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Performance of Public and Private Sector Sunflower (*Helianthus annuus* L.) Hybrids for Drought Tolerant Traits under Different Water Regimes

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Abstract

The present study was conducted mainly to find out the hybrids which could perform well under water limited conditions by adopting drought tolerant traits for better yield. Initial screening was carried out with 17 public and private sunflower hybrids for various drought tolerant parameters under different water regimes (100, 70 and 40 per cent). Root traits, *viz.,* root length, root volume and root to shoot ratio were better in public hybrids compared to private hybrids contributing to drought tolerance by utilizing deeper levels of soil moisture. Among the public sunflower hybrids, KBSH-44 showed higher RWC (64.02 per cent), surface wax (45.81 per cent), root length (74 cm), root to shoot ratio (128 per cent) and maximum TDM (30.50 g) at severe moisture stress condition. Also, the hybrid K-618 exhibited biomass (28.50 g) with higher root to shoot ratio (68.3 per cent) compared to all other private sunflower hybrids. The drought-tolerant indices, DMSI and PHSI values of sunflower hybrids affected morpho-physiological, root traits and biochemical parameters in case of private sector (45.93 and 64.09 per cent) sunflower hybrids compared to public sector hybrids (47.33 and 70.10 per cent) under moderate and severe moisture stress.

Keywords: Proline, Melondealdehyde, Plant height stress tolerance index, Dry matter stress tolerance index

In the global climate change scenario, water availability would be the most important input that will determine crop growth and productivity. Thus, improving the drought tolerance of important crop species like sunflower is being regarded as one of the most important global research agenda. Being a highly cross-pollinated crop, sunflower crop improvement is best achieved through development of drought tolerant hybrids. Several high yielding hybrids have already been developed and are extensively being cultivated extensively. However, most of these sunflower hybrids were developed for resource rich environments than for stress conditions. Thus, developing climate resilient crop varieties for sustainability under drought assumes greater significance (Condon *et al*., 2004).

Root characteristics are important while breeding for drought tolerance. Response of roots to the drought has been reported earlier in sunflower hybrids and inbred lines (Rauf, 2008). These studies indicated that higher root growth was linked with better drought tolerance. However, breeding sunflower for direct improvement of root characteristics was not taken previously. This may be due to laborious measure of this trait. Several researchers reported that there is a variation in morpho-physiological, oil content and fatty acid accumulation under stress during different growth stages and seasons, which can be manipulated by regulating the moisture status of the soil (Rauf and Sadaqat, 2008).

Several high yielding hybrids have already been developed and being cultivated extensively by farmers. However, most of these sunflower hybrids were developed for resource rich environments than for stress conditions. Most of these hybrids show a higher yield in rainfed conditions and high yield increase can be obtained in response to irrigation. It has been found that a worldwide reduction in sunflower yield has been associated with drought. Different hybrids of sunflower depict differential response to drought. Due to different agro-ecological circumstances of their development, evaluation and production, full yield potential has not been achieved (Rauf and Sadaqat, 2008b).

Relative water content (RWC) and Root length are the important plant traits for discriminating drought tolerant and sensitive genotypes (Rauf and Sadaqat, 2008). Recent studies indicated that some root traits such as root length and diameter, root density, root volume, fresh and dry root weight and also total dry matter are significant indicators of drought tolerance in sunflower (Geetha *et al*., 2012; Nagarathna *et al*., 2012; Rauf *et al*., 2008 and Rauf *et al*., 2009). Therefore, these traits are so useful to develop the drought tolerant hybrids. In addition to root traits, developing whole plant strategies by sunflower breeders with specifics of genotype as well as genotype x environment interactions is key issue in drought resistance breeding (Ghaffari *et al*., 2013; Safavi *et al*., 2015 and Asadolaei *et al*., 2015).

Therefore, the present study emphasises on understanding the physiological and biochemical mechanism of drought tolerance at different water regimes, enabling a direct comparison of the performance of all the available public and private sector sunflower hybrids under drought and non-drought conditions.

Material and Methods

The main goal of the present experiment was to identify the tolerant sunflower hybrids at different levels of moisture stress. The study material included sunflower hybrids released by public (9) and private sectors (8) and research was carried out in containers under rain out shelter (ROS) at ZARS, UAS, Bangalore during early *kharif,* 2017 with two replications at different levels of moisture stress *viz.,* 40, 70 and 100 per cent of field capacity. Moisture stress was imposed by withholding irrigation for 30 days from 25 to 55 DAS to create different moisture stress regimes. The plants were harvested at flowering and several observations were recorded. On 56th day the containers were fully irrigated so as to excavate the root and different root traits were recorded on 60th day in addition to total dry matter of each hybrid in two replications.

The crop was grown following recommended package of practices. All the containers were irrigated to maintain 100, 70 and 40 per cent of field capacity up to harvest. The exposed soil surface in the containers was mulched by straw to reduce soil evaporative losses. The weight of individual container with soil at field capacity, straw and plant was recorded with the help of a mobile electronic load cell balance of 60 kg capacity with a resolution of 100 g. The load cell balance was fixed on a mobile gantry system with a provision for movement along the rails horizontally to access every pot. The containers were placed in an open area and protected from any external moisture entry (rain interruption) by using a mobile rain out shelter (ROS). Soil moisture stress was imposed gradually following gravimetric approach (Julyane *et al*., 2016). Once the desired level of stress was reached (100, 70 and 40% of FC), the same level of stress was maintained up to harvest. During the experimental period, days after achieving the desired moisture stress level morpho-physiological observations like Plant height (cm), total biomass (g/plant), SPAD chlorophyll meter readings (SCMR), relative water content (%), rate of water loss and root traits *viz*., root length (cm), root volume (cc), root dry weight (g) and also biochemical parameters like proline, epicuticular wax and melondialdehyde (per cent) were recorded. After harvest, Plant Height Stress Tolerance Index (PHSI), Dry Matter Stress Tolerance Index (DMSI) and Relative Water Content Tolerance Index (RWCSI) were calculated using below mentioned formulae.

$$\text{PHSI} = \frac{\text{Plant height of stressed plants}}{\text{Plant height of control plants}} \times 100$$

$$\text{DMSI} = \frac{\text{Dry matter of stressed plants}}{\text{Dry matter of control plants}} \times 100$$

$$\text{RWCSI} = \frac{\text{RWC of stressed plants}}{\text{RWC of control plants}} \times 100$$

Statistical analysis was carried out by Fisher's method of "Analysis of Variance" (ANOVA) as outlined by Panse and Sukhatme (1967).

Results and Discussion

Results of the experiment on morpho-physiological characters (Table 1) shows that moisture stress has drastically affected all the parameters. Per cent reduction in plant height ranged from 12-24 among public sector hybrids compared to 4-24 per cent in private hybrids at 70 per cent stress. At 40 per cent stress, plant height was affected by 23-45 per cent in public hybrids and 20-36 per cent in private hybrids. Drought stress has led to reduction in stem water potential affecting cell elongation and consequently shorter internodes and stem height. The results are in conformity with Kaya, *et al*. (2009). Moisture stress prolonged days to flowering by at 40 per cent stress for approximately for 2 days whereas, at 70 per cent flowering was not affected.

Similar results were observed for SPAD chlorophyll content where moisture stress affected chlorophyll content compared to 100 per cent water regime. All these parameters did not significantly differ between the hybrids. SPAD chlorophyll meter reading (SCMR), a reflection of leaf chlorophyll / leaf nitrogen declined in stress treatment due to degradation of leaf chlorophyll content under moisture stress conditions. This is in conformity with Rauf and Sadaqat (2008).

Significant difference was observed for total dry matter at different water regimes and also between hybrids irrespective of public or private sector hybrids. More reduction in accumulation of total dry matter was recorded at 40 per cent stress (Table 1) wherein, the reduction was maximum in KBSH-1 (66%) and KBSH-53 (63%). A common adverse effect of water stress on crop plants is reduction in fresh and dry biomass production. Under extreme deficiency of water, cell elongation of plants has hindered the flow of water from xylem tissue to the surrounding elongating cells. This is in conformity with the findings of Farooq *et al*. (2009). Also the number of leaves per plant and individual leaf size decreased with decreasing water potential of the soil. It may be because of reduced photosynthesis by suppression of leaf expansion. Similar results were also reported by Rauf and Sadaqat (2008a).

After harvest, root traits were recorded and the results pertaining to root characters (Table 2) shows that maximum increase in root length was observed at 40 per cent moisture stress though it did not significantly differ between public and private hybrids. At 70 per cent stress, 8.2 per cent increase in root length was recorded among public hybrids compared to private hybrids (4.3%) and at 40 per cent stress, the increase in root length was more for in public hybrids (26.2%) compared to private hybrids (16.5%). Among public sector hybrids, maximum increase in root length was recorded in KBSH-44 (50%), KBSH-41 (43%) followed by DRSH-1 (36%) and NDSH-102 (33%) compared with normal irrigation condition whereas, PSH-1962 did not exhibit much variation in root length even under different water regimes. Only two private hybrids exhibited better root system with increase in root length (SB-207 & K-618). Computed values indicating Critical Difference (CD @ 5 %), Co-efficient of variation (CV) and Standard error of mean (SEM) for different public and private sunflower hybrids are presented in Table 2. CD value indicates statistical significance for all root characters at different levels of water stress which explains that there is significant difference among the hybrids performance over different levels of water stress. Among all the root characteristics studied, the root dry weights of hybrids had maximum variation at 100 per cent field capacity followed by 40 per cent field capacity and least CV (3.65) for root length at 100 per cent field capacity. Also there is a significant interaction between the hybrids and different soil moisture regimes (100, 70 and 40 %) for all the root traits studied.

Increase in root length is an adaptive mechanism used by drought tolerant genotypes. Therefore, higher values may be used for discrimination between drought tolerant and susceptible hybrids. Increase in root length due to higher osmotic adjustment ability of drought tolerant genotypes also indicated that increased root length occurred at the expense of lateral root number and the longer root length may help to explore nutrients at deeper soil profile. These findings are in line with Rauf and Sadaqat (2008). The results also corroborate with Rauf and Sadaqat (2008), that the phenomenon is especially important when the water supply is limited.

TABLE 1

Morpho-physiological characteristics of public and private sunflower hybrids at different water stress regimes

	Hybrids	Plant Height (cm)			Days to flowering			SPAD			Total dry matter (g)		
		100 %	70 %	40 %	100 %	70 %	40 %	100 %	70 %	40 %	100 %	70 %	40 %
Public Hybrids	DRSH-1	127	99	86	55.00	56.50	56.50	40.40	36.75	34.60	82.75	55.25	36.75
	KBSH-41	132	109	81	51.00	55.00	57.00	41.85	41.10	37.90	71.75	54.25	34.75
	NDSH-1012	131	107	96	57.00	54.00	56.50	38.25	35.85	35.60	74.25	53.25	36.75
	PSH-1962	135	116	83	53.00	55.50	55.00	36.55	34.40	32.60	90.75	52.50	38.50
	RSFH-130	113	94	73	55.00	54.50	59.00	38.90	38.50	34.70	59.75	46.25	32.00
	RSFH-1887	107	92	71	55.50	55.00	57.50	35.95	34.75	34.20	51.50	47.25	30.50
	KBSH-1	132	110	85	57.00	54.50	55.50	38.55	37.10	36.80	74.00	45.75	25.00
	KBSH-53	100	88	64	56.00	59.50	60.00	42.00	38.05	37.75	81.00	45.25	30.00
	KBSH-44	106	80	58	56.00	57.50	60.00	37.95	37.20	35.95	67.75	28.50	30.50
	Mean	**120**	**99**	**77**	**55.06**	**55.78**	**57.00**	**38.93**	**37.08**	**35.57**	**72.61**	**47.58**	**32.75**
Private Hybrids	SB-207	131	119	95	55.00	52.00	54.00	37.95	37.60	36.15	69.00	49.50	31.50
	SH-416	99	95	79	56.00	57.50	57.00	42.10	41.20	35.45	70.75	58.75	31.75
	GK-2008	82	76	54	57.00	59.00	57.00	38.35	36.70	34.00	35.50	19.25	23.25
	K-618	125	95	73	53.50	52.50	53.00	37.65	35.15	33.60	80.25	57.00	28.50
	GK-202	107	91	69	54.00	55.50	56.00	39.50	34.60	32.95	83.00	51.50	35.25
	GK-2009	112	93	85	54.00	55.50	59.00	38.70	37.10	36.45	74.75	41.75	34.50
	GK-2002	116	92	82	51.50	58.00	55.00	38.35	37.20	36.00	76.25	57.25	45.25
	PAC-3794	99	86	73	58.50	56.50	59.00	39.80	38.90	37.90	83.75	48.00	32.75
	Mean	**109**	**93**	**76**	**54.94**	**55.81**	**56.25**	**39.05**	**37.31**	**35.31**	**71.66**	**47.88**	**32.84**
	Total Mean	**115**	**96**	**77**	**55.00**	**55.79**	**56.25**	**38.99**	**37.19**	**35.45**	**72.16**	**47.73**	**32.80**
	S. Em. (±)	5.90	6.06	4.42	1.91	0.81	1.30	1.74	2.04	2.07	5.12	5.92	3.01
	C.V.	7.28	8.91	8.16	4.92	2.05	3.24	6.32	7.77	8.26	10.03	17.56	12.98
	C. D. @ 5%	17.69	18.17	13.26	5.73	2.42	3.91	5.22	6.12	2.33	15.34	17.76	9.02

TABLE 2

Root traits of public and private sunflower hybrids at different water stress condition

	Hybrids	Root Length (cm)			Root Volume (cc)			Root Dry Weight (g)			R to S Ratio (%)		
		100 %	70 %	40 %	100 %	70 %	40 %	100 %	70 %	40 %	100 %	70 %	40 %
Public Hybrids	DRSH-1	26.00	33.00	62.00	55.00	30.00	22.50	18.75	11.50	7.00	20.5	33.5	73.5
	KBSH-41	19.00	27.50	62.00	60.00	27.50	27.50	12.75	6.25	3.50	14.5	25.7	76.6
	NDSH-1012	20.00	29.00	53.50	62.50	35.00	17.50	6.50	8.00	5.50	15.3	27.5	55.9
	PSH-1962	21.00	26.50	29.00	40.00	22.50	22.50	10.25	7.00	8.00	15.6	22.8	35.4
	RSFH-130	21.50	34.00	47.50	65.00	32.50	20.00	14.25	9.50	4.00	19.0	37.6	65.3
	RSFH-1887	20.50	24.00	30.50	57.50	27.50	17.50	14.00	14.25	4.50	19.2	26.3	43.3
	KBSH-1	23.00	28.50	32.50	60.00	37.50	32.50	12.25	10.25	2.75	17.6	25.9	38.4
	KBSH-53	29.50	28.50	49.00	57.50	40.00	27.50	15.75	11.50	4.25	29.5	32.9	77.2
	KBSH-44	24.00	47.50	74.00	55.00	20.00	20.00	12.50	8.25	4.75	23.0	59.7	128.7
	Mean	**22.72**	**30.94**	**48.89**	**56.94**	**30.28**	**23.06**	**13.00**	**9.61**	**4.92**	**19.36**	**32.43**	**66.03**
Private Hybrids	SB-207	25.50	29.00	50.00	37.50	30.00	20.00	13.00	7.50	3.50	19.6	24.4	52.9
	SH-416	25.50	32.50	33.50	37.50	40.00	30.00	15.50	10.00	3.50	25.7	34.4	42.6
	GK-2008	17.50	19.00	31.50	30.00	25.00	15.00	10.50	6.75	2.75	21.8	25.2	59.6
	K-618	30.50	28.50	50.00	55.00	25.00	25.00	15.50	8.50	3.50	24.7	30.0	68.3
	GK-202	21.50	33.50	39.00	42.50	40.00	20.00	15.25	8.25	7.25	20.4	37.6	57.3
	GK-2009	24.00	37.00	47.00	52.50	50.00	27.50	36.00	16.25	8.00	21.7	40.1	55.3
	GK-2002	26.00	32.00	38.50	37.50	45.00	20.00	32.25	9.50	8.75	22.4	35.2	47.1
	PAC-3794	34.50	28.50	47.50	67.50	37.50	22.50	17.00	8.25	5.00	35.0	33.4	66.0
	Mean	**25.63**	**30.00**	**42.13**	**45.00**	**36.56**	**22.50**	**19.38**	**9.38**	**5.28**	**23.91**	**32.54**	**56.14**
	Total Mean	**24.09**	**30.50**	**45.71**	**51.32**	**33.24**	**22.79**	**16.00**	**9.50**	**5.09**	**21.50**	**32.48**	**61.38**
	S. Em. (+)	2.32	3.29	4.05	7.23	4.93	2.25	3.96	0.79	1.04	2.67	3.76	6.21
	C.V.	3.65	15.02	12.52	19.93	20.98	13.95	34.97	11.78	28.85	17.57	16.38	14.31
	C. D. @ 5%	6.97	9.71	12.13	21.68	14.78	6.74	11.86	2.37	3.11	8.01	11.28	18.61

Fig. 1: Variability for root traits under different water regimes

Under severe moisture stress (40%), root volume was significantly reduced though root length was increased. More fibrous roots were observed under normal irrigation condition which has contributed for more root volume (Fig. 1) whereas, though root length was more under stress, fibrous roots were less on the upper part of root. Similarly, root dry weight (g) was also less at 40 per cent stress compared to normal irrigation regime. Although there was an increase in the root length, increase in root dry weight was not observed under different water regimes, rather diminishing effects of drought were observed on root dry weight. This showed that root weight was independent of root length.

Root to shoot ratio is also an important character which depends on the root and shoot dry weight of plants. Significantly higher root to shoot ratio was observed in public hybrids (66%) under stress compared to private hybrids (56%). Maximum root to shoot ratio was recorded in KBSH-44 (128%) and the least was recorded in PSH-1962 (35%). It may be due to decreased water potential, roots are less sensitive than shoots to growth inhibition resulting in increased root: shoot ratio of plants and also decreased leaf growth leading to decrease in dry matter partitioning by increase in root: shoot ratio. A similar result was observed by Rauf and Sadaqat (2007).

Biochemical studies were also conducted to understand the reason for tolerance or susceptibility of sunflower hybrids for moisture stress (Table 3). There was no significant difference observed among the hybrids within same water regimes for relative water content (RWC). However, RWC reduced at severe moisture stress compared to normal irrigation regime. Similar trend was observed for relative water loss (RWL) and maximum water loss from leaves has recorded for PSH-1962 (22.8 per cent) and less in RSFH-1887 (7.9 per cent). Drought stress resulted in the loss of water in plants as well as reduction of RWC. This is in conformity with the findings of Mozhgan *et al*. (2017). RWC is widely used as one of the most reliable indices for characterization of both sensitivity and tolerance of plants to water stress. As RWC is related to cell volume, it may closely reflect the balance between water supply to the leaf and transpiration rate. Reduced water status of plant tissue (RWC) alters membrane permeability causing solute leakage.

Accumulation of compatible osmolytes such as proline and MDA has been regarded as a basic strategy for the protection and survival of plants under drought stress conditions. Irrespective of hybrids, plants tend to accumulate more proline, MDA and surface wax under severe moisture stress (40%). Many plants use organic osmolites for osmotic regulation and to better tolerate the stress and this act as potent scavengers of ROS and prevent induction of programmed cell death by ROS at severe stress. Accumulation of MDA under severe stress is by-product of fatty acid peroxidation, synthesized by cellular membrane lipid

TABLE 3

Biochemical changes in public and private sunflower hybrids at different water stress condition

	Hybrids	RWC (%)			RWL (%)			Proline (%)			MDA (%)			Surface Wax (%)		
		100 %	70 %	40 %	100 %	70 %	40 %	100 %	70 %	40 %	100 %	70 %	40 %	100 %	70 %	40 %
Public Hybrids	DRSH-1	73.96	62.20	58.60	7.65	11.17	12.39	6.52	15.57	21.00	23.04	40.22	47.19	24.03	32.75	40.62
	KBSH-41	69.23	69.00	57.45	11.04	17.31	20.01	10.14	14.84	22.08	18.53	27.40	46.08	24.46	32.07	42.08
	NDSH-1012	67.73	65.07	50.42	12.85	13.71	17.87	7.60	22.81	30.05	15.17	21.70	35.47	24.67	32.32	42.22
	PSH-1962	66.72	60.82	59.93	10.40	10.90	22.86	7.96	13.39	19.91	21.87	33.41	34.05	22.97	31.36	40.49
	RSFH-130	71.76	63.50	59.86	10.98	11.61	8.61	10.50	27.87	35.48	21.38	36.74	45.61	28.44	35.45	41.71
	RSFH-1887	68.95	63.08	62.99	13.06	13.10	7.92	9.46	25.48	37.68	24.60	35.30	38.23	22.00	31.21	39.67
	KBSH-1	67.16	57.04	56.22	11.35	12.47	14.68	9.05	18.46	25.34	19.29	24.07	46.72	23.91	32.68	40.32
	KBSH-53	70.07	57.26	56.68	10.43	13.12	16.08	9.05	19.91	28.60	20.32	22.49	42.28	23.10	32.76	40.94
	KBSH-44	71.50	71.31	64.02	12.99	12.63	18.33	6.88	13.76	18.46	15.52	23.44	46.40	25.57	36.53	45.81
	Mean	**69.68**	**63.25**	**58.46**	**11.19**	**12.89**	**15.42**	**8.57**	**19.12**	**26.51**	**19.97**	**29.42**	**42.45**	**24.35**	**33.01**	**41.54**
Private Hybrids	SB-207	74.22	67.21	61.24	10.44	12.79	14.61	8.33	21.36	27.87	17.92	22.01	48.62	22.28	35.01	43.77
	SH-416	78.89	77.15	65.81	7.54	11.75	10.15	10.50	13.76	21.00	16.08	30.88	23.91	25.79	32.83	44.74
	GK-2008	76.76	66.34	64.48	15.20	16.86	20.09	10.86	16.29	20.63	22.65	29.30	50.99	23.36	32.98	38.47
	K-618	70.96	60.07	55.52	11.99	12.81	16.51	9.41	13.39	30.77	17.16	19.80	32.62	25.19	32.72	40.55
	GK-202	78.92	68.05	62.11	8.58	13.84	17.77	6.16	13.76	24.62	18.84	23.44	33.57	26.54	34.27	42.88
	GK-2009	68.62	65.67	62.76	9.91	16.96	20.85	7.24	18.82	34.03	18.84	27.87	39.75	25.61	33.93	43.67
	GK-2002	73.44	63.89	55.93	11.22	15.24	12.86	8.33	22.44	38.37	13.46	20.27	33.57	25.00	31.95	40.06
	PAC-3794	68.67	67.06	59.63	9.07	13.60	12.71	7.60	18.10	27.15	15.75	19.16	48.93	24.30	37.18	44.99
	Mean	**73.81**	**66.93**	**60.94**	**10.49**	**14.23**	**15.69**	**8.55**	**17.24**	**28.06**	**17.59**	**24.09**	**39.00**	**24.76**	**33.86**	**42.39**
	Total Mean	**71.62**	**64.98**	**59.63**	**10.87**	**13.52**	**15.55**	**8.56**	**18.24**	**27.24**	**18.85**	**26.91**	**40.82**	**24.54**	**33.41**	**41.94**
	S. Em. (±)	6.62	0.97	0.75	1.27	1.11	1.62	0.48	0.98	1.23	0.93	3.28	2.02	0.76	0.87	0.68
	C. V.	3.20	2.12	1.77	16.50	11.64	14.73	7.96	7.64	6.36	6.98	17.25	7.01	4.41	3.61	2.28
	C. D. @ 5%	4.86	2.92	2.24	3.80	3.34	4.86	1.45	2.95	3.67	2.79	9.84	6.06	2.29	2.60	2.03

peroxidation. This was in conformity with Muhammad and Zamin (2018).

Different drought tolerant indices were calculated based on the data obtained under severe moisture stress conditions. The results of the experiment indicated that all the studied indices decreased at the increasing level of drought stress. Sunflower hybrids differed significantly for PHSI, DMSI, and RWSCI. Higher PHSI was recorded in SH-416 (79.69) compared to all other sunflower hybrids. Higher RWSCI was recorded in GK-2009 (91.46) followed by RSFH-1887 (91.36) and KBSH-44 (89.54). The highest DMSI percentage was observed in the GK-2008 (65.49 per cent) under severe stress conditions followed by RSFH-1887 and GK-2002 (59.34 and 59.22, respectively). Higher RWCSI was recorded higher in private sunflower hybrids (83.93) compared to public hybrids (82.67). Whereas, public sunflower hybrids maintained higher PHSI and DMSI (70.10 and 47.33) at 40 per cent field capacity and the lower was observed in private sector sunflower hybrid (64.09 and 45.93) (Fig. 2). Variation among the hybrids is due to the presence of genetic variability, mean values of all

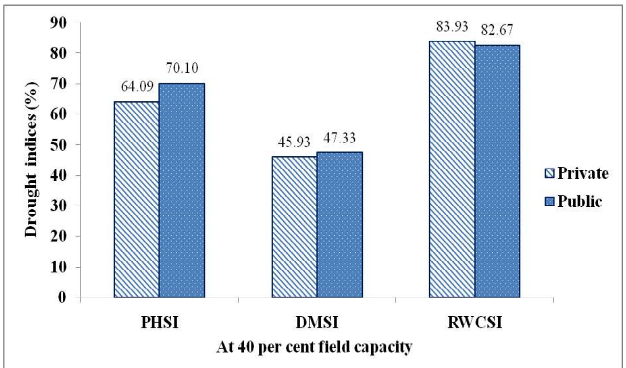

Fig. 2: Effect of severe stress on different drought tolerant indices of public and private sunflower hybrids

the studied hybrids showed the variability among the tolerant and sensitive with high and low mean values respectively. Variation among hybrids for DMSI was found to be a reliable indicator of drought tolerance in sunflower. Decrease in indices by increasing the drought stress has also been reported by various researchers, which was confirmed by Rauf and Sadaqat (2008). The results also corroborate those of Rauf (2008) and Ahmad *et al.* (2009), Water is the most important factor which is adversely affecting crop growth and productivity in water limited conditions. Therefore, the crop should tolerate the drought period for better growth and development by utilizing available water efficiently.

In the present study, various parameters contributing for drought tolerance were analysed. It was observed that morpho-physiological and biochemical parameters of different sunflower hybrids. Root characteristics are one of the important traits contributing to drought tolerance (Rauf, 2008). All root characters i.e., root length, root dry weight, root volume and root to shoot ratio were maximum in public hybrids as compare to private sunflower hybrids, which contribute to drought tolerance by utilizing water at deeper levels for growth and development of plant. This is in conformity with the findings of Nagarathna *et al.* (2012) and Geetha *et al.* (2012). Among the public sunflower hybrids KBSH-44 showed maximum TDM (13.67 g) with higher RWC (64.02 per cent), surface wax (45.81 per cent), root length (74 cm) and root to shoot ratio (128.7 per cent) at severe moisture stress conditions. Also, the hybrid K-618 exhibited relatively higher biomass (14.08 g) with higher root to shoot ratio (68.3 per cent) compared to all other private sunflower hybrids. This depicts that dry matter production is most important for the crop in stress conditions in order to remobilize the available assimilates to the yield attributes of the crop.

KBSH-44 and K-618 performed better than all other sunflower hybrids studied under different water regimes (40, 70 and 100 per cent). Also the drought-tolerant indices, DMSI and PHSI values of sunflower hybrids existing in the study affected more for plant morpho-physiological, root traits and biochemical parameters in case of private sector sunflower hybrids as compared to public hybrids under moderate and severe moisture stress. The experiment was carried out in containers mainly to study the root traits, further confirmation under field conditions would be useful.

REFERENCES

AHMAD, S., AHMAD, R., ASHRAF, M. Y., ASHRAF, M. AND WARRAICH, E. A., 2009, Sunflower (*Helianthus annuus* L.) response to drought stress at germination and seedling growth stages. *Pakistan J. Bot.*, **42** : 647 - 654.

ASADOLAEI, M. V., NASSIRI, B. M. AND YOUSEFIFARD, M., 2015, Diversity of drought tolerance and seed yield in sunflower (*Helianthus annuus* L.) hybrids. *J. Biodiv. Envi. Sci.*, **6** (5) : 305 - 310.

CONDON, A. G., RICHARDS, R. A., REBETZKE, G. J. AND FARQUHAR, G. D., 2004, Breeding for high water-use efficiency. *J. Expt. Bot.*, **55** : 2447 - 2460.

FAROOQ, M., WAHID, A., KOBAYASHI, N., FUJITA, D. AND BASRA SMA, 2009, Plant drought stress: effects, mechanisms and management. *Agron. Sustain. Dev.,* **29** : 185 - 212.

GEETHA, A., SURESH J. AND SAIDAIAH, P., 2012, Study on response of sunflower (*Helianthus annuus* L.) genotypes for root and yield characters under water stress. *Cur. Biotica*, **6** (1) : 32 - 41.

GHAFFARI, M., TOORCHI, M., VALIZADEH, M. AND KOMATSU, S., 2013, Differential response of root proteome to drought stress in drought sensitive and tolerant sunflower inbred lines. *Funct. Plant Bio.*, **40** : 609 - 617.

GOMEZ, K. A. AND GOMEZ, A. A., 1984, Statistical procedures for agricultural research (2 ed.). *John wiley and sons, NewYork*, pp. 680.

JULYANE, V. F., TONNY, J. A., EDNA, M. B. AND HELON, H. F., 2016, Soil moisture maintenance methods in cultivation in a greenhouse. *African J. Agril. Res.*, **11** (5) : 317 - 323.

KAYA, Y., EVCI, G., DURAK, S., PEKCAN, V. AND GUCER, T., 2009, Yield components affecting seed yield and their relationships in sunflower (*Helianthus annuus* L.). *Pak. J. Bot.,* **41** (5) : 2261 - 2269.

MOZHGAN SARVARI, REZA DARVISHZADEH, ROGHAYEH NAJAFZADEH AND HAMID HATAMI MALEKI, 2017, Physio-biochemical and Enzymatic Responses of Sunflower to Drought Stress. *J. Plant Physiol and Breeding,* **7** (1) : 105 - 119.

MUHAMMAD UMAR AND ZAMIN SHAHEED SIDDIQUI, 2018, Physiological performance of sunflower genotypes under combined salt and drought stress environment. Stress Physiology Lab., Department of Botany, University of Karachi, Pakistan. *Acta Bot. Croat.*, **77** (1) : 36 - 44.

NAGARATHNA, T. K., SHADAKSHARI, Y. G., RAMAKRISHNA, P. V. R., JAGADISH, K. S. AND PUTTARANGASWAMY, K. T., 2012, Examination of root characters, isotope discrimination, physiological and morphological traits and their relationship used to identify the drought tolerant sunflower (*Helianthus annuus* L.) genotypes. *Helia*, **35** (56) : 1 - 8.

PANSE V. G. AND SUKHATME, P. V., 1967, Statistical methods for Agriculture workers. *Indian council of Agriculture, New Delhi*.

RAUF, S. AND SADAQAT, H. A., 2007, Effects of varied water regimes on root length, dry matter partitioning and endogenous plant growth regulators in sunflower (*Helianthus annuus* L.). *J. Plant Interactions*, **2** (1) : 41 - 51.

RAUF, S. AND SADAQAT, H. A., 2008a, Effect of osmotic adjustment on root length and dry matter partitioning in sunflower (*Helianthus annuus* L.) under drought stress. Acta Agric. Scand. Sect. B-*Soil Plant Sci*. **58** : 252 - 260.

RAUF, S. AND SADAQAT, H. A., 2008b, Identification of physiological traits and genotypes combined to high achene yield in sunflower (*Helianthus annuus* L.) under contrasting water regimes. *Australian J. Crop Sci.*, **1** (1) : 23 - 30.

RAUF, S., 2008, Breeding sunflower (*Helianthus annuus* L.) for drought tolerance. *Int. J. Faculty Agric. Biol.*, **3** : 29 - 44.

RAUF, S., SADAQAT, H. A., AHMAD, R. AND KHAN, I. A., 2009, Genetics of root characteristics in sunflower (*Helianthus annuus* L.) under contrasting water regimes. *Indian J. Plant Physiol.,* **14** (4) : 319 - 327.

SAFAVI, S. M., SAFAVI, A. S. AND SAFAVI, S. A., 2015, Evaluation of drought tolerance in sunflower (*Helianthus annuus* L.) inbred lines and synthetic varieties under non stress and drought stress conditions. *Biol. Forum.*, **7** (1) : 1849 - 1854.

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