International Journal of Farm Sciences **4(4)** : 26-35, 2014

Genetic analysis of sunflower genotypes under water stress environments

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ABSTRACT

The present investigation was undertaken in the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab to evaluate 41 genotypes of sunflower (*Helianthus annuus* L) for morphological and yield traits affecting water use efficiency under different water stress environments. The traits under study were days to 50 per cent flowering, days to maturity, plant height, head diameter, seed yield per plant, 100-seed weight and oil content. Analysis of variance revealed significant differences due to genotypes and environments for all the characters under study. Among the four environments W_1 (control) yielded the maximum value for all the parameters followed by W_4 (withholding of irrigation at anthesis completion stage and thereafter complete withholding of irrigation after soft dough stage), W_3 (withholding of irrigation at 50 per cent flowering stage and soft dough stage thereafter complete withholding of irrigations after hard dough stage) and W_2 (withholding of 2nd irrigation ie before button stage and thereafter complete withholding of irrigation after soft dough stage). The estimates of heritability and genetic advance were found maximum for seed yield per plant followed by 100-seed weight indicating the predominance of additive gene effects. Hence this trait can be improved to a considerable extent by limited selection cycles. Estimation of GCV and PCV values were also higher for seed yield per plant as compared to other traits indicating high genetic variability for this trait. The genotypes P-87-R, P-93-R, P-100-R and P-110-R were identified as water use efficient genotypes. The stress environment W_4 (withholding of irrigation at anthesis completion stage and thereafter complete withholding of irrigation after soft dough stage) could be considered as good as the control to realize maximum yield in sunflower..

Keywords: Water use efficiency; heritability; genetic advance; GCV; PCV

INTRODUCTION

Sunflower (*Helianthus annuus* L) is an important oilseed crop widely adopted and accepted for its high quality edible oil. Furthermore sunflower oil contains fat soluble vitamins A, B, E and K good for heart proteins. Inherent capacity of sunflower to capitalize on favourable agroclimatic conditions renders it a crop of worldwide importance. Being a thermo and photoinsensitive crop it can be raised in the plains throughout the year. In Punjab since majority of the farmers grow sunflower after potato most of the area is planted late ie in the month of February and March because of delay in the vacation of fields and availability of hybrid seed of private sector. Due to the delayed sowing the water requirement of the crop increases because of high temperature at the time of anthesis and maturity in the months of May and June and there is requirement of irrigation every week and sometimes in the light soils twice a week. However the present alarming situation of depleting underground water advocates the saving of water. Thus to cope up with such a situation the water use efficient genotypes need to be identified so that the number of irrigations can be reduced. Knowledge of genetic parameters is essential for understanding and their manipulation in any crop improvement programme. Further success in plant breeding depends upon the nature and magnitude of variability present in the germplasm (Ali and Khan 2007). Assessment of heritable and non-heritable components of total variability will have immense value in the choice of suitable breeding procedure (Habib et al 2007).

MATERIAL and METHODS

The experimental material comprised of 41 lines of sunflower comprising of 16 maintainer lines and 25 restorer lines planted in a randomized complete block design with three replications. Physical properties of soil were analyzed to determine the native fertility and soil texture of experimental field. Initially before sowing of crop composite soil samples were collected from 0-15 cm deep layer of the experimental site and analyzed for sand, silt, clay content and soil temperature (Table 1a). The experiment was repeated four times to create four different environments by providing following irrigation regimes viz W_1 (irrigation level 01, irrigating the plots during the entire growth cycle to maintain the soil water content close to field capacity, W_2 (irrigation level 02, withholding of 2nd irrigation ie before button stage and thereafter complete withholding of irrigation after soft dough stage, W_3 (irrigation level 03, withholding of irrigation at 50 per cent flowering stage and soft dough stage thereafter complete withholding of irrigations after hard dough stage, W_4 (irrigation level 04, withholding of irrigation at anthesis completion stage and thereafter complete withholding of irrigation after soft dough stage).

RESULTS and DISCUSSION

Analysis of variance (Table 1b) for all the seven characters studied revealed highly significant differences among the genotypes in all the four environments. The status of morphological and yield characters are presented in Table 2. Days to 50 per cent flowering were found to be higher in control ie W_1 followed by W_4, W_2 and $W_{3.}$ In W_1 the genotype 48-B was the earliest (57 days) and P-111-R was the latest (81 days) to flower. In W_2, genotypes P-6-R, P-75-R, P-94-R, P-119-R, 11-B, 50-B and RHA-297 recorded earliest flowering

Table 1a: Physical properties of experimental soil

Soil property	Value
Sand (%)	82.2
Silt (%)	7.1
Clay (%)	10.7
Textural class	loamy sand
Soil temperature	13°C

(60 days) and P-112-R registered the (76 days) latest. In W_3, 48-B recorded to be earliest (56 days) while P-111-R and P-112-R took maximum days (74 days) to flowering. In W_4, 48-B was observed as earliest (57 days) and P-111-R latest (79 days). In overall the genotype P-111-R followed by P-112-R took maximum number of days to 50 per cent flowering and 48-B the minimum. The reduction in number of days to flowering under water stress environments can be attributed to warmer temperature during the growth period which promotes early stem growth, reduced flowering time and thereafter reduced photosynthesis resulting in lower yields. This is supported by the findings of Abelardo et al (2002) on sunflower. In confirmation with Tahir et al (2004) a significant decrease was observed for days to maturity in all treatments in comparison with control. In W_1, the range for days to maturity was 89 to 99 days whereas in W_2, W_3 and W_4 it was 83 to 92, 85 to 93 and 88 to 96 days respectively. The genotypes P-100-R and P-119-R recorded the same and less number of days to maturity over all environments. Genotypes P-69-R and 48-B were found to be least affected by water stress whereas genotypes P-107-R-P_2, P-119-R, 234-B and 36-B reported a drastic reduction in days to maturity. Drought during the vegetative phase of the plants affects both final biological and economic yield. During vegetative development it reduces the main stem height (Turhan and Basar 2004) while an increase in root length occurs at the expense of above ground dry matter. The average plant height was significantly higher in W_1 (130 cm) as compared to W_2 (113 cm), W_3 (115 cm) and W_4 (125cm). The differences due to irrigation levels and genotypes were also significant during the experiment. Reductions of plant height with increasing water stress have earlier been reported by Ahmad and Abdella (2009). In the W_1 range for plant height was 96 to 207 cm whereas in W_2 it was 87 to 182 cm, W_3 (81 to 192 cm) and W_4 (89 to 203 cm). The perusal of Table 3 reveals that in all the treatments plant height was less than the control. The genotypes P-100-R, P-87-R, P-75-R and P-94-R showed maximum reduction in plant height under water stress in all treatments whereas P-61-R, 50-B and RCR-8297 exhibited minimum reduction.

The reduction in vegetative biomass due to water stress results in lowering of plant surface area which reduces the radiation use efficiency and photosynthetic activities (Germ et al 2005). This finally lowers the assimilation of photosynthates during the reproductive phase which reduces head diameter (Rauf and Sadaqat 2007). The average head diameter was significantly higher in control ie W_1 (14.4 cm) as compared to W_2 (12.3 cm), W_3 (12.1 cm) and W_4 (13.4 cm). In W_1 head diameter ranged from 9.7 to 17.9 cm whereas it was reduced (8.4 to 14.6), (8.8 to 15.5) and (7.5 to 16.3) in W_2, W_3 and W_4 respectively. The genotypes P-93-R, P-91-R, P-100-R, P-87-R and NDLR-2 were observed to be least affected by water stress while P-119-R, 395-B and 50-B were severely affected over all environments. The average seed yield was significantly higher in W_1 (32.9 g) as compared to W_2 (25.8 g), W_3 (25.9 g) and W_4 (29.2 g). Reduction in seed yield under water stress was also observed earlier by Asbagh et al (2009). The genotype 95-C-1-R and P-87-R recorded minimum and maximum seed yield per plant respectively in all treatments. Seed yield ranged from 10.3 to 54.7 g in W_1, 7.2 to 52.2 in W_2, 9.7 to 49.8 in W_3 and 10.0 to 51.8 g in W_4. The genotypes P-94-R, P-115-R and P-119-R were found to be severely affected by the treatments however 95-C-1-R and P-87-R exhibited resistance to water stress and showed minimum reduction in seed yield. Irrigation is an important factor which directly influences the yield of sunflower and practically all the farmers realize its importance. Judicious and timely application of irrigation at critical growth stage increases yield considerably. The crop uses only 20-25 per cent of its total water needs during first 30 days. However the peak demand is during its reproduction and shortage of water during this period reduces the seed yield.

Stress during the flowering stage causes abortion of ovaries and embryo, sterility of pollen and decrease in leaf area index. This reduces the fertile achene per head and 100-seed weight (Reddy et al 2003). In the present investigation the environment-wise analysis showed that water stress had significant effect on 100-seed weight. The average 100-seed weight was significantly high in W_1 (7.1 g) as compared to W_2 (5.5 g), W_3 (5.7 g) and W_4 (6.1 g). Genotype 7-1-B recorded the highest 100-seed weight followed by P-75-R and the genotype 95-C-1-R exhibited minimum 100-seed weight followed by and RCR-8297 over the entire respective environment. The genotypes P-107-R-P_1, P-75-R, 10-B and 45-B were least effected for 100-seed weight by water stress in all environments. However the effect of water stress was highly significant in 95-C-1-R, NDLR-1, 7-1-B and RCR-8297. Sunflower is categorized as low to medium drought sensitive crop. It has been found that both quantity and distribution of water have a significant impact on oil yield in sunflower (Reddy et al 2003, Iqbal et al 2009). Results indicated that oil content was significantly influenced by different water stress environments (Table 2). The average oil content was significantly higher under W_1 (43.2%) as compared to W_2 (37.2%), W_3 (37.9%) and W_4 (39.3%). Similar results were reported by Asbagh et al (2009). In W_1 the range for oil content was 34.1 to 47.6 per cent whereas in W_2 it ranged between 32.9 to 41.6 per cent. In W_3 the range was 33.4 to 41.8 per cent and in W_4 32.0 to 43.6 per cent. The genotype 48-B recorded the highest oil content in W_1 and W_2 (47.6 and 41.6% respectively). Whereas 52-B (41.8%) and P-69-R (41.9%) were found to be best in W_3 and W_4 respectively. The genotypes P-75-R, 49-B and 304-B exhibited non-significant effect of water stress while P-107-R-P_2, P-107-R-P_1, P-100-R and 11-B were found to be severely affected by treatments over all the environments.

Genetic parameters

Variability is the prerequisite for the initiation of any breeding programme for any crop (Ali and Khan 2007). The significant genetic variance among genotypes advocates the presence of enough scope for the selection of good performing lines in relation to oil content (Habib et al 2007). Most cultivated hybrids or open pollinated varieties are evolved near optimum agronomic conditions and often have some common parentage and history of origin. Therefore breeding for drought tolerance must expand genetic variability. This depends on the incorporation of diverse germplasm so that potential source of drought tolerance may be identified and subsequently incorporated to ensure yield when drought occurs. The first approach to develop water stress tolerant line is to screen high yielding germplasm accompanied by superior yield contributing traits. It is likely that this germplasm also contains extensive variation for stress tolerance traits. Genetic parameters include genetic advance, heritability, genotypic coefficient of variance (GCV) and phenotypic coefficient of variance (PCV). In W_1 (control) seed yield per plant recorded the maximum heritability (98.58%) followed by days to 50 per cent flowering (94.23%) and 100-seed weight (93.46%) while the lowest heritability was recorded by oil content (56.38%) followed by days to maturity (83.26%) (Table 3). The plant height exhibited highest genetic advance (41.66) while 100-seed weight (2.43%) recorded the lowest. GCV and PCV were maximum for seed yield per plant (29.65 and 29.86) and minimum for days to maturity (2.30 and 2.52).

In W_2 seed yield per plant recorded the maximum heritability (98.28%) followed by plant height (97.23%) and 100-seed weight (93.46%) whereas oil content showed minimum heritability (56.38%) followed by days to 50 per cent flowering (93.31%). Genetic advance was observed to be maximum in plant height (40.49) and

Table 1b. Analysis of variance

	Mean sum of squares											
	W_1 Source of variation			W_2 Source of variation			W_3 Source of variation			W_4 Source of variation		
	R (df= 2)	G (df= 40)	E (df= 80)	R (df= 2)	G (df= 40)	E (df= 80)	R (df= 2)	G (df= 40)	E (df= 80)	R (df= 2)	G (df= 40)	E (df= 80)
DF	4.8	17.1**	3.5	25.6	29.3**	5.2	4.3	16.5**	4.7	28.2	48.9**	3.4
DM	5.5	14.8**	0.9	90.6	9.7**	0.9	2.1	26.2**	1.0	0.1	8.9**	0.9
PH	16.9	1263.9**	9.4	21.9	1203.6**	11.3	4.8	1016.9**	9.1	20.5	1219.9**	9.2
HD	0.2	11.0**	0.4	0.2	10.0**	0.3	0.3	8.4**	0.3	0.1	13.6**	0.4
SY	0.4	287.0**	1.4	1.9	247.5**	2.8	4.8	256.4**	1.8	4.1	246.5**	1.6
SW	0.1	4.6**	0.1	0.1	4.4**	0.1	0.1	3.3**	0.1	0.2	6.1**	0.1
OC	4.8	17.1**	3.5	25.7	29.3**	5.2	4.3	16.5**	4.7	28.2	48.9**	3.4

R: replication, G: genotype, E: error, DF: days to 50% flowering, DM: days to maturity, PH: plant height, HD: head diameter, SY: seed yield/plant, SW: 100-seed weight, OC: oil content

Table 2. Yield parameters under different environments

	DF			DM			PH			HD			SY			SW			OC		
	$\bar{x}$	Min	Max	$\bar{x}$	Min	Max	$\bar{x}$	Min	Max	$\bar{x}$	Min	Max	$\bar{x}$	Min	Max	$\bar{x}$	Min	Max	$\bar{x}$	Min	Max
W_1	65	57	81	93	89	99	130	96	207	14.4	9.7	17.9	32.9	10.3	54.7	7.1	4.9	12.8	43.2	34.1	47.6
W_2	63	60	76	91	83	92	112	87	182	12.3	8.3	14.6	25.7	7.2	52.2	5.5	2.2	10.5	37.2	32.9	41.6
W_3	62	56	74	92	85	93	115	81	192	12.1	8.8	15.5	25.8	9.7	49.8	5.7	4.0	9.6	37.9	33.8	41.8
W_4	64	57	79	91	88	96	125	89	203	13.4	7.5	16.3	29.2	10.0	51.8	6.1	2.7	10.9	39.3	32.0	43.6

W_1: control, W_2: second water stress environment, W_3: third water stress environment, W_4: third water stress environment, : mean of all genotypes, Min: minimum value, Max: maximum value

Table 3a. Evaluation of Genetic parameters in variable water stress environments

	W_1					W_2					W_3				
	GM	h^2	GA	GCV	PCV	GM	h^2	GA	GCV	PCV	GM	h^2	GA	GCV	PCV
DF	65.60	94.23	9.06	6.91	7.12	63.83	93.31	7.86	6.19	6.41	63.54	91.37	7.34	5.87	6.14
DM	93.50	83.26	4.04	2.30	2.52	91.11	77.52	3.11	1.88	2.14	90.53	89.21	5.64	3.20	3.39
PH	130.43	97.80	41.66	15.68	15.85	112.82	97.23	40.49	17.67	17.92	115.46	97.36	37.26	15.88	16.09
HD	14.48	89.95	3.67	12.99	13.70	12.37	92.39	3.57	14.59	15.17	12.15	88.89	3.18	13.49	14.31
SY	32.91	98.58	19.96	29.65	29.86	32.91	98.58	19.96	29.65	29.86	25.87	97.98	18.79	35.62	35.98
SW	7.11	93.46	2.43	17.16	17.75	7.11	93.46	2.43	17.16	17.75	5.75	92.43	2.06	18.1	18.82
OC	43.27	56.38	3.29	4.92	6.55	43.27	56.38	3.29	4.92	6.55	38.32	45.68	2.76	5.18	7.66

Table 3a. Contd…

	W_4					Pooled over environments				
	GM	h^2	GA	GCV	PCV	GM	h^2	GA	GCV	PCV
DF	64.89	90.44	6.74	5.30	5.57	64.46	81.85	1.35	1.12	1.25
DM	91.66	76.08	2.95	1.79	2.05	91.69	86.26	1.57	0.88	0.96
PH	124.96	97.76	40.92	16.08	16.26	120.91	89.46	6.18	2.62	2.76
SD	13.43	92.14	4.16	15.66	16.31	13.11	77.19	0.67	2.85	3.23
SY	29.22	98.02	18.42	30.92	31.23	28.44	92.06	3.39	6.02	6.27
SW	5.85	95.59	2.85	24.16	24.72	6.07	85.14	0.66	5.7	6.16
OC	38.40	81.68	7.26	10.15	11.23	39.62	78.86	2.54	3.51	3.95

GM: generation mean, h^2: heritability (%), GA: genetic advance, GCV: genotypic coefficient of variation (%), PCV: phenotypic coefficient of variation (%)

minimum in 100-seed weight (2.43). Seed yield per plant recorded highest GCV and PCV (29.65 and 29.86) while lowest was observed for days to maturity (1.88 and 2.14). In W_3 seed yield per plant exhibited maximum heritability (97.98%) followed by plant height (97.36%) and oil content showed the minimum (45.68%) followed by days to maturity (89.21%). Highest genetic advance was observed in plant height (37.26) while the lowest by 100-seed weight (2.06). Seed yield per plant recorded maximum GCV and PCV (35.62 and 35.98) whereas days to maturity had minimum GCV and PCV (3.20 and 3.29). This observation was in consistence with Iqbal et al (2009). In irrigation level 04 (W_4) seed yield per plant recorded highest heritability (98.02%) followed by plant height (97.76%) while the minimum by days to maturity (76.08%). Plant height (40.92) and 100-seed weight (2.85) showed maximum and minimum genetic advance respectively. Similar to other environments seed yield per plant exhibited highest GCV and PCV (30.92 and 31.23) whereas days to maturity registered the minimum (1.79 and 2.05). Even under pooled environments seed yield per plant recorded the maximum heritability (92.06%) followed by plant height (89.46) whereas the minimum heritability was recorded by head diameter (77.19%). Plant height recorded the maximum genetic advance (6.18) and 100-seed weight to be the minimum (0.66).

It can be concluded from this study that significant reduction in yield and its components was caused by water stress. Seed yield per plant, 100-seed weight and oil content were found to be significantly influenced while days to flowering and days to maturity were less affected. The W_2 and W_3 have shown maximum reduction in the yield parameters as compared to W_4. These results indicate that irrigation at button stage, 50 per cent flowering, soft dough stage and hard dough stage are crucial for crop growth cycle whereas withholding of irrigation at anthesis completion stage does not affect the yield related characters too much. These results suggest that seed yield per plant had high magnitude of broad sense heritability which advocates that this character might be improved through selection. Plant height exhibited highest genetic advance which reveals that selection for the high plant height could be better for its improvement under water stressed conditions. GCV and PCV were highest for seed yield per plant and 100-seed weight which indicated maximum amount of variability to be subjected to selection for these traits. The oil content revealed lower GCV and PCV which was an indication of limited scope for selection of this trait due to inadequate variability and implies the need to introgress desirable genes from diverse genetic resource through introduction and hybridization with germplasm. The genotypes P-87-R, P-93-R, P-100-R and P-110-R have been identified as water use efficient genotypes and the W_4 (withholding of irrigation at anthesis completion stage and thereafter complete withholding of irrigation after soft dough stage) can be considered as best water stress environment to realize maximum yields.

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Received: 17.7.2014 ***Accepted: 21.10.2014***