Effect of water stress on physiological traits of sunflower (*Helianthus annuus* L.) restorer lines

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ABSTRACT

A field experiment was conducted during *rabi,* 2018 to evaluate the performance of eight sunflower restorer lines *viz.,* RGP 21-P6, RGP 32-P1, RGP 33-P5, RGP 50-P1, RGP 60-P2, RGP 61-P1, RGP 61-P2 and RGP 95-P1 for physiological traits under water stress conditions in a split-plot design with three replications. Water stress was imposed in stress plots from flowering to harvest. Results indicated that the traits, leaf area index (LAI), total drymatter (TDM), proline accumulation, and crop growth rate (CGR) were more sensitive to moisture stress with above 30% reduction. Whereas, SPAD chlorophyll meter readings (SCMR) was less sensitive with less than 10% reduction due to water stress. Significant decrease and variation was observed among the restorer lines for LAI, SCMR, TDM, relative water content (RWC) and CGR, whereas leaf temperature and proline concentration increased due to water stress. Restorer lines RGP 21-P6, RGP 61-P1, RGP-61-P2, and RGP 95-P1 recorded superiority in LAI, CGR, TDM and leaf temperature among the physiological traits studied even under water stress.

Keywords: Physiological traits, Restorer lines, Sunflower, Water stress

Among abiotic stress factors, drought is the most significant one, which creates problems on the one third of the world's agriculture area. The amplified water shortage and recurrent drought in agricultural ecosystems have caused problems worldwide, causing the yield losses for many crops. The latest findings suggest that, in recent decades, the frequency of occurrence of drought has significantly increased in India (Aadhar and Mishra, 2017). And this frequency is set to increase between 2020 and 2049 (Collison *et al*., 2000). India has about 140 M.ha of cultivable land. 42% of the country's cultivable land lies in drought-prone areas/districts. Moreover, 54% of India's net sown areas depend on rain, and rainfed agriculture plays an important role in the country's economy (BMEL, India Country Report, 2016). It is therefore important to breed drought-resistant crops to ensure food security.

Sunflower (*Helianthus annuus* L.) is the most important source of cooking oil and the third largest oilseed crop in the world. The productivity of sunflower is greatly affected by drought (Debaeke *et al.,* 2017), though it is considered moderately tolerant to drought stress (Tahir *et al.,* 2002). It is well known that sunflower yield decreases under drought stress (Erdem *et al.,* 2006) and is dependent on the level of water deficit and cultivar (Rodriguez *et al.,* 2002).

Major area of sunflower is occupied by hybrids which are developed using a 3 line system (CMS, maintainer and restorer) where R lines act as male parent. In this context, the identification of water stress-tolerant parental lines to develop resistant varieties or hybrids through breeding programme may constitute long-lasting measures to mitigate the negative impacts of global warming and resultant climate change. Moreover, seed-based technologies are easy to transfer to a farmer's field compared to the management technologies that require skill. The identification and development of water stress tolerant types will let more active utilization of dry lands (Ucak, 2017). Therefore, the objective of this study was to evaluate the effect of water stress on physiological characteristics of sunflower restorer lines for superior line identification under water stress.

MATERIALS AND METHODS

A field trial was conducted during *rabi,* 2018-2019 at ICAR-IIOR Narkhoda farm in a split-plot design with control and water stress as main plot treatments and restorer lines as subplot treatments replicated thrice. The weather data during the crop period was presented in the Fig.1. The subplots included eight sunflower R-lines *viz.,* RGP 21-P6, RGP 32-P1, RGP 33-P5, RGP 50-P1, RGP 60-P2, RGP 61-P1, RGP 61-P2, RGP 95-P1 and two checks DRSH-1, 298R developed at ICAR-Indian Institute of Oilseeds Research (ICAR-IIOR). Plots were irrigated at 10 days interval until crop reached flowering stage, water stress was imposed by withholding irrigation to the stress plots from flowering till harvest. The crop was subjected to stress intensity index of 0.33 which is considered as moderate. Each treatment plot size was 3.6 m^2 and the row spacing of 60 cm and intra row spacing of 30 cm. Sowing was done by dibbling and applied recommended fertilizer dose [60 Kg N (2 splits) + 90 Kg P_2O_5 + 30 kg K_2O], and other package of practices were followed to raise a healthy crop. Prophylactic measures were

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adopted against pests and diseases. Non-destructive analysis data was taken by tagging 5 plants in each replication. SCMR values were measured in upper, middle, and lower leaves at five points on each leaf using SPAD meter (Konica Minolta). The average of these five readings was considered as SCMR reading of the leaf. The leaf temperature was measured on the same leaf using Infra-Red thermal gun (AGRI-THERM-6210L). The total leaf area per plant was measured by LI-3100C Leaf area meter. From the leaf area of these five plants, the LAI was calculated using the formula LAI = leaf area/ground area. RWC was determined from the youngest fully expanded leaves, and calculated by the formula modified by Smart and Bingham (1974). Proline content was estimated by following the method of Bates et al. (1973). TDM was obtained by uprooting three plants from each treatment and separating them into component parts like stem, leaf, and capitulum and kept in brown paper bags and dried to a constant weight in a hot air oven at 80°C. CGR was calculated from the TDM.

RESULTS AND DISCUSSION

Assessment of various physiological characteristics of the sunflower restorer lines under water stress is essential to identify lines with superior traits. The variation for traits - LAI, SCMR, RWC, proline concentration, TDM, and CGR was significant among the restorer lines and also between the control and stress treatment (drought intensity index of 0.33).

Leaf area expansion and division are affected by water stress causing decrease in leaf area. Lines that maintain better water status even under water stress record minimal reduction. LAI ranged from 0.9 to 1.5 among different lines in stress with 54% reduction and the maximum was recorded in RGP 61-P2. Restorer lines RGP 21-P6, RGP 61-P1, RGP 61-P2, RGP 95-P1, and hybrid check DRSH-1 were on par with each other and have significantly (p=0.05) higher LAI than restorer check 298R (Table 1). Hussain *et al.* (2017) and Umar and Siddiqui (2018) also reported similar decrease of LAI due to water stress. Among these lines, RGP-21-P6 and RGP 61-P2 also recorded higher seed yield in water stress (Yasaswini *et al*., 2020).

SCMR was the only physiological trait that was affected least due to water stress (4%). SCMR ranged from 34.3 to 47.0 and 33.8 to 46.1 under control and stress treatments respectively among the genotypes tested (Table 1). All the restorer lines under study had significantly higher SCMR values than check 298R under control and stress treatments except RGP 21-P6. Most of the R-lines under study recorded higher SCMR values than hybrid check DRSH-1. RGP 61-P1, RGP 61-P2 had higher SCMR under water stress conditions. A similar trend of reduction in SCMR under stress was confirmed by the findings of Santhosh *et al.* (2016) and Ucak *et al.* (2017). Relative water content (RWC) which indicates plant water status, ranged in different lines from 71-79 and 61-73 respectively in control and water stress with mean reduction of 15% due to stress (Table 1). A decrease in RWC could inhibit the photosynthesis capacity of sunflower and thereby affecting the yield (Tezara *et al.,* 2002). High RWC was reported by check 298R followed by RGP 21-P6 under control and water stress. All the restorer lines were on par with 298R and significantly greater than DRSH-1 under control. RGP 21-P6 was the only restorer line that was on par with check 298R under stress. Similar results were also reported by Gholinezhad *et al.* (2009) and Umar and Siddiqui (2018).

Proline content ranged from 2.5-4.2 µmole/g and 3.9-16.3 µmole/g under control and water stress respectively. It was increased by 45% due to water stress (Table 1). All the restorer lines were on par with each other under control conditions. DRSH-1 recorded the least proline accumulation under stress and RGP 60-P2 recorded significantly high proline under water stress followed by RGP 95-P1, which were on par with check 298R. Proline acts as an osmolyte, and also propels cellular signalling processes that promote cellular apoptosis or survival (Xinwen Liang *et al.,* 2013). Increased proline concentration under water stress was reported by Oraki *et al.* (2012) and Umar and Siddiqui (2018).

A significant decrease in TDM at 70 DAS (32%) and during harvest (36%) was observed due to water stress. TDM ranged from 27-60 g/plant and 18-39g/plant under control and stress respectively at 70 DAS (Table 2). During harvest, the TDM recorded was 57-94g/plant and 35-69g/plant under control and stress respectively. RGP 61-P2 recorded significantly higher TDM (94 g/plant) than checks in control. RGP 61-P2 followed by RGP 95-P1 recorded TDM at par with restorer check 298R. Least percent reduction under stress was shown by checks DRSH-1 and 298R closely followed by RGP-95-P1. Reduction in biomass due to water stress was observed in almost all genotypes of sunflower studied by Tahir and Mehid (2001) and Geetha *et al.* (2012) and the present findings were in tune with them.

Restorer lines under study showed significant variation for CGR at 40-70 DAS and 70 DAS-harvest (Table 2). Water stress reduced the CGR by 32 and 36% at 40-70 DAS and 70 DAS to harvest respectively. A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Farooq *et al.,* 2009). High CGR both under control and water stress was recorded by RGP 21-P6 and RGP 61-P2 respectively at 40-70 DAS and 70 DAS-harvest respectively. RGP 61-P2 recorded significantly higher CGR compared to checks under control during 70 DAS-harvest. Highest CGR under stress was recorded by DRSH-1 and no restorer line under study was on par with it. All the restorer lines except RGP 32-P1, RGP 33-P5 and RGP 50-P1 were on par with the check 298-R. Reduction in biomass due to water stress was observed in almost all genotypes of sunflower (Tahir and Mehid, 2001).

Table 1 LAI, SCMR, RWC, proline concentration and membrane stability of the restorer lines under control and water stress (mean values of 15 plants of the three replications under each treatment)

R Line	LAI		SCMR		RWC(%)		Proline (µmole/g)	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
RGP 21-P6	3.4	1.2	36.4	34.5	79	72	2.7	6.9
RGP 32-P1	1.7	0.9	42.1	41.8	78	63	4.2	5.3
RGP 33-P5	2.4	1.0	40.5	38.6	76	61	3.5	3.8
RGP 50-P1	2.6	1.0	47.0	42.0	77	65	2.7	5.0
RGP 60-P2	2.3	1.1	44.5	42.4	76	62	3.8	16.3
RGP 61-P1	2.4	1.3	46.3	42.7	76	63	2.5	3.9
RGP 61-P2	2.6	1.5	45.3	43.6	75	65	3.6	5.0
RGP 95-P1	2.2	1.3	40.0	39.4	74	62	3.8	9.8
DRSH-1	3.8	1.3	41.8	41.1	71	62	2.4	3.5
298-R	2.4	0.9	34.3	33.8	79	73	2.8	14.5
Mean	2.6	1.1	42	40	76	65	3.2	7.4
CD (P=0.05)								
Stress	0.5		1.3		1.0		2.5	
R lines	0.3		1.6		6.0		4.0	
Interactions	0.6		NS		NS		5.7	

Table 2 TDM, CGR and leaf temperature of the restorer lines under control (C) and water stress (WS)

R Line	TDM(g/plant)				CGR ($g/m^2/d$)				Leaf temperature (˚C)			
	70 DAS		Harvest		70 DAS		Harvest		65 DAS		75 DAS	
	C	WS	C	WS	C	WS	C	WS	C	WS	C	WS
RGP 21-P6	60	29	71	43	8.5	4.1	10.1	6.0	20.6	24.4	20.5	24.2
RGP 32-P1	31	18	76	35	4.4	2.6	10.7	4.9	23.2	23.9	22.2	25.7
RGP 33-P5	27	24	57	35	3.9	3.4	8.1	5.0	23.6	23.7	22.7	23.5
RGP 50-P1	41	21	78	37	5.9	3.0	11.1	5.2	23.6	24.7	20.6	23.8
RGP 60-P2	41	24	71	40	5.7	3.4	10.0	5.6	23.1	23.9	22.0	25.3
RGP 61-P1	40	28	66	45	5.6	4.0	9.4	6.3	23.3	25.1	20.8	24.3
RGP 61-P2	43	41	94	50	6.1	5.8	13.3	7.1	22.9	23.5	20.5	25.0
RGP 95-P1	41	31	64	49	5.9	4.4	9.1	6.9	22.7	22.8	21.2	23.8
DRSH-1	49	39	70	69	6.9	5.5	9.9	9.8	21.5	23.5	21.5	24.0
298-R	46	27	67	52	6.6	3.8	9.5	7.4	21.6	23.6	20.7	24.4
Mean	42	28	71	45	5.9	4.0	10.1	6.4	22.6	23.9	21.3	24.4
CD (P=0.05)												
Stress	1.4		2.0		NS		0.9		0.6		NS	
R lines	2.2		2.7		1.5		2.0		0.9		0.7	
Interactions	3.3		4.1		2.3		NS		1.3		1.1	

A significant increase in leaf temperature of stressed plants was observed at 65 DAS (Table 2). However, significant variation among restorer lines was observed both at 65 and 72 DAS. Maximum and minimum temperatures ranged from 20.6-23.6°C and 22.8-25.1°C under control and stress respectively at 65 DAS. RGP 95-P1 (+0.1°C), RGP 61-P2 (+0.6°C), RGP 60-P2 (+1.1°C), RGP 32-P1 (+0.7°C) and RGP 33-P5 (+0.1°C) showed a minimal increase in temperature and were having significantly lower temperatures compared to checks at 65DAS. Among the restorer lines, RGP 95-P1 and RGP 33-P5 showed significantly lower temperatures under water stress even at 75 DAS. Similar results were reported by Canavar (2013).

Based on several parameters, the restorer lines RGP 21-P6, RGP 61-P1, RGP-61-P2, and RGP 95-P1 that recorded high values for the traits - LAI, proline, RWC and CGR under stress condition with negligible increase in leaf temperature could be considered as water stress tolerant lines and they could be used in breeding programmes aimed at developing water stress tolerant hybrids.

Table 3 Summary table for superiority in physiological traits

	RGP 21-P6	RGP 32-P1	RGP 33-P5	RGP 50-P1	RGP 60-P2	RGP 61-P1	RGP 61-P2	RGP 95-P1	DRSH-1	298-R
LAI (> 1.1)	✓					✓	✓	✓	✓	✓
TDM (> 45 g/plant) at harvest						✓	✓	✓	✓	✓
SPAD (> 40.0)		✓		✓	✓	✓	✓		✓	
Leaf temperature (< 24.4°C at 75 DAS)	✓		✓	✓	✓		✓		✓	✓
RWC (>65%)	✓			✓			✓			✓
Proline (> 7.4 µ mole per g FW)					✓			✓		✓
CGR (> 6.4 g $m^{-2}day^{-1}$) at harvest							✓	✓	✓	✓

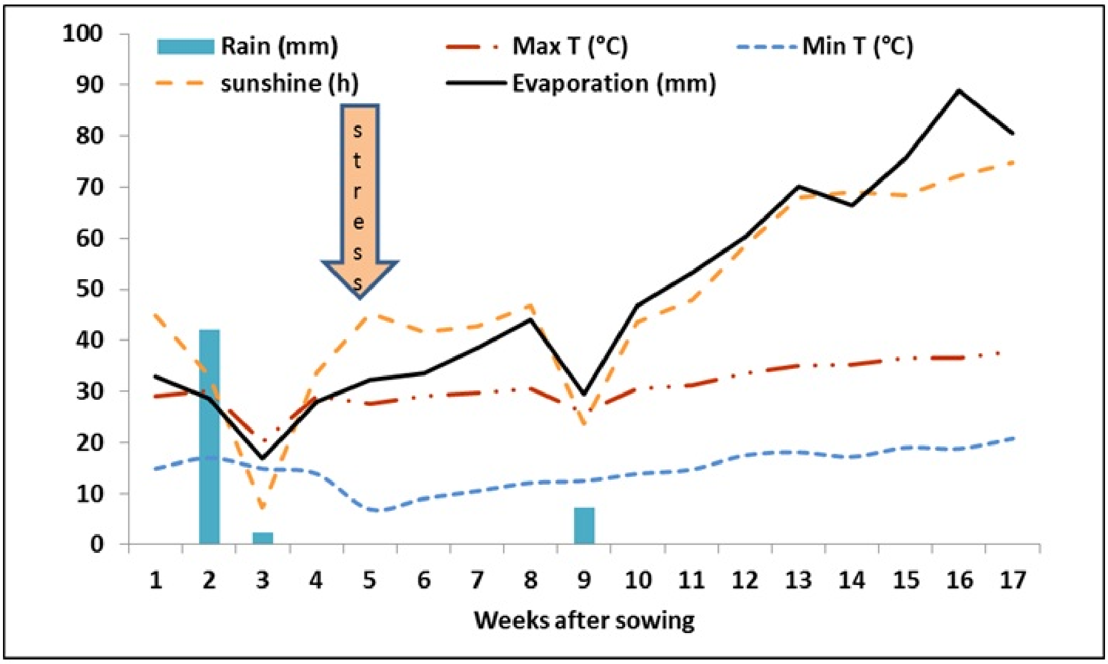

Fig. 1. Weekly weather data (temperature, evaporation, sunshine hours and rainfall) during crop growth period from 01-12-2018 to 29-03-2019

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