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Original scientific paper

GENETIC DIVERSITY OF SUNFLOWER GENOTYPES UNDER DROUGHT STRESS BY PRINCIPLE COMPONENT ANALYSIS

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Seventy diverse genotypes were evaluated for drought stress for morphological (shoot and root length, fresh and dry shoot weight, fresh and dry root weight) and physiological traits (stomatal conductance, photosynthesis and transpiration rate) to increase the area under arid and semi-arid climatic condition to overcome the deficiency of edible oil. All genotypes varied significantly for all evaluated traits. High variability for photosynthesis rate and lower for transpiration rate but highly significant. Genotypic variance and its coefficient are almost higher for all characters then environmental variance and its coefficient. Additive gene action was found for stomatal conductance and fresh root weight, good characters for selection having high heritability with increased genetic advance used to find out drought tolerating genotypes. Genotypes ORI 29 and ORI 30 performed better in normal and drought stress condition can be used further breeding programme as a drought tolerant material. In PCA, genotypes ORI 30, ORI 27, ORI 38 and ORI 105 expressed maximum diversity can be used in further hybrid programme.
Keywords: Sunflower, drought stress, morphological traits, PCA, genetic variability

INTRODUCTION

Changing climate prolong duration of water deficiency causing reduction in crop production and decrease food security in the world (KRANNICH *et al*., 2015; ZHOU *et al*., 2016).

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Increasing population, decreasing fresh water and climatic changes aggregating the demand of drought tolerant crops (XIAO *et al*., 2007).

Drought reduce the soil water uptake, transpiration rate, stomatal conductance as a result photosynthetic rate also decrease (SKORIC, 2009).

Water is very important component of plant metabolism for all critical stages of growth like germination, seedling, flowering and seed production of sunflower (TURHAN and BASER, 2004; MOHAMMAD *et al*., 2002).

Sunflower (*Helianthus annuus* L.) is third important oilseed crop (POURDAD and BEG, 2008) after cotton and rapeseed & mustard grown an area of 264000 acres, its seed production is 142000 tonnes and good quality oil production is 54000 tonnes. Pakistan imports 2.421 million tonnes edible oil of worth rupees 192.203 billion (Economic Survey of Pakistan, 2018-19). In Arid and semi-arid belt, the production of sunflower and its yield sustainability is reduced due to drought stress (SAENSEE *et al.*, 2012). To reduce the huge import bill, the area under rainfed can be utilized by cultivating drought tolerant genotypes and their hybrids for high seed production (TAHIR *et al*., 2002).

Sunflower is used as important oilseed crop due to judicious crop production requirement and good quality oil (DEMIR *et al*., 2006). Due to high percentage of oil 35-45 % in sunflower seed, it can reduce the gap of consumption and production in the country (SABA *et al*., 2016). Development of drought tolerant genotypes from diverse germplasm of sunflower would be helpful to overcome the deficiency of oilseed requirement in the country (AHMAD *et al*., 2009).

Genetic diversity predict the genetic behavior of the traits and their inheritance pattern. The diverse germplasm of sunflower was analyzed to study the genetic components along with heritability and genetic advance to develop drought tolerance in sunflower. Characters enhancement on the basis of heritability and genetic advance guide the breeder to choose the way of varietal development either through selection or heterosis breeding (RAUF *et al*., 2008; GHAFFARI *et al*., 2011).

Different morphological and physiological markers have been used to study the variation against drought stress. The seedling stage is the best stage to check response of sunflower genotypes against drought stress and variability among genotypes (TURHAN and BASER, 2004). At initial growth stage of the sunflower seedling that root length and plant height was the good characters for screening against water stress that express variations (AHMAD *et al*., 2009). Head & stem diameter, plant height, Root to shoot ratio, seed weight and yield was reduced by increasing drought stress (HOSSAIN *et al*., 2010; VANAJA *et al*., 2011). Root characteristics such as root length density, root diameter and length, root volume, fresh and dry root weight and total dry matter are important indicator for development of drought tolerant material (GEETHA *et al*., 2012).

MATERIALS AND METHODS

Seventy diverse genotypes were collected from Oilseeds Research Institute, Faisalabad, Department of Plant Breeding & Genetics, UAF and Plant Genetic Resources Institute, NARC-Islamabad to identify the drought tolerant lines by using controlled conditions at glass house, Department of PBG, University of Agriculture, Faisalabad. Genotypes were sown in a polythene bags using complete randomized Designed under two factors. Drought was maintained by using field capacity level. Two factors were used (T1: Normal at 100% field Capacity, T2: Drought Stress at 50% field Capacity). 10 plants were sown in each replication. One plant was maintained in each polythene bag and three replications for each factor were maintained. Six morphological Characters i.e. shoot length (cm), root length (cm), fresh shoot weight (g), fresh root weight (g), dry shoot weight (g), dry root weight (g) and three physiological traits i.e. stomatal conductance, photosynthesis rate and transpiration rate were recorded after 20 days of emergence of seedlings. The polythene Bags were cut out with blade and Bags was dipped in distilled water to wash out the roots. The root and shoot length were measured with meter rod and fresh root and shoot weight was done by using weighing balance while for dry root and shoot weight the plant roots and shoots were kept at 70℃ for 72h. Infra-Red Gas Analyzer (IRGA) was used to record morphological characters.

To determine the genetic variability among the genotypes, analysis of variance was done (STEEL *et al*., 1997). FRANKHAM *et al*. (2002) formula was used to estimates genetic heritability parameters and broad sense heritability. Estimation of genetic advance formula was given by JOHNSON *et al*. (1955). Principle component analysis was done with the software "Minitab 18" and "R Studio" method fallowed by HUSSON *et al*. (2011).

Principle component analysis was used to recognize basic structural relationship among genotypes depend upon multivariate traits. By using PCA bi-plot of all traits, a clear cut association among different genotypes and plant characteristics against drought stress was viewed (GAFFARI, 2014).

RESULTS

Combined analysis of variance at both levels of drought expressed that all genotypes having high significance variability for all traits (Table.1). Genotypes x drought levels also showed highly significance ($P \leq 0.01$) for all traits (TAHIR *et al*., 2002). Genotype mean square for photosynthesis rate was found maximum (90.20) and Minimum for transpiration rate (0.002) but highly significant.

Table 1. Mean square of combined analysis of variance for 70 sunflower genotypes at both levels of drought

SOV	Df	SL	RL	FRW	DRW	FSW	DSW	SC	TR	PR
Genotype	69	18.71**	26.10**	7.62**	0.29**	8.41**	0.30**	4.00**	0.002**	90.20**
Drought	1	316.77**	82.37**	57.67**	3.31**	318.21**	1.43**	134.33**	0.113**	11596.7**
Genotype x drought	69	6.16**	13.13**	1.02**	0.06**	1.89**	0.08**	3.59**	0.002**	94.30**
Error	278	1.82	4.22	0.05	0.05	0.05	0.04	0.17	0.001	4.10

*=Significance at 5%, ** Significance at both 5% and 1%, SOV: source of variance, SL:shoot length (cm), RL: root length (cm), FRW:fresh root weight (g), DRW:dry root weight (g), FSW:fresh shoot weight (g), DSW:dry shoot weight (g), SC:stomatal Conductance, TR:transpiration rate and PR:photosynthesis rate.

Shoot and root length

Genotypic mean square ware found highly significant ($P \leq 0.01$) at both drought levels for shoot and root length. Grand mean was high (13.51) for root length at normal condition. Range of Shoot length varies from 16.73 to 8.53 cm at normal level while in drought stress shoot length decrease from 15.07 to 7.13 cm (Table 2). Root length range increase in drought stress condition (19.07-7.73 cm) as compere to range in normal condition (17.13 to 9.07cm). ORI-29 has maximum shoot length at both drought levels i.e. 16.73 cm and 15.07 cm. ORI-11 has maximum Root length (17.13 cm) at normal and ORI-87 has maximum Root length (19.07 cm) at drought stress condition. Maximum coefficient of variability was found for Root length at normal level (17.64). Genotypic and Phenotypic coefficient of variance were higher from environmental coefficient of variance for root and shoot length. Standard Deviation was low (2.25) for Shoot length at drought stress. Maximum heritability in broad sense and genetic advance (31.26) ware found for root length at drought stress condition.

Table 2. Genetic variability parameters of 70 sunflower genotypes for Shoot length (SL) and Root Length (RL) at both levels of drought

	SL (cm)		RL (cm)	
Parameter	(Normal)	(Drought stress)	(Normal)	(Drought stress)
Genotypic Mean Square	13.58**	11.28**	16.78**	22.65**
Error Mean Square	1.64	1.96	5.68	2.28
Grand Mean	12.73	11.00	13.51	12.62
Maximum Value	16.73	15.07	17.13	19.07
Minimum Value	8.53	7.13	9.07	7.73
Coefficient of Variability	10.07	12.73	17.64	11.97
Genotypic Variance	3.98	3.11	3.70	6.79
Environmental Variance	1.64	1.96	5.68	2.28
Phenotypic Variance	5.62	5.07	9.38	9.07
Standard Deviation	2.37	2.25	3.06	3.01
Genotypic Coefficient of Variance	15.67	16.03	14.24	20.65
Phenotypic coefficient of Variance	18.62	20.47	22.67	23.86
Environmental Coefficient of Variance	10.06	12.73	17.64	11.97
Heritability (B.S)	70.80	61.35	39.45	74.86
Genetic Advance i=1.76	2.94	2.42	2.11	3.95
Genetic Advance %	23.07	21.98	15.65	31.26

Fresh and dry shoot weight

All sunflower genotypes showed significant difference. Fresh and dry shoot weight decrease with the increase in drought stress (Table 3). The fresh shoot weight range from 2.85 to 9.13 gm under normal condition while in drought stress situation its ranges varies from 1.56 to 6.75 gm. Dry shoot weight varies from 0.13 to 1.74 gm under normal situation while under stress it ranges from 0.01 to 1.50 gm. Genotype ORI 105 gave maximum fresh shoot weight 9.13 gm in normal water condition but ORI 27 performing better in drought stress condition by giving maximum fresh (2.85 gm) and dry shoot weight (1.50 gm). Genotype ORI 39 performing better in normal situation by giving maximum fresh shoot weight (1.74 gm). Environment variance found less than Genotypic and phenotypic variance. Coefficient of variability showed greater by dry shoot weight (26.83) under drought stress. Fresh and dry shoot weight gave high heritability values (97.89 & 95.77) and high genetic advance (43.85 and 42.75) respectively.

Table 3. Genetic variability parameters of 70 sunflower genotypes for Fresh Shoot Weight (FSW) and Dry Shoot Weight (DSW) at both levels of drought

Parameter	FSW (grams)		DSW(grams)	
	(Normal)	(Drought stress)	(Normal)	(Drought stress)
Genotypic Mean Square	6.91**	3.39**	0.25**	0.13**
Error Mean Square	0.05	0.04	0.04	0.05
Grand Mean	5.97	4.23	0.94	0.83
Maximum Value	9.13	6.75	1.74	1.50
Minimum Value	2.85	1.56	0.13	0.01
Coefficient of Variability	3.72	5.25	23.51	26.83
Genotypic Variance	2.29	1.12	0.07	0.03
Environmental Variance	0.05	0.05	0.05	0.05
Phenotypic Variance	2.34	1.17	0.12	0.08
Standard Deviation	1.53	1.08	0.34	0.28
Genotypic Coefficient of Variance	25.32	24.97	27.81	20.24
Phenotypic coefficient of Variance	25.60	25.51	36.42	33.61
Environmental Coefficient of Variance	3.72	5.25	23.51	26.83
Heritability (B.S)	97.89	95.77	58.31	36.28
Genetic Advance i=1.76	2.62	1.81	0.35	0.18
Genetic Advance %	43.85	42.75	37.16	21.34

Fresh and dry root weight

In both (normal and drought stress) condition all genotypes showed highly significant difference for fresh and dry root weight (Table 4). Fresh root weight varies from 0.66 to 6.00 gm under normal situation while in drought stress its range was 0.54 to 5.52 gm. Dry root weight gave range of weight from 0.13 to 1.80 g in normal condition while 0.11 to 1.50 g under drought stress.

Table 4. Genetic variability parameters of 70 sunflower genotypes for Fresh root Weight (FRW) and Dry Root Weight (DRW) at both levels of drought

Parameter	FRW(grams)		DRW(grams)	
	(Normal)	(Drought stress)	(Normal)	(Drought stress)
Genotypic Mean Square	4.45**	4.20**	0.21**	0.14**
Error Mean Square	0.06	0.05	0.04	0.05
Grand Mean	3.07	2.32	0.86	0.69
Maximum Value	6.00	5.52	1.80	1.50
Minimum Value	0.66	0.54	0.13	0.11
Coefficient of Variability	7.70	10.18	12.76	32.41
Genotypic Variance	1.46	1.38	0.06	0.03
Environmental Variance	0.06	0.06	0.05	0.05
Phenotypic Variance	1.52	1.44	0.11	0.08
Standard Deviation	1.23	1.20	0.33	0.28
Genotypic Coefficient of Variance	39.46	50.68	27.50	24.64
Phenotypic coefficient of Variance	40.21	51.69	37.68	40.77

Environmental Coefficient of Variance	7.70	10.18	25.76	32.48
Heritability (B.S)	96.33	96.12	53.25	36.52
Genetic Advance i=1.76	2.08	2.02	0.30	0.18
Genetic Advance %	67.78	86.96	35.12	26.05

Genotype ORI 30 gave maximum fresh and dry root weight (6.00 g and 1.50 g) in normal and drought stress conditions respectively while genotype ORI 21 gave maximum dry root weight (1.80 g) in normal situation and genotype ORI 28 performing better (5.52 g) in drought stress situation. Genotypic and phenotypic variance and their coefficient were higher than environmental variance and its coefficient. Maximum heritability (96.33 and 96.12) and genetic advance (67.78 and 86.96) was found for fresh root weight under normal and drought stress conditions respectively.

Physiological traits

All physiological traits (stomatal conductance, transpiration rate and photosynthesis rate) expressed highly significance differences for Genotypes (Table 5).

Table 5. Genetic variability parameters of 70 sunflower genotypes for Physiological traits (stomatal Conductance (SC), transpiration rate (TR) and photosynthesis rate (PR)) at both levels of drought

	SC (mile mole $m^{-2}s^{-1}$)		TR(mile mole $m^{-2}s^{-1}$)		PR (micro mole $m^{-2}s^{-1}$)	
Parameter	(Normal)	(Drought stress)	(Normal)	(Drought stress)	(Normal)	(Drought stress)
Genotypic Mean Square	4.06**	3.52**	0.0029**	0.0017**	95.87**	88.85**
Error Mean Square	0.27	0.06	0.0003	0.0005	4.68	3.22
Grand Mean	2.99	1.86	0.11	0.08	40.05	29.54
Maximum Value	6.98	4.56	0.60	0.25	57.95	38.03
Minimum Value	1.91	1.01	0.10	0.04	23.78	18.23
Coefficient of Variability	17.48	13.10	17.29	29.17	5.40	6.08
Genotypic Variance	1.26	1.16	0.001	0.0004	30.40	28.54
Environmental Variance	0.27	0.06	0.0004	0.001	4.68	3.22
Phenotypic Variance	1.54	1.22	0.001	0.001	35.08	31.77
Standard Deviation	1.24	1.10	0.04	0.03	5.92	5.64
Genotypic Coefficient of Variance	37.59	57.80	26.77	26.57	13.77	18.08
Phenotypic coefficient of Variance	41.46	59.27	31.89	39.40	14.79	19.08
Environmental Coefficient of Variance	17.49	13.11	17.34	29.10	5.40	6.08
Heritability (B.S)	82.20	95.11	70.45	45.47	86.65	89.85
Genetic Advance i=1.76	1.78	1.83	0.04	0.02	8.98	8.86
Genetic Advance %	59.65	98.64	39.32	31.35	22.43	30.00

Stomatal conductance gave range 1.91 to 6.98 mmole $m^{-2}s^{-1}$ under normal while in drought stress its range reduced 1.01 to 4.56 mmole $m^{-2}s^{-1}$. In normal condition transpiration rate varies from 0.10 to 0.60 mmole $m^{-2}s^{-1}$ while in drought stress its range reduced 0.04 to 0.25

mmole m^{-2}s^{-1}. Photosynthesis rate expressed a range 23.78 to 57.95 µmole m^{-2}s^{-1} but in drought stress scenario its range 18.23 to 38.03 µmole m^{-2}s^{-1} also reduced. Genotype ORI 35 had high stomatal conductance (6.98 mmole m^{-2}s^{-1}) in normal condition while in drought stress condition ORI 47 genotypes performing better (4.56 mmole m^{-2}s^{-1}). ORI 35 had also high transpiration rate (0.60 mmole m^{-2} s^{-1} and 0.25 mmole m^{-2}s^{-1}) under both environment and high photosynthesis rate (38.03 µmole m^{-2}s^{-1}) in drought stress. Genotype ORI 46 expressed high photosynthesis rate (to 57.95 µmole m^{-2}s^{-1}) under normal condition. Maximum coefficient of variability (29.17) was observed in transpiration rate under drought stress. Environmental variances were lower than genotypic and phenotypic variances for all characters under normal and drought stress but transpiration rate has high environmental variance in drought stress conditions only. Maximum heritability (B.S) (95.11) and Genetic advance (98.64) was found for stomatal Conductance under drought stress.

Principle component analysis

Principle component analysis expresses the genetic diversity among genotypes that is the basic tool of the plant breeder. The genotypes ORI 26, ORI 35, ORI 30, ORI 29, ORI 27, ORI 38, ORI 25, ORI 39, ORI 105, RL 36 and RL 102 expressed maximum diversity according to the first and second component of the graph (Fig. 1) in normal conditions.

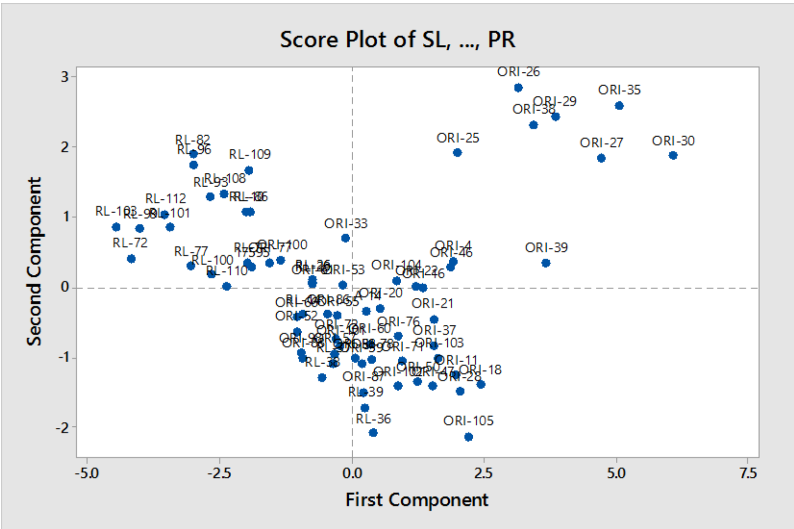

Figure 1. Physiological and morphological contributing traits in PC1 and PC2 of 70 genotypes of sunflower under normal condition

Bi-plot graph also expressed the relationship among all the traits (Fig. 2). The genotypes ORI 26, ORI 35, ORI 30, ORI 29, ORI 27, ORI 38 & ORI 25 having maximum transpiration rate and stomatal Conductance. Shoot length and photosynthesis rate was found high in ORI 4, ORI 46 and ORI 39. ORI 21 having high root length, fresh root weight, dry root weight, fresh and dry shoot weight.

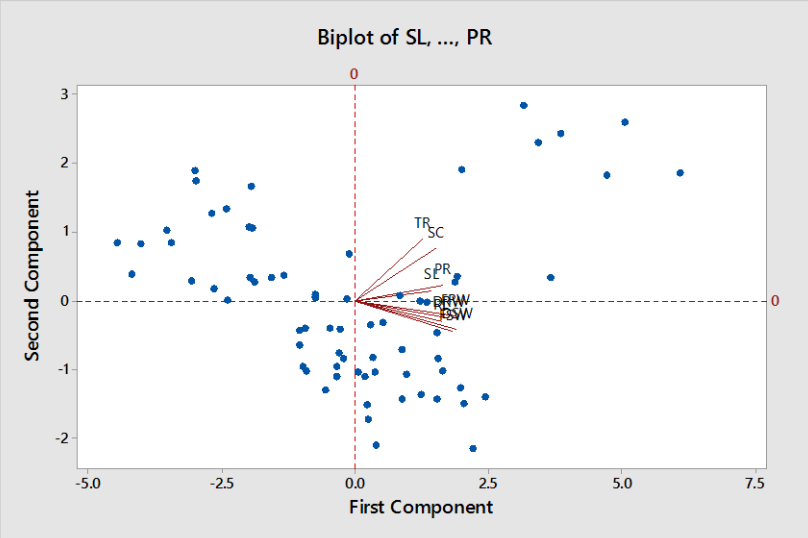

Figure 2. Bi-plot of PC1 and PC2 for all traits (SL:shoot length (cm), RL: root length (cm), FRW:fresh root weight (g), DRW:dry root weight (g), FSW:fresh shoot weight (g), DSW:dry shoot weight (g), SC:stomatal Conductance, TR:transpiration rate and PR:photosynthesis rate) of sunflower under normal conditions

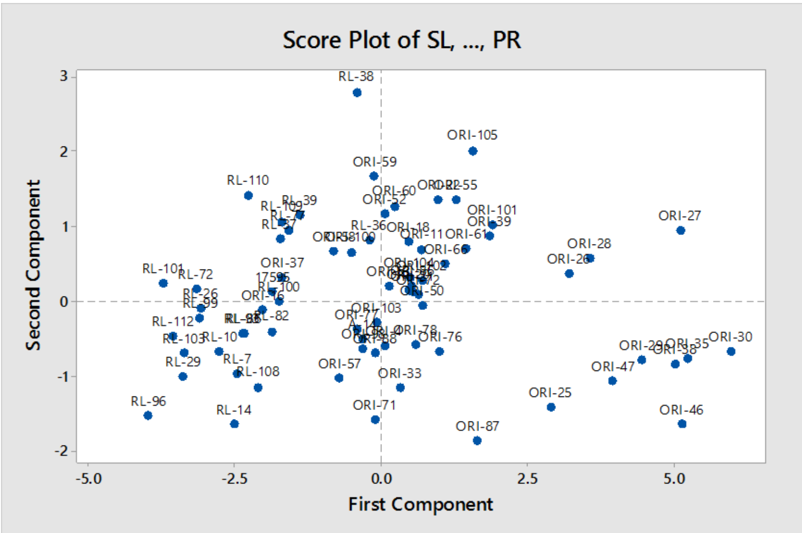

Figure 3. Physiological and morphological contributing traits in PC1 and PC2 of 70 genotypes of sunflower under drought stress condition

Under drought stress conditions the genotypes ORI 46, ORI 105, ORI 30, ORI 27, ORI 38, ORI 87, RL 110, RL 101, RL 96 and RL 14 expressed maximum diversity according to the first and second component of the graph (Fig. 3).

Bi-plot graph also expressed the relationship among all the traits (Fig. 4) under drought stress. The genotypes ORI 61, ORI 66 and ORI 39 had maximum association with fresh and dry shoot weight. Photosynthesis rate, shoot length, fresh and dry root weight projected toward the genotypes ORI 26 and ORI 28. Transpiration rate, stomatal Conductance and root length was found higher in ORI 50, ORI 47 and ORI 29.

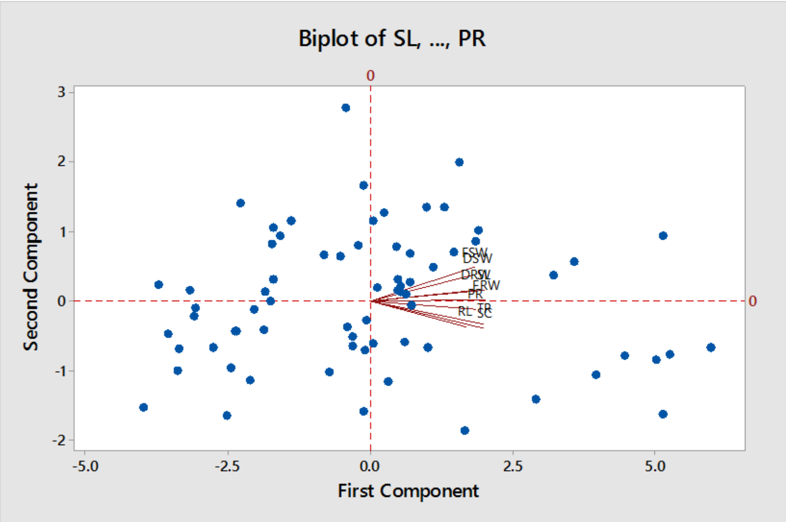

Figure 4. Bi-plot of PC1 and PC2 for all traits (SL:shoot length (cm), RL: root length (cm), FRW:fresh root weight (g), DRW:dry root weight (g), FSW:fresh shoot weight (g), DSW:dry shoot weight (g), SC:stomatal Conductance, TR:transpiration rate and PR:photosynthesis rate) of sunflower under normal conditions

DISCUSSION

Diversity in genetic material is important component for the development of breeding material in crop plants against abiotic stress like drought (SHAMSHAD *et al.*, 2014; TYAGI *et al.*, 2014; JANNATDOUST *et al.*, 2016). Variability found for all the traits under study for 70 genotypes under normal and drought stress conditions (KIANI, *et al.*, 2007; RAUF and SADAQAT, 2008; VUKICH *et al.*, 2009). All genotypes significantly differ from each other for evaluated traits and their interaction with drought also significantly differ in combined analysis of variance (FAROOQ *et al.*, 2018).

Stem length decrease with the increase the water stress (16.73 - 8.53 cm) to (15.07 - 7.13 cm) which also decreases plant height (MEO, 2000). Root length increase (17.13 - 9.07cm) to (19.07-7.73 cm) in the search of water under drought stress (ANGADI and ENTZ, 2002). In severe water stress root length increase while decrease in moderate stress (Najad, 2011). Root and shoot weight (fresh and dry) also decrease with the increase of drought stress (TURHAN and BASER, 2004; AHMAD *et al*., 2009; PEKCAN *et al*., 2016).

Genotypic variance and its coefficient are almost higher for all characters then environmental variance and its coefficient revealed that there is very little role of environment. All the characters are genetically influenced in phenotypic variance (REHMAN *et al.*, 2012; FAROOQ *et al.*, 2018). Stomatal conductance and fresh root weight are the good character having high heritability with increased genetic advance that's reliable for selection used to find out drought tolerating genotypes because of additive gene action was found for these traits (SHANKER *et al*., 2019).

Genotypes ORI 29, ORI 11, ORI 105, ORI 39, ORI 30, ORI 21performed better by giving higher values of morphological traits like shoot length, root length, fresh shoot weight, dry shoot weight, fresh root weight and dry root weight respectively in normal conditions. In physiological traits genotype ORI 35performed excellently for stomatal conductance and transpiration rate while genotype ORI 46 performed better for photosynthesis rate in normal conditions. Genotypes ORI 29, ORI 87, ORI 27, ORI 28, ORI 30 performed better by giving higher values of morphological traits like shoot length, root length, fresh & dry shoot weight, fresh root weight and dry root weight respectively in drought stress conditions. In physiological traits genotype ORI 35 performed excellently for transpiration rate and transpiration rate while genotype ORI 47 performed better for stomatal conductance in drought stress conditions.

Principle component analysis (PCA) was used to check out the relationship among stress levels and genotypes depend upon physiological and morphological traits (SAENSEE *et al*., 2012; RAZZAQ *et al.*, 2017). In PCA all the character showed cumulative effect at the same level. The genotypes ORI 30, ORI 27, ORI 38 and ORI 105 expressed maximum diversity according to the first and second component of the graph in both levels of stress (Fig. 1 and 3).

In bi-plot graph genotypes ORI 26, ORI 35, ORI 30, ORI 29, ORI 27, ORI 38 & ORI 25 having maximum transpiration rate and stomatal Conductance (Fig. 2). Shoot length and photosynthesis rate was found higher in ORI 4, ORI 46 and ORI 39. ORI 21 having high root length, fresh root weight, dry root weight, fresh and dry shoot weight under normal conditions. Under drought stress the genotypes ORI 61, ORI 66 and ORI 39 having maximum association with fresh and dry shoot weight. Photosynthesis rate, shoot length, fresh and dry root weight projected toward the genotypes ORI 26 and ORI 28. Genotypes ORI 50, ORI 47 and ORI 29 (Fig. 4) having higher transpiration rate, stomatal conductance and root length.

CONCLUSION

All the Morphological traits (shoot and root length, fresh and dry shoot weight, fresh and dry root weight) and physiological traits (stomatal conductance, transpiration rate and photosynthesis rate) showed variability, can be used for screening of the germplasm. Environmental variance was less than genotypic and phenotypic variance revealed that error through environment was minute. Additive gene action was found for stomatal conductance and fresh root weight used for selection rather than heterosis. Genotypes ORI 29 and ORI 30 performed better in normal and drought stress condition can be used further breeding programme as a drought tolerant material. In PCA genotypes ORI 30, ORI 27, ORI 38 and ORI 105 expressed maximum diversity can be used in hybrid programme of sunflower.

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GENETIČKI DIVERZITET GENOTIPOVA SUNCOKRETA U STRESU SUŠE PREMA PCA ANALIZI

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Izvod

Kod sedamdeset različitih genotipova suncokreta ocenjen je odgovor na stres zbog suše preko morfoloških (dužina izdanka i korena, težina svežeg i suvog izdanka, težina svežeg i suvog korena) i fizioloških svojstava (provodljivost stoma, fotosinteza i brzina transpiracije) u cilju povećanja gajenja u sušnim i polusušnim spoljašnjim sredinama, da bi se prevazišao nedostatak jestivog ulja. Svi genotipovi su se značajno razlikovali za sve ocenjivane osobine. Utvrđena je velika varijabilnost za brzinu fotosinteze i niža za brzinu transpiracije, ali izrazito značajna. Genetička varijansa i njen koeficijent veći su za skoro sve osobine u odnosu na varijansu spoljašnje sredine i njen koeficijent. Utvrđeno je aditivno delovanje gena za provodljivost stoma i težinu svežeg korena, što su dobre osobine za selekciju,sa visokom heritabilnošću.
Genotipovi ORI 29 i ORI 30 koji se ponašaju bolje u normalnim i sušnim stresnim uslovima mogu se koristiti u daljim oplemenjivačkim programima kao materijal koji je tolerantan na sušu. U PCA analizi genotipovi ORI 30, ORI 27, ORI 38 i ORI 105 pokazali su maksimalan diverzitet i mogu se koristiti u daljim programima stvaranja hibrida suncokreta.

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