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Genetic Variability for Seed Yield, Oil Content and Fatty Acid Composition in Germplasm Accessions of Sunflower (*Helianthus annuus* L.) and their Response to Different Seasons

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A B S T R A C T

An investigation was carried out to study the genetic variability and effect of environmental factors on oil content and fatty acid composition in two different seasons using 33 sunflower accessions. Significant variability for physiological, morphological, yield and yield attributing characters and also for oil content and fatty acid composition due to the effect of seasons, temperature and genetic makeup of genotypes were observed. Plants grown in *kharif* had 36.4 per cent more grain yield compared to *rabi*. Hybrids yielded more followed by inbreds and seed setting was less in RHA lines. Higher TDM was recorded with hybrids compared to CMS lines, RHA-lines and inbreds. Out of 33, 22 genotypes recorded higher oil percentage in *rabi* than in *kharif*. Oil content was less in most of the genotypes during rabi/summer due to physiological maturity of genotypes coincided with higher temperature and bright sunshine hours. Accumulation of maximum grain oil content was found in early matured genotypes. Depending on their consistent performance, genotypes can be selected for heterosis breeding to develop good fatty acid containing hybrids combined with high seed yield.

Introduction

Sunflower is a rich source of edible oil (28-45%). Oil stability, plasticity and nutritional quality are mainly determined by fatty acid composition. In recent years, the increasing demand for vegetable oils has renewed interest in quality of sunflower oil. The areas of sunflower production vary for climate, weather (rainfall and temperature) and other environmental factors such as intercepted solar radiation, altitude, and latitude and soil type. Fatty acid composition of sunflower seeds is determined by plant genotype and more or less affected by environmental conditions such as light and temperature (Schulte *et al.*, 2013).

Temperature and the amount of moisture in the soil are the major factors influencing sunflower seed oil composition and especially oleic acid content (Baldini *et al.,* 2002). Fatty acid composition of sunflower is also affected by the genotype and its interaction with the environment. Genotype by environment interaction (GXE) has also been reported (Lajara *et al.*, 1990). As a result, the study of G × E interaction for sunflower hybrids is necessary in order to select stable and widely adapted hybrids in production areas. Among several environmental factors, temperature is the main environmental factor affecting not only plant growth, development and productivity but also fatty acid composition in sunflower (Piva *et al.,* 2000). The change in the temperature especially from anthesis to maturity has a profound effect on oleic to linoleic acid ratio in the seeds. This is due to the response of oleate desaturase enzyme to the temperature causing change in the accumulation of oleic and linoleic acids (Flagella *et al.,* 2002, Grompone, 2005). However, the duration of this temperature effect varies with plant species, while in sunflower seeds the percentage of linoleic acid is highly influenced by growth temperature (Lajara *et al.,* 1990).

Due to large influence of genotype and environmental conditions on oil content and fatty acid composition, it is necessary to analyze the stability of genotypes also which should be stable irrespective of the growing environment. In this regard, an investigation was carried out to assess the performance of different sunflower accessions for oil content and fatty acid composition to a change in weather and seasons.

Materials and Methods

A field experiment was conducted during *kharif* 2013 and *rabi*/summer 2013-14 at All India Coordinated Research Project on Sunflower, ZARS, UAS, GKVK, Bengaluru with 33 sunflower germplasm accessions comprising hybrids (3), CMS-lines (8), RHA-lines (7) and inbreds (5) (Table 1). These accessions were selected from our previous research based on the accumulation of oleic and linoleic acids using simple sequence repeat markers (SSR markers) with confirmation using gas chromatography (Nagarathna *et al.,* 2011).

During the experimental period in *kharif* the Tmax was 27.7°C and Tmin 19°C with an average rainfall about 503mm. Similarly in *rabi* 28°C was recorded as maximum temperature and 15.5°C minimum temperature with 10 mm rainfall.

During the crop growth period, several physiological and morphological observations were recorded. Days to 50 per cent flowering are an important trait to synchronize the flowering time and to know the duration of the crop after flowering. The number of days required for the florets to appear in 50 per cent of the plants in each plot was recorded as days to 50 per cent flowering. Total leaf area, an indication of total photosynthesizing area of the plant was measured following non-destructive method proposed for sunflower by Nanja Reddy *et al.,* (1995).

To get seed yield per plant, seeds were separated from the head, dried and weighed and expressed as gram per plant. Completely dried hundred seeds randomly sampled from all the harvested plants from each genotype were counted and weighed to 100 seed weight.

Using 100ml volumetric flask hundred ml of well-filled seeds obtained after threshing and cleaning was recorded on dry weight basis, to obtain seed weight on volume basis (cc per100 ml).

To record total dry weight, **c**ompletely dried leaves, stem and thalamus of individual plants from each genotype was recorded separately using weighing balance.

Harvest index was determined using the following formula and expressed the values in percentage.

$$\text{Harvest index} = \frac{\text{Economical Yield}}{\text{Biological yield}} \times 100$$

Approximately 30 g of properly dried random seeds from each genotype was taken to estimate oil content using pulsed Nuclear Magnetic Resonance (NMR) spectrometer, available at AICRP Sunflower, UAS, Bengaluru which gives direct values of oil content in the seeds in terms of percentage.

All the germplasm lines were analyzed for oleic acid, linoleic acid, palmitic acid and stearic acid using gas chromatography (Agilent technologies 7890A) fitted with DB-wax column (30 m long and 0.25µm) packed with polymer of methyl silicon, using flame ionization detector (FID). The conditions maintained were column temperature: 150°C-270°C, injector temperature: 250°C and detector temperature, 250°C. GLC was programmed for the temperature at the rate of 10°C per minute increase and finally it was maintained at 270°C.

Data were analyzed statistically using analysis of variance according to Gomez and Gomez (1984) procedure for a randomized complete block design.

Results and Discussion

Days to 50 per cent flowering

Days to 50 per cent flowering varied from as low as 53 days to 66 days. On an average more number of days was taken by hybrids, CMS lines and inbreds compared to RHA lines (Table 2). Hence, the RHA lines were short duration genotypes. Though the results were non-significant in a few entries, reduced number of days to 50 percent flowering during *rabi*/summer 2014 was due to higher temperature at reproductive stage which stimulated the induction of reproductive phase early. Days to flowering in most of the accessions were found to be longer in *kharif*. However days to flowering in some genotypes *viz.,* GMU-702, GKVK-2, GPR-17, GPR-47, GPR-55, RHA-23 were found to be longer in *rabi*/summer than in *kharif* due to interaction between genotypes and the season which might have affected the days to flowering.

Total leaf area

More total leaf area per plant was recorded in *kharif* compared to *rabi*/summer by 20 per cent. Among all the genotypes, hybrids produced broader leaves and hence the maximum leaf area. RHA lines showed lesser leaf area per plant due to less number of leaves.

The mean between two seasons revealed that, maximum values were recorded in hybrids (12654.6) followed by other accessions (10,000). Lesser leaf area (cm^2/plant) was recorded in indreds (2590) followed by RHA lines (2629.5) and more reduction in *rabi*/summer was observed in hybrids (30.7 %) followed by inbreds (28 %).

Seed Yield

The data on seed yield per plant (Table 3) indicates that maximum mean yield was recorded in *kharif* (32.6g) compared to *rabi*/summer (20.7g). Hybrids which remained for longer duration in the field produced more yield than other genotypes. Hybrids produced more seed yield with a mean 50 in *kharif* and 35 in *rabi*/summer followed by inbreds and CMS lines. RHA lines seem to be low yielders (27g in *kharif* and 17g in *rabi*/summer) compared to other genotypes. Among hybrids KBSH-1 yielded more with 53.4g in *kharif* and 32g in *rabi*/summer followed by RSFH-1 which was on par with KBSH-44. Among CMS lines, CMS-103A showed maximum seed yield which was on par with hybrids followed by CMS-54A. In addition, ID-3/147/3-163 also recorded maximum seed yield (48.7g in *kharif* and 29.6g in *rabi*/summer 2013-14). Though the mean seed yield value was less in RHA lines some of them *viz.* RHA-341 and RHA-308 recorded maximum seed yield per plant. The more favorable rainfall in *kharif* resulted in higher number of seeds per head, 100 seed weight and seed volume increased the seed yield.

Test weight

The data on 100 achene weight (test weight) presented in Table 3 shows non-significant differences between seasons. In *kharif*, the mean was marginally higher (4.53) than *rabi*/summer (4.4) and also with the range. However, around 8 per cent reduction was recorded in hybrids in *rabi*/summer and it was 12 per cent in CMS lines.

Inbreds were least affected by seasons. In KBSH-1, CMS-335A, GKVK-2, GPR-29 and RHA-88, 100 achene weight was increased in *rabi*/summer whereas, in most of the accessions it was higher in *kharif*. In KBSH-1, though 100 achene weights was less in *kharif* by 14 per cent, seed yield maintained to be higher compared to *rabi*/summer 2013-14 due to higher seed number per head. RHA lines showed very less test weight compared to all other genotypes (around 3g) and least was recorded in RHA-87 (1.9).

Total dry matter

Maximum mean total dry matter was recorded in *kharif* (91g) which was 16 per cent more than *rabi*/summer crop. Hybrids showed 23.6 per cent more TDM in *kharif* followed by CMS lines and RHA lines (around 15 per cent) and least TDM was recorded in inbreds and the percent reduction in *rabi*/summer was less (13 per cent) compared to *kharif*. Maximum TDM was observed in KBSH-44 due to its vigorous growth followed by CMS-17A (170.6g) and CMS-335A (140.4g) among CMS lines.

The mean value among RHA lines was less due to their reduced plant height, lesser number of leaves with less total plant leaf area. The least TDM was recorded in GKVK-2 in both the seasons (Table 4). The values for TDM ranged from 32.8 to 217 in *kharif* with a mean 91 and 27.1g to 170 with a mean 76 in *rabi*/summer 2013-14. The average values from two seasons shows that in RHA lines the least TDM (68) followed by inbreds (80.7).

However, these plants maintained same trend in both the seasons indicating TDM was not affected by seasons whereas; more reduction (24 percent) was recorded in hybrids.

Table.1 Classification of 33 Sunflower genotypes as hybrids, CMS-lines, RHA lines and inbreds

SI No.	Hybrids		RHA-lines		
1	KBSH-41	1	95-C-1	14	RHA-87
2	KBSH-44	2	GKVK-2	15	RHA-88
3	RSFH-1	3	GPR-11	16	RHA-341
	CMS-lines	4	GPR-14	17	RHA-308
1	CMS-57A	5	GPR-17		**Inbreds**
2	CMS-54A	6	GPR-24	1	GMU-702
3	CMS-17A	7	GPR-29	2	GMU-704
4	CMS-17B	8	GPR-30	3	DRSF 106
5	CMS-58A	9	GPR-47	4	CSFI-5387
6	CMS-103A	10	GPR-55	5	ID-3/147/3-163
7	CMS-135A	11	RCR-39		
8	CMS-335A	12	RHA-23		
		13	RHA-89		

Table.2 Days to 50% flowering and total plant leaf area of different sunflower accessions

Genotypes	Days to 50% flowering			Total leaf area (cm^{2}/pl)		
	Kharif	Rabi	Mean	Kharif	Rabi	Mean
KBSH 1	62	59	60.5	6965.52	4351.97	5658.75
RSFH 1	62	63	62.5	8681.04	9891.20	9286.12
KBSH 44	64	63	63.5	15418.12	7286.91	11352.52
CMS 57 A	62	59	60.5	8213.08	10627.47	9420.28
CMS 54 A	66	65	65.5	4942.60	4392.06	4667.33
CMS 17 A	61	60	60.5	7190.96	6049.58	6620.27
CMS 17 B	66	65	65.5	5818.73	4369.91	5094.32
CMS 58A	65	63	64	4830.24	2718.88	3774.56
CMS 103A	64	60	62	7383.13	4867.47	6125.30
CMS 135A	60	60	60	8790.01	5010.62	6900.32
CMS 335A	61	62	61.5	10701.09	6657.03	8679.06
GMU 702	54	56	55	5571.32	3852.11	4711.72
GMU 704	65	65	65	6121.48	3001.19	4561.34
DRSF 106	62	60	61	13246.14	7907.26	10576.70
CSFI 5387	54	56	55	7898.42	7019.47	7458.95
IB/3/147	60	56	58	6011.70	2607.92	4309.81
95-C-1	55	55	55	6033.15	6770.42	6401.79
GKVK 2	54	57	55.5	2585.40	2586.52	2585.96
GPR 11	62	61	61.5	6792.95	5966.78	6379.87
GPR 14	63	64	63.5	3576.89	2678.03	3127.46
GPR 17	51	57	54	4620.90	3766.38	4193.64
GPR 24	63	61	62	5112.79	4130.58	4621.69
GPR 29	56	55	55.5	6948.84	2211.04	4579.94
GPR 30	58	57	57.5	6252.56	9166.03	7709.30
GPR 47	56	59	57.5	4783.70	3374.03	4078.87
GPR 55	55	60	57.5	10235.37	8854.22	9544.80
RCR 39	63	61	62	7475.34	8495.97	7985.66
RHA 23	55	59	57	6993.98	3049.52	5021.75
RHA 86	56	54	55	3048.06	6108.26	4578.16
RHA 87	61	60	60.5	3161.24	2949.27	3055.26
RHA 88	57	57	57	4143.54	2954.24	3548.89
RHA 341	55	56	55.5	10946.19	4572.91	7759.55
RHA 308	57	56	56.5	10282.10	6320.33	8301.22
Mean	**59.55**	**59.42**	**59.5**	**6993.23**	**5289.87**	**6141.55**
Range	**51-66**	**54-65**		**2585.4-15418.1**	**2211.0-10627.5**	
CV %	**7.79**	**8.52**		**9.57**	**9.37**	
SEM±	**9.42**	**10.27**		**473.69**	**350.69**	
CD@5%	**3.27**	**3.56**	**NS**	**1364.56**	**1010.23**	**S**

Table.3 Seed yield per plant, 100 seed weight and seed volume of 33 sunflower accessions

Genotypes	Seed yield per plant (g)			100 seed weight (g)			Seed weight on volume basis (g/100ml)		
	Kharif	Rabi	Mean	Kharif	Rabi	Mean	Kharif	Rabi	Mean
KBSH 1	53.40	31.50	42.45	6.18	7.21	6.70	40.75	39.50	40.13
RSFH 1	49.10	35.80	42.45	7.00	5.49	6.25	38.25	36.00	37.13
KBSH 44	48.70	38.20	43.45	8.05	6.75	7.40	41.75	40.00	40.88
CMS 57 A	36.80	19.10	27.95	5.55	5.46	5.51	37.75	36.75	37.25
CMS 54 A	45.30	26.20	35.75	4.14	4.07	4.11	38.50	36.75	37.63
CMS 17 A	34.70	16.80	25.75	6.09	5.81	5.95	43.00	38.50	40.75
CMS 17 B	25.50	18.20	21.85	4.01	4.00	4.01	36.00	29.75	32.88
CMS 58A	26.00	21.00	23.50	4.62	4.08	4.35	38.25	39.00	38.63
CMS 103A	48.60	35.70	42.15	6.29	5.85	6.07	40.75	40.50	40.63
CMS 135A	36.80	17.60	27.20	6.10	4.96	5.53	39.75	34.25	37.00
CMS 335A	26.60	17.20	21.90	7.33	3.03	5.18	39.25	28.50	33.88
GMU 702	31.00	17.60	24.30	7.91	7.45	7.68	48.00	44.00	46.00
GMU 704	31.50	24.20	27.85	2.23	3.22	2.73	25.25	26.00	25.63
DRSF 106	29.00	27.30	28.15	7.33	7.95	7.64	39.25	35.75	37.50
CSFI 5387	46.60	22.00	34.30	5.77	4.41	5.09	47.25	30.40	38.83
IB/3/147	48.70	29.60	39.15	7.53	6.94	7.24	32.00	33.00	32.50
95-C-1	15.80	17.80	16.80	2.43	2.51	2.47	38.50	39.00	38.75
GKVK 2	30.30	25.80	28.05	2.26	3.94	3.10	44.50	44.50	44.50
GPR 11	17.80	16.80	17.30	2.84	2.87	2.86	44.25	42.50	43.38
GPR 14	18.10	13.80	15.95	3.10	3.02	3.06	40.75	42.30	41.53
GPR 17	20.30	14.40	17.35	3.37	3.21	3.29	42.00	42.25	42.13
GPR 24	21.50	15.40	18.45	2.27	2.98	2.63	34.00	36.50	35.25
GPR 29	31.30	21.00	26.15	2.48	3.71	3.10	37.50	35.30	36.40
GPR 30	26.40	14.70	20.55	2.71	3.08	2.90	38.75	39.50	39.13
GPR 47	25.40	19.20	22.30	2.32	3.08	2.70	41.50	39.00	40.25
GPR 55	38.90	17.90	28.40	3.06	3.12	3.09	38.25	37.25	37.75
RCR 39	31.40	15.30	23.35	5.10	4.61	4.86	37.25	37.00	37.13
RHA 23	28.70	15.70	22.20	2.81	2.95	2.88	38.50	39.00	38.75
RHA 86	17.50	16.00	16.75	2.81	2.52	2.67	40.25	41.50	40.88
RHA 87	16.00	14.30	15.15	1.91	1.90	1.91	41.75	40.75	41.25
RHA 88	22.80	15.70	19.25	2.13	4.96	3.55	43.50	40.00	41.75
RHA 341	44.40	16.30	30.35	5.67	5.39	5.53	36.00	39.00	37.50
RHA 308	52.80	17.20	35.00	6.01	4.70	5.36	36.25	36.50	36.38
Mean	32.66	20.77	26.72	4.53	4.40	4.47	39.37	37.59	38.48
Range	**15.8-53.4**	**13.8-38.2**		**1.9-8.1**	**1.9-7.9**		**25.3-48**	**26-44.5**	
CV %	**8.17**	**8.29**		**9.68**	**9.03**		**7.84**	**6.61**	
SEM	**5.44**	**3.51**		**0.30**	**0.28**		**2.18**	**1.75**	
CD@5%	**1.89**	**1.22**	**S**	**0.89**	**0.80**	**NS**	**6.29**	**5.06**	**S**

Table.4 Total dry matter, harvest index and oil content of 33 sunflower accessions

Genotypes	Total dry matter (g/pl)			Harvest index (%)			Oil content (%)		
	Kharif	Rabi	Mean	*Kharif*	Rabi	Mean	*Kharif*	Rabi	Mean
KBSH 1	162.75	133.35	148.05	24.71	19.11	21.91	39.05	32.93	35.99
RSFH 1	160.10	108.80	134.45	23.47	24.76	24.12	33.89	35.80	34.85
KBSH 44	216.90	170.05	193.48	18.34	18.34	18.34	35.32	31.45	38.39
CMS 57 A	142.20	105.90	124.05	20.56	15.28	17.92	40.93	36.03	38.48
CMS 54 A	77.60	70.85	74.23	36.86	27.00	31.93	35.70	36.32	36.01
CMS 17 A	170.63	128.45	149.54	16.90	11.57	14.24	20.39	26.72	23.56
CMS 17 B	119.20	106.40	112.80	17.62	14.61	16.12	17.68	23.67	20.68
CMS 58A	109.20	94.60	101.90	19.23	18.17	18.70	38.35	40.03	39.19
CMS 103A	90.50	71.50	81.00	34.94	33.30	34.12	35.88	31.15	33.52
CMS 135A	77.08	71.25	74.17	32.31	19.81	26.06	30.59	32.87	31.73
CMS 335A	140.40	135.95	138.18	15.93	11.23	13.58	28.19	30.79	29.49
GMU 702	79.45	77.60	78.53	28.07	18.49	23.28	36.31	36.45	36.38
GMU 704	74.60	57.15	65.88	29.69	29.75	29.72	27.41	23.29	25.35
DRSF 106	138.65	98.55	118.60	17.30	21.69	19.50	31.75	29.44	30.60
CSFI 5387	82.30	101.55	91.93	36.15	17.81	26.98	38.79	36.43	37.61
IB/3/147	53.25	37.75	45.50	47.77	43.95	45.86	32.14	30.04	31.09
95-C-1	68.18	63.45	65.82	18.81	21.91	20.36	38.45	39.56	39.01
GKVK 2	32.78	28.25	30.52	48.03	47.73	47.88	41.33	41.51	41.42
GPR 11	65.70	62.15	63.93	21.32	21.28	21.30	37.36	33.04	35.20
GPR 14	39.75	30.65	35.20	31.29	31.05	31.17	40.27	38.20	39.24
GPR 17	47.95	31.75	39.85	29.74	31.20	30.47	40.88	41.79	41.34
GPR 24	69.75	45.08	57.42	23.56	25.46	24.51	30.55	33.57	32.06
GPR 29	61.10	37.45	49.28	33.87	35.93	34.90	36.36	39.03	37.70
GPR 30	50.75	50.80	50.78	34.22	22.44	28.33	40.53	41.70	41.12
GPR 47	44.80	32.95	38.88	36.18	36.82	36.50	32.23	34.09	33.16
GPR 55	64.80	51.40	58.10	37.51	25.83	31.67	29.78	34.23	32.01
RCR 39	98.60	82.10	90.35	24.15	15.71	19.93	32.22	34.60	33.41
RHA 23	71.25	61.50	66.38	28.71	20.34	24.53	30.89	32.18	31.54
RHA 86	39.45	28.25	33.85	30.73	36.16	33.45	39.49	41.09	40.29
RHA 87	34.90	27.15	31.03	31.43	34.50	32.97	38.27	40.36	39.32
RHA 88	78.30	63.55	70.93	22.55	19.81	21.18	41.07	29.77	35.42
RHA 341	129.66	123.90	126.78	25.51	11.63	18.57	33.71	29.07	31.39
RHA 308	110.25	118.35	114.30	32.38	12.69	22.54	27.84	28.30	28.07
Mean	**90.99**	**76.01**	**83.50**	**28.18**	**24.10**	**26.14**	**34.35**	**34.10**	**34.08**
Range	**32.8-216.9**	**27.1-170.1**		**15.9-48.0**	**11.2-47.7**		**17.7-41.3**	**23.3-41.8**	
CV %	**11.58**	**15.14**		**8.90**	**12.03**		**6.30**	**4.95**	
SEM	**7.45**	**8.14**		**1.78**	**2.13**		**1.52**	**1.19**	
CD@5%	**21.45**	**23.45**	**NS**	**5.11**	**6.13**	**S**	**4.38**	**3.44**	**NS**

Table.5 Fatty acid profiling of 33 sunflower accessions with their seasonal means

Genotypes	Oleic acid (%)			Linoleic acid (%)			Palmitic acid (%)			Stearic acid (%)		
	Kharif	Rabi	Mean	*Kharif*	Rabi	Mean	*Kharif*	Rabi	Mean	*Kharif*	Rabi	Mean
KBSH 1	48.13	59.36	53.75	42.8	27.47	35.14	6.3	8.7	7.50	2.76	4.46	3.61
RSFH 1	69.52	79.04	74.28	21.7	13.79	17.75	6.03	5.86	5.95	2.73	1.29	2.01
KBSH 44	41.9	62.29	52.10	49.13	23.34	36.24	5.48	9.35	7.42	3.48	5.01	4.25
CMS 57 A	40.12	48.64	44.38	45.05	43.36	44.21	9.6	5.6	7.60	5.21	2.38	3.80
CMS 54 A	70.16	71.98	71.07	20.8	19.33	20.07	6.05	5.69	5.87	2.98	2.99	2.99
CMS 17 A	57.38	58.63	58.01	29.67	29.07	29.37	8.96	8.39	8.68	3.97	3.89	3.93
CMS 17 B	49.06	48.64	48.85	36.11	37.8	36.96	9.6	8.5	9.05	5.21	5.04	5.13
GMU 702	62.67	67.14	64.91	28.1	24.77	26.44	6.05	4.99	5.52	3.17	3.09	3.13
GMU 704	58.96	50.05	54.51	29.18	39.85	34.52	7.75	5.88	6.82	4.1	4.21	4.16
CMS 58A	75.45	75.45	75.45	13.84	15.25	14.55	6.13	5.98	6.06	4.56	3.3	3.93
CMS 103A	73.64	84.97	79.31	11.04	8.52	9.78	9.59	4.43	7.01	5.73	2.07	3.90
CMS 135A	55.21	60.22	57.72	33.58	27.95	30.77	6.52	7.74	7.13	4.68	4.08	4.38
CMS 335A	23.98	24.63	24.31	67.56	64.62	66.09	4.86	7.64	6.25	3.59	3.1	3.35
DRSF 106	41.94	34.05	38.00	46.61	51.81	49.21	8.22	8.86	8.54	3.22	5.27	4.25
CSFI 5387	56.51	32.01	44.26	32.57	55.59	44.08	7.38	8.63	8.01	3.53	3.76	3.65
IB/3/147	36.47	38.64	37.56	50.01	47.67	48.84	10.27	9.56	9.92	3.24	4.12	3.68
95-C-1	50.19	49.19	49.69	42.04	43.14	42.59	7.66	7.56	7.61	0.09	0.09	0.09
GKVK 2	51.69	52.06	51.88	35.97	35.59	35.78	8.01	8.12	8.07	4.32	4.22	4.27
GPR 11	40.12	40.74	40.43	47.22	47.09	47.16	7.92	7.58	7.75	4.73	4.58	4.66
GPR 14	35.32	37.34	36.33	54.66	50.17	52.42	7.34	9.51	8.43	2.66	2.96	2.81
GPR 17	35.96	29.57	32.77	51.77	58.48	55.13	8.88	8.42	8.65	3.38	3.52	3.45
GPR 24	41.47	44.85	43.16	46.29	43.04	44.67	8.22	7.94	8.08	4.0	4.15	4.08
GPR 29	34.02	30.16	32.09	49.35	56.07	52.71	11.71	9.42	10.57	4.91	4.34	4.63
GPR 30	29.17	34.5	31.84	56.93	49.54	53.24	9.64	10.93	10.29	4.25	5.02	4.64
GPR 47	31.09	41.68	36.39	56.32	42.74	49.53	8.4	10.36	9.38	4.17	5.2	4.69
GPR 55	31.29	25.82	28.56	55.16	62.02	58.59	10.44	9.41	9.93	3.1	2.74	2.92
RCR 39	69.95	71.41	70.68	20.6	17.16	18.88	6.24	7.11	6.68	3.19	4.3	3.75
RHA 23	31.66	71.41	51.54	58.9	15.95	37.43	6.24	7.46	6.85	3.19	5.17	4.18
RHA 86	64	41.26	52.63	25.01	49.46	37.24	7.72	7.07	7.40	3.24	2.18	2.71
RHA 87	54.36	61.38	57.87	35.14	28.93	32.04	7.6	6.56	7.08	2.89	3.12	3.01
RHA 88	57.89	82.36	70.13	32.74	8.20	20.47	6.39	5.44	5.92	2.97	3.99	3.48
RHA 341	50.23	49.49	49.86	38.68	39.36	39.02	6.22	6.41	6.32	4.86	4.73	4.80
RHA 308	52.53	69.19	60.86	39.36	18.18	28.77	5.22	8.11	6.67	2.88	4.51	3.70
Mean	**49.15**	**52.37**	**50.76**	**39.51**	**36.22**	**37.87**	**7.66**	**7.67**	**7.67**	**3.67**	**3.72**	**3.70**
Range	**23.9-75.5**	**24.6-84.9**		**11.0-67.5**	**8.2-64.6**		**4.8-1.7**	**4.4-10.9**		**0.09-5.7**	**0.09-5.3**	

Harvest index

Considerably higher harvest index was achieved in GKVK-2 and ID-3/147/3-163 with more than 45 per cent achieved due to utilization of more photo assimilates for grain development and also they consistently performed better in both the seasons.

Minimum HI was recorded in hybrids and a few CMS lines (CMS- 335A and CMS-17-A).

Oil content

Compared to *kharif*, more reduction in oil content was recorded among hybrids (15 per cent) followed by CMS lines (10 %) and the least was among RHA lines (3.9 per cent). Interestingly, early maturing genotypes recorded higher oil content and their per cent reduction between two seasons was minimal, whereas some of the hybrids and CMS lines extended number of days to 50 per cent flowering to more than 6 days. More reduction in oil content in hybrids indicates that these are more sensitive to higher temperature compared to CMS and RHA lines. KBSH-1 (39.1%), CMS-57A (41%) and GKVK-2 (41.3%) produced maximum grain oil content. In some of the genotypes, (CMS-135A, GPR-17, RHA 95-C-1 and RHA- 86) days to 50 per cent flowering was less (55days) and in these genotypes more oil accumulation was noticed.

The shortest duration genotypes completed their life cycle 5-11 days earlier than the other genotypes. Hence these plants did not coincide with the higher temperature at the time of harvest. In case of long duration crops, where days to 50 per cent flowering was more than 60 days were exposed to higher temperature especially from anthesis to harvest which affected the oil accumulation. During this stage the maximum temperature was 27.8 to 30^{0}C whereas, it was around 27^{0}C in early maturing genotypes. There was no variation in minimum temperature and did not show any major effect on the accumulation of oil content.

Fatty acids

Significant differences were observed among all the genotypes for different fatty acids. The mean value for oleic acid in hybrids is 53.2 per cent in *kharif* and 66.9 per cent in *rabi* /summer. It was 60.9 and 63.2 per cent for CMS lines and RHA lines showed 44.7 and 48.9 in *kharif* and *rabi*/summer, respectively (Table 5). The reduction in percent values between seasons was higher in hybrids. In *rabi*/summer 20 per cent increase in oleic accumulation was recorded in hybrids. Similarly, it was reduced to 8.6 per cent among RHA lines and the least reduction was observed in CMS lines (4.3%). Among all the genotypes CMS-103A has maximum accumulation of oleic acid 84.9 in *rabi*/summer followed by RHA-88 (82.4).

Sunflower genotypes accumulated significantly different linoleic acid in two seasons. The data on linoleic acid indicate that the average linoleic accumulation was higher in *kharif* (39.5%) compared to *rabi*/summer (36.2%) which was inversely related to oleic content. Among all the genotypes CMS-335A accumulated higher linoleic content (67.6%) in *kharif* followed by GPR-30 (56.9%) and the least was in CMS-58A (13.8 per cent). RCR-39 also showed some linoleic content with higher oleic accumulation. Among hybrids RSFH-1 has lower linoleic content and is known to be high oleic hybrid. The concentration of saturated fatty acids (palmitic and stearic acid) was not significantly influenced by seasons and temperature. The average palmitic acid and stearic acid contents were around 7.6 per cent and 3.6 per cent respectively. These two fatty acids were inversely related whereas, whenever palmitic content increased, there was a reduction in stearic content. All these results indicated that oil content and fatty acid composition, mainly oleic acid and linoleic acids are affected by climatic changes. Among all the weather factors, temperature plays a major role in the accumulation of these fatty acids. Oleic acid content was inversely related to linoleic acid. In both the seasons wherever oleic accumulated in a higher proportion, linoleic content reduced.

The sunflower oil contains more of unsaturated fatty acids, mainly oleic acid and linoleic acid and very less quantity of saturated fatty acids, palmitic acid and stearic. Healthy oil should contain more of unsaturated fatty acids compared to saturated fatty acids.

A significant variability was observed for all the physiological, morphological traits, yield and yield attributing characters and also for oil content and fatty acid composition in all the genotypes and also between the seasons which was due to season, temperature and genetic make up for all the physio-morphological parameters, seed yield and fatty acid accumulation. Environmental changes affect morphological, physiological, quantitative and qualitative traits in sunflower.

Temperature and bright sunshine hours during seed filling are the major determinants of oleic and linoleic acid accumulation in sunflower. The existing genetic variability for different traits can be exploited for trait specific crop improvement programme.

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