Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; Sp 9(4): 541-544
Received: 14-05-2020
Accepted: 16-06-2020

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Effect of drought on yield traits of sunflower restorer lines

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DOI: https://doi.org/10.22271/phyto.2020.v9.i4Si.12215

Abstract
A study was conducted to screen eight sunflower restorer lines for tolerance to drought under field conditions based on yield characteristics. Moisture stress was imposed in stress plots from 45 DAS to harvest. Whereas, control plots were irrigated at 10 days intervals throughout the crop growth period. Results revealed that water stress showed repressing effect on yield related attributes like capitulum dry weight by 36%, total number of seeds per capitulum by 25%, seed yield per plant by 34% compared to control. Significant difference among R-lines was observed for head weight, test weight, harvest index and oil content. R-lines RGP 33-P5, RGP 50-P1, RGP 61-P1and RGP 61-P2 showed high HI under water stress conditions. Most of the R-lines have increased oil content under stress. RGP 50-P1, RGP 60-P2 and RGP 61-P1 have decreased oil content under stress. Based on Stress Tolerance Index and seed yield under stress, RGP 21-P6 and RGP 61-P1were identified as tolerant to water stress out of eight R-lines studied. These lines also showed superior morphological, physiological traits. RGP 32-P1 and RGP 33-P5 were found to be more sensitive.

Keywords: Sunflower, drought tolerance, screening, yield traits

Introduction
Sunflower (*Helianthus annuus* L.) is an important oilseed crop whose oil content varies from 25 to 50% of seed content. Sunflower oil contains large quantity of unsaturated fatty acids, mainly linoleic and oleic acid. Water stress is a major limiting factor for sunflower production in the many regions in the world especially when the frequency and amount of rainfall are often quite variable during sunflower growing season. These kinds of situations reduces crop yield and quality by limiting water and nutrient uptakes thereby restricting plant growth and development. Developing varieties and hybrids with high yield even under stress conditions was a cheap strategy compared to other agronomic practices to avoid yield loss. The primary objectives of this study was to evaluate the effect of drought stress on yield traits of sunflower restorer lines developed in Indian Institute of Oilseeds Research.

Materials and Methods
The study was conducted at Indian Institute of Oilseeds Research, Narkoda farm in a split plot design with control and water stress as main plot treatments and restorer lines and checks as subplot treatments. DRSH-1 a commercial hybrid and 298-R an existing restorer line are used as checks. Trail was planted on 29-11-2018 with a spacing of 60 cm between rows and 30 cm between plants within the row. The crop was irrigated at ten days interval during the whole crop growth period, whereas water was withheld in stress treatment from 45 DAS to harvesting. Five tagged plants in each plot used for taking non destructive data were harvested and Capitulum diameter, capitulum weight, total number of seeds per capitulum, test weight, seed yield, oil content and harvest index were measured in the study by taking the average from five plants. Oil content of dry seeds was estimated by Nuclear Magnetic Resonance (NMR) method against a standard reference sample. After obtaining yield per plant under stress and non stress conditions stress tolerance index (STI) is calculated according to the formula given by Fernandez (1992) [4].

Results and Discussion

Quantification of traits under water deficit conditions was a requisite to identify the traits contributing to higher yields and R-line with maximum yield having better adaptability. Capitulum diameter was decreased by 10% under stress treatment, which was not significant. RGP 21-P6 recorded highest capitulum diameter of 12.7 cm in control and 11.1 cm under stress with 13% reduction. It was higher than restorer check 298R and lesser than hybrid check DRSH-1. RGP61-P1 and RGP61-P2 are on par with restorer check 298-R. The reduction of capitulum diameter may be attributed to reduction in leaf area index and inefficient photosynthetic activity leading to poor translocation of photosynthates from source to sink at flower bud initiation stage. The results are in accordance with the findings of Geetha *et al.* (2012) [5], Buriro *et al.* (2015) [3].

Table 1: Effect of drought stress on capitulum diameter

Capitulum Diameter														
Treatment	**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**	**Mean**	**Stress levels**	**R lines**	**Interactions**
												C.D(p=0.05)		
Control	12.7	9.0	8.9	10.7	12.3	11.2	9.7	9.5	14.0	12.7	11.1	NS	0.81	1.61 / 1.84
Stress	11.1	8.2	8.9	8.9	9.1	10.0	9.7	8.5	13.7	10.9	9.9			
Mean	11.9	8.6	8.9	9.8	10.7	10.6	9.7	9.0	13.8	11.8	10.5			
% Reduction	13	9	0	17	26	11	1	10	2	14	10			

Capitulum dry weight was reduced significantly (36%) under stress treatment. No single R-line recorded significantly higher capitulum dry weight compared to the checks. Moisture stress at flower bud initiation stage causes abortion of ovaries and embryo and sterility of pollen due to insufficient assimilates for developing sinks and increase percentage of unfilled grains or chaffy grains leading to decrease in capitulum dry weight and capitulum diameter (Reddy *et al*., 2003) [12]. The greater number of chaffy and unfilled seeds causes decrease in capitulum dry matter. This is further supported by the findings of Geetha *et al.* (2012) [5], Santosh *et al.* (2016) [13].

Table 2: Effect of drought stress on capitulum dry weight

Capitulum Dry Weight														
Treatment	**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**	**Mean**	**Stress levels**	**R lines**	**Interactions**
												C.D(p=0.05)		
Control	17.5	25.5	10.4	22.3	17.7	14.2	30.3	16.9	20.0	15.8	19.0	8.29	NS	10.23 / 10.68
Stress	11.3	11.0	8.9	8.7	9.2	13.8	9.4	12.2	16.1	12.5	11.3			
Mean	14.4	18.3	9.6	15.5	13.5	14.0	19.9	14.5	18.0	14.1	15.2			
% Reduction	36	57	14	61	48	3	69	28	19	21	36			

Water stress significantly reduced total number of seeds per capitulum by 25% over control. RGP 95-P-1 followed by RGP 21-P6 and RGP 61-P1 had more total number of seeds per capitulum over other R-lines under control and stress conditions and were on par with both the checks. The reduction in number of seeds per capitulum might be due to pollen sterility and reduced fertilization under moisture stress condition (Reddy *et al*., 2003) [12]. Nezami *et al.* (2008) [8] attributed the reduction in number of seeds per capitulum due to reduction in leaf area and photosynthesis. Similar results were also reported by Buriro *et al.* (2015) [3].

Table 3: Effect of drought stress on number of seeds per capitulum

Number of Seeds Per Capitulum														
Treatment	**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**	**Mean**	**Stress levels**	**R lines**	**Interactions**
												C.D(p=0.05)		
Control	625	407	235	443	564	469	409	714	655	480	500	95.24	193.61	NS / NS
Stress	449	194	206	313	328	437	347	478	579	386	372			
Mean	537	300	221	378	446	453	378	596	617	433	436			
% Reduction	28	52	12	29	42	7	15	33	12	20	25			

The difference in test weight due to water stress was minimal and was not significant. Among R-lines RGP 60-P2 is on par with check 298-R under control and stress. RGP 21-P6 and RGP 33-P5 are on par with RGP 60-P2 under stress. Check DRSH-1 recorded higher test weight under both treatments and no R-line under study was on par with this. The reduction in seed weight due to drought may be attributed to reduction of photosynthesis, translocation of assimilates and also to the dehydration of grains (Hossain *et al*., 2010) [7]. The decrease in test weight under stress was also reported by Banaei-Asl *et al.* (2013) [2], Buriro *et al.* (2015) [3].

Table 4: Effect of drought stress on test weight

Test Weight														
Treatment	**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**	**Mean**	**Stress levels**	**R lines**	**Interactions**
												C.D(p=0.05)		
Control	3.1	2.7	2.8	3.2	3.7	2.7	2.6	1.7	4.5	4.0	3.1	NS	0.54	NS / NS
Stress	2.7	2.4	2.7	2.4	2.8	2.1	2.4	1.7	4.3	3.0	2.6			
Mean	2.9	2.5	2.7	2.8	3.3	2.4	2.5	1.7	4.4	3.5	2.9			
% Reduction	14	12	3	26	25	23	9	3	4	23	14			

Seed yield per plant recorded significant reduction (34%) under water stress. RGP 21-P6 recorded highest seed yield per plant in stress treatment which is at par with check 298-R and less than DRSH-1. RGP 60-P2 and RGP 61-P2 are also on par with the check 298-R. The interaction between stress levels and R-lines was found to be significant. The decrease in yield under stress might be due to decreased sink size (mainly number of seeds) and seed weight. It may be related with decreased photosynthetic efficiency by the degradation of chlorophyll, lower production and translocation of organic material from source to sink. This was further supported by Buriro *et al.* (2015) [3].

Table 5: Effect of drought stress on seed yield per plant

Seed Yield Per Plant														
Treatment	**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**	**Mean**	**Stress levels**	**R lines**	**Interactions**	
												C.D(p=0.05)			
Control	19.5	10.5	6.6	14.4	20.9	11.8	10.6	12.1	27.8	18.6	15.3	2.93	2.29	3.86	3.97
Stress	12.0	4.5	5.6	7.5	9.2	9.1	8.2	7.7	26.3	11.9	10.2				
Mean	15.8	7.5	6.1	10.9	15.0	10.5	9.4	9.9	27.1	15.3	12.7				
% Reduction	38	57	15	48	56	23	22	36	5	36	34				

Decrease in harvest index due to stress was not significant. RGP 21-P6 recorded highest harvest index among the studied R-lines and was on par with check 298-R under control and stress. DRSH-1 recorded highest harvest index and no line under study was on par with it. R-lines RGP 60-P2 is on par with check 298-R with 22% reduction. RGP 61-P1and RGP 50-P1 recorded increase of harvest index under stress and were also on par with check. R-lines RGP 33-P5, RGP 50-P1, RGP 61-P1and RGP 61-P2 recorded higher harvest index under stress than under control. This may be due to greater reduction in biological yield than economic yield under stress in those R-lines. The reduction in harvest index due to drought may be attributed to reduction of photosynthesis, translocation of assimilates and also to the dehydration of grains (Hossain *et al.,* 2010) [7]. Similar results were also reported by Gholinezhad *et al.*, (2009) [6], Geetha *et al.* (2012) [5].

Table 6: Effect of drought stress on harvest index

Harvest Index															
Treatment	**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**	**Mean**	**Stress levels**	**R lines**	**Interactions**	
												C.D(p=0.05)			
Control	29.7	15.3	11.9	18.8	29.6	17.9	11.3	25.1	39.7	27.9	22.7	NS	10.95	NS	NS
Stress	28.6	13.3	15.9	20.7	23.2	22.0	16.5	16.8	39.8	25.0	22.2				
Mean	29.2	14.3	13.9	19.8	26.4	20.0	13.9	20.9	39.8	26.4	22.5				
% Reduction or Increase	4	13	33	10	22	23	46	33	0	11					

Oil content was not influenced significantly by water stress. Though not significant, most of the R-lines has increased oil content under stress compared to control. R-lines RGP 50-P1, RGP 60-P2 and RGP 61-P1 has decreased oil content under stress by less than 5%. Highest oil content was recorded by RGP 21-P6 and is on par with both the checks with 5% increase compared to control. RGP 33-P5 has 12% increase in oil content under stress. Oil content was almost not influenced from drought stress because the adjustment was at yield level while maintaining oil content. But there were many reports contrary to this where oil content decreases due to stress Alahdadi *et al.*, 2011[1]. Conversely there was some increase in oil contents of lines as reported by Pekcan *et al.*(2015) [10].

Table 7: Effect of drought stress on oil content

Oil Content															
Treatment	**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**	**Mean**	**Stress levels**	**R lines**	**Interactions**	
												C.D(p=0.05)			
Control	34.8	28.9	30.6	30.2	33.3	33.6	32.9	33.0	35.4	34.5	32.7	NS	1.68	NS	NS
Stress	36.4	31.3	34.3	28.7	31.6	33.1	33.3	34.3	37.0	35.3	33.5				
Mean	35.6	30.1	32.4	29.4	32.5	33.3	33.1	33.6	36.2	34.9	33.1				
% Reduction or Increase	5	9	12	5	5	1	1	4	5	2					

Among R-lines RGP 21-P6 (1.01) ranked first followed by RGP 60-P2 (0.82), RGP 61-P1(0.46) and RGP 50-P1 (0.46). RGP 32-P1 (0.21) and RGP 33-P5 (0.16) were ranked least among the lines under study. RGP 21-P6 and RGP 60-P2 with high STI can tolerate drought. Selections based on STI were also made in crops like in rice (Raman *et al*., 2012) [11] and maize (Papathanasiou *et al*., 2015) [9].

Table 8: Stress tolerance index of studied restorer lines

R-lines	STI	Rank
RGP 21-P-6	1.01	1
RGP 32-P-1	0.21	7
RGP 33-P5	0.16	8
RGP 50-P1	0.46	4
RGP 60-P-2	0.82	2
RGP 61-P-1	0.46	3
RGP 61-P-2	0.37	6
RGP 95-P-1	0.40	5

Conclusions

Based on Stress Tolerance Index and seed yield in stress, RGP 21-P6 and RGP 61-P1were identified as tolerant to water stress out of eight R-lines studied. These lines also showed superior morphological, physiological traits along with yield attributes. RGP 32-P1 and RGP 33-P5 were found to be more sensitive.

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