KC3 recorded 5.24 mg cm^{-2} (T_1) and 4.79 mg cm^{-2} (T_2). At flowering stress (T_3) Co 17 recorded 5.22 mg cm^{-2} of SLW when compared to control (T1) 6.39 mg cm^{-2} and KC3 recorded 6.74 mg cm^{-2} (T_3) and 7.25 mg cm^{-2} (T_1). In both the varieties, SLW was reduced under flowering stress. But least values were found to be observed in Co 17. After re-watering, both the varieties gradually increased the SLW (T_2 - Co 17: 4.08 mg cm^{-2}, KC3: 5.12 mg cm^{-2}, T_3 – Co 17: 6.01 mg cm^{-2}, KC3: 6.23 mg cm^{-2}) (Table.2.). Many studies found that varieties with thick leaves are usually drought resistant. Li *et al.* (2017) showed that the specific leaf weight increased with increasing water stress under field conditions but the gas exchange traits got reduced. It has indicated that higher SLW had influence on the higher yield Landiver *et al.* (1983) [12].

KC3 had higher SLW along due to the ability of high water use efficiency. It has indicated that higher SLW had influence on the higher yield. These results are in conformity with the results of Landiver *et al.* (1983) [12] and Wang *et al.* (2016) [23].

3.2.2. Leaf area index (LAI)

Generally LAI is associated with yield potential of a given variety. Among the treatments, the increased leaf area index (T_2 - Co 17:0.47, KC3:0.53, T_3 – CO 17:3.17, KC3:3.25 respectively) was recorded in control (T_1) plants. Under stress treatments LAI was reduced in both the varieties (T_2 - Co 17:0.36, KC3:0.48, T_3 – CO 17:2.82, KC3:2.98), but the reduction was found to be higher in Co 17 (T_3: 15%) than KC3 (T_3: 7%) (Table.2.). Results were in consonance with the findings of Brodrick *et al.* (2013) and Rademacher, 2000 in cotton. Reduced LAI under stress was due to reduced plant height, number of leaves per ground area and less diversion of more photoassimilates towards vegetative growth of the plant (Heitholt, 1994) [6]. Tollenaar *et al.* (2004) [22] have demonstrated the same in cotton varieties in drought and found LAI is an indication of varietal superiority. Chauhan *et al.* (2009) [2] have reported in cotton, LAI would be used as a measure of high yield and showed that this character is associated with abiotic stress tolerance.

Table 3: Effect of drought stress on specific leaf weight and leaf area index in cotton varieties

Varieties	Stage	Treatments	Specific leaf weight (mg cm^{-2})			Leaf area index		
Co 17	Squaring stage	Control (T_1)	4.28			0.47		
		20 DAS (T_2)	3.46			0.36		
		10 DARW	4.08			0.42		
	Flowering stage	Control (T_1)	6.39			3.17		
		20 DAS (T_3)	5.22			2.82		
		10 DARW	6.01			3.05		
		Mean	4.90			1.71		
			V	T	V x T	V	T	V x T
		SEd	0.345	0.423	0.598	0.004	0.053	0.077
		CD (0.05)	0.073**	0.090**	0.127**	0.009**	0.011**	0.016**
KC3	Squaring stage	Control (T_1)	5.24			0.53		
		20 DAS (T_2)	4.79			0.48		
		10 DARW	5.12			0.51		
	Flowering stage	Control (T_1)	7.25			3.25		
		20 DAS (T_3)	6.74			2.98		

		10 DARW	6.23			3.11		
		Mean	5.895			1.81		
			V	T	V x T	V	T	V x T
		SEd	0.066	0.081	0.115	0.023	0.029	0.041
		CD (0.05)	0.142**	0.174**	0.246**	0.051**	0.062**	0.088**

3.3. Earliness traits

3.3.1. Days to 50 per cent flowering and Days to first opening of bolls

Days to 50 per cent flowering, boll opening and maturity were the reliable method of finding out earliness in cotton, while time of appearance of fruiting nodes on first sympodial branch and mean dates of maturity were the next best method in its reliability. In the present study, days to 50 per cent flowering was found to be reduced under drought stress. Days to 50% flowering Co 17 was T_1 – 54, T_2 - 51, T_3 – 49 and in KC3 was T_1 – 56, T_2 - 54, T_3 – 51 respectively. Co 17 was found to possess earlier flowering and earlier days to 50% flowering. First opening of boll was also observed to Co 17 (T_1 – 110, T_2 - 112, T_3 – 95, KC3: T_1 – 124, T_2 - 119, T3 – 100) (Fig.2.).

Though the earliness traits were actively found in both varieties, Co 17 recorded more earliness characters than KC3 and control treated plants. At the same time early flowered buds and matured bolls were mostly dried and wilted under flowering stress (T_3) in Co 17.

This was due to in adequate nutrients and assimilates under drought. Singh *et al.* (2018) [20] reported that when water was withheld from flowering for 10 days in cotton, phenology changed and flowering advanced but flowers were found to be dried, reduced size and lesser boll size.

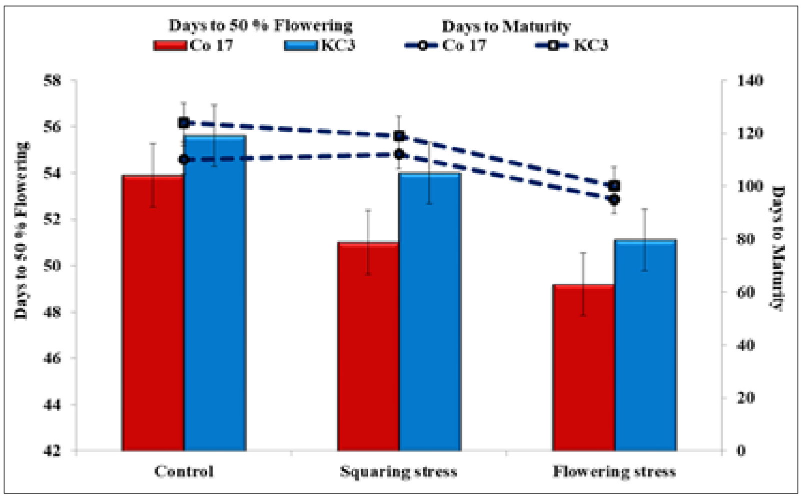

Fig 2: Effect of Drought stress on earliness traits in cotton varieties

Pilon (2019) [16] indicated that moisture deficit created by the dry land treatment consistently affected reproductive part development of cotton at all stages even if flowering is earlier. These findings were also in accordance with Takeno (2016) [21].

3.4. Nutrient content

Direct and indirect effects of nutrient availability during drought have impacts on survival of plants. In present investigation, nutrients like N, P, K were reduced under drought stress. Both under squaring (T_2) and flowering stress (T_3) Co 17 (N: 31.9 Kg/ha, P: 4.3 Kg/ha, K: 28.9 Kg/ha) and KC3 (N: 32.8 Kg/ha, P: 5.1 Kg/ha, K: 29.3 Kg/ha) were found to have less nutrient contents (Table.3.). But the reduction percentage was higher in Co 17 (N: 16 %, P: 35%, K: 22%) than KC3 (N: 10%, P: 17%, K: 16%) under T_3. KC3 showed its supremacy with less reduction of nutrient contents drought at both stages. This is probably due to less availability of these elements to the plant under drought stress condition.

The uptake of nitrogen, phosphorous and potassium was significantly reduced by water stress in cotton plants as observed by Zhang *et a.l* (2011) [25].

Zhong *et al.* (2017) [26] stated that nutrition uptake was affected by water stress in cotton. These findings were also in accordance with Iqbal (2020) [9] and Kirnak *et al.* (2001) [11].

Table 4: Effect of Drought stress on nutrient uptake (Kg/ha) in cotton varieities

a. At squaring stage

Varieties	N			P			K		
	Control	20 DAS	10 DARW	Control	20 DAS	10 DARW	Control	20 DAS	10 DARW
Co 17	32.1	26.1	31.3	4.7	3.2	4.5	21.3	17.8	20.7
KC3	30.9	28.4	30.1	4.3	3.7	4.1	19.2	16.5	18.6
Mean									
	V	T	V x T	V	T	V x T	V	T	V x T
SEd	0.261	0.320	0.452	0.384	0.047	0.066	0.163	0.202	0.283

CD (0.05)	0.557**	0.682**	0.964**	0.081**	0.101**	0.141**	0.481**	0.590**	0.834**

Table 5

b. At flowering stage

Varieties	N			P			K		
	Control	20 DAS	10 DARW	Control	20 DAS	10 DARW	Control	20 DAS	10 DARW
Co 17	37.8	31.9	35.2	6.8	4.3	5.5	37.4	28.9	34.4
KC3	36.5	32.8	35.9	6.2	5.1	5.8	35.1	29.3	33.2
Mean									
	V	T	V x T	V	T	V x T	V	T	V x T
SEd	0.289	0.354	0.501	0.048	0.059	0.0835	0.180	0.220	0.312
CD (0.05)	0.616**	0.755**	1.068**	0.102**	0.125**	0.177**	0.383**	0.470**	0.665**

3.5. Yield traits

Yield components were also reduced due to water stress. By evaluating cotton varieties for yield components significant differences was observed among varieties and water treatments and decreased seed cotton yield. In our study, during squaring stress the reduction in boll weight of Co 17 was recorded as 3.22g/boll over control (6.02 g/boll) and KC3 recorded 3.06g/boll over control (4.02 g/boll). Seed cotton yield showed a drastic reduction during the flowering stress (T_3) (Co 17: 1463Kg/ha over control: 2125 Kg/ha; KC3: 1089Kg/ha over control (1377Kg/ha). Similarly in case of flowering stage stress the percentage reduction was very high in Co 17 (41%) when compared with KC3 (12%). The percentage reduction of Co 17 was 37% over control, whereas KC3 recorded 22% reduction from control (Fig.3.). The varieties CO 17 performed least during flowering period and were adversely affected by water deficit for yield and other traits. Singh *et al.* (2018) [20] evaluated the cotton genotypes under stress and recorded significant decrease in seed cotton yield, number of bolls, boll weight. Similar results were reported by Gu *et al.* (2014) and Hu *et al.* (2020). Yield formation is highly dependent on carbon availability and partitioning within the plant, therefore the sensitivity of plant growth to drought is related to remobilization and utilization of carbohydrates under water-deficit stress**.** The results suggest that water stress during flowering stages is sensitive to both Co 17 and KC3. These results are in accordance with Wang *et al.* (2016) [23].

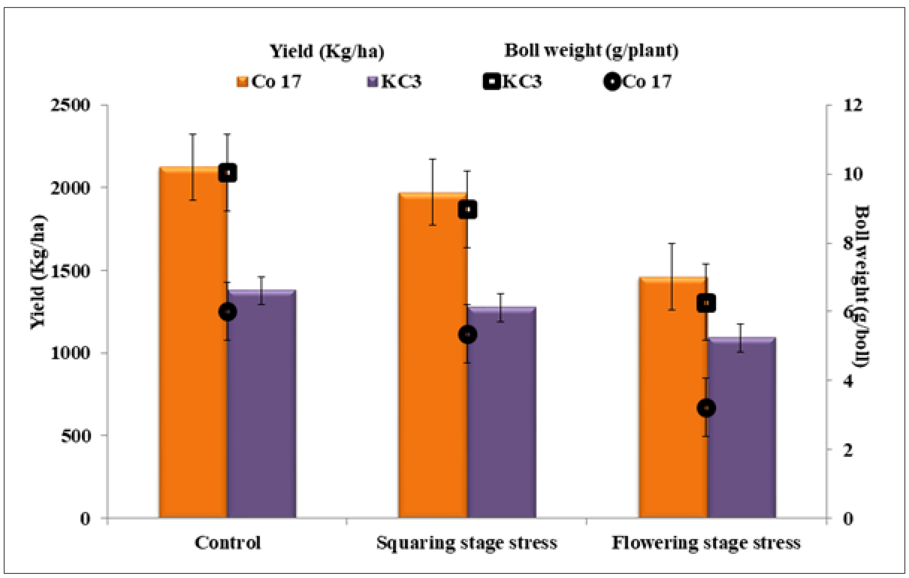

Fig 3: Effect of drought stress on boll weight and seed cotton yield in cotton varieties

4. Conclusion

From the present study, it is concluded that, compact cotton Co 17 when undergoes drought condition, it showed significant changes in its growth, phenology, nutrients and yield attributes. The results suggest that drought stress during flowering stages is sensitive to Co 17 than KC3. It is evident from the study that Co 17 requires one-time irrigation during flowering period to survive water deficit when compared to KC3. The traits observed in the study could be the potential indicators for drought tolerance in breeding programme

5. References

1. Brodrick R, Bange MP, Milroy SP, Hammer GL. Physiological determinants of high yielding ultra- narrow row cotton: Canopy development and radiation use efficiency. Field Crops Research. 2013; 148:86-94
2. Chauhan JS, Meena ML, Saini M, Meena DR, Singh M, Meena SS, *et al.* Heat stress effects on morpho-physiological characters of Indian mustard (*Brassica juncea* L.). Proceedings of 16th Australian Research Assembly on *Brassicas* on changing foods, changing climate, changing canola, Ballarat, Australia, 2009, 91-97.

3. Du CL, Huang GQ. Research progress of major identification indicators in the cotton drought-resistance. Chinese Agricultural Science Bulletin. 2011; 27:17-20.
4. Feng FJ, Song M, Chen QJ, Yao ZP, Li YY, Liu Y, *et al*. Analysis and comprehensive evaluation on principal component of relative indices of drought resistance at the seedling stage of cotton. Journal of Xinjiang Agricultural University. 2011; 34:211-217.
5. Gu Z, Huang C, Li F, Zhou X. A versatile system for functional analysis of genes and microRNAs in cotton. Plant Biotechnology Journal. 2014; 12:638-649.
6. Heitholt JJ, Pettigrew WT, Meredith WR. Light interception and lint yield of narrow-row cotton. Crop Science. 1992; 32(3):728-733.
7. Hu W, Huang Y, Loka DA, Bai H, Liu Y, Wang S, *et al*. Zhiguo Zhou1 Drought-induced disturbance of carbohydrate metabolism in anthers and male abortion of two *Gossypium hirsutum* cultivars difering in drought tolerance. Plant Cell Reports. 2020; 39:195-206.
8. Humphries EC. Mineral components and ash analysis. Modern methods of plant analysis. Springer-Verlang, Berlin, 1956, 468-502.
9. Iqbal A, Dong Q, Wang X, Gui H, Zhang H, Zhang X, *et al*. Variations in Nitrogen Metabolism are Closely Linked with Nitrogen Uptake and Utilization Efficiency in Cotton Genotypes under Various Nitrogen Supplies. Plants. 2020; *9*:250.
10. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 1973, 1-498.
11. Kirnak H, Kaya C, Higgs D, Gercek S. A long term experiment to study the role of mulches iin physiology and macro nutrienion of strawberry grown under water stress. Crop Pasture Science. 2011; 52:937-943
12. Landiver JA, Baker DN, Jenkins JN. Application of GOSSYM to genetic feasibility studies II - Analysis of increasing photosynthesis, specific leaf weight and longevity of leaves in cotton. Crop Science. 1983; 23:504-510.
13. Li ZW, Chen YL, Luo JJ, Shi YT, Feng KY, Chen ZX, *et al*. Screening and evaluation for drought resistance of cotton varieties. Agricultural Research in the Arid Areas. 2017; 35:240-247.
14. Parida AK, Dagaonkar VS, Phalak MS, Umalkar G, Aurangabadkar LP. Alterations in photosynthetic pigments, protein and osmotic components in cotton genotypes subjected to short-term drought stress followed by recovery. Plant Biotechnology Reports. 2007; 1:37-48.
15. Pearce RB, Brown RH, Blaser RE. Photosynthesis of alfalfa leaves as influenced by age and environment. Crop Science. 1968; 8:677-680.
16. Pilon C, Loka D, Snider JL, Oosterhui DM. Drought-induced osmotic adjustment and changes in carbohydrate distribution in leaves and flowers of cotton *(Gossypium hirsutum L.)*. Journal of Agronomy and Crop Sciences. 2019; 205**:**168-178.
17. Rademacher W. Growth retardants: Effect of gibberellins biosynthesis and other metabolic Pathways. Annual Reviews on Plant Physiology and Molecular Biology, 2000, 501-531.
18. Riaz M, Farooq J, Sakhawat G, Mahmood A, Sadiq M, Yaseen M, *et al*. Genotypic variability for root/shoot parameters under water stress in some advanced lines of cotton (*Gossypium hirsutum* L.). Genetic Molecular Research. 2013; 12:552-561.
19. Shi YT, Chen YL, Luo JJ, Pei HD, Zhang YP, Nan HY. Identification and evaluation of drought tolerant indices of colored cotton. Crops. 2013; 29:62-67.
20. Singh K, Wijewardana C, Gajanayake B, Suresh L, Ted W, Don J. Genotypic variability among cotton cultivars for heat and drought tolerance using reproductive and physiological traits. Euphytica. 2018; 214:57.
21. Takeno K. Stress-induced flowering: the third category of flowering response. Journal of Experimental Botany. 2016; 67(17):4925-4934.
22. Tollenaar M, Ahmadzadeh A, Lee EA. Physiological basis of heterosis for grain yield in maize. Crop Science. 2004; 44:2086-2094.
23. Wang R, Gao M, Ji S, Wang S, Men Y, Zhou Z, *et al*. Carbon allocation, osmotic adjustment, antioxidant capacityy and growth in cotton under long term soil drought during flowering and boll-forming period. Plant Physiology and Biochemistry. 2016; 107:137.
24. Williams SRF. Methods of growth analysis. Plant photosynthetic production manual methods. Drow, Jenk N.U. Publishers. The Hague, 1946, 348-391.
25. Zhang YL, Hu YY, Luo HH, Chow WS, Zhang WF. Two distinct strategies of cotton and soybean dimering in leaf movement to perform photosynthesis under drought in the field. Functional Plant Biology. 2011; 38:567-575.
26. Zhong C, Cao X, Hu J, Zhu L, Zhang J, Huang J, *et al*. Nitrogen metabolism in adaptation of photosynthesis to water stress in rice grown under di_erent nitrogen levels. Frontiers in Plant Science. 2017; 8:1079.