Madras Agric. J., 99 (1-3): 26-33, March 2012
https://doi.org/10.29321/MAJ.10.100008

# Screening of Sunflower Genotypes for Drought Tolerance Based on Certain Morpho-Physiological Parameters

**A. Geetha*, P. Saidaiah, A. Sivasankar, J. Suresh, Lakshmi Prayaga and G. Anuradha**
Department of Plant Physiology,
College of Agriculture, Acharya N.G. Ranga Agricultural University,
Rajendranagar, Hyderabad (A.P.) – 500 030, India.

**A study was conducted to screen twenty nine sunflower genotypes for tolerance to drought under field conditions based on morpho - physiological characteristics. Moisture stress treatment was imposed at flower bud initiation stage (irrigation withheld for 20 days from 40 DAS to 60 DAS) where as, control plots were irrigated at 10 days intervals throughout the crop growth period. Results revealed that water stress showed repressing effect on plant height, total leaf area, SPAD chlorphyll meter reading, chlorophyll fluorescence (Fv/Fm), total dry matter weight at harvest, capitulum diameter per plant, capitulum weight per plant, seed yield per plant, drought susceptibility index and harvest index. However, genotypic variation was significant for characters studied. Based on drought susceptibility index and various morpho-physiological traits, eight genotypes viz., TSF-103, RSF-107, TSF-106, ASF-104, DSF-104, SH-491, RSF-106 and DSF-111 were selected as promising lines under water limited situation. These lines may further be used in stress physiology studies and drought resistance breeding.**

**Key words:** Drought, Genotypes, Morphological, Physiological traits, Screening, Sunflower.

Sunflower has the maximum potential for bridging the edible oil gap in India as its seed contain high oil contents ranging from 35 to 40 per cent. Physiological changes in plants, which occur in response to water stress conditions decrease photosynthesis and respiration (Human *et al*., 1990) and as a result, overall production of crop is decreased. Although, sunflower has good potential for drought tolerance because of its well developed system, decrease in plant height, 100-seed weight, head diameter and seed yield per plant under water stress conditions has been observed (Ravishankar *et al*., 1991).The objective of the present study was to investigate the effect of water stress on morpho-physiological traits in sunflower genotypes. The information collected will be useful in planning the future breeding strategies for the improvement of sunflower cultivars for drought resistance.

## Materials and Methods

The experiment was laid out in factorial Randomized Block Design with two factors and 29 treatments which were replicated thrice during *rabi*, 2009-10 at College Farm, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad. Control (irrigated) and water stress were used as factors. Control plots were irrigated at 10 days intervals throughout the crop growth period whereas, in stress treatment irrigation withheld from 40 DAS to 60 DAS. This period of drought was imposed, when crop was at flower bud initiation stage. The treatments comprised of 29 lines. Each genotype was sown in two rows at 5 m length with spacing of 60 x 30 cm. Two to three seeds were sown per hill to achieve uniform stand. Thinning was done at two weeks after sowing to retain one seedling per hill. Recommended package of practices (seed rate, weeding,fertilizer dosage-30 kg N, 60 kg $P_2O_5$, 30 kg $K_2O$ per hectare. Fifty percent nitrogen and entire doses of phosphorous and potassium was applied at the time of planting as band placement at the side of seed rows. The remaining 50% N was applied as top dressing in two equal splits, first at 35 days after planting and second dose at fortnight later of first dose and need based plant protection measures) of crop were followed to raise a healthy crop. The data were recorded on plant height, total leaf area, SPAD chlorophyll meter reading, chlorophyll fluorescence (Fv/Fm), total dry matter weight at harvest, capitulum diameter per plant, capitulum weight per plant, seed yield per plant, drought susceptibility index and harvest index at five days after imposition of stress and fifteen days after release of stress whereas, yield and yield related parameters were recorded. Plant height (cm) was measured from base of the plant to the terminal bud of the plant. Total leaf area was estimated by

*Corresponding author email: geethagri_100@yahoo.co.in

measuring length and width of top, middle and bottom leaves using the formula.

Leaf area ($cm^2$) = Length (cm) x Width(cm) x 0.90 .

Chlorophyll concentration was assessed using a chlorophyll meter (SPAD-502, Minolta, Japan). Measurements were taken at three points of each leaf (upper, middle and lower part). Average of these three readings was considered as SPAD reading of the leaf. The optimal and effective quantum yields of PSII were measured using the fluorometer OS-500 (Opti-Science, USA). Total dry matter accumulation (g $m^{-2}$) of harvested plants were separated into stem, leaf, petiole and capitulum and kept in brown paper bags and dried to a constant weight in hot air oven at 80æ%C for 48 hours. Each component of the plant was weighed in gram. Capitulum diameter (cm) of the mature head at its maximum width was measured and its dry weight was taken to get single capitulum weight (g). Seed yield per plant (g) was determined after threshing the seeds and allowing it to dry up to 9-10% moisture content. Weight of total seeds of the ten heads is measured in each treatment, averaged and expressed in gram (g).

Drought susceptibility index (S) was calculated according to Fischer and Maurer (1978).

$$S= (1-Y/Y_P) / (1-X_d/X_p)$$

Where, Y is the achenes yield per head of a given genotype under drought,

$Y_P$ is the achenes yield per head of he same genotype under irrigation,

Xd is the mean achenes yield of all the genotypes within group (inbred or parent) under drought,

Xp is the achenes yield per head of all genotypes within group under irrigation.

Harvest index was estimated as the proportion of total dry matter production Partitioned to economic parts expressed in (%)

$$\text{Harvest index (\%)} = \frac{\text{Economical yield per plant}}{\text{Biological yield per plant}} \times 100$$

## Results and Discussion

Plant height was reduced when drought was imposed at flower bud initiation stage. The percent reduction in plant height was more during fifteen days after stress recovery when compared to five days after imposition of stress (Table1). Differences among genotypes were significant at 15 days after stress recovery. Genotypes DSF-111 and $GP_4$-2935 under control condition and DSF-111 and RSF-107 under stressful condition, were at par and significantly superior over other genotypes. However, the interaction data revealed that genotype DSF-111 recorded maximum height followed by RSF -107.

**Table 1. Mean of plant height (cm) of sunflower genotypes during stress and after stress as influenced by moisture stress**

| Genotype | Five days after imposition of stress | | | Fifteen days after release of stress | | |
|---|---|---|---|---|---|---|
| | Control | Stress | Mean | Control | Stress | Mean |
| RSF-101 | 54.33 | 52.67 | 53.50 | 102.00 | 76.00 | 89.00 |
| TSF-103 | 71.00 | 55.67 | 63.33 | 167.00 | 121.67 | 144.33 |
| ASF-107 | 78.00 | 76.67 | 77.33 | 132.33 | 112.67 | 122.50 |
| DSF-114 | 74.67 | 65.67 | 70.17 | 150.00 | 113.33 | 131.67 |
| SH-177 | 73.00 | 70.33 | 66.67 | 130.00 | 107.67 | 118.83 |
| DSF-104 | 84.83 | 82.43 | 83.63 | 162.00 | 132.00 | 147.00 |
| RSF-106 | 49.33 | 45.00 | 47.17 | 138.00 | 119.33 | 128.67 |
| DSF-111 | 82.00 | 70.10 | 76.05 | 187.33 | 140.00 | 163.67 |
| RSF-107 | 71.00 | 69.00 | 67.50 | 177.67 | 140.00 | 158.83 |
| ASF-104 | 60.33 | 53.20 | 56.77 | 167.67 | 130.33 | 149.00 |
| TSF-106 | 64.17 | 49.70 | 56.93 | 162.67 | 113.67 | 138.17 |
| SH-491 | 50.50 | 37.33 | 43.92 | 162.67 | 112.00 | 137.33 |
| M-1029 | 77.00 | 46.67 | 61.83 | 114.67 | 79.67 | 97.17 |
| GP-812-5 | 45.67 | 35.67 | 40.67 | 131.67 | 97.67 | 114.67 |
| GP-247-4 | 100.33 | 83.00 | 91.67 | 135.33 | 108.67 | 122.00 |
| GP4-2605 | 86.67 | 59.67 | 73.17 | 99.67 | 65.33 | 82.50 |
| GP-69 | 60.33 | 41.83 | 51.08 | 95.67 | 48.00 | 71.83 |
| $GP_4$-2935 | 102.67 | 67.13 | 84.90 | 180.33 | 126.33 | 153.33 |
| GP-978 | 97.00 | 69.40 | 83.20 | 113.33 | 94.00 | 103.67 |
| DK-3849 | 72.67 | 56.77 | 64.72 | 126.33 | 98.33 | 112.33 |
| $GP_9$-515-7-3 | 115.33 | 85.00 | 100.17 | 137.33 | 98.67 | 118.00 |
| $GP_4$-2885 | 55.00 | 45.33 | 50.17 | 82.00 | 63.00 | 72.50 |
| RHA-274 | 82.33 | 64.00 | 73.17 | 114.67 | 96.00 | 105.33 |
| $GP_4$-187 | 87.33 | 64.10 | 75.72 | 131.67 | 107.00 | 119.33 |
| GP-2793 | 73.33 | 60.83 | 67.08 | 134.00 | 114.67 | 124.33 |
| $GP_4$-2704 | 59.33 | 54.73 | 57.03 | 118.67 | 95.33 | 107.00 |
| EC-512690 | 53.00 | 20.00 | 36.50 | 117.00 | 80.33 | 98.67 |
| $GP_9$-846-4-4 | 76.67 | 60.00 | 68.33 | 137.33 | 99.00 | 118.17 |
| $GP_9$-38-C-2-1 | 87.33 | 60.40 | 73.87 | 149.00 | 107.33 | 128.17 |
| Mean | 73.49 | 58.67 | 66.08 | 136.48 | 103.38 | 119.93 |
| CD at 5% for treatments | 1.06 | | | 0.85 | | |
| CD at 5% for genotypes | 9.03 | | | 7.25 | | |
| CD at 5% for T x G | 10.70 | | | 8.60 | | |

These results are in accordance with observations of several researchers who reported reduction in plant height under stress condition (Nezami *et al.,* 2008 and Shao *et al.,* 2008). Drought stress has led to reduction in stem cell's water potential to a lower level needed for cell elongation and consequently shorter internodes and stem height (Nezami *et al.,* 2008). The reduction in plant height was associated with a decline in the cell enlargement and more leaf senescence in *A. esculentus* under water stress (Bhatt and Srinivasa Rao, 2005).

Total leaf area was significantly affected by stress treatment imposed at flower bud initiation stage. Higher percent reduction was resulted at fifteen days after release of stress (32.4 %) when compared to 5 days after imposition of stress (31.7%) (Table 2). At 15 days after release of stress $GP_9$-515-7-3 under control and $GP_9$-515-7-3 and $GP_4$-2704 in stress treatment exhibited higher total leaf area over other genotypes. Maximum and minimum values of total

**Table 2. Mean of total leaf area (cm[2] plant[-1]) of sunflower genotypes as influenced by moisture stress**

| Genotype | Five days after imposition of stress | | | | Fifteen days after release of stress | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | Stress | Mean | % decrease | Control | Stress | Mean | % decrease |
| RSF-101 | 4188 | 3060 | 3624 | 27 | 5314 | 4670 | 4992 | 14 |
| TSF-103 | 4344 | 3279 | 3812 | 25 | 8036 | 4294 | 6165 | 87 |
| ASF-107 | 5401 | 4324 | 4862 | 20 | 7178 | 6392 | 6785 | 12 |
| DSF-114 | 4271 | 3393 | 3832 | 21 | 7471 | 5488 | 6480 | 36 |
| SH-177 | 4410 | 2669 | 3540 | 39 | 1095 | 1001 | 1048 | 9 |
| DSF-104 | 4439 | 2925 | 3682 | 34 | 7012 | 6240 | 6626 | 12 |
| RSF-106 | 3184 | 2557 | 2870 | 20 | 6251 | 5659 | 5955 | 10 |
| DSF-111 | 5755 | 3944 | 4850 | 31 | 7310 | 4780 | 6045 | 53 |
| RSF-107 | 6615 | 4321 | 5468 | 35 | 11973 | 9047 | 10510 | 32 |
| ASF-104 | 8493 | 5203 | 6848 | 39 | 9775 | 8453 | 9114 | 16 |
| TSF-106 | 8650 | 3179 | 5915 | 63 | 9151 | 4768 | 6959 | 92 |
| SH-491 | 4003 | 2185 | 3094 | 45 | 9172 | 5771 | 7472 | 59 |
| M-1029 | 9248 | 8019 | 8634 | 13 | 10991 | 10031 | 10511 | 10 |
| GP-812-5 | 2011 | 1756 | 1884 | 13 | 7102 | 6303 | 6703 | 13 |
| GP-247-4 | 6252 | 3110 | 4681 | 50 | 7772 | 4985 | 6379 | 56 |
| GP4-2605 | 5751 | 4536 | 5143 | 21 | 7191 | 6756 | 6974 | 6 |
| GP-69 | 3827 | 2076 | 2952 | 46 | 7898 | 4208 | 6053 | 88 |
| $GP_4$-2935 | 9267 | 3167 | 6217 | 66 | 10887 | 8525 | 9706 | 28 |
| GP-978 | 5687 | 3935 | 4811 | 31 | 6684 | 6123 | 6403 | 9 |
| DK-3849 | 8133 | 4719 | 6426 | 42 | 12549 | 5525 | 9037 | 127 |
| $GP_9$-515-7-3 | 9862 | 9354 | 9608 | 5 | 18905 | 12822 | 15864 | 47 |
| $GP_4$-2885 | 5834 | 2877 | 4356 | 51 | 8519 | 4831 | 6675 | 76 |
| RHA-274 | 4798 | 4451 | 4625 | 7 | 6950 | 5941 | 6446 | 17 |
| $GP_4$-187 | 4736 | 4302 | 4519 | 9 | 8584 | 7569 | 8076 | 13 |
| GP-2793 | 4595 | 4232 | 4414 | 8 | 11196 | 10155 | 10676 | 10 |
| $GP_4$-2704 | 7776 | 6499 | 7138 | 16 | 12892 | 12217 | 12555 | 6 |
| EC-512690 | 5930 | 3905 | 4918 | 34 | 11106 | 7334 | 9220 | 51 |
| $GP_9$-846-4-4 | 7494 | 4727 | 6111 | 37 | 9251 | 7800 | 8525 | 19 |
| $GP_9$-38-C-2-1 | 4975 | 3399 | 4187 | 32 | 5633 | 4222 | 4927 | 33 |
| Mean | 5860 | 4004 | 4932 | 32 | 8753 | 6618 | 7685 | 32 |
| CD at 5% for treatments | 387 | | | | 249 | | | |
| CD at 5% for genotypes | 1475 | | | | 950 | | | |
| CD at 5% for T x G | 2085 | | | | 1343 | | | |

leaf area were recorded in $GP_9$-515-7-3 and SH-177 respectively in interactions. Wullschleger *et al*.( 2005), Farooq *et al*.( 2009) and Manivannan *et al.* (2007 and 2008) concluded that water stress reduces the leaf area by limiting size of individual leaf, prevents the leaf growth and leaf cell expansion due to reduction in turgour pressure and accelerates leaf senescence process in sunflower.

SPAD chlorophyll meter readings declined in stress treatment when stress was imposed at flower bud initiation stage. Water stress at stress imposition period decreased SPAD value from 4.7% to 0.3% to stress recovery period compared with respective controls (Table 3). At stress recovery period, $GP_4$-2885 under control and RHA-274 under both stress and interactions recorded significantly more SPAD meter reading and GP-247-4 recorded less SPAD meter values. Sawhney and Singh (2002) found that chlorophyll content of flag leaf in several wheat genotypes was reduced towards the end of growing season. SPAD chlorophyll meter reading, a reflection of leaf chlorophyll/leaf nitrogen declined in stress treatment of present investigation due to degradation of leaf chlorophyll content.

Maximum quantum efficiency of PS-II (Fv/Fm) was found reduced under drought condition. Reduction in Fv/Fm by stress at 45 DAS was 6.7 per cent in comparison with control (Table 4). In general, fluorescence value declined at recovery period (7.5%) compared to stress imposition period. At stress release period (75 DAS), ASF-107, DSF-114 and SH-177 followed by TSF-103 and $GP_4$-2885 under control recorded higher fluorescence over most of the other genotypes, whereas under stress

**Table 3. Mean of SPAD chlorophyll meter reading of sunflower genotypes as influenced by moisture stress**

| Genotype | Five days after imposition of stress | | | | Fifteen days after release of stress | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | Stress | Mean | % decrease | Control | Stress | Mean | % decrease |
| RSF-101 | 40.07 | 32.23 | 36.15 | 19.55 | 30.83 | 27.17 | 29.00 | 11.89 |
| TSF-103 | 39.07 | 40.43 | 39.75 | -3.50 | 32.40 | 35.13 | 33.77 | -8.44 |
| ASF-107 | 41.93 | 40.03 | 40.98 | 4.53 | 32.50 | 30.60 | 31.55 | 5.85 |
| DSF-114 | 40.97 | 39.27 | 40.12 | 4.15 | 37.57 | 37.44 | 37.51 | 0.33 |
| SH-177 | 40.30 | 36.00 | 38.15 | 10.67 | 39.60 | 36.90 | 38.25 | 6.82 |
| DSF-104 | 44.60 | 41.33 | 42.97 | 7.32 | 35.60 | 33.00 | 34.30 | 7.30 |
| RSF-106 | 40.33 | 36.13 | 38.23 | 10.41 | 34.77 | 34.00 | 34.38 | 2.21 |
| DSF-111 | 43.00 | 38.73 | 40.87 | 9.92 | 31.67 | 31.67 | 31.67 | 0.00 |
| RSF-107 | 38.80 | 39.13 | 38.97 | -0.86 | 34.53 | 34.13 | 34.33 | 1.16 |
| ASF-104 | 40.00 | 36.40 | 38.20 | 9.00 | 32.90 | 32.00 | 32.45 | 2.74 |
| TSF-106 | 39.77 | 36.30 | 38.03 | 8.72 | 32.00 | 32.00 | 32.00 | 0.00 |
| SH-491 | 44.57 | 38.93 | 41.75 | 12.64 | 33.03 | 32.94 | 32.99 | 0.28 |
| M-1029 | 34.63 | 30.07 | 32.35 | 13.19 | 29.37 | 29.33 | 29.35 | 0.11 |
| GP-812-5 | 42.33 | 39.57 | 40.95 | 6.54 | 37.43 | 35.10 | 36.27 | 6.23 |
| GP-247-4 | 42.40 | 38.30 | 40.35 | 9.67 | 27.00 | 26.73 | 26.87 | 0.99 |
| GP4-2605 | 39.57 | 39.43 | 39.50 | 0.34 | 36.53 | 34.83 | 35.68 | 4.65 |
| GP-69 | 44.57 | 39.00 | 41.78 | 12.49 | 37.60 | 37.33 | 37.47 | 0.71 |
| $GP_4$-2935 | 41.97 | 39.83 | 40.90 | 5.08 | 39.27 | 37.27 | 38.27 | 5.09 |
| GP-978 | 40.53 | 40.97 | 40.75 | -1.07 | 29.00 | 29.67 | 29.33 | -2.30 |
| DK-3849 | 40.10 | 40.47 | 40.28 | -0.91 | 38.33 | 40.00 | 39.17 | -4.35 |
| $GP_9$-515-7-3 | 38.13 | 40.17 | 39.15 | -5.33 | 33.27 | 34.53 | 33.90 | -3.81 |
| $GP_4$-2885 | 40.97 | 37.70 | 39.33 | 7.97 | 45.43 | 37.67 | 41.55 | 17.09 |
| RHA-274 | 40.27 | 42.87 | 41.57 | -6.46 | 39.63 | 45.33 | 42.48 | -14.38 |
| $GP_4$-187 | 40.33 | 40.80 | 40.57 | -1.16 | 40.33 | 43.33 | 41.83 | -7.44 |
| GP-2793 | 37.00 | 36.37 | 36.68 | 1.71 | 39.40 | 39.00 | 39.20 | 1.02 |
| $GP_4$-2704 | 37.37 | 32.30 | 34.83 | 13.56 | 37.10 | 34.13 | 35.62 | 8.00 |
| EC-512690 | 38.43 | 41.00 | 39.72 | -6.68 | 23.33 | 34.87 | 29.10 | -49.43 |
| $GP_9$-846-4-4 | 43.40 | 43.00 | 43.20 | 0.92 | 30.80 | 27.60 | 29.20 | 10.39 |
| $GP_9$-38-C-2-1 | 43.07 | 46.23 | 44.65 | -7.35 | 32.57 | 36.93 | 34.75 | -13.41 |
| Mean | 40.64 | 38.72 | 39.68 | 4.71 | 34.61 | 34.51 | 34.56 | 0.31 |
| CD at 5% for treatments | 0.23 | | | | NS | | | |
| CD at 5% for genotypes | 0.89 | | | | 1.03 | | | |
| CD at 5% for T x G | 1.26 | | | | 1.45 | | | |

condition, DSF-114 and $GP_4$-187 exhibited significant and superior fluorescence value. While in mean effect, DSF-114 recorded maximum Fv/Fm value followed by $GP_4$-187 and SH-177. The genotypes with high values of Fv/Fm are associated with the resistance of the photosynthetic processes to water deficit (Pankoviæ *et al.,* 1999), whereas genotypes with low value of Fv/Fm under drought stress decreases the flux of electron flow out of photo system–II , which consequently lowers the rates of ATP and $NADPH_2$ formation and in turn leads to slower enzymatic conversion of $CO_2$ into organic carbon, thereby yield (Reddy *et al.,* 2004). Lower fluorescence is either due to a smaller antenna cross-section or to a process increasing the non-radioactive energy dissipation (Konstantina *et al.,* 2004).

Greater plant fresh and dry weights under water limited conditions are desirable characters.A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Farooq *et al.,* 2009). Diminished biomass due to water stress was observed in almost all genotypes of sunflower (Tahir and Mehid, 2001). However, some genotypes showed better stress tolerance than the others. Drought induced at flower bud initiation stage cause significant reduction in dry weights. The percent reduction in dry weight in stress treatment was 21.9 per cent compared to its control (Table 5). M-1029 exhibited highest total dry weights in control, stress and interaction of genotype with treatments at harvest and lowest dry weight was reported by DSF-114 in treatments as well as in interaction.

**Table 4. Mean of chlorophyll fluorescence (Fv/Fm) of sunflower genotypes as influenced by moisture stress**

| Genotype | Five days after imposition of stress | | | | Fifteen days after release of stress | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | Stress | Mean | % decrease | Control | Stress | Mean | % decrease |
| RSF-101 | 0.76 | 0.71 | 0.73 | 6.17 | 0.63 | 0.51 | 0.57 | 18.52 |
| TSF-103 | 0.72 | 0.67 | 0.70 | 6.05 | 0.64 | 0.56 | 0.60 | 12.04 |
| ASF-107 | 0.72 | 0.66 | 0.69 | 8.37 | 0.65 | 0.59 | 0.62 | 10.16 |
| DSF-114 | 0.75 | 0.70 | 0.73 | 6.67 | 0.65 | 0.63 | 0.64 | 3.08 |
| SH-177 | 0.74 | 0.72 | 0.73 | 1.81 | 0.65 | 0.61 | 0.63 | 6.19 |
| DSF-104 | 0.75 | 0.63 | 0.69 | 15.18 | 0.58 | 0.51 | 0.55 | 12.00 |
| RSF-106 | 0.74 | 0.68 | 0.71 | 7.24 | 0.61 | 0.57 | 0.59 | 6.52 |
| DSF-111 | 0.72 | 0.67 | 0.70 | 6.05 | 0.53 | 0.51 | 0.52 | 4.38 |
| RSF-107 | 0.68 | 0.65 | 0.67 | 3.45 | 0.50 | 0.47 | 0.49 | 6.62 |
| ASF-104 | 0.70 | 0.67 | 0.69 | 3.35 | 0.61 | 0.57 | 0.59 | 7.61 |
| TSF-106 | 0.66 | 0.66 | 0.66 | -1.02 | 0.57 | 0.58 | 0.58 | -0.58 |
| SH-491 | 0.60 | 0.56 | 0.58 | 6.70 | 0.56 | 0.54 | 0.55 | 3.59 |
| M-1029 | 0.67 | 0.67 | 0.67 | 0.50 | 0.57 | 0.54 | 0.55 | 5.29 |
| GP-812-5 | 0.65 | 0.64 | 0.65 | 2.04 | 0.58 | 0.53 | 0.56 | 9.14 |
| GP-247-4 | 0.71 | 0.65 | 0.68 | 7.98 | 0.63 | 0.52 | 0.57 | 17.99 |
| GP4-2605 | 0.61 | 0.58 | 0.59 | 4.40 | 0.59 | 0.54 | 0.56 | 9.04 |
| GP-69 | 0.72 | 0.69 | 0.71 | 3.26 | 0.53 | 0.50 | 0.52 | 5.63 |
| GP$_4$-2935 | 0.69 | 0.70 | 0.70 | -1.44 | 0.62 | 0.63 | 0.62 | -1.08 |
| GP-978 | 0.72 | 0.68 | 0.70 | 4.65 | 0.56 | 0.53 | 0.55 | 5.92 |
| DK-3849 | 0.76 | 0.67 | 0.71 | 11.89 | 0.60 | 0.51 | 0.55 | 15.56 |
| GP$_9$-515-7-3 | 0.76 | 0.66 | 0.71 | 13.22 | 0.60 | 0.54 | 0.57 | 11.05 |
| GP$_4$-2885 | 0.65 | 0.62 | 0.63 | 4.64 | 0.64 | 0.50 | 0.57 | 22.28 |
| RHA-274 | 0.66 | 0.63 | 0.65 | 4.04 | 0.59 | 0.55 | 0.57 | 6.25 |
| GP$_4$-187 | 0.68 | 0.66 | 0.67 | 2.94 | 0.65 | 0.62 | 0.64 | 4.62 |
| GP-2793 | 0.66 | 0.58 | 0.62 | 12.12 | 0.55 | 0.52 | 0.54 | 5.45 |
| GP$_4$-2704 | 0.73 | 0.61 | 0.67 | 17.27 | 0.58 | 0.53 | 0.55 | 8.09 |
| EC-512690 | 0.72 | 0.70 | 0.71 | 3.69 | 0.61 | 0.58 | 0.59 | 5.46 |
| GP$_9$-846-4-4 | 0.70 | 0.65 | 0.68 | 6.22 | 0.56 | 0.54 | 0.55 | 4.73 |
| GP$_9$-38-C-2-1 | 0.68 | 0.60 | 0.64 | 11.82 | 0.58 | 0.53 | 0.56 | 7.51 |
| Mean | 0.70 | 0.65 | 0.68 | 6.28 | 0.59 | 0.55 | 0.57 | 8.16 |
| CD at 5% for treatments | 0.003 | | | | 0.004 | | | |
| CD at 5% for genotypes | 0.011 | | | | 0.013 | | | |
| CD at 5% for T x G | 0.016 | | | | 0.019 | | | |

Similar results are found by researchers in several crops including soybean (Specht *et al.,* 2001), *Poncirus trifoliatae* seedlings (Wu *et al.,* 2008), common bean and green gram (Webber *et al.,* 2006) and *Petroselinum crispum* (Petropoulos *et al.,* 2008). Capitulum diameter was highly reduced when drought was imposed at flower bud initiation stage when compared to non-stress. Stress recorded 32.2 per cent reduction in capitulum diameter. At harvest stage, SH-491 followed by DSF-111 and RSF-107 under control condition and RSF-107 and TSF-103 under stress condition showed higher capitulum diameter. In combined effect, RSF-107 recorded highest capitulum diameter followed by DSF -111, SH-491, while ASF-104 recorded lowest capitulum diameter. The reduction of capitulum diameter may be due to reduction in LAI and insufficient photo assimilates required for development of head.

Capitulum weight was highly reduced when drought was imposed at flower bud initiation stage. Maximum capitulum weight was recorded in control (74.78g) and was significantly superior to stress treatment (52.72 g) (Table 6). Genotype DK-3849 and SH-491 exhibited more capitulum weight in non stress, whereas SH-491 recorded highest capitulm weight both in stress and interaction and were superior over other genotypes. While DSF-114 recorded lowest capitulum weight in both the treatments and mean effect. Poor photosynthetic performance and reduction in assimilatory structure

**Table 5. Mean of total dry matter weight (g plant$^{-1}$) per plant at harvest and capitulum diameter (cm) per plant of sunflower genotypes as influenced by moisture stress**

| Genotype | Total dry matter weight (g plant$^{-1}$) per plant at harvest | | | | Capitulum diameter (cm) per plant | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | Stress | Mean | % decrease | Control | Stress | Mean | % decrease |
| RSF-101 | 203.73 | 170.00 | 186.86 | 16.55 | 15.33 | 11.00 | 13.17 | 28.26 |
| TSF-103 | 308.32 | 234.67 | 271.49 | 23.89 | 28.00 | 19.63 | 23.82 | 29.88 |
| ASF-107 | 242.76 | 198.30 | 220.53 | 18.31 | 26.33 | 19.33 | 22.83 | 26.58 |
| DSF-114 | 144.05 | 114.78 | 129.42 | 20.32 | 10.67 | 6.17 | 8.42 | 42.19 |
| SH-177 | 348.19 | 292.00 | 320.10 | 16.14 | 26.67 | 11.73 | 19.20 | 56.00 |
| DSF-104 | 207.89 | 187.07 | 197.48 | 10.02 | 19.33 | 14.00 | 16.67 | 27.59 |
| RSF-106 | 159.00 | 123.53 | 141.26 | 22.31 | 13.67 | 8.67 | 11.17 | 36.59 |
| DSF-111 | 359.23 | 299.17 | 329.20 | 16.72 | 30.67 | 19.33 | 25.00 | 36.96 |
| RSF-107 | 319.40 | 252.67 | 286.03 | 20.89 | 30.00 | 21.27 | 25.63 | 29.11 |
| ASF-104 | 251.67 | 215.25 | 233.46 | 14.47 | 9.67 | 5.93 | 7.80 | 38.62 |
| TSF-106 | 291.95 | 257.33 | 274.64 | 11.86 | 21.67 | 19.33 | 20.50 | 10.77 |
| SH-491 | 484.50 | 346.87 | 415.69 | 28.41 | 31.67 | 18.00 | 24.83 | 43.16 |
| M-1029 | 544.77 | 414.00 | 479.38 | 24.00 | 30.67 | 15.17 | 22.92 | 50.54 |
| GP-812-5 | 233.67 | 187.67 | 210.67 | 19.69 | 14.17 | 10.67 | 12.42 | 24.71 |
| GP-247-4 | 184.63 | 156.83 | 170.73 | 15.06 | 20.97 | 15.60 | 18.28 | 25.60 |
| GP4-2605 | 214.92 | 187.33 | 201.13 | 12.83 | 11.33 | 9.10 | 10.22 | 19.71 |
| GP-69 | 293.56 | 255.00 | 274.28 | 13.13 | 14.70 | 11.90 | 13.30 | 19.05 |
| $GP_4$-2935 | 368.72 | 324.17 | 346.44 | 12.08 | 25.67 | 16.33 | 21.00 | 36.36 |
| GP-978 | 224.88 | 171.67 | 198.27 | 23.66 | 14.93 | 9.63 | 12.28 | 35.49 |
| DK-3849 | 504.62 | 319.50 | 412.06 | 36.68 | 28.83 | 13.33 | 21.08 | 53.76 |
| $GP_9$-515-7-3 | 306.17 | 240.00 | 273.08 | 21.61 | 23.67 | 18.10 | 20.88 | 23.52 |
| $GP_4$-2885 | 177.10 | 147.17 | 162.14 | 16.90 | 13.57 | 11.03 | 12.30 | 18.67 |
| RHA-274 | 183.35 | 146.96 | 165.16 | 19.85 | 10.93 | 7.97 | 9.45 | 27.13 |
| $GP_4$-187 | 224.06 | 183.17 | 203.61 | 18.25 | 13.50 | 11.17 | 12.33 | 17.28 |
| GP-2793 | 293.23 | 230.67 | 261.95 | 21.33 | 16.20 | 13.13 | 14.67 | 18.93 |
| $GP_4$-2704 | 221.48 | 196.00 | 208.74 | 11.51 | 15.33 | 11.13 | 13.23 | 27.39 |
| EC-512690 | 279.09 | 249.64 | 264.36 | 10.55 | 18.67 | 12.89 | 15.78 | 30.93 |
| $GP_9$-846-4-4 | 249.00 | 189.67 | 219.33 | 23.83 | 16.43 | 13.37 | 14.90 | 18.66 |
| $GP_9$-38-C-2-1 | 241.33 | 188.33 | 214.83 | 21.96 | 13.90 | 9.67 | 11.78 | 30.46 |
| Mean | 279.28 | 220.11 | 249.70 | 21.19 | 19.56 | 13.26 | 16.41 | 32.19 |
| CD at 5% for treatments | 2.96 | | | | 0.47 | | | |
| CD at 5% for genotypes | 11.26 | | | | 1.80 | | | |
| CD at 5% for T x G | 15.92 | | | | 2.55 | | | |

leads to carbohydrates and mineral deficiency which cause abortions of ovaries, pollen sterility leading to production of less achenes results in reduction in capitulum weight (Rauf and Sadaqat, 2007).

Seed yield per plant was reduced when stress was imposed at flower bud initiation stage. The percent reduction in seed yield during stress was 27.8 compared to control (Table 6). Significant variation was noticed among the genotypes studied with respect to seed yield. SH-491 followed by DK-3849 under control and SH-491 under stress recorded significantly superior seed yield in comparison to rest of the genotypes. However, genotype x treatments data revealed that SH-491 recorded highest seed yield and significantly superior over the rest of the genotypes. 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 degradation of chlorophyll, lower production and translocation of organic material from source to sink (Amrutha *et al.*, 2007).

There were significant differences among the genotypes in DSI values. Genotype $GP_9$-38-C-2-1 recorded lowest (0.20) drought susceptible index (Table 7). A higher value of susceptibility index indicates higher susceptibility of a genotype to the stress. Higher drought susceptibility index of some genotype under water stress situations is due to degradation of membrane system, poor photosynthetic performance, failure to produce anti oxidants defense mechanism, inability to maintain water potential or lack of production of osmolytes, poor translocation of assimilates to developing

**Table 6.Mean of capitulum weight (g) per plant and seed yield (g) per plant of sunflower genotypes as influenced by moisture stress**

| Genotype | Capitulum weight (g) per plant | | | | Seed yield (g) per plant | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | Stress | Mean | % decrease | Control | Stress | Mean | % decrease |
| RSF-101 | 48.67 | 39.00 | 43.83 | 19.86 | 25.17 | 14.98 | 20.08 | 40.46 |
| TSF-103 | 83.00 | 59.17 | 71.09 | 28.71 | 44.92 | 40.06 | 42.49 | 10.82 |
| ASF-107 | 81.89 | 40.67 | 61.28 | 50.34 | 40.00 | 23.00 | 31.50 | 42.50 |
| DSF-114 | 38.67 | 19.00 | 28.83 | 50.86 | 11.43 | 8.37 | 9.90 | 26.78 |
| SH-177 | 101.70 | 83.33 | 92.52 | 18.06 | 66.53 | 32.73 | 49.63 | 50.80 |
| DSF-104 | 60.55 | 50.07 | 55.31 | 17.31 | 24.60 | 20.36 | 22.48 | 17.24 |
| RSF-106 | 44.53 | 32.63 | 38.58 | 26.74 | 19.27 | 15.30 | 17.28 | 20.59 |
| DSF-111 | 105.00 | 84.67 | 94.83 | 19.37 | 87.17 | 66.97 | 77.07 | 23.17 |
| RSF-107 | 105.41 | 82.00 | 93.71 | 22.21 | 67.67 | 59.67 | 63.67 | 11.82 |
| ASF-104 | 41.74 | 31.41 | 36.57 | 24.75 | 19.27 | 15.60 | 17.43 | 19.03 |
| TSF-106 | 73.00 | 62.33 | 67.67 | 14.61 | 38.00 | 32.00 | 35.00 | 15.79 |
| SH-491 | 131.33 | 85.67 | 108.50 | 34.77 | 102.00 | 81.03 | 91.52 | 20.56 |
| M-1029 | 120.38 | 71.00 | 95.69 | 41.02 | 95.17 | 51.00 | 73.08 | 46.41 |
| GP-812-5 | 56.67 | 40.33 | 48.50 | 28.82 | 35.42 | 15.33 | 25.38 | 56.71 |
| GP-247-4 | 60.64 | 41.67 | 51.16 | 31.29 | 32.95 | 23.58 | 28.26 | 28.45 |
| GP4-2605 | 61.58 | 52.33 | 56.96 | 15.02 | 25.66 | 23.45 | 24.55 | 8.60 |
| GP-69 | 51.33 | 41.33 | 46.33 | 19.48 | 54.67 | 48.49 | 51.58 | 11.29 |
| $GP_4$-2935 | 91.26 | 68.00 | 79.63 | 25.48 | 66.20 | 40.20 | 53.20 | 39.27 |
| GP-978 | 69.68 | 52.00 | 60.84 | 25.38 | 54.33 | 49.33 | 51.83 | 9.20 |
| DK-3849 | 133.63 | 74.00 | 103.82 | 44.62 | 100.25 | 48.78 | 74.51 | 51.34 |
| $GP_9$-515-7-3 | 91.33 | 69.67 | 80.50 | 23.72 | 47.33 | 21.33 | 34.33 | 54.93 |
| $GP_4$-2885 | 53.51 | 38.67 | 46.09 | 27.74 | 23.65 | 14.33 | 18.99 | 39.39 |
| RHA-274 | 41.33 | 31.67 | 36.50 | 23.39 | 9.93 | 8.47 | 9.20 | 14.77 |
| $GP_4$-187 | 58.48 | 42.33 | 50.41 | 27.61 | 35.72 | 33.33 | 34.53 | 6.68 |
| GP-2793 | 78.33 | 56.00 | 67.17 | 28.51 | 45.08 | 36.25 | 40.67 | 19.59 |
| $GP_4$-2704 | 75.43 | 48.00 | 61.72 | 36.37 | 41.77 | 38.26 | 40.01 | 8.40 |
| EC-512690 | 76.33 | 45.00 | 60.67 | 41.05 | 37.77 | 33.26 | 35.52 | 11.94 |
| $GP_9$-846-4-4 | 63.67 | 46.33 | 55.00 | 27.23 | 31.00 | 24.00 | 27.50 | 22.58 |
| $GP_9$-38-C-2-1 | 69.67 | 40.67 | 55.17 | 41.63 | 30.33 | 28.67 | 29.50 | 5.49 |
| Mean | 74.78 | 52.72 | 58.89 | 42.50 | 45.28 | 32.69 | 38.99 | 27.80 |
| CD at 5% for treatments | 0.99 | | | | 0.80 | | | |
| CD at 5% for genotypes | 3.77 | | | | 3.07 | | | |
| CD at 5% for T x G | 5.33 | | | | 4.34 | | | |

sinks ultimately leading to reduction in yield under stress conditions compared to irrigated conditions. Moisture stress treatment imposed at flower bud initiation stage recorded decrease in harvest index (27.1%) compared to irrigated treatment (Table 7). Control, stress and interactions showed significant differences among genotypes for HI values. $GP_4$-2704 followed by ASF-107 and RSF-107 in control and GP-247-4 and RSF-107 in stress showed higher harvest index over rest of other genotypes. However, in genotype x treatments interaction, RSF-107 recorded maximum harvest index, which was significantly superior over other genotypes, whereas lowest harvest index was recorded in ASF-104. Exposure of sunflower plants to drought stress at bud initiation stage was more detrimental to seed and biological yield than at seed filling stage (Prabhudeva *et al.,* 1998). Higher harvest index was obtained due to better translocation of photosynthates to the reproductive part under drought stress (Rauf and Sadaqat, 2008).

The results indicated that water stress at flower bud initiation stage negatively affected plant height, total leaf area, total dry weight at harvesting, SPAD reading, chlorophyll fluorescence (Fv/Fm) , yield and yield related parameters. However, some genotypes performed better under drought stress than others. No genotype was tolerant to all the characters studied. Candidate genes tolerant to particular trait should be identified by breeders and those genes have to be incorporated in high yielding varieties. Based on DSI, genotypes TSF-103, RSF-107, TSF-106, ASF-104, DSF-104, SH-491, RSF-106, DSF-111 were selected as tolerant and SH-177, ASF-107, RSF-101,DSF-114 were selected as

**Table 7. Mean of drought susceptibility index (DSI) and harvest index % of sunflower genotypes as influenced by moisture stress**

| Geno type | Drought Susceptibility Index | Harvest index (%) | | | |
|---|---|---|---|---|---|
| | | Control | Stress | Mean | % decrease |
| RSF-101 | 1.47 | 23.96 | 22.95 | 23.45 | 4.22 |
| TSF-103 | 0.38 | 26.92 | 25.22 | 26.07 | 6.33 |
| ASF-107 | 1.53 | 33.73 | 20.50 | 27.12 | 39.22 |
| DSF-114 | 1.01 | 26.88 | 16.64 | 21.76 | 38.12 |
| SH-177 | 1.85 | 29.28 | 28.57 | 28.92 | 2.44 |
| DSF-104 | 0.63 | 29.22 | 26.80 | 28.01 | 8.26 |
| RSF-106 | 0.75 | 28.12 | 26.49 | 27.30 | 5.80 |
| DSF-111 | 0.85 | 29.23 | 28.30 | 28.76 | 3.17 |
| RSF-107 | 0.43 | 33.06 | 32.49 | 32.77 | 1.72 |
| ASF-104 | 0.69 | 16.59 | 14.61 | 15.60 | 11.93 |
| TSF-106 | 0.55 | 25.02 | 24.27 | 24.64 | 2.98 |
| SH-491 | 0.75 | 27.11 | 24.71 | 25.91 | 8.86 |
| M-1029 | 1.68 | 22.13 | 17.16 | 19.65 | 22.49 |
| GP-812-5 | 2.06 | 24.29 | 21.50 | 22.90 | 11.49 |
| GP-247-4 | 1.03 | 32.95 | 26.59 | 29.77 | 19.32 |
| GP4-2605 | 0.24 | 28.69 | 27.95 | 28.32 | 2.57 |
| GP-69 | 0.33 | 17.51 | 16.19 | 16.85 | 7.51 |
| $GP_4$-2935 | 1.40 | 24.77 | 21.02 | 22.89 | 15.12 |
| GP-978 | 0.33 | 31.00 | 30.38 | 30.69 | 2.01 |
| DK-3849 | 1.84 | 26.49 | 23.19 | 24.84 | 12.47 |
| $GP_9$-515-7-3 | 1.98 | 29.81 | 29.07 | 29.44 | 2.49 |
| $GP_4$-2885 | 1.38 | 30.25 | 26.30 | 28.27 | 13.08 |
| RHA-274 | 0.54 | 22.55 | 21.61 | 22.08 | 4.17 |
| $GP_4$-187 | 0.21 | 26.13 | 23.11 | 24.62 | 11.56 |
| GP-2793 | 0.72 | 26.77 | 24.26 | 25.52 | 9.37 |
| $GP_4$-2704 | 0.29 | 34.07 | 24.48 | 29.27 | 28.15 |
| EC-512690 | 0.45 | 27.36 | 18.03 | 22.70 | 34.09 |
| $GP_9$-846-4-4 | 0.83 | 25.56 | 24.39 | 24.98 | 4.59 |
| $GP_9$-38-C-2-1 | 0.20 | 29.03 | 21.58 | 25.31 | 25.66 |
| Mean | 0.91 | 26.80 | 19.54 | 23.17 | 27.07 |
| CD at 5% for treatments | - | | 0.48 | | |
| CD at 5% for genotypes | 0.52 | | 1.83 | | |
| CD at 5% for T x G | - | | 2.60 | | |

susceptible lines. These lines may be studied further using molecular markers to identify stress tolerant markers and used in development of drought tolerant cultivars using appropriate breeding methods.

## References


Amrutha, R., Muthulaksmi, S., Baby Rani, W., Indira, W. K. and Mareeswari, P. 2007. Alleviation of High Temperature Stress in Sunflower (*Helianthus Annus* L.) by Plant Growth Regulators and Chemicals. *Res. J. Agric.. Biol. Sci.,* **3**: 1658-1662.

Bhatt, R.M. and Srinivasa Rao, N.K. 2005. Influence of pod load response of okra to water stress*. Indian J.Plant Physiol.,* **10**: 54–59.

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D. and Basra, S.M.A. 2009. Plant drought stress: effects, mechanisms and management. *Agron. Sustainable Development*. **29**: 185-212.

Human, J.J., Toit, D., Bezuidenhout, H.D. and Bruyn, L.P.D. 1990. The influence of plant water stress on net photosynthesis and yield of sunflower (*Helianthus annuus* L.). *J. Agron. Crop Sci.,* **164**: 231-241.

Konstantina, K., Petar Lambrev, Georgy Georgiev, Vasilii Goltsevc and Miroslav Karabaliev. 2004. Evaluation of chlorophyll fluorescence and membrane injury in the leaves of barley cultivars under osmotic stress. *Bioelectrochemistry.* **63**: 121-124.

Nezami, A., Khazaeia, H.R., Boroumand Rezazadehb, Z. and Hosseinic, A. 2008. Effects of drought stress and defoliation on sunflower (*Helianthus annuus*) in controlled conditions. *Desert*, **12**:99-104.

Pankoviæ, D., Sakaè, Z., Kevrešan, S., Plesnièar, M. 1999. Acclimation to long-term water deficit in the leaves of two sunflower hybrids: photosynthesis, electron transport and carbon metabolism. *J. Expl. Botany*. **330**: 127-138.

Petropoulos, S.A., Dimitra Daferera., M.G., Polissiou. and Passam, H.C. 2008. The effect of water deficit stress on the growth, yield and composition of essential oils of parsley. *Scientia Horti*.,**115**:393-397.

Prabhudeva, T.V., Chalapathi, M.V., Thimmegowda, S., Devakumar, N., Rao, G.G. and Mallikarjuna, K. 1998. Soil moisture stress and drought susceptibility index in sunflower. *Indian Agriculturist*. **42**: 287-289.

Rauf, S. and Sadaqat, H.A. 2007. Effect of varied water regimes on root length, dry matter partitioning and endogenous plant growth regulators in (*Helianthus annuus* L.) *Plant interactions* **2**:41-51.

Rauf, S. and Sadaqat, H.A. 2008. Effect of varied water regimes on root length, dry matter partitioning and endogenous plant growth regulators in sunflower (*Helianthus anuus* L.)*.J.Plant Interactions.***2**: 41-51.

Ravishankar, K.V., Shanker, R.U., Ravishankar, H.M., Kumar, M.U. and Prasad, T.G. 1991. Development of drought tolerant sunflower for semiarid tracts of India : duration of genotypes influence their performance under imposed moisture stress. *Helia*. **14** : 77-85.

Reddy, A.R., Chaitanya, K.V., Vivekanandan, M. 2004. Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants. *J. Plant Physiol*., **161**: 1189-1202.

Shao, H.B., Chu, L.Y., Shao, M.A., Abdul Jaleel, C. and Hong-Mei, M. 2008. Higher plant antioxidants and redox signaling under environmental stresses. *Comp Rend Biol.,* **331**: 433–441.

Specht, J.E., Chase, K., Macrander, M., Graef, G.L., Chung, J., Markwell, J.P.**,** Germann, M., Orf, J.H. and Lark, K. J. 2001. Soybean response to water. A QTL analysis of drought tolerance. *Crop Sci*., **41**: 493–509.

Tahir, M.H.N. and Mehid, S.S. 2001. Evaluation of open pollinatedsunflower (*Helianthus annuus* L.) populations under water stress and normal conditions. *Intnl J..Agric. Biol.*, **3**: 236–238.

Webber, M., Barnett, J., Finlayson, B. and Wang, M. 2006. Pricing China's Irrigation Water. Working Paper, School of Anthropology, Geography and Environmental Studies, the University of Melbourne, Victoria, Australia.

Wu, Q.S., Xia, R.X. and Zou, Y.N. 2008. Improved soil structure and citrus growth after inoculation with three arbuscular mycorrhizal fungi under drought stress. *European J. Soil Biol*., **44**: 122-128.

Wullschleger, S.D.,Yin, T.M., Difazio, S.P., Tschaplinski, T. J., Gunter, L.E., Davis, M.F, and Tuskan, G. A. 2005. Phenotypic variation in growth and biomass distribution for two advanced-generation pedigrees of hybrid poplar. *Canadian J. Forest Res.,* **35**: 1779–1789.


Received: November 11, 2011; Accepted: February 3, 2012