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Physiological attributes of sunflower (*Helianthus annuus* L.) as influenced by moisture regimes

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ABSTRACT

Investigations were carried out to study the physiological and yield variability in sunflower lines at college farm, College of Agriculture, PJTSAU, Hyderabad during late *rabi* 2013-14. The material composed of four sunflower hybrids (GMU-337, GMU-437, EC-602063 and DRSF-113). Water stress imposed from 30-65 DAS resulted in decreased SCMR values, stomatal conductance, fluorescence, and photosynthetic rate. The analysis of variance revealed the presence of sufficient variability for physiological attributes. The genotype DRSF-113 showed maximum values for SPAD chlorophyll meter readings (31.5), stomatal conductance (193.5 mmol (H_2O) m^{-2} s^{-1}), photosynthetic rate (25.5 μ moles CO_2 $m^{-2}s^{-1}$), fluorescence (Fv/ Fm) (0.565) and yield (1488 kg/ha) . The results also shown that the yield positively correlated with leaf greenness (SPAD chlorophyll meter readings) and fluorescence (Fv/ Fm). Based on the results, out of the four genotypes studied DRSF-113 and EC-602063 can be concluded as tolerant for moisture stress than genotypes GMU-337 and GMU-437.

Key words : *Drought tolerance, Helinathus annuus, Physiological attributes, Sunflower, Water stress.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) occupies a prominent place among oilseed crops as it contributes about 12% to the edible oil production. Globally, the crop is grown in an area of 20m ha with total production of 12-24 m tones. It contains about 40-45% edible oil and the average productivity in India is very low 655 kg/ha compared to the world average of 1500 kg/ha. Only 25% of sunflower area is under irrigation and 75% depends on rain. Among several biotic and abiotic stresses constraining crop productivity, drought is most prevalent and important. As stress affects different physiological parameters and processes, it causes up to 50% reduction in biomass and more than 50% reduction in yields.

Among different problems faced by crop plants, water stress is considered to be the most critical one. Plants being immobile cannot evade water stress in the same way as mobile organisms. So, they show many morphological and physiological alterations to acclimatize to unfavorable environment.

Several traits have been reported to play a role in imparting drought tolerance. The physiological parameters such as photosynthetic rate and SPAD chlorophyll meter readings (SCMR) among them are important to study the influence of water deficit on sunflower plants. The present study was conducted to find the responses of sunflower to water stress.

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MATERIALS AND METHODS

A research project entitled "Physiological Attributes of Sunflower (*Helianthus annuus* L.) as Influenced by Moisture Regimes" This experiment was conducted on sandy loam soil at student's farm, College of Agriculture, PJTSAU, Rajendranagar, during late *rabi* 2013-14. The farm falls under the Southern Telangana agro-climatic of Telangana. The mean weekly maximum and minimum temperatures during the crop growth period was 31.7 ^{0}C and 17.1 ^{0}C. While the average RH during the crop growing period was 81 %.The total rainfall received during the crop growth period was 57.8 mm in 5 rainy days.

The sunflower lines DRSF-113 and EC-602063 were selected as tolerant and GMU-337 and GMU-437 were selected as less tolerant to moisture stress. These genotypes were studied in field experiment, and various physiological parameters were observed. The experiment had two main plots for stress imposition *viz.,* control and water stress and constituted sub-plots which were genotypes mentioned above. Stress was assigned to main plots *viz.,* control and water stress and constituted sub-plots. Water stress imposed to the field from 30-65 DAS.

The SPAD-502 (soil plant analytical development) meter was used for measuring the relative chlorophyll content of leaves. The SCMR values were measured for recent fully expanded leaves at three points of each leaf (upper, middle and lower part). This meter enables to obtain instant readings without destroying the plant tissue. Fluorescence was measured by using fluorometer OS-500 (Opti-Science, USA) from leaves that had expanded recently and expressed as fluorescence (Fo, Fm and ratio of Fv/Fm). The photosynthetic rate was measured by using Infra Red Gas Analyser (Model- TPS-1) from leaves that had expanded recently. The net exchange of CO_2 between a leaf and the atmosphere is measured by enclosing the leaf in closed chamber, and monitoring the rate at which the CO_2 concentration in chamber changes over a fairly short time interval. Photosynthetic rate was expressed in μ moles CO_2 m^{-2} s^{-1}. The stomatal conductance measurements were made by using Infra Red Gas Analyser (Model-TPS-1) and expressed in mmol (H_2O) m^{-2} s^{-1}. Net assimilation rate (*E*) is useful measure of the photosynthetic efficiency of plants as the rate of increase of dry weight (*W*) per unit of leaf area (*L*); that is

$$E = 1/L\,(dW/dt)$$

The data recorded was subjected to statistical analysis in a strip plot design. Critical difference for examining significance was calculated at 5 per cent level of probability.

RESULTS and DISCUSSION

In the present investigation, SPAD chlorophyll meter reading of 4 genotypes was significantly affected by stress. It was decreased with increase in stress duration. The SPAD meter readings were increased with age up to 55 DAS and there after decreased (**Table 1**). There is significant difference between control and stress with respect to SPAD chlorophyll meter readings of sunflower crop at 45, 55, 65, 75 and 85 DAS. Highest SPAD chlorophyll meter reading was recorded in control conditions (42) at 55 DAS. The percentage reduction in SPAD chlorophyll meter readings in moisture stress treatment as compared to control treatment was highest at 85 DAS (21.2%), followed by at 65 DAS (15.4%). The sunflower genotypes differed significantly in SPAD chlorophyll meter readings at 45, 55, 65 and 75 DAS. The highest SPAD chlorophyll meter reading was recorded in DRSF-113 and EC-602063 (41) at 55 DAS. A similar trend was found by several workers Sudhakar *et al.* (2006). SPAD chlorophyll meter reading, a reflection of leaf chlorophyll/leaf nitrogen declined in stress treatment due to degradation of leaf chlorophyll content (Geetha *et al.,* 2012a).

Stomatal conductance decreased significantly under stress compared to non-stress treatments in all genotypes studied (**Table 2**). There is significant difference between control and stress in stomatal conductance of sunflower crop at 45, 55, 65 and 75 DAS. Highest stomatal conductance was recorded in control conditions (189 mmol [H_2O] m^{-2} s^{-1}) at 75 DAS. At fifteen days after imposition of stress, stomatal conductance decreased greatly (32.2%) and did not recover even ten days after release of stress (30.7%). Significant difference for stomatal conductance was observed among the genotypes of sunflower at 45, 55, 65 and 75 DAS. The highest stomatal conductance was recorded in DRSF-113 (193 mmol [H_2O] m^{-2} s^{-1}) at 75 DAS. The significant interaction between genotypes and moisture stress was found at 55 and 65 DAS. The treatment combination of DRSF-113 and EC-602063 under control has recorded highest stomatal conductance during these stages of the crop.

Table 1. SPAD chlorophyll meter reading (SCMR) values of sunflower genotypes as influenced by moisture stress

	35 DAS	45 DAS			55 DAS			65 DAS			75 DAS			85 DAS		
Treatments	Control	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean
GMU-337	39	37	34	35.5	41	38	39.5	41	34	37.5	35	33	34.0	32	25	28.5
GMU-437	34	37	33	35.0	40	34	37.0	37	29	33.0	36	30	33.0	31	24	27.5
EC-602063	34	37	33	35.0	43	39	41.0	41	34	37.5	38	33	35.5	31	28	29.5
DRSF-113	38	41	38	39.5	43	39	41.0	38	33	35.5	39	34	36.5	36	27	31.5
Mean	36	38	35		42	38		39	33		37	33		33	26	
CD (1)	-		1.82			2.82			3.03			1.27			2.72	
CD (2)	2.46		2.13			2.23			3.67			2.04			NS	
CD (3)	-		NS			NS			NS			NS			NS	
CD (4)	-		NS			NS			NS			NS			NS	

CD (1) : Comparing means of moisture levels (stress & control) CD (2) : Comparing means of genotypes
CD (3) : Comparing means of moisture levels (stress & control) at the same genotype
CD (4) : Comparing means of genotypes at the same moisture level (stress & control)

Table 2. Stomatal conductance (mmol (H_2O) m^{-2} s^{-1}) of sunflower genotypes as influenced by moisture stress

	35 DAS	45 DAS			55 DAS			65 DAS			75 DAS			85 DAS		
Treatments	Control	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean
GMU-337	39	37	34	35.5	41	38	39.5	41	34	37.5	35	33	34.0	32	25	28.5
GMU-437	34	37	33	35.0	40	34	37.0	37	29	33.0	36	30	33.0	31	24	27.5
EC-602063	34	37	33	35.0	43	39	41.0	41	34	37.5	38	33	35.5	31	28	29.5
DRSF-113	38	41	38	39.5	43	39	41.0	38	33	35.5	39	34	36.5	36	27	31.5
Mean	36	38	35		42	38		39	33		37	33		33	26	
CD (1)	-		1.82			2.82			3.03			1.27			2.72	
CD (2)	2.46		2.13			2.23			3.67			2.04			NS	
CD (3)	-		NS			NS			NS			NS			NS	
CD (4)	-		NS			NS			NS			NS			NS	

Table 3. Photosynthetic rate (μ moles CO_2 m^{-2} s^{-1}) of sunflower genotypes as influenced by moisture stress

Treatments	45 DAS			55 DAS			65 DAS			75 DAS			85 DAS		
	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean
GMU-337	18	15	16.5	19	17	18.0	20	18	19.0	22	19	20.5	21	19	20.0
GMU-437	19	16	17.5	20	18	19.0	20	20	20.0	22	21	21.5	21	20	20.5
EC-602063	22	18	20.0	24	21	22.5	25	22	23.5	26	24	25.0	25	23	24.0
DRSF-113	22	19	20.5	25	22	23.5	26	24	25.0	27	25	26.0	26	25	25.5
Mean	20	17		22	20		23	21		24	22		23	22	
CD (1)		0.38			0.17			0.13			0.59			0.29	
CD (2)		0.50			0.37			0.19			0.43			0.18	
CD (3)		NS			0.54			0.59			NS			NS	
CD (4)		NS			0.49			0.53			NS			NS	

Lowest stomatal conductance has been observed under stress by GMU-337 during these stages of the crop. All genotypes showed lower stomatal conductance under water stress. Similar results were reported by Rauf (2008) and Ghobadi *et al.* (2013).

The photosynthetic rate increased irrespective of treatments up to 75 DAS and decreased later. The data reveals the significant variation in photosynthetic rate among stress and control treatments at 45, 55, 65, 75 and 90 DAS. The highest photosynthetic rate (24 μ moles CO_2 $m^{-2}s^{-1}$) was recorded in control at 75 DAS (**Table 3**). The percent reduction of photosynthetic rate in stress treatments was highest (15%) at 45 DAS followed by 55 DAS (9.1 %) than other stages of crop compared to respective control treatments. The tolerant genotypes showed significantly superior photosynthetic rates over other less tolerant genotypes. Significant difference for photosynthetic rate was observed among the genotypes of sunflower at 45, 55, 65, 75 and 90 DAS. The genotype DRSF-113 (26 μ moles CO_2 m^{-2} s^{-1}), followed by EC-602063 (25 μ moles CO_2 $m^{-2}s^{-1}$) recorded highest photosynthetic rate at 75 DAS. The interaction between genotypes and moisture stress was found to be significant at 55 and 65 DAS. The decreased photosynthetic rate under moisture stress can be attributed to reduced SPAD readings and fluorescence. These results are in accordance with findings of Xu and Zhou (2005). Both stomatal and non-stomatal limitation was generally accepted to be the main determinant of reduced photosynthesis under drought stress (Farooq *et al.*, 2009). The limitation of photosynthesis under drought through metabolic impairment is more complex phenomenon than stomatal limitation and mainly it is through reduced photosynthetic pigment contents in sunflower (Reddy *et al.*, 2004).

The control and moisture stress treatments were showing significant difference in fluorescence value at 45 DAS, 55 DAS and 75 DAS (**Table 4**). From the results it was evident that fluorescence was reduced by moisture stress at 45 DAS (3.5%), 55 DAS (6.6%) and at 75 DAS (14%) in comparison with control. The fluorescence was reduced with the duration of stress period and also with age. At 45 DAS the sunflower genotypes haven't shown significant difference for fluorescence values. At 55, 65 and 75 DAS there was significant difference for fluorescence value among the genotypes. The highest fluorescence values recorded by DRSF-113 (0.84), followed by EC-602063 (0.83) at 45 DAS. In general fluorescence value declined at recovery period compared to stress imposition period. At 75 DAS, DRSF-113 followed by EC-602063 under control recorded higher fluorescence over other genotypes, even under stress condition also the same genotypes exhibited superior fluorescence value. Maintenance of Fv/Fm at high values demonstrated the resistance of the photosynthetic processes to water deficit, similar results were also reported by Pankovic *et al.* (1999), Germ *et al.* (2005), Kiani *et al.* (2008) and Ghaffari *et al.* (2012).

A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Farooq *et al.*, 2009). The data pertaining to NAR as affected by stress is given in **Table 5**. The data on Net Assimilatory Rate during various stages of crop revealed that total dry weight was increased till final crop growth stage and leaf are was increased up to physiological maturity. The net assimilatory rate differed significantly among the control and moisture stress treatments at 15-30, 30-45 & 60-75 DAS. Highest net assimilatory rate was recorded in control conditions (14.9 g $m^{-2}day^{-1}$) at 30-45 DAS.

Table 4. Fluorescence (Fv/Fm) values of sunflower genotypes as influenced by moisture stress

Treatments	45 DAS			55 DAS			65 DAS			75 DAS		
	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean
GMU-337	0.84	0.82	0.83	0.74	0.67	0.705	0.71	0.70	0.705	0.56	0.48	0.520
GMU-437	0.84	0.82	0.83	0.75	0.70	0.725	0.71	0.70	0.705	0.54	0.47	0.505
EC-602063	0.84	0.82	0.83	0.77	0.74	0.755	0.75	0.74	0.745	0.59	0.49	0.540
DRSF-113	0.86	0.83	0.84	0.78	0.74	0.760	0.76	0.74	0.750	0.60	0.53	0.565
Mean	0.85	0.82		0.76	0.71		0.73	0.72		0.57	0.49	
CD (1)		0.009			0.021			NS			0.021	
CD (2)		NS			0.018			0.024			0.022	
CD (3)		NS			NS			NS			NS	
CD (4)		NS			NS			NS			NS	

Table 5. Net Assimilation Rate (g m^{-2} day^{-1}) of sunflower genotypes as influenced by moisture stress

Treat-ments	15-30 DAS	30-45 DAS	45-60 DAS			60-75 DAS		
	Control	Control	Control	Stress	Mean	Control	Stress	Mean
GMU-337	5.4	12.8	8.8	5.4	7.1	2.4	5.5	4.0
GMU-437	5.6	13.5	9.7	5.8	7.7	4.5	5.2	4.9
EC-602063	7.3	13.7	8.8	7.6	8.2	13.9	8.6	11.2
DRSF-113	8.0	14.9	9.6	8.5	9.1	13.0	10.7	11.8
CD (1)	0.009	0.021			NS			0.021
CD (2)	NS	0.018			0.024			0.022
CD (3)	NS	NS			NS			NS
CD (4)	NS	NS			NS			NS

Water stress induced at flower bud initiation stage caused reduction in yield (kg/ ha). There was significant variation between control and moisture stress treatments. Higher yield was recorded in control treatment (1465 kg/ ha) as compared to drought stress treatment (1127.5 kg/ ha) (**Table 6**). Among genotypes there was significant difference in yield in kg per hectare. Genotype DRSF-113 recorded highest yield (1488 kg/ ha) followed by EC-602063 (1376 kg/ ha). And GMU-337 recorded lowest yield (1105 kg/ ha).

Table 6. Yield (kg/ha) of sunflower genotypes as influenced by moisture stress

Treatments	Control	Stress	Mean
GMU-337	1180	1031	1105
GMU-437	1399	1030	1214
EC-602063	1544	1209	1376
DRSF-113	1737	1240	1488
Mean	1465	1127.5	
CD (1)		164	
CD (2)		224	
CD (3)		NS	
CD (4)		NS	

Correlation between physiological attributes and yield given in **Table 7**. The character SPAD chlorophyll meter readings (0.89367) followed by Fluorescence (0.85957) manifested significant and positive correlation with yield. Thus it can be inferred that selection based on any one of these traits either in alone or in combination will result in identifying high yielding strains.

CONCLUSION

Based on performance, out of the four genotypes studied, two genotypes *viz.,* DRSF-113 and EC-602063 were identified as tolerant to moisture stress and other two genotype *viz.,* GMU-337 and GMU-437 were less tolerant to water stress.

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Table 7. Estimates of correlation coefficients among physiological attributes and yield

Characters	SCMR	Stomatal conductance	Photosynthetic rate	Fluorescence	Yield
SCMR	1.0000	0.73007*	0.03362	0.84946**	0.89367**
Stomatal conductance		1.00000	0.15737	0.30323	0.51045
Photosynthetic rate			1.00000	0.13289	0.12659
Fluorescence				1.00000	0.85957**
Yield					1.00000

*Significance at 5% level **Significance at 1% level