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Studies on genotype x environment interactions of F_1 hybrids of sunflower (*Helianthus annuus* L.)

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Abstract
An investigation was made to test the genotype x environment interactions of forty two hybrids along with three check hybrids for seed yield and their yield contributing characters over three environments. Analysis of variance for stability revealed that mean square due to genotypes and environments indicating presence of variation among hybrids and environments. All the characters exhibited non-significant genotype x environment interactions and hence showed constant response for that trait under environmental changes. The regression analysis showed that the mean sum of squares due to environment (linear) was highly significant for all the traits. The genotype x environment (linear) were non-significant for almost all the characters except harvest index per cent under studied when tested against pooled deviation, it indicates unpredictable performance of genotypes over the environments. Considering the stability parameters the hybrids CMS-17A x HAM-183, CMS-17A x 3376-R, CMS-17A x (KOP-I x 15 NB-7) and CMS-17A x (RHA-6D-1 x R-272-4) identified for stable seed yield and hybrids CMS-234A x PISF-110-8-1and ND-2A x 3376-R identified for stable for oil content as indicated by their mean and stability indices.

Keywords: sunflower, hybrids, G x E interaction, seed yield

Introduction
Sunflower (*Helianthus annuus* L.) is the fourth important oilseed crop in the world next to soybean, groundnut and rapeseed. Its adaptability to a wide range of soil and climatic conditions which makes its cultivation possible during any part of the year in the tropical and sub-tropical regions of the country with high yield potential and consistence performance over diverse environments.
Breeding for buffering capacity is another important aspect in genetic improvement of crops. It is well known that a specified genotype may not exhibit the same performance in all the environments nor all the genotypes respond alike to a specified environment. Such differential response of genotypes to varying environmental conditions reduces the agricultural production. For this, it is desirable to study the impact of various environments in order to identify the stable crosses. Hybrids developed from genetically diverse parental lines are more heterotic and stable. Many techniques have been developed to evaluate the stability of crop varieties or lines over a range of environments. The regression method developed by Yates and Cochron (1938) provides the main basis of this type of study. The method was later modified by Finlay and Wilkinson (1963) [7] and refined by Eberhart and Russell (1966) [6] and Perkins and Jinks (1968) [19]. The method which does not use the regression of crop performance on environments but uses the conventional coefficient of variation (%) was developed by Francis and Kannenberg (1978) [8]. Therefore, the purpose of this study was to evaluate the performance of resultant hybrids of sunflower for yield and yield related traits as per the Eberhart and Russell (1966) [6] method.

Materials and Methods
In the present study 42 hybrids obtained by adopting line x tester mating design consisted 3 lines (CMS-17A, CMS-234A and ND-2A) and 14 testers {HAM-183, IB-19, IB-2M, PISF-110-8-1, 3376-R, (IB-19 x R274), (KOP-I x RHA-856, (KOP-I x 15 NB-7), (P-356 x R-274), (R-296 x 15 NB-7), (R-348 x R-274), (RHA-6D-1 x R-272-4), (15 NB-7 x HRA-5) (15 NB-7 x R-35)}. along with three checks *viz*; (DRSH-1, KBSH-44 and Phule raviraj) were evaluated in randomized block design with three replication and tested in three environments *viz*. Udaipur (E_1), Vallabhnagar (E_2) and Savalvihir (E_3) during *rabi* 2016-17. The performance of different genotypes in respect to twelve characters was studied for estimating the stability and significance of genotype environment interactions. Each hybrid was represented by single

Rows of 4.5 m length with 60 x 30 cm spacing between and within rows, respectively. Recommended packages of practices were followed by each centre to raise the healthy crop. Observations were recorded in each entries on randomly selected ten plants for twelve characters *viz*; days to 50 per cent flowering, days to physiological maturity, plant height (cm), head diameter (cm), per cent seed filling, seed yield per plant (g), 100 grain weight, volume weight (g/100 ml), hull content (%), oil content (%), biological yield per plant (g) and harvest index (%). The analysis was carried out in computer using software INDOSTAT as per standard method of Eberhart and Russell (1966) [6] in order to estimate the three parameters of stability *viz*; mean, regression coefficient (b), and mean squared deviation (sd^2) for each genotype.

Results and discussion

The analysis of variance (Table 1) showed highly significant differences due to genotypes and environments indicating presence of variation among the hybrids and among environments. All the characters exhibited significant genotype x environment interactions indicating that genotypes and environments are quite variable for all the traits. The regression analysis showed that the mean sum of squares due to environment (linear) was highly significant for all the traits under study. The significance of E (G x E) interactions for days to 50 per cent flowering, days to physiological maturity, plant height and harvest index were predominance compared to nonlinear component suggested that the genotypes differed greatly in their linear response to different environments.

The genotype x environment (linear) were non-significant for almost all the characters except harvest index per cent under studied when tested against pooled deviation, it indicates unpredictable performance of genotypes over the environments. Mean squares due to pooled deviation were found significant for all the characters indicating that the genotypes varied considerably for stabilities and hence prediction of their performance across environment for these traits is not possible. Similar observations were made by Shinde *et al.,* (1992) [24] and Binodh *et al.,* (2009) [4].

Estimates of environmental indices (Ij), given in the Table 2 suggested that E_3 was the most favourable environment for all the characters except biological yield.

The estimate of stability parameters for days to 50 per cent flowering revealed that eleven hybrids had shown significant non-linear component (S^2di) thus manifesting least stability for days to flowering to changing environments. Least days to flowering than population mean with regression coefficient less than one (bi<1) and non-significant S^2di showed by CMS-17A x PISF-110-8-1, CMS-234A x IB-19, CMS-234A x (P-356 x R-274), and CMS-234A x (RHA-6D-1 x R-272-4) indicating their stability under unfavourable environment. Six hybrids *viz*; CMS-17A x (IB-19 x R-274), CMS-17A x (P-356 x R-274), CMS-234A x (KOP-I x 15 NB-7), CMS-234A x (15 NB-7 x HRA-5), ND-2A x IB-2Mand ND-2A x PISF-110-8-1 exhibited regression coefficient above unity (bi>1) along with lower mean value than population mean indicating their stability under favourable environment for earliness. The hybrids *viz*; CMS-17A x (R-296 x 15 NB-7), CMS-17A x (R-348 x R-274), CMS-234A x PISF-110-8-1and CMS-234A x (R-296 x 15 NB-7) had regression coefficient equal to unity and non-significant S^2di associated with early flowering could be considered as stable hybrids as far as flowering is considered. Earlier workers, Pillai *et al*. (1995) [20], Panduranga (2000) [16], Mohan Rao *et al*. (2004) [15] Sheoran *et al*. (2012) [23] reported hybrid stability for 50 per cent flowering in sunflower.

Stability analysis for days to physiological maturity revealed that the below average stability was observed in eight hybrids namely CMS-17A x (IB-19 x R-274), CMS-17A x (P-356 x R-274), CMS-17A x (R-348 x R-274), CMS-17A x (15 NB-7 x R-356), CMS-234A x (KOP-I x 15 NB-7), CMS-234A x (15 NB-7 x HRA-5), ND-2A x IB-2M and ND-2A x PISF-110-8-1 with less number of days to maturity than population mean and non-significant deviation from regression (S^2di) thus considered as suitable in favorable or rich environment. Whereas, CMS-17A x 3376-R, CMS-234A x (P-356 x R-274), CMS-234A x (RHA-6D-1 x R-272-4), ND-2A x IB-19 and ND-2A x (IB-19 x R-274) showed (above average) stability with lower mean than general mean hence showed specific adaptation to poor environment. These results are in confirmation with the results of Laisharam and Singh (1997) [13] and Matasagar (2016).

Considering the plant height the six hybrids *viz*; CMS-17A x (P-356 X R-274), CMS-17A x (15 NB-7 x R-356), CMS-234A x (RHA-6D-1 X R-272-4), CMS-234A x (15 NB-7 x R-356), ND-2A x (KOP-I x RHA-856) and ND-2A x (RHA-6D-1 x R-272-4) showed above average stability with less deviation from regression line indicating stability of performance in poor environments. Only one hybrid CMS-234A x IB-2M had showed below average stability with less deviation from regression line indicating stability of performance in rich environments. Pillai *et al*., (1995) [20], and Kaya and Atakisi (2002) also reported stable hybrids for plant height in sunflower.

The below average stability was observed in seven hybrids *viz*; CMS-17A x 3376-R, CMS-17A x (RHA-6D-1 x R-272-4), CMS-17A x (15 NB-7 x HRA-5), CMS-234A x 3376-R, CMS-234A x (KOP-I x RHA-856), CMS-234A x (R-348 X R-274) and ND-2A x (IB-19 x R-274) with maximum head size than population mean and non-significant deviation from regression (S^2di) thus considered as suitable in favorable environment. However, the hybrids, CMS-17A x (KOP-I x 15 NB-7), CMS-17A x (R-296 x 15 NB-7) and IB-19 x (KOP-I x 15 NB-7) recorded higher mean, bi < 1 and non significant value of S^2di indicating their suitability in poor environment for head diameter. The hybrid CMS-17A x HAM-183 and Phule raviraj showed higher mean, regression coefficient near to unity and deviation from regression coefficient indicating average stability and suitable for all environments. Similar findings on head diameter were reported by Bharati (2000) [2], Kaya and Atakisi (2002), Mohan Rao *et al*., (2004) [15], Amala Balu *et al*., (2007) [1] and Dhootmal (2017) [5].

The estimate of stability parameters for seed filling percentage revealed that high mean, regression coefficient less than unity (bi<1) and least deviation from regression was found in hybrids CMS-17A x (RHA-6D-1 x R-272-4), CMS-17A x (R-296 x 15 NB-7) and CMS-234A x (KOP-I x 15 NB-7) thus showed specific adaptation to poor environment. Average stability with high mean and least deviation was manifested in CMS-17A x HAM-183, CMS-17A x 3376-R, CMS-17A x (RHA-6D-1 x R-272-4), CMS-234A x 3376-R and Phule raviraj indicating that the crosses are stable and widely adapted over environments, while, crosses CMS-17A x (KOP-I x 15 NB-7), CMS-17A x (P-356 x R-274), CMS-234A x (KOP-I x RHA-856), CMS-234A x (R-296 x 15 NB-7), CMS-234A x (R-348 x R-274) and ND-2A x 3376-R were stable and of below average stability tend to respond favorably to better environment. Similar observation was made by Dhootmal (2017) [5].

With regards to seed yield, cross combinations CMS-17A x (KOP-I X RHA-856), CMS-234A x HAM-183, CMS-234A x (KOP-I X 15 NB-7), and KBSH-44 was with significantly higher mean than population mean and regression coefficient less than unity indicated stable and wide adaptability to poor environment, while, hybrids, *viz*. CMS-17A x (R-296 x 15 NB-7), CMS-17A x (15 NB-7 x HRA-5), CMS-234A x 3376-R, CMS-234A x (KOP-I x RHA-856), CMS-234A x (R-296 x 15 NB-7), CMS-234A x (R-348 x R-274), ND-2A x HAM-183, ND-2A x (IB-19 x R-274) and Phule raviraj were with high mean, regression coefficient more than unity (bi>1) with least deviation from regression line indicated specific adaptation to favorable or rich environments. However, CMS-17A x HAM-183, CMS-17A x 3376-R, CMS-17A x (KOP-I x 15 NB-7) and CMS-17A x (RHA-6D-1 x R-272-4) identified to be highly stable for seed yield as indicated by their mean and stability indices. Pathak and Dixit (1984) [17], Pillai *et al*. (1995) [20], Halaswamy *et al*. (2000) [10], Kumar *et al*. (2002) [12], Goud and Sarala (2004) [9], Amala Balu *et al*. (2007) [1], Reddy *et al*., (2009) [21], Bhoite *et al*. (2010) [3] and Dhootmal (2017) [5] also reported stable hybrids for seed yield in sunflower.

Stability studies in hybrids revealed that CMS-234A x (15 NB-7 x HRA-5), ND-2A x (IB-19 x R-274) and DRSH-1 recorded significantly higher test weight than population mean with regression coefficient less than unity and least deviation from regression, thus found stable and specific adaptable to poor environment, while below average stability (bi>1) was exhibited in CMS-17A x T_4, CMS-17A x (KOP-I x 15 NB-7), CMS-17A x (R-296 x 15 NB-7), CMS-234A x (KOP-I x 15 NB-7), CMS-234A x (R-296 x 15 NB-7), CMS-234A x (R-348 x R-274), ND-2A x 3376-R, ND-2A x (RHA-6D-1 x R-272-4), KBSH-44 and Phule raviraj hence were stable and specific adaptation to favorable or rich environment. Whereas, CMS-17A x HAM-183, CMS-17A x 3376-R and CMS-17A x (RHA-6D-1 x R-272-4) recorded average stability over the environments. Earlier workers Kaya and Atakisi (2002) and Pawankumar *et al*., (2003) [18] also noticed stable performance for 100 seed weight in their studies.

Among hybrids, CMS-17A x (RHA-6D-1 x R-272-4), CMS-17A x (15 NB-7 x HRA-5), CMS-234A x (R-348 x R-274) and DRSH-1 showed above average stability with significantly higher mean than population mean and wide adaptation to poor environment for seed volume weight. Below average stability was observed in CMS-17A x T_1, CMS-17A x T_2, CMS-17A x T_3, CMS-17A x T_4, CMS-17A x 3376-R, CMS-17A x (IB-19 X R-274), CMS-17A x (KOP-I X 15 NB-7), CMS-234A x 3376-R, ND-2A x 3376-R, and Phule raviraj thus found adaptable to favorable or rich environments. Mohan Rao *et al*., (2014) [15] and Dhootmal (2017) [5] reported similar results for stability in seed volume weight.

With regard to hull content the cross combinations CMS-17A x 3376-R, CMS-17A x (KOP-I x 15 NB-7), CMS-17A X (R-296 x 15 NB-7), ND-2A x (RHA-6D-1 x R-272-4), and KBSH-44 were significantly higher mean than population mean and regression coefficient less than unity indicated stable and wide adaptability to poor environment, while, hybrids, *viz*. CMS-17A x HAM-183, CMS-17A x IB-19, CMS-17A x IB-2M, CMS-17A x (R-348 x R-274), CMS-17A x (RHA-6D-1 x R-272-4), CMS-17A x (15 NB-7 x HRA-5), CMS-234A x (KOP-I x 15 NB-7), CMS-234A x (15 NB-7 x HRA-5) and Phule raviraj were with high mean, regression coefficient more than unity (bi>1) with least deviation from regression line indicated specific adaptation to favorable or rich environments. However, only one hybrid, ND-2A x 3376-R identified to be highly stable for hull content as indicated by their mean and stability indices. These results are in confirmation with the results of Waghmare *et al*., (2011) [26] and Dhootmal (2017) [5].

The estimate of stability parameters for oil content revealed that cross combinations CMS-234A x (R-348 x R-274), CMS-234A x (RHA-6D-1 x R-272-4), CMS-234A x (15 NB-7 x HRA-5), ND-2A x (KOP-I x 15 NB-7), and KBSH-44 was with significantly higher mean than population mean and regression coefficient less than unity indicated stable and wide adaptability to poor environment, while, hybrids, *viz*. CMS-234A x HAM-183, CMS-234A x 3376-R, CMS-234A x (IB-19 x R-274), CMS-234A x (P-356 x R-274), CMS-234A x (15 NB-7 x R-356), ND-2A x IB-19, ND-2A x IB-2M, ND-2A x PISF-110-8-1, ND-2A x (IB-19 x R-274), ND-2A x (RHA-6D-1 x R-272-4), ND-2A x (15 NB-7 x HRA-5), DRSH-1 and Phule raviraj were with high mean, regression coefficient more than unity (bi>1) with least deviation from regression line indicated specific adaptation to rich environments. However, hybrids CMS-234A x PISF-110-8-1and ND-2A x 3376-R identified to be highly stable for oil content as indicated by their mean and stability indices. Similar findings for oil content were reported by Laishram and Singh (1997) [13], Bharathi (2000), Subbalakshmi *et al*. (2001) [25], Rukminidevi *et al*. (2006),Binodh *et al*. (2009) [4], Sheoran *et al.* (2012) [23] and Dhootmal (2017) [5].

Among hybrids, only one hybrid CMS-234A x IB-2M showed above average stability with significantly higher mean than population mean and wide adaptation to poor environment for biological yield. Below average stability was observed in CMS-17A x 3376-R, CMS-17A x (RHA-6D-1 x R-272-4), CMS-234A x HAM-183, CMS-234A x IB-19, CMS-234A x (IB-19 X R-274), CMS-234A x (P-356 X R-274), CMS-234A x (R-348 X R-274), ND-2A x (R-296 X 15 NB-7), KBSH-44 and Phule raviraj thus found adaptable to favorable environments. While looking at stability parameters, it is revealed that hybrid CMS-17A x (KOP-I x 15 NB-7) showed stable performance as indicated by their highest mean and stability indices. With regards to harvest index, the hybrids CMS-234A x (R-348 x R-274), CMS-234A x (RHA-6D-1 x R-272-4), CMS-234A x (15 NB-7 x HRA-5), ND-2A x (KOP-I x 15 NB-7), and KBSH-44 was with significantly higher mean than population mean and regression coefficient less than unity indicated stable and wide adaptability to poor environment, while, hybrids, CMS-234A x HAM-183, CMS-234A x 3376-R, CMS-234A x (IB-19 x R-274), CMS-234A x (P-356 x R-274), CMS-234A x (15 NB-7 x R-356), ND-2A x IB-19, ND-2A x IB-2M, ND-2A x PISF-110-8-1, ND-2A x (IB-19 x R-274), ND-2A x (RHA-6D-1 x R-272-4), ND-2A x (15 NB-7 x HRA-5), DRSH-1 and Phule raviraj were with high mean, regression coefficient more than unity (bi>1) with least deviation from regression line indicated specific adaptation to rich environments. Dhootmal (2017) [5] also noticed stability for biological yield and harvest index in their studies.

From the above findings, it is concluded that three hybrids; CMS-17A x (KOP-I X RHA-856), CMS-234A x HAM-183, CMS-234A x (KOP-I X 15 NB-7) stability for seed yield and two hybrids; CMS-234A x PISF-110-8-1 and ND-2A x 3376-R should be tested directly in multilocation trials for future breeding programme.

Table 1: Analysis of variance (M.S.S) for stability parameters for seed yield and other important characters in sunflower hybrids

Characters	Genotype	Environment	G x E	E + (G x E)	E (L)	G x E (L)	Pooled deviation	Pooled Error
	61	2	122	124	1	61	62	366
Days to 50 per cent flowering	24.83**	2115.18**	11.20++	45.13**	4230.35**	10.33	11.87@@	3.69
Days to physiological maturity	21.50*	3117.33**	11.55++	61.64**	6234.66**	10.30	12.60@@	7.02
Plant height	1341.76**	2062.71**	2062.71+	64.21**	4125.43**	29.02	33.33	30.41
Head diameter	31.45**	19.95**	1.68++	1.98	39.89**	1.85	1.49@@	0.30
Seed filling	133.60**	165.60**	21.07++	23.41	331.20**	20.17	21.62@@	3.59
Seed yield per plant	185.83**	132.23**	9.33++	11.31	264.46**	7.97	10.52@@	2.19
100 grain weight	2.19**	0.50**	0.07++	0.08	1.00**	0.06	0.08@@	0.01
Seed volume weight	54.53**	13.39	4.77++	4.91	26.77*	4.95	4.53@@	1.04
Hull content	38.70**	86.90**	7.56++	8.84	173.79**	7.19	7.80@@	1.10
Oil content	17.67**	3.11*	0.61++	0.65	6.22**	0.54	0.67@@	0.20
Biological yield	1461.42**	253.05*	76.15++	79.00	506.11*	73.94	77.10@@	10.03
Harvest index	111.40**	80.95**	6.84++	8.04*	161.90**	8.31*	5.28@@	2.49

*, ** = Significant at P= 0.05 and 0.01 respectively, when tested against pooled deviation
+, ++ = Significant at P= 0.05 and 0.01 respectively, when tested against G xE
@, @ @ = Significant at P= 0.05 and 0.01 respectively, when tested against Pooled error

Table 2: Environmental indices for different traits of sunflower hybrids

Characters	Environmental indices		
	E_1	E_2	E_3
Days to 50 per cent flowering	4.93	1.52	-6.45
Days to physiological maturity	6.86	0.44	-7.30
Plant height (cm)	-0.06	-5.74	5.80
Head diameter (cm)	-0.01	-0.56	0.57
Seed filling (%)	0.56	-1.84	1.28
Seed yield per plant (g)	0.13	-1.52	1.39
100 grain weight (g)	-0.02	-0.08	0.10
Seed volume weight (g/100 ml)	-0.11	-0.40	0.51
Hull content (%)	0.17	-1.26	1.09
Oil content (%)	-0.10	-0.16	0.26
Biological yield per plant (g)	1.84	-2.16	0.32
Harvest index (%)	-0.45	-0.85	1.30

Table 3a: Estimates of stability parameters in sunflower hybrids

Crosses	Days to 50 per cent flowering			Days to physiological maturity			Plant height (cm)			Head diameter (cm)		
	μ	bi	S^2di	μ	bi	S^2di	μ	bi	S^2di	μ	bi	S^2di
(CMS-17A x HAM-183)	80.33	0.73**	1.04	112.56	0.81**	-3.26	165.04	0.93**	-22.58	18.63	0.97	0.21
(CMS-17A x IB-19)	82.00	0.88	13.87**	114.11	0.81**	2.14	163.72	0.19	52.71	16.65	0.33	2.89**
(CMS-17A x IB2M)	79.78	0.67	33.83**	112.56	0.55	39.04**	147.44	1.13**	-25.7	12.38	2.04**	-0.25
(CMS-17A x PISF-110-8-1)	75.00	0.82**	0.06	109.00	1.08*	11.17	162.62	0.47	37.44	14.39	3.17**	-0.17
(CMS-17A x 3376-R)	77.78	0.17	26.45**	110.44	0.41	40.58**	174.44	1.41**	-28.33	19.89	1.10**	-0.25
{CMS-17A x (IB-19 x R-274)}	74.00	1.27**	-3.14	109.00	1.45**	-2.75	150.78	1.83**	-13.35	18.26	2.71	1.23**
{CMS-17A x (KOP-I x RHA-856)}	79.56	1.61**	0.74	112.33	1.57**	-5.44	150.77	1.35**	-17.03	14.92	0.25	0.16
{CMS-17A x (KOP-I x 15 NB-7)}	82.33	0.93**	-1.86	114.78	1.01**	-6.56	148.93	0.96*	-18.88	17.44	0.43**	-0.3
{CMS-17A x (P-356 x R-274)}	74.33	1.18**	3.49	107.11	1.21**	-2.94	140.08	0.65	49.6	15.27	0.89	7.28**
{CMS-17A x (R-296 x 15 NB-7)}	77.67	1.06**	0.38	110.11	0.95**	2.64	147.21	0.73	57.71	18.75	0.22	-0.22
{CMS-17A x (R-348 x R-274)}	74.67	1.08**	-2.26	107.11	1.29**	-6.32	148.98	-0.71	-29.96	16.48	-2.81	1.52**
{CMS-17A x (RHA-6D-1 x R-272-4)}	80.11	0.81	73.83**	113.89	0.95	35.39**	158.07	1.31**	-30.06	18.88	1.70**	-0.14
{CMS-17A x (15 NB-7 x HRA-5)}	79.56	1.43**	7.66	112.89	1.4**	0.08	150.44	2.06**	-24.88	19.60	2.72**	-0.17
{CMS-17A x (15 NB-7 x R-356)}	72.44	1.11*	15.23**	105.67	1.14**	0.06	136.26	0.68**	-27.09	12.42	1.75*	0.12
(CMS-234A x HAM-183)	82.56	0.66*	3.34	114.89	0.72*	4.73	169.02	-0.73	24.80	14.66	2.62**	-0.2
(CMS-234A x IB-19)	77.44	0.20	8.22	111.00	0.46	0.27	156.96	1.11**	-21.17	13.61	0.25	-0.07
(CMS-234A x IB2M)	81.56	1.44**	-2.33	112.78	1.23**	-6.84	140.06	1.35**	-30.37	12.17	-3.05	0.37
(CMS-234A x PISF-110-8-1)	79.44	0.99**	-2.26	113.33	1.27**	-7.22	154.93	1.61	21.27	15.13	-0.68	2.49**
(CMS-234A x 3376-R)	81.56	1.12	27.03**	114.22	0.93	36.33**	159.07	1.74**	-14.51	18.77	1.37	0.05
{CMS-234A x (IB-19 x R-274)}	79.89	0.77**	-0.62	113.78	0.78**	-6.95	163.06	0.93*	-19.17	15.19	4.98**	0.24
{CMS-234A x (KOP-I x RHA-856)}	80.67	1.08*	14.09**	112.78	1.03**	4.51	162.33	0.62**	-27.85	18.50	1.61**	-0.3
{CMS-234A x (KOP-I x 15 NB-7)}	76.89	1.23**	-3.68	109.00	1.28**	-6.13	164.42	1.62**	-29.71	17.45	0.53	0.24
{CMS-234A x (P-356 x R-274)}	73.11	0.25*	-3.14	107.22	0.55*	-2.15	155.30	1.27**	-28.55	14.80	-1.79	4.29**
{CMS-234A x (R-296 x 15 NB-7)}	75.78	0.95**	-1.32	109.56	0.94**	-6.41	141.34	0.35	151.48**	15.69	1.99*	0.22
{CMS-234A x (R-348 x R-274)}	83.33	0.51	29.12**	116.56	0.68	11.17	153.78	1.95**	-22.61	18.26	1.38*	-0.03
{CMS-234A x (RHA-6D-1 x R-272-4)}	76.44	-0.38	0.06	109.11	-0.05	10.62	138.04	0.73**	-30.3	15.25	-1.43	2.55**
{CMS-234A x (15 NB-7 x HRA-5)}	75.11	1.39**	-3.21	108.11	1.25**	-7.02	157.27	1.16	64.17	16.54	-0.05	15.83**
{CMS-234A x (15 NB-7 x R-356)}	78.67	1.27**	9.98	110.89	1.09**	1.43	138.34	0.60	35.73	10.35	1.25	0.97**

(ND-2A x HAM-183)	78.56	1.02	64.32**	111.44	0.89	70.13**	150.26	0.74**	-27.44	15.90	3.19**	0.01
(ND-2A x IB-19)	76.11	0.64	14.77**	108.89	0.73	8.57	140.83	-0.17	143.14**	14.07	1.75	4.61**
(ND-2A x IB2M)	76.56	1.73**	-3.65	108.11	1.62**	-6.33	145.68	0.86**	-30.11	10.44	-0.22	9.64**
(ND-2A x PISF-110-8-1)	74.89	1.51**	-3.32	107.89	1.57**	1.78	154.93	1.86**	-17.63	13.75	2.05	1.73**
(ND-2A x 3376-R)	78.56	1.15*	17.84**	111.22	1.22**	5.69	168.20	1.22**	-27.92	15.14	2.45**	-0.16
{ND-2A x (IB-19 x R-274)}	78.11	1.11**	4.06	110.33	0.88**	-4.56	168.51	0.48**	-28.85	17.53	1.55*	-0.08
{ND-2A x (KOP-I x RHA-856)}	80.44	0.96**	-3.62	112.00	0.86**	-0.73	136.58	-0.30	-27.62	13.35	1.33	3.59**
{ND-2A x (KOP-I x 15 NB-7)}	79.44	1.26**	-2.25	112.56	1.23**	-6.53	158.76	0.75	204.96**	14.34	-2.26	9.70**
{ND-2A x (P-356 x R-274)}	78.56	0.91**	-2.33	111.78	0.91**	-1.91	164.33	0.45	102.95**	15.38	2.57**	-0.21
{ND-2A x (R-296 x 15 NB-7)}	74.44	0.90**	-1.64	107.67	1.02**	7.57	155.41	0.66	156.57**	11.95	-1.42	0.79
{ND-2A x (R-348 x R-274)}	80.44	1.21	26.73**	113.00	1.04	24.28**	147.81	-0.73	-30.07	15.83	3.5**	0.08
{ND-2A x (RHA-6D-1 x R-272-4)}	81.44	1.83**	3.34	113.44	1.62**	11.48	135.78	0.78**	-29.82	17.78	4.44	3.70**
{ND-2A x (15 NB-7 x HRA-5)}	80.11	0.89	16.16**	113.00	0.78	13.1	169.79	1.93**	-23.15	12.13	2.99	1.79**
{ND-2A x (15 NB-7 x R-356)}	75.89	1.04	57.09**	109.33	0.87	58.86**	145.88	1.74**	-30.33	12.73	0.91**	-0.35
KBSH-44-C	81.56	1.44**	2.13	113.67	1.34**	4.31	159.69	1.24**	-30.41	16.45	0.47**	-0.28
DRSH-1-C	80.22	1.12**	-3.68	112.44	0.97**	-6.99	158.29	1.19**	-29.14	15.96	0.32	-0.24
P. Raviraj-C	84.22	1.33**	-1.79	116.67	1.07**	-1.81	165.29	1.63**	-24.5	17.54	0.98**	-0.26
Mean	77.93			110.76			142.99			14.20		
SEm± mean	5.25			5.91			6.28			1.23		
SE (bi)	0.90			0.83			1.09			2.16		

BI=Regression coefficient, S^2di= Deviation from regression, *, ** = Significant at 5% and 1% level, respectively.

Table 3b: Estimates of stability parameters in sunflower hybrids

Crosses	Per cent seed filling			Seed yield per plant (g)			100 grain weight (g)			Volume weight (g/100ml)		
	μ	bi	S^2di	μ	bi	S^2di	μ	bi	S^2di	μ	bi	S^2di
(CMS-17A x HAM-183)	89.69	1.03	0.09	44.53	1.09	0.01	6.19	1.00	-0.01	38.69	2.00*	-0.71
(CMS-17A x IB-19)	80.48	0.66	-1.82	35.44	2.14	22.59**	5.70	-2.11	0.05**	37.36	2.66**	-1.02
(CMS-17A x IB2M)	65.65	2.61**	-3.53	29.78	1.31**	-1.77	4.36	3.50	0.06**	32.14	1.09	-0.80
(CMS-17A x PISF-110-8-1)	74.30	4.53*	21.45**	33.76	2.76*	3.86	5.17	3.91**	-0.01	37.82	-2.43	1.26
(CMS-17A x 3376-R)	91.55	1.01	0.04	47.41	1.12	0.06	6.75	0.99**	-0.01	35.00	1.73	0.09
{CMS-17A x (IB-19 x R-274)}	84.95	3.01**	-3.43	41.22	2.88	8.40**	5.99	4.85*	0.05**	37.90	1.87*	-0.76
{CMS-17A x (KOP-I x RHA-856)}	73.55	0.61	18.84**	35.63	0.79**	-1.86	4.88	-0.61	0.05**	31.00	1.38	10.74**
{CMS-17A x (KOP-I x 15 NB-7)}	87.14	1.77**	-3.56	42.07	1.05	-0.97	5.39	1.38**	-0.01	35.41	1.45	-0.63
{CMS-17A x (P-356 x R-274)}	83.76	-1.72	4.01	35.83	0.83	37.11**	4.73	2.25	0.02	32.66	3.86	6.61**
{CMS-17A x (R-296 x 15 NB-7)}	88.79	-0.27	-2.98	41.51	1.35**	-1.55	6.03	1.81	0.01	38.27	1.96**	-0.89
{CMS-17A x (R-348 x R-274)}	77.62	-1.57	187.19**	34.29	-2.55	14.9**	5.08	-1.16	0.16**	31.03	-4.33	3.05**
{CMS-17A x (RHA-6D-1 x R-272-4)}	91.10	1.08	0.09	47.58	1.02	0.02	6.35	1.13	0.01	39.15	0.37	0.70
{CMS-17A x (15 NB-7 x HRA-5)}	87.73	2.02**	-1.18	42.86	1.51	-1.42	6.40	-0.06	0.13**	38.89	0.34	-0.83
{CMS-17A x (15 NB-7 x R-356)}	72.16	3.13	14.06**	28.62	0.62*	-1.95	4.36	1.36	0.04**	27.60	9.21**	0.84
(CMS-234A x HAM-183)	74.47	5.91	77.5**	35.69	0.81	5.27	4.41	-1.29	0.02	35.19	4.02	5.65**
(CMS-234A x IB-19)	72.13	-0.31	14.84**	28.56	0.19	4.76	4.64	-0.57	0.02	32.11	2.74	13.54**
(CMS-234A x IB2M)	69.45	-2.83	-2.22	23.95	-0.94	-2.19	3.63	1.33**	-0.01	30.85	3.58	10.12**
(CMS-234A x PISF-110-8-1)	79.43	-0.42	80.28**	30.42	-1.22	58.91**	4.89	-3.88	0.51**	26.06	-0.94	0.82
(CMS-234A x 3376-R)	86.54	0.94	-1.97	41.27	1.27*	-0.89	5.64	0.82	0.09**	35.89	-1.26	0.12
{CMS-234A x (IB-19 x R-274)}	74.01	4.66**	12.61**	32.52	2.58**	1.25	4.96	0.24	0.07**	35.19	2.62	2.01
{CMS-234A x (KOP-I x RHA-856)}	84.67	1.76**	-3.49	40.44	1.18**	-2.19	5.93	1.10	0.11**	32.86	3.5	0.5
{CMS-234A x (KOP-I x 15 NB-7)}	83.86	-0.17	9.48	37.37	0.68**	-1.99	5.13	3.88**	-0.01	33.93	-1.65	-0.47
{CMS-234A x (P-356 x R-274)}	74.63	-3.37	192.5**	32.37	1.26	4.41	4.93	3.39	0.99**	35.06	-1.39	11.77**
{CMS-234A x (R-296 x 15 NB-7)}	83.02	1.22**	-3.59	34.67	1.57	-1.46	5.47	3.76**	-0.01	29.79	0.77**	-1.04
{CMS-234A x (R-348 x R-274)}	85.20	1.32**	-3.36	39.50	1.71**	-0.51	5.30	3.83**	-0.01	38.01	-0.94	-0.19
{CMS-234A x (RHA-6D-1 x R-272-4)}	78.66	-3.05	-3.44	31.42	-0.78	1.95	4.51	2.03	0.06**	32.86	-2.76	12.19**
{CMS-234A x (15 NB-7 x HRA-5)}	80.04	-1.29	54.6**	35.30	-0.59	70.87**	4.36	-0.39	0.02	34.58	2.79	20.72**
{CMS-234A x (15 NB-7 x R-356)}	68.83	0.72	24.24**	25.36	2.63	10.6**	3.75	0.65	0.43**	27.10	-2.65	24.93**
(ND-2A x HAM-183)	79.15	3.24**	-3.41	35.17	1.64**	-1.07	5.06	0.75	0.06**	36.69	8.06	18.42**
(ND-2A x IB-19)	75.97	2.41	126.16**	30.32	1.77	41.45**	4.30	1.55	0.10**	26.34	7.21	12.55**
(ND-2A x IB2M)	67.98	0.94	25.12**	22.18	-0.07	49.69**	3.68	-0.73	0.11**	24.25	-5.59	21.98**
(ND-2A x PISF-110-8-1)	76.13	2.99**	-3.59	33.23	2.42	15.58**	4.41	3.55	0.04**	32.36	4.84	10.28**
(ND-2A x 3376-R)	80.20	1.67	6.34	33.26	2.20**	-0.25	4.92	1.34	0.02	35.21	1.57	1.82
{ND-2A x (IB-19 x R-274)}	84.36	2.83**	-1.89	37.19	1.67	-1.84	5.12	0.19	-0.01	32.95	-1.58	8.59**
{ND-2A x (KOP-I x RHA-856)}	74.68	1.26	5.58	29.68	2.36**	57.15**	5.05	0.76	0.22**	31.72	1.40	2.06
{ND-2A x (KOP-I x 15 NB-7)}	74.14	-0.52	220.3**	30.34	-1.37	81.05**	4.87	-4.62	0.73**	32.95	-5.58	6.02**
{ND-2A x (P-356 x R-274)}	77.18	4.11**	1.55	33.61	2.74**	0.19	5.41	2.69	0.17**	33.58	4.84	2.26
{ND-2A x (R-296 x 15 NB-7)}	75.42	-0.64	20.55**	26.93	-1.36	9.96**	4.73	-1.32	-0.01	27.90	-5.72	-0.55
{ND-2A x (R-348 x R-274)}	77.78	6.01**	-3.32	34.15	3.91**	-1.87	5.21	4.92**	-0.01	34.31	4.44	8.74**
{ND-2A x (RHA-6D-1 x R-272-4)}	84.05	3.53**	-0.18	38.43	4.41**	3.71	5.67	2.27	0.02	36.79	5.77*	1.73
{ND-2A x (15 NB-7 x HRA-5)}	76.70	2.13	40.37**	26.38	3.21	29**	4.03	2.63*	0.01	29.58	9.97*	5.74**
{ND-2A x (15 NB-7 x R-356)}	69.03	3.29*	6.06	30.87	1.18	4.37	4.73	1.42**	-0.01	28.53	1.72	8.11**

KBSH-44-C	89.96	0.57**	-3.41	37.27	0.76**	-2.08	5.15	1.68**	-0.01	36.86	-2.84	-0.97
DRSH-1-C	86.00	0.51*	-3.27	33.53	0.66**	-2.15	5.06	0.89	0.01	37.15	0.92*	-0.98
P. Raviraj-C	88.94	0.98	1.65	36.67	1.22	-0.16	4.90	1.45**	-0.01	36.86	-1.19	-0.64
Mean	78.77			31.17			4.71			32.08		
SEm± mean	4.53			3.01			0.25			2.09		
SE (bi)	2.77			2.06			2.81			4.50		

BI= Regression coefficient, S^2di= Deviation from regression, *, ** = Significant at 5% and 1% level, respectively.

Table 3c: Estimates of stability parameters in sunflower hybrids

Crosses	Hull content (%)			Oil content (%)			Biological yield per plant (g)			Harvest index (%)		
	μ	bi	S^2di	μ	bi	S^2di	μ	bi	S^2di	μ	bi	S^2di
(CMS-17A x HAM-183)	34.62	1.29	2.36	32.92	5.35*	0.35	86.20	2.83	145.65**	36.35	1.73*	-0.62
(CMS-17A x IB-19)	33.41	2.05	2.41	32.83	-1.48	0.51	80.28	-1.72	2.55	31.25	-2.33	7.94**
(CMS-17A x IB2M)	32.21	1.29**	-1.09	30.25	2.48	1.28**	82.70	2.78	14.63	26.99	0.18	-2.03
(CMS-17A x PISF-110-8-1)	31.16	1.44	5.38**	35.24	2.95	2.43**	94.68	2.31**	-4.48	35.01	5.05**	2.82
(CMS-17A x 3376-R)	37.71	0.89**	-0.96	33.65	4.44**	-0.03	98.38	-2.31	-9.04	39.21	-0.04	-0.76
{CMS-17A x (IB-19 x R-274)}	35.03	2.58*	1.57	35.52	0.44	1.61**	76.74	-1.27	-9.05	37.49	2.54	3.57
{CMS-17A x (KOP-I x RHA-856)}	24.90	0.66	30.49**	29.75	3.43	0.95**	91.51	-0.25	7.07	30.52	1.64	9.74**
{CMS-17A x (KOP-I x 15 NB-7)}	37.04	-0.55	2.29	32.76	7.76*	1.01**	100.25	-1.03	-9.39	33.63	-0.20	5.69
{CMS-17A x (P-356 x R-274)}	33.96	1.32	60.74**	33.86	2.05	2.11**	99.60	-6.21	266.04**	21.68	1.08	-0.39
{CMS-17A x (R-296 x 15 NB-7)}	33.02	-0.38	-1.10	29.66	0.07	-0.13	97.85	-4.93	256.94**	35.09	0.84	3.64
{CMS-17A x (R-348 x R-274)}	33.77	-2.48	-0.12	31.24	0.76	0.68**	66.87	-0.61	-4.6	30.93	0.32	-2.15
{CMS-17A x (RHA-6D-1 x R-272-4)}	35.98	1.58	2.14	34.24	2.26	3.76**	107.83	2.43	13.15	51.09	1.17	1.34
{CMS-17A x (15 NB-7 x HRA-5)}	36.92	2.13**	-1.02	33.19	-1.32	-0.11	92.91	-1.71	24.76	32.64	1.80**	-1.74
{CMS-17A x (15 NB-7 x R-356)}	30.49	2.8**	1.76	34.51	3.83	0.98**	82.94	6.58	338.91**	31.64	-0.53	-0.55
(CMS-234A x HAM-183)	32.44	3.42*	4.10**	36.11	-3.29	-0.16	123.15	3.85**	-6.00	34.20	0.91	6.75
(CMS-234A x IB-19)	34.64	2.13	5.17**	35.54	3.16**	-0.16	101.63	3.52**	-8.52	21.59	0.03	-0.66
(CMS-234A x IB2M)	29.17	-0.52	-0.61	33.43	-0.13	0.44	95.11	0.51	-1.07	43.11	-1.49	-2.04
(CMS-234A x PISF-110-8-1)	28.70	0.51	6.65**	38.79	0.93	0.01	92.81	0.89	156.76**	35.14	-1.58	2.36
(CMS-234A x 3376-R)	34.86	1.61	21.89**	35.39	1.25	-0.11	79.90	2.63	294.4**	51.63	4.14**	2.38
{CMS-234A x (IB-19 x R-274)}	32.29	2.51**	-0.75	34.75	2.21	-0.04	103.81	5.38**	-6.17	39.26	2.03	2.21
{CMS-234A x (KOP-I x RHA-856)}	27.02	1.71*	0.56	32.01	-1.86	1.64**	105.73	-4.79	763.97**	42.75	0.18	-0.77
{CMS-234A x (KOP-I x 15 NB-7)}	32.02	2.70**	0.32	33.30	-1.88	-0.10	90.12	-0.17	-9.33	38.14	1.54	3.11
{CMS-234A x (P-356 x R-274)}	29.10	2.16	62.40**	36.05	-1.29	0.17	101.31	1.96	17.4	42.33	2.69**	-2.47
{CMS-234A x (R-296 x 15 NB-7)}	31.92	0.69	21.52**	27.81	-0.46	0.17	118.84	3.25	112.64**	37.89	1.18	8.97**
{CMS-234A x (R-348 x R-274)}	32.09	2.47	4.16**	34.26	0.23	-0.19	120.16	6.73**	-9.21	39.51	1.67	12.4**
{CMS-234A x (RHA-6D-1 x R-272-4)}	33.59	1.78	35.13**	36.41	0.73	-0.16	82.77	1.26	-1.71	32.06	4.00**	-1.94
{CMS-234A x (15 NB-7 x HRA-5)}	33.47	-3.98	-0.65	35.90	0.01	-0.09	84.69	1.06	10.29	36.08	-0.96	0.77
{CMS-234A x (15 NB-7 x R-356)}	28.99	2.7**	0.10	37.49	-1.74	0.02	103.19	2.34**	-6.73	37.96	3.48**	0.41
(ND-2A x HAM-183)	32.96	-2.22	6.08**	33.14	-0.37	5.76**	82.14	-0.45	12.88	32.66	0.27	-1.97
(ND-2A x IB-19)	34.95	2.76	23.95**	35.00	-2.26	0.26	98.29	5.45	157.86**	32.36	3.17	6.65
(ND-2A x IB2M)	32.36	-1.62	12.33**	33.94	-2.64	0.34	66.92	1.33	19.69	26.67	0.07	-2.48
(ND-2A x PISF-110-8-1)	35.90	1.12	7.97**	36.39	-1.32	-0.07	68.10	0.63	5.16	26.88	0.75	4.86
(ND-2A x 3376-R)	37.61	1.01**	-0.93	34.18	-1.04	-0.11	83.09	-0.36	50.53**	32.76	1.97	2.42
{ND-2A x (IB-19 x R-274)}	32.55	1.61	3.75**	34.60	-1.40	-0.19	68.47	2.09	571.87**	39.21	1.84	4.72
{ND-2A x (KOP-I x RHA-856)}	26.24	-0.17	0.84	33.36	2.16	0.39	70.76	-1.27	4.09	32.09	2.59	40.52**
{ND-2A x (KOP-I x 15 NB-7)}	29.01	0.74	3.16**	34.71	0.30	-0.09	54.95	1.9	1.55	37.95	-0.89	3.73
{ND-2A x (P-356 x R-274)}	30.47	2.49**	-0.74	32.33	0.63	-0.08	58.73	1.35	13.32	32.50	2.06	8.01**
{ND-2A x (R-296 x 15 NB-7)}	28.44	1.95**	-0.93	29.73	3.72**	-0.19	101.83	3.16	23.45	25.87	2.41	3.47
{ND-2A x (R-348 x R-274)}	31.67	5.11**	-1.01	31.04	3.43**	-0.09	65.74	0.56	26.70	37.98	4.72	18.42**
{ND-2A x (RHA-6D-1 x R-272-4)}	36.27	0.18	0.59	35.68	1.52**	-0.18	53.11	-1.50	-9.96	37.81	2.99	19.36**
{ND-2A x (15 NB-7 x HRA-5)}	31.18	4.42**	3.06	35.78	1.37*	-0.16	59.63	4.11**	-5.35	22.07	2.65	5.98
{ND-2A x (15 NB-7 x R-356)}	28.25	1.51	4.85**	36.33	5.91**	0.09	65.89	-0.65	-8.56	25.74	-0.33	-1.01
KBSH-44-C	34.94	-0.74	2.71	34.41	-0.43	-0.08	100.01	-1.59	29.33**	37.43	2.67**	-1.21
DRSH-1-C	31.35	0.69	0.69	34.68	1.16*	-0.17	93.63	0.79	31.37**	35.89	-0.75	-2.38
P. Raviraj-C	34.61	1.16**	-0.79	34.46	-1.48	-0.17	112.06	-1.59	-2.68	32.83	2.32**	-1.95
Mean	31.55			33.64			94.94			33.22		
SEm± mean	2.75			0.67			7.54			2.44		
SE (bi)	2.32			3.01			3.73			2.13		

BI= Regression coefficient, S^2di= Deviation from regression, *, ** = Significant at 5% and 1% level, respectively.

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