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STABILITY ANALYSIS FOR SEED YIELD AND OIL CONTENT IN SUNFLOWER OVER DIVERSIFIED ECOLOGIES OF INDIA

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ABSTRACT

Present investigation was undertaken in sunflower to study stability parameters for seed yield, its 10 component traits and oil content in newly developed sunflower hybrids using diverse parental lines and across diverse agro-climatic conditions in India. Stability studies for lines revealed that all lines recorded below average stability (bi>1) for oil content while for seed yield, PET 2-7-1B, ARM 249B among lines and R 16, EC-601957 and EC-623023 among testers were stable and indicated greater resistance to environmental change (above average stability). From the present investigation on stability hybrids identified for early maturity were CMS 234A XEC-601957 and ARM 249A X EC-6230323. Among the crosses, CMS 234A XEC- 601957, CMS 234A X RHA 138-2, 234A X R 16, ARM 249A X EC-6230323, ARM 249A X RHA 138-2 and ARM 249A X R-271-1 found stable for seed yield and important component character in a study on sunflower hybrids for adoptability and stability revealed that complete hybrid stability over all parameters was not proved. For seed oil content, stable hybrids with high heterosis and positive SCA effects were recorded in crosses CMS 234A X RHA 138-2 and ARM 249A X EC-6230323. Stable hybrids for yield and oil were CMS 234A X RHA 138-2 and ARM 249A X EC-6230323.

KEYWORDS: Sunflower, Stability, Seed yield, Oil Content.

INTRODUCTION

Genetic homeostasis refers to a genotype's ability to survive environmental changes. Heterozygosity, heterogeneity, and method of pollination are three major elements impacting genotype ability. A genotype's performance is mostly determined by its ability to be phenotypically stable across contexts, which can be obtained through a variety of approaches. Stability analysis or genotype x environment (G x E) analysis is the statistical investigation of genotypic stability across settings.

Sunflower's prominence as an oilseed crop in India dates back only three decades. However, its contribution to the country's self-sufficiency in edible oil as well as the "yellow revolution" is notable (Mangala Rai, 2002). In India, first ever sunflower hybrid developed by Seetharam (1980), gave a fillip and renewed the interest in crop because of well-defined CMS system. Hybrids are preferred over varietal populations because of their high productivity in terms of seed and oil yield.

With the increased demand for edible oils, there is a need to develop novel sunflower hybrids with a high degree of heterosis for economic features that are also suitable for India's various agro-climatic zones. The goal of the stability of newly produced hybrids is to discover genotypes that are well adapted to a wide range of environmental situations. Eberhart and Russell's (1966) stability model is an ideal approach for identifying stable genotypes across environments/locations/years. The phenotypic stability was determined by taking into account the genotype's mean performance over environments (X), the linear regression of the genotypes over environment indexes (bi), and the deviation from this regression. The stable genotype has a high mean, a regression coefficient (bi) equal to unity, and a modest deviation from regression (S2di).

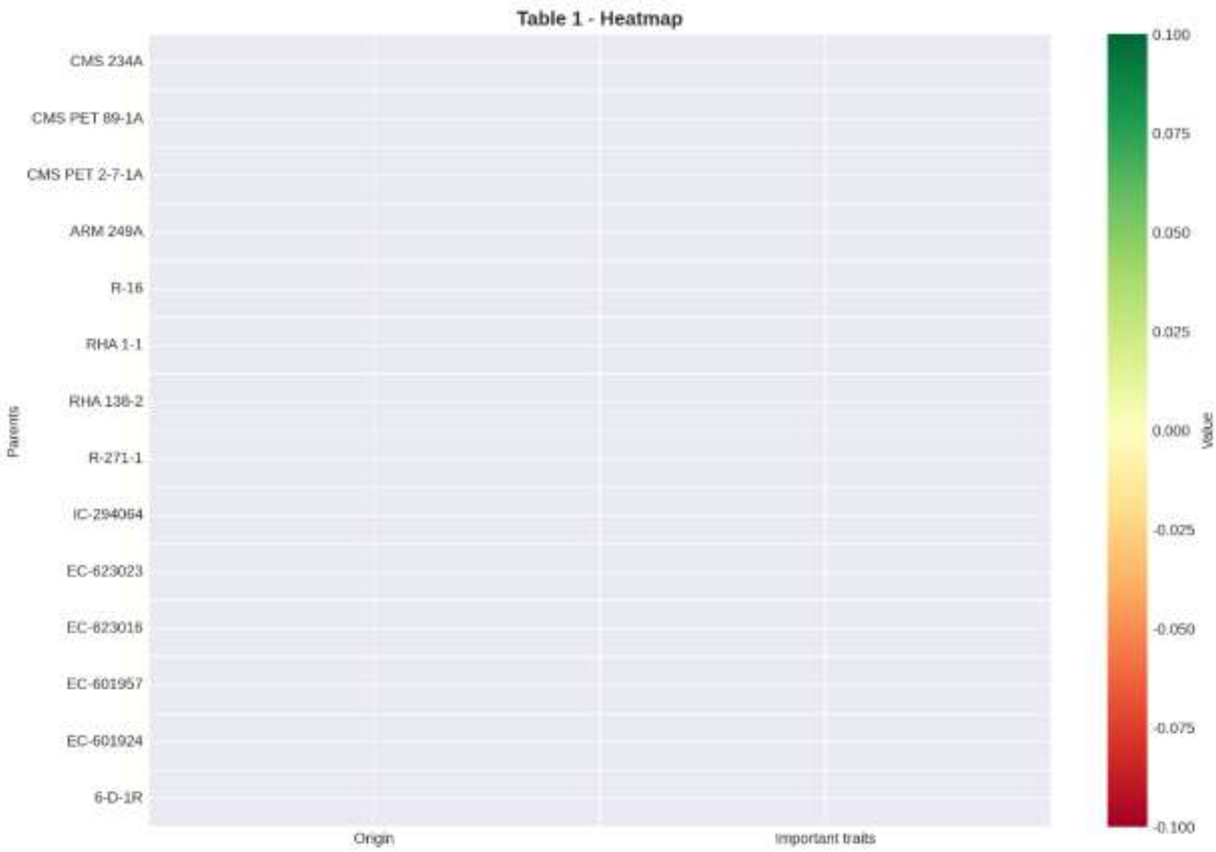
Keeping in view, the present investigation was undertaken in sunflower to study stability parameters for seed yield, its 10 component traits and oil content in newly developed sunflower hybrids using diverse parental lines and across diverse agro-climatic conditions in India.

MATERIALS AND METHODS

The experimental for the present field investigation comprised of four lines and ten testers selected on the basis of their diverse origin, growth habit, phenology and adaptation (Table 1) These were crossed in line x tester design to develop 40 experimental hybrids during *summer* season of 2015 at Oil Seed Research Station, Latur (Maharashtra, India).

Table 1. Description of parents

Parents	Origin	Important traits
CMS 234A	UAS, Bangalore	Early maturity and high oil content
CMS PET 89-1A	IIOR, Hyderabad	High seed yield.
CMS PET 2-7-1A	IIOR, Hyderabad	High seed yield.
ARM 249A	IIOR, Hyderabad	High seed yield.
R-16	IIOR, Hyderabad	Early maturity and High seed yield.
RHA 1-1	ORS, Latur	Downy mildew resistant.
RHA 138-2	ORS, Latur	High seed yield and black colour seed.
R-271-1	ORS, Latur	Early maturity and High seed yield.
IC-294064	NBPGR, New Delhi	Early maturity.
EC-623023	IIOR, Hyderabad	High seed yield.
EC-623016	IIOR, Hyderabad	High seed yield.
EC-601957	IIOR, Hyderabad	High seed yield.
EC-601924	IIOR, Hyderabad	High oil content and Downy mildew resistant.
6-D-1R	UAS, Bangalore	High oil content.



The 40 F_1s along with 14 parents) and two high yielding popular checks in the State of Maharashtra viz., LSFH 171 and LSFH 35 and were grown in randomized block design with three replications in three environments during two crop seasons at two locations i.e. Udaipur and Latur as per details, given below:

Envs.	**Location / Season**	**N:P: K**	**Irrigations**	**Soil type**
E_1	Udaipur, *Kharif*, 2015	80:40:40	1	Clay loam
E_2	Latur, *Kharif*, 2015	80:40:40	1	Medium- black
E_3	Latur, *Rabi*, 2016	80:40:40	3	Medium- black

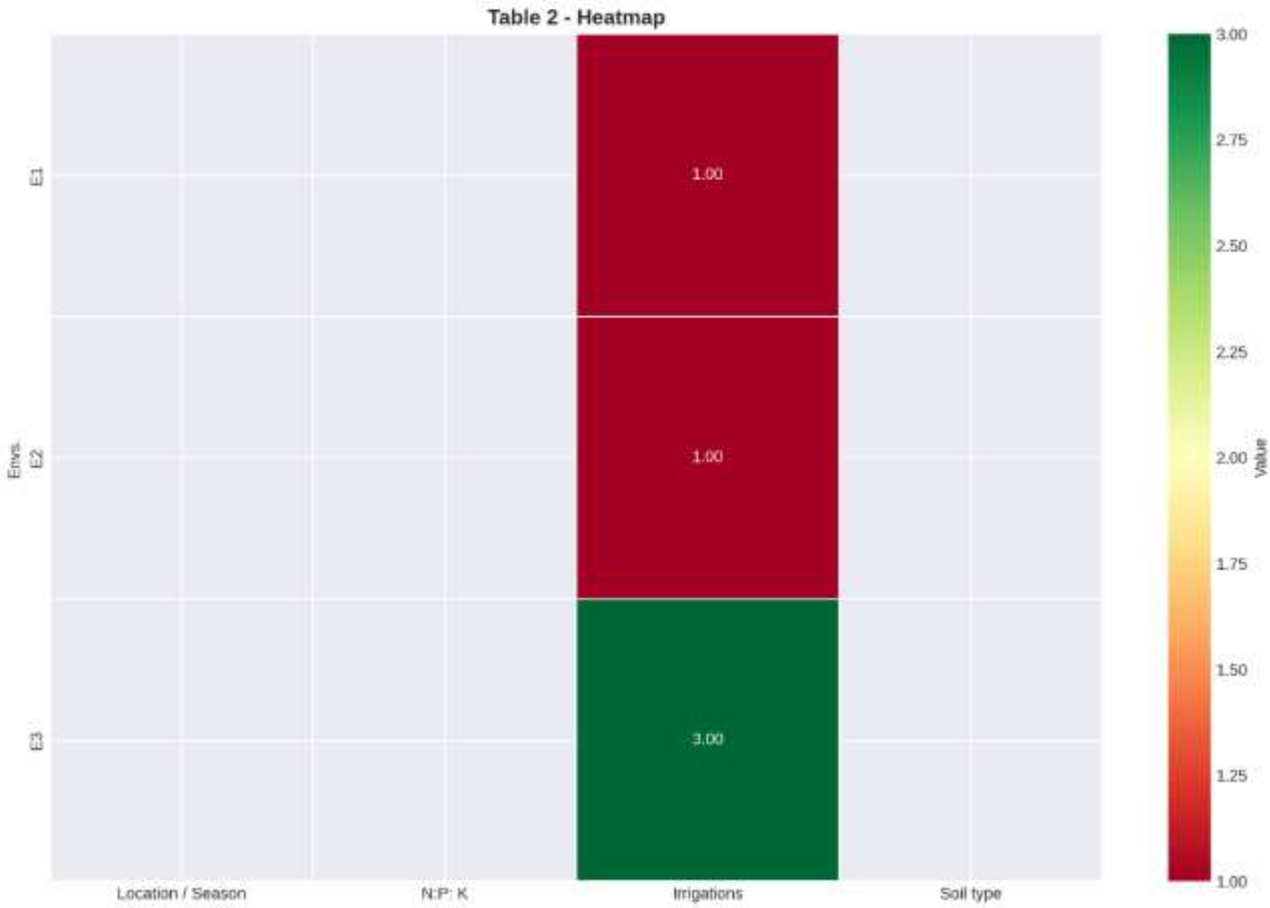


Figure: Heatmap for Table 2

The hybrids, parents and checks were sown in a single row of 3.0 m length following randomized block design with three replications. Non-experimental material was planted around the layout to eliminate border effects and recommended cultural practices were followed to raise healthy crop. Observations were recorded on 12 characters: days to 50% flowering, days to maturity, plant height, head diameter, seed filling percentage, oil content, hull content, volume weight, 100-seed weight, biological yield, seed yield and harvest index. The performance of different genotypes in respect to eight characters was studied for estimating the stability and significance of genotype environment interaction.

Observations:

Days to 50% flowering: Days required from sowing to the flowering of 50 percent plants in a plot were recorded.
Plant height (cm): It was the average height in cm from the base of the plant to the base of capitulum at harvest.
Head diameter (cm): Head diameter was measured in centimeter at maturity by measuring tape.
Volume weight (g/100 ml): The measuring cylinder was filled to 100 ml volume with seeds of each entry and was weighed in gram as volume weight / 100 ml using Semi-Micro Electronic Balance.
Hull content (%): Ten gram of well filled seed was extracted from each sample and it was dehulled and recorded as hull content.
Hull content = Weight of Hull (g) x 100 / Weight of seed (10g)
Seed filling (%): It is the percent ratio of number of filled seeds to the total seeds of each selected plants in each treatment.
Seed yield per plant (g): The cleaned produce of 5 selected plants was weighed in gram on Top Pan Digital Balance and averaged for each genotype.
Oil content (%): A randomly bulk sample of filled seeds were drawn from selected plant produce weighing 50 grams. The oil content in percentage was measured using Nuclear Magnetic Resonance (NMR) facility available at AICRP on Safflower, VNMKV, Parbhani (MS, India).

RESULTS AND DISCUSSION

ANOVA for stability analysis

The presence of variation for all of the traits was revealed by highly significant variations due to genotypes and environments. Except for volume weight, 100-seed weight, and harvest index, there was a significant G x E interaction component for all parameters, indicating that genotypes responded differently to environmental changes. Significant G x E (linear) and pooled deviation for various characteristics revealed that both linear and non-linear components were important in constructing total G x E interaction in the majority of traits.

Mean squares owing to pooled deviation were found to be substantial for all characters, demonstrating that genotypes differed significantly for stabilities and that prediction of their performance across environments for these traits is not achievable (Table 1).

Phenological traits:

The estimation of stability parameters for days to 50% flowering revealed that the line PET 2-7-1B had a significant non-linear component (S2di), indicating the least stability to changing environments, whereas other lines, such as PET 89-1B, CMS 234B, and ARM 249B, had regression coefficients around unity (bi=1) and non-significant S^2di, indicating average stability. Among the testers, R 16 had the shortest flowering time, as well as a regression coefficient around unity (bi=1) and a non-significant S2di, along with EC-623023 and IC-294064, but RHA 138-2 and R-271-1 (bi1) had above-average stability and were thus appropriate for poor environments. Eighteen hybrids had shown significant non-linear component (S2di) thus manifesting least stability for days to flowering to changing environments. CMS 234A X EC-601957, PET 89-1A X 6D-1R, and ARM 249A X EC-6230323 had low mean and above average stability, with regression coefficients less than one (bi1) and low S2di, and these hybrids flower earlier than best check LSFH 35 in unfavorable circumstances. CMS 234A X RHA 1-1 and CMS 234A X EC-623016 hybrids with regression coefficients equal to unity and non-significant S2di related with early flowering could be considered stable hybrids in terms of flowering. Above average stability (bi<1) with lower mean than check LSFH 171 was observed in 4 hybrids *viz*. PET 89-1A X IC 294064, CMS 234A X EC- 601957, ARM 249A X EC-6230323 and CMS 234A X R-271-1. Below average stability and desirable lower mean than best check LSFH 35 were observed in 7 hybrids *viz*., PET 2-7-1A X R 16, PET 2-7-1X 6D-1R, PET 2-7-1A X EC-623016, PET 2-7-1A x EC-623023, PET 89-1A X RHA 1-1, CMS 234A X RHA 138-2 and ARM 249A X 6D-1R (Table 4).

Sheoran *et al.* (2012) identified adoptive and stable sunflower hybrids for four characters including days to 50% flowering suitable for spring season in northern states of India which shall be highly essential for increasing the cultivation of sunflower in the country.

Agronomic and biochemical traits

For plant height, all lines and testers showed significantly shorter height than check LSFH 171 and LSFH 35. Two lines and 2 testers although showed bi around unity but were with non-significant but higher magnitude of deviation from regression line (Table 4). Thirteen hybrids recorded lesser plant height than check LSFH 171 out of which, only 6 hybrids namely PET 2-7-1X 6D-1R, PET 89-1A x RHA 138-2, ARM 249A X IC-294064, 234A x RHA 138-2, CMS 234A x EC 601957 and ARM 249A x EC 623023 showed average stability with regression coefficient around unity, whereas, hybrid 234A X R 16 with plant height at par with check LSFH 171 showed above average stability with less deviation from regression line indicating stability of performance in poor environments. PET 2-7-1A X R 16 showed below average stability with comparable height as compared to best check LSFH 35.

Table 4 revealed that CMS 234B recorded highest head diameter among all lines and also recorded above average stability (bi<1) with least deviation from regression line, whereas ARM 249B recorded average (bi=1) and PET 89-1B below average stability (bi>1) thus found suitable for unfavorable and favorable environments, respectively. Among testers, EC-623016 showed highest head diameter but below average stability (bi>1) hence found suitable for favorable or rich environment, whereas, EC-623023, EC-601957, and R-271-1 recorded above average stability (bi<1) with least deviation from regression line hence these testers were stable and specific adapted to poor environment. A total of 6 hybrids *viz*. CMS 234A X EC-623023, , ARM 249A X R-271-1, PET 89-1A X EC-623023, PET 89-1A X EC-601957, PET 2-7-1A x EC-623023 and PET 2-7-1A X RHA 138-2 recorded high mean, regression less than unity (bi<1) and least deviation from regression, thus showed above average stability and adaptation to poor environment. Whereas, 7 hybrids namely 234A X R 16, CMS 234A X RHA 138-2, ARM 249A X EC-6230323, 234A x EC 601957, ARM 249A X R 16, PET 2-7-1A x EC-601957 and PET 2-7-1A X EC-601924 showed average stability over environments as they had manifested regression coefficient around unity with least deviation from regression line. Below average (bi>1) stability was recorded in crosses and CMS 234A X R-271-1, ARM 249A X R 16, PET 89-1A X R 16, Arm 249 x EC 623023 and PET 2-7-1A X R-271-1 which perform better in favorable or rich conditions.

Out of 14 parents only 4 *viz*. CMS 234B, PET 89-1B (lines), R 16 and R-271-1 (testers) manifested stability to favorable or rich condition (bi>1) for seed filling percentage, while rest of the parents found unstable. High mean, regression coefficient less than unity (bi<1) and least deviation from regression was found in hybrids CMS 234A X IC-294064, CMS 234A X R-271-1, ARM 249A X IC-294064, ARM 249A X EC-601924, PET 89-1A X EC-601957, PET 89-1A X R 16 and PET 2-7-1A x EC-623023 thus showed specific adaptation to poor environment. Average stability with high mean and least deviation was manifested in ARM 249A X EC-6230323, ARM 249A X R 16 and CMS 234 x R 16 indicating that the crosses are stable and widely adapted over environments, further crosses CMS 234A XEC- 601957, PET 89-1A X EC-623023 and PET 2-7-1A X R-271-1 were stable and of below average stability tend to respond favorably to better environment. Stable hybrids for filled seed percentage in sunflower were also reported by Rukminidevi *et al*. (2006) and Reddy (2009).

Stability studies in lines revealed that all lines recorded below average stability (bi>1) for oil content (Table 5). Similarly, EC-623016, EC-601924 and 6D-1R besides having higher oil content showed below average stability (bi>1), however R 16, RHA 138-2 were of above average stability and adoptability to poor environment. High oil percentage than checks, regression less than unity (bi<1) and least deviation from regression was observed in 13 hybrids including CMS 234A X IC-294064, , ARM 249A X RHA 138-2 and ARM 249A X R-271-1. The above environment specific hybrids can suitably be exploited for better oil yield. Seetharam *et al*. (1980) also reported that sunflower hybrids in general had greater specificity of adaptation to favorable environments. Total 4 hybrids manifested below average stability in which, the hybrids CMS 234A XEC- 601957, CMS 234A X EC-601924, ARM 249A X EC-623023 and PET 2-7-1X 6D-1R expressed high oil content than both the checks, thus found better under favorable condition. While, average stability was recorded by CMS 234A x RHA 138-2.

For hull content among parents, CMS 234B, PET 89-1B and PET 2-7-1B (lines) and R-271-1 and RHA 138-2 had (bi) value more than unity and least non-significant magnitude of S^2di concluded a stable and widely adopted to rich environment, above average stability was observed in 6D-1R, EC-601957 and EC-601924 (bi>1). For hull content, out of 40 hybrids 5 *viz.* CMS 234A X EC-601924, 234A X 6D-1R, 234A X R 16, ARM 249A X IC-294064 and ARM 249A X EC-6230323 showed significantly lower hull content than check LSFH 171, by less than unity and least deviation of non-linear components confirmed above average stability and specific adaptation to poor environment. Eight hybrids exhibited below stability which includes CMS 234A X EC-623023, and ARM 249A X 6D-1R found suitable for specific environmental conditions could be exploited for lower hull content. Cross CMS 234A X RHA 138-2 found widely stable with bi around unity and non-significant S^2di.

For volume weight, above average stability (bi<1) was observed in CMS 234B, ARM 249B and PET 2-7-1B (lines) and RHA 138-2 (testers) (Table 5). All these parents exhibited mean at par with check LSFH 171. The tester R 16 manifested average stability over environment whereas, IC-294064, EC-623016, RHA 1-1 and 6D-1R although exhibited above average stability (bi<1). Among hybrids, CMS 234A X RHA 138-2, 234A X R 16, ARM 249A X EC-601957, ARM 249A X RHA 138-2, PET 89-1A X EC-623023, and PET 2-7-1A X R 16 showed above average stability with significantly higher mean than both checks and wide adaptation to poor environment, whereas 3 hybrids namely CMS 234A X R-271-1, PET 89-1A x RHA 138-2 and PET 2-7-1A x EC-623023 found widely adopted over environment. Below average stability was observed in CMS 234A X EC- 601957, ARM 249A X EC-6230323 and PET 2-7-1A X RHA 138-2 thus found adaptable to favorable or rich environments and can be exploited for volume weight as theses had also recorded significantly higher mean than both checks.

Table 5 revealed that for seed yield, parents PET 2-7-1B, ARM 249B among lines and R 16, EC-601957 and EC-623023 were stable and indicated greater resistance to environmental change (above average stability) and therefore increasing specificity to poor environment. Cross combinations ARM 249 X RHA 271-1 was with significantly higher mean than check LSFH 171 and regression coefficient less than unity indicated stable and wide adaptability to poor environment, further, cross combinations, *viz*. PET 2-7-1A x RHA 138-2, PET 89-1A x RHA 271-1, PET 89-1A x RHA 138-2, ARM 249A x R 16, ARM 249A x EC 601957, ARM 249A x EC 623016, ARM 249A x IC294064 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. Greater specificity of adoptability of hybrids to favorable environments for seed yield was also reported by Seetharam *et al*. (1980) and Pathak and Dixit (1984). However, crosses CMS 234A x EC 601957, CMS 234A x RHA 138-2, CMS 234A x R 16 and ARM 249A x EC 623023 found stable across environments

Shaw *et al*. (1990) reported hybrids with high mean seed yields and highest sensitivity (bi>1) have performed best in the sunflower growing areas. However, hybrids with low seed yield and low sensitivity (bi<1) are poorly adapted to most of the sunflower growing environments. Sheoran *et al.* (2012) observed more adoptive and stable hybrids with high mean, regression coefficient (bi) around unity and deviation from regression coefficient (S^2di) around zero for seed yield and supported by Mijic *et al*. (2007) in a study on sunflower, average and above average stability for seed yield.

Comparative study of four stable hybrids *viz*. CMS 234A x RHA 138-2, CMS 234A x EC 601957, CMS 234A x R 16 and ARM 249A x EC 623023 had high seed yield and stability for at least 4 characters. It is evident from Table 6 that stability of hybrids might have resulted due to stability for various components traits. Fifteen hybrids had higher mean than average yield, non-significant deviation, mean square (S^2di) with high, low or unit regression values therefore, categorized then as stable, better for good environment and poor environment. The stability of genotypes revealed that none of the parents and hybrids were found to be ideal for better as well as poor management condition for all the characters. In general, the hybrids found stable for seed yield also depicted stability in respect of its one or more yield component traits. This indicated that the stability of various components traits might be responsible for the observed stability of different hybrids for seed yield. The chances for selecting of stable hybrid could be strengthen by selection in favor of stability in individual component.

The characterization of cross combination with high mean, high heterosis, desirable SCA effects with stability over environments is of immense value in hybrid breeding programme. In the resent investigation hybrids CMS 234A x RHA 138-2, CMS 234A x EC 601957, CMS 234A x R 16 and ARM 249A x EC 623023 had high *per se*, high heterosis (Dhutmal *et al*. 2021a & b) and desirable SCA effects for seed yield and some of its component's traits.

CONCLUSION

Highly significant differences due to genotypes and environments indicating presence of variation for all the characters. Significant G x E interaction component for all the traits except for volume weight, indicating differential response of genotypes to environmental changes.

Stability studies for lines revealed that all lines recorded below average stability (bi>1) for oil content while for seed yield, PET 2-7-1B, ARM 249B among lines and R 16, EC-601957 and EC-623023 among testers were stable and indicated greater resistance to environmental change (above average stability). From the present investigation on stability hybrids identified for early maturity were CMS 234A XEC- 601957 and ARM 249A X EC-6230323. Among the crosses, CMS 234A XEC- 601957, CMS 234A X RHA 138-2, 234A X R 16, ARM 249A X EC-6230323, ARM 249A X RHA 138-2 and ARM 249A X R-271-1 found stable for seed yield and important component character in a study on sunflower hybrids for adoptability and stability revealed that complete hybrid stability over all parameters was not proved.

For seed oil content, stable hybrids with high heterosis and positive SCA effects were recorded in crosses CMS 234A X RHA 138-2 and ARM 249A X EC-6230323. Stable hybrids for yield and oil were CMS 234A X RHA 138-2 and ARM 249A X EC-6230323.

Table 2. Analysis of variance for stability in hybrids and parents in sunflower

Sources of Variation	DF	Days to FF	Plant Height	Head diameter	Seed filling percentage	Oil content	Hull%	Vol. Weight	Yield
Rep within Env.	6	0.32	8.27	0.29	2.61	0.67	1.22	1.39	13.299
Varieties	55	20.62**	1211.09**	18.15**	123.1**	27.61**	16.86	22.67**	291.423**
Env. + (Var.* Env.)	112	19.86**	442.78	1.75**	40.22*	6.15**	14.06**	8.18**	95.897**
Environments	2	801.93**	11324.69 **	29.66**	365.53**	3.29	10.41	54.73***	1638.766**
Var.* Env.	110	5.64**	244.93	1.24*	34.31	6.2	14.13	7.34	67.845
Environments (Lin.)	1	1603.87**	22649.38 **	59.33**	731.06**	6.59	20.83	109.46**	3277.533**
Var.* Env. (Lin.)	55	8.67**	131.31	1.65**	44.48*	6.43**	11.86	8.43**	57.56**
Pooled Deviation	56	2.57**	352.14**	0.82**	23.70**	3.36	16.1	4.13**	30.734
Pooled Error	330	0.43	11.82	0.32	2.31	1.02	1.2	1.08	6.925
Total	167	20.11	695.82	7.15	67.54	13.21	14.98	12.95	160.292

*Significant at 5% level and **significant at 1% level

Figure: Heatmap for Table 2

Table 3. Mean and range of different characters for lines, tester and hybrids in sunflower

Characters	Environments	GM	Parents					
			Testers		Lines		F_1	
			Mean	Range	Mean	Range	Mean	Range
Days to flowering	E_1	55.17	57.5	52.67-63.33	57.33	54.67-59.33	54.27	46.00-63.33
	E_2	58.91	60.37	54.00-65.67	59.00	56.67-62.67	58.42	52.33-63.67
	E_3	62.70	63.08	56.50-66.50	64.33	62.50-67.00	62.17	56.67-66.00
	P	58.89	60.32	54.9-63.06	60.22	58.28-63.00	58.28	53.44-63.11
Days to maturity	E_1	82.54	85.2	75.67-94.33	80.83	60.00-91.33	81.91	72.67-93.33
	E_2	86.8	88.47	85.33-92.00	87.00	83.00-90.00	86.51	80.67-90.33
	E_3	95.09	94.47	91.00-97.50	96.33	91.50-98.33	94.96	90.33-99.00
	P	88.19	89.38	85.17-94.44	88.06	81.56-92.44	87.79	82.39-92.06
Plant height	E_1	154.7	127.55	101.10-160.70	137.71	130.00-154.83	164.35	124.40-211.87
	E_2	175.40	146.31	135.07-166.66	151.51	128.41-177.33	186.36	154.37-227.67
	E_3	148.35	120.6	70.33-153.00	132.17	112.17-159.67	158.14	120.00-192.67
	P	160.1	131.50	123.00-142.50	140.48	123.60-163.90	169.62	146.80-203.30
Head diameter	E_1	17.65	13.45	10.35-16.54	14.01	12.11-15.83	19.22	16.11-22.07
	E_2	16.46	13.25	11.13-14.60	12.98	11.83-14.47	17.74	14.30-20.97
	E_3	16.38	13.52	11.33-15.83	13.54	12.67-14.17	17.51	14.00-21.12
	P	16.92	13.50	11.53-15.27	13.51	12.65-14.18	18.15	15.39-21.06
Seed setting percentage	E_1	83.15	79.67	63.00-89.67	80.50	64.00-87.00	85.02	75.-93.00
	E_2	81.45	68.53	51.0-80.67	78.92	76.00-82.00	85.32	76.00-93.00
	E_3	78.2	67.5	59.00-78.00	68.83	61.00-84.00	81.99	68.00-88.00
	P	81.17	71.90	62.67-80.3	76.08	74.67-77.44	84.11	76.00-90.11
Oil %	E_1	34.37	32.57	28.10-36.26	31.74	30.65-32.80	35.17	25.32-4.70
	E_2	34.03	31.26	28.33-35.48	30.08	29.27-31.23	35.26	24.36-40.23

	E_3	33.89	31.56	29.42-34.73	31.00	29.66-32.43	34.86	24.31-40.20
	P	34.17	31.80	29.95-35.12	30.94	29.99-32.15	35.10	28.33-39.62
Hull %	E_1	29.94	29.48	23.73-33.67	28.75	22.49-30.57	30.16	23.91-42.45
	E_2	30.53	31.39	25.87-35.68	32.15	31.03-34.70	30.11	24.45-40.34
	E_3	29.64	32.45	29.21-36.80	27.38	26.30-28.81	29.01	20.35-36.40
	P	30.03	31.11	29.88-33.12	29.33	27.83-30.23	29.76	24.74-34.50
Volume weight	E_1	32.41	29.2	25.80-33.52	29.63	28.43-30.90	33.61	21.92-37.96
	E_2	30.60	28.57	24.10-31.55	30.44	25.63-32.96	31.12	21.71-36.97
	E_3	30.99	30.33	28.00-33.00	31.22	29.33-32.46	31.09	20.28-38.42
	P	31.37	29.57	26.26-31.43	30.43	28.95-32.11	31.44	26.02-37.04
100-seed weight	E_1	5.5	4.68	3.03-5.43	4.55	3.85-5.36	5.93	3.22-6.77
	E_2	4.78	4.37	3.77-5.20	4.28	3.50-4.80	4.94	3.06-6.80
	E_3	4.64	4.28	3.21-4.84	4.35	3.68-4.90	4.79	2.55-6.74
	P	5.01	4.44	3.88-5.06	5.39	3.82-4.73	5.22	4.06-6.23
Biological yield	E_1	165.01	109.51	72.98-138.30	120.03	95.17-120.03	184.73	133.96-244.93
	E_2	155.45	107.37	82.92-119.20	114.35	109.00-120.99	172.97	133.00-210.15
	E_3	139.28	108.38	79.00-127.00	123.50	91.03-148.00	149.8	113.00-189.00
	P	154.4	108.41	91.90-119.70	119.30	111.00-128.70	169.16	136.70-208.60
Harvest index	E_1	28.91	29.1	25.13-33.41	28.37	22.51-30.72	28.94	20.65-38.86
	E_2	29.22	28.23	24.73-30.97	27.29	25.39-28.94	29.7	20.79-36.09
	E_3	27.89	28.58	20.81-39.12	25.73	19.43-35.90	27.94	19.10-39.88
	P	25.69	28.64	25.83-32.41	27.13	23.63-31.56	28.66	23.47-35.08
Seed yield	E_1	48.11	35.54	22.45-49.05	38.56	28.53-45.01	52.5	24.40-67.36
	E_2	46.05	33.16	26.74-43.72	31.42	27.67-34.10	51.17	26.44-65.53
	E_3	38.01	30.47	25.89-35.63	30.20	26.76-32.58	40.99	20.98-63.18
	P	44.37	33.05	28.74-38.37	33.39	28.62-37.17	48.22	32.37-63.55

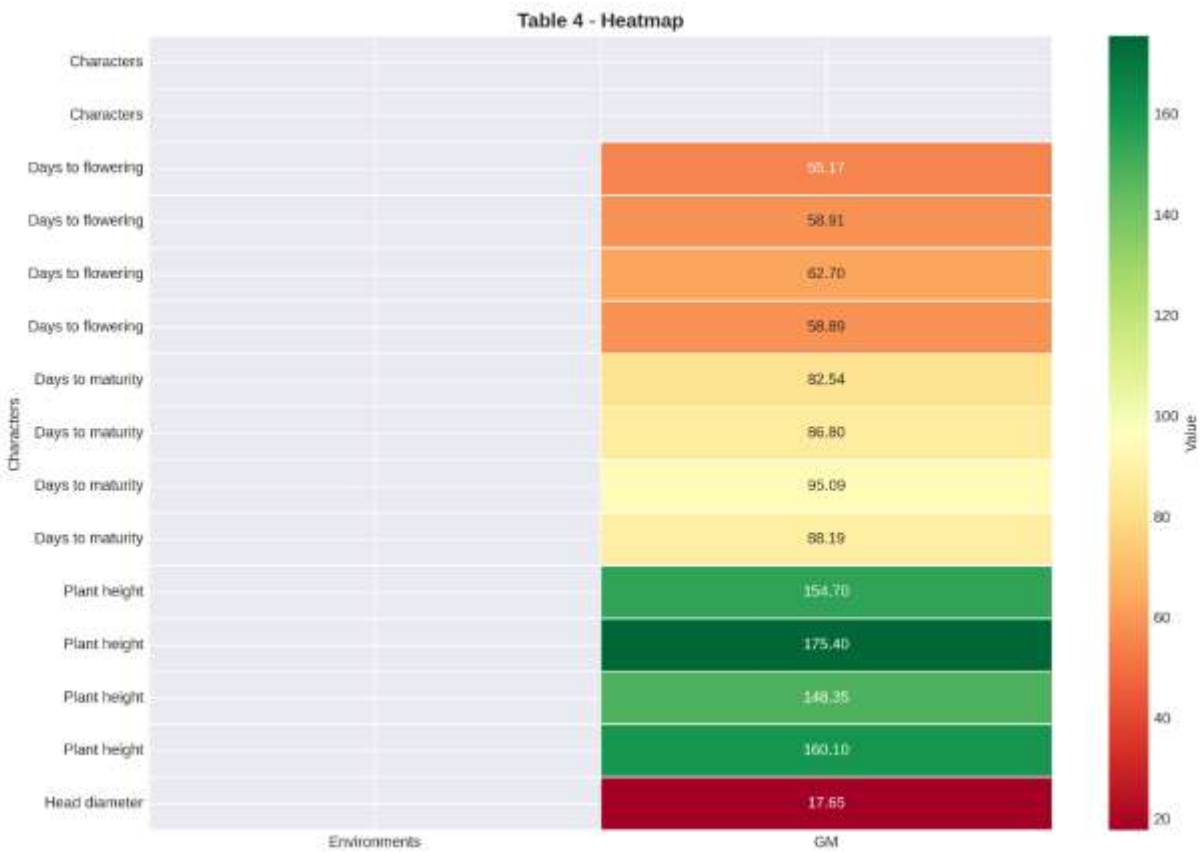


Figure: Heatmap for Table 4

Table 4. Estimation of stability parameters in sunflower hybrids and parents for days to 50% flowering, days to maturity, plant height and head diameter under three environments

Genotype	Days to 50% flowering			Days to maturity			Plant height			Head diameter		
	μ	b	S²di	μ	b	S²di	μ	b	S²di	μ	b	S²di
1 x 1	57.17	1.43	-0.39	86.72	1.40	-0.99	160.30	1.48	-1.40	18.59	0.768*	-0.33
1 x 2	56.33	1.762*	-0.43	86.72	1.67	4.94*	155.50	0.80	5.30	15.39	2.712*	-0.32
1 x 3	54.94	1.78	3.46**	84.17	1.28	1.89	158.90	0.69	253.9**	16.61	2.57	-0.28
1 x 4	56.56	1.50	1.41*	86.28	1.53	0.19	182.50	0.90	1136.9**	18.26	1.76	0.27
1 x 5	55.11	2.25	1.79*	85.17	1.92	8.66**	174.20	1.20	236.2**	17.64	-1.38	-0.27
1 x 6	58.44	1.72	4.90***	87.61	1.54	4.64*	169.30	0.52	656.8**	15.91	1.09	0.28
1 x 7	53.44	2.11	1.42*	82.50	1.52	1.72	156.70	0.00	1695.6**	18.61	1.14	-0.33
1 x 8	55.33	1.762*	-0.43	84.67	1.36	12.79**	157.00	0.74	767.8**	17.77	1.63	4.22**
1 x 9	55.17	1.56	0.61	84.39	1.15	7.43**	146.80	1.73	144.4**	18.41	0.381*	-0.33
1 x 10	55.89	1.23	1.414*	85.44	1.03	2.23	159.50	1.32	109.2**	15.42	2.73	-0.28
2 x 1	61.17	0.82	-0.06	91.44	0.96	9.22**	180.20	0.85	210.6**	19.24	1.33	0.33
2 x 2	59.83	0.73	-0.39	89.89	1.18	10.69**	162.10	0.72	1425.7**	16.24	2.99	-0.26
2 x 3	54.78	1.76	0.75	85.50	1.603*	-1.14	159.30	0.91	184.9**	16.75	2.02	-0.13
2 x 4	60.56	0.75	0.47	91.44	1.06	-0.14	186.40	1.47	798**	18.30	1.64	1.75*
2 x 5	61.67	0.48	1.07	91.39	0.80	3.52*	158.50	1.18	-3.00	17.89	-0.13	1.50*
2 x 6	61.00	0.88	0.23	90.22	0.93	0.64	181.20	0.08	548.2**	16.93	2.07	-0.29
2 x 7	61.00	-0.31	7.73**	91.50	0.17	6.91**	157.20	1.21	228.1**	18.95	0.19	0.63
2 x 8	59.11	1.15	-0.36	88.56	1.34	-0.66	164.30	0.26	786.6**	18.18	1.41	0.84
2 x 9	59.33	0.40	7.73**	88.00	0.49	3.45*	159.70	0.52	177.1**	19.10	0.55	0.29
2 x 10	58.22	0.62	1.41*	88.06	0.73	0.91	165.40	0.78	95.5**	16.82	0.83	-0.24
3 x 1	61.44	1.37	1.80*	90.78	0.83	1.97	179.80	1.61	342.7**	20.47	1.15	0.36
3 x 2	58.94	1.61	1.23	87.67	1.70	0.66	181.30	2.05	-2.20	17.19	4.23	1.57*
3 x 3	58.61	1.04	-0.43	89.22	0.73	-0.47	169.70	1.52	49.8*	17.47	0.62	1.90**
3 x 4	62.56	0.48	0.47	90.78	0.69	1.29	201.50	1.45	485.6**	20.56	-0.48	-0.07
3 x 5	59.67	0.31	-0.27	88.89	0.79	0.13	203.30	1.36	144.9**	19.13	0.65	-0.27
3 x 6	63.11	0.84	0.03	92.06	0.68	6.47*	199.20	1.59	252**	17.81	2.78	2.68**
3 x 7	58.17	1.34	2.93**	86.83	1.10	8.58**	177.90	0.50	368.8**	19.34	1.58	2.30**
3 x 8	60.89	0.49	2.69**	89.50	0.81	0.95	177.20	0.86	-11.70	19.19	2.34	-0.18
3 x 9	59.11	1.22	0.75	87.33	0.76	-0.62	191.60	1.15	21.90	20.84	0.52	-0.27
3 x 10	57.61	1.34	3.46**	87.67	1.05	-0.94	156.30	1.05	10.40	16.93	1.73	0.74
4 x 1	61.44	0.22	2.69**	91.56	0.25	36.15**	166.80	0.72	6.90	21.06	1.24	-0.07

4 x 2	60.11	0.93	0.48	89.83	0.69	9.733**	165.80	0.95	-11.50	16.60	1.07	0.08
4 x 3	53.72	1.30	-0.32	82.39	1.472*	-1.15	148.00	1.17	58.6*	17.07	0.96	-0.02
4 x 4	57.44	0.93	4.91**	87.67	0.71	2.48	169.60	3.03	311**	19.37	3.16	0.01
4 x 5	57.72	1.42	-0.21	85.94	1.38	10.53**	166.00	1.10	-5.80	18.66	0.98	0.61
4 x 6	59.06	0.90	5.2328**	88.17	0.95	15.91**	178.10	1.56	80.1**	17.40	0.16	-0.28
4 x 7	55.78	0.18	-0.14	86.56	0.46	3.05	166.10	0.95	429.6**	20.65	0.97	0.41
4 x 8	57.78	1.06	-0.14	87.17	1.11	-0.02	156.10	0.18	619**	18.08	2.65	-0.24
4 x 9	57.94	0.64	7.35**	88.50	0.52	1.04	164.10	0.96	-9.90	20.28	0.21	0.14
4 x 10	55.17	1.39	4.60**	83.50	1.27	5.3531*	171.40	1.11	-0.90	17.03	-0.98	3.52**
PET 2-7-1B	59.39	0.55	5.90**	89.50	0.26	-0.76	133.90	0.65	30.80	12.65	-0.73	1.88**
PET 89-1B	60.22	0.97	0.75	81.56	2.86	104.87**	123.60	0.43	111.7**	14.01	2.20	-0.10
ARM 249B	63.00	1.01	-0.27	92.94	0.54	6.83	163.90	0.76	37.2*	13.20	1.11	0.56
CMS 234B	58.28	1.17	1.47	88.22	1.23	0.11	140.50	0.96	43.90	14.18	-0.32	-0.27
R 16	58.89	1.15	-0.14	90.22	0.68	-0.59	142.50	1.59	30.70	14.76	-0.56	1.09*
6D-1R	63.06	-0.33	9.79**	91.78	-0.108*	-1.15	134.70	-0.14	467.4**	13.24	1.98	0.67
RHA 1-1	61.33	1.28	-0.27	88.89	0.86	-0.78	126.10	1.27	87.1**	12.56	-1.06	0.11
R-271-1	54.39	0.51	-0.21	85.44	1.06	6.27*	135.90	1.15	141.6**	13.32	0.34	0.61
RHA 138-2	61.39	0.815*	-0.43	89.83	0.62	0.60	137.30	0.10	284**	13.66	0.95	0.77
EC-601924	61.11	0.84	9.35**	91.22	0.92	2.66	133.20	0.89	21.40	11.61	-1.59	1.79**
EC-601957	59.22	0.66	1.80*	85.17	1.46	4.72*	129.70	-0.09	1374.5**	13.78	-0.52	0.00
EC-623016	63.06	0.42	20.35**	94.44	0.26	5.79*	123.60	1.67	33.38**	15.27	1.51	-0.31
EC-623023	62.33	0.97	-0.43	89.72	1.02	5.88*	123.30	1.68	63.5*	14.32	0.37	0.80
IC-294064	58.39	1.08	-0.43	87.06	0.61	-0.54	128.70	1.23	455.3**	11.53	-1.03	0.65
LSFH 171 ©	62.11	1.59	-0.36	90.22	1.03	0.24	155.90	1.09	-11.50	17.06	1.14	-0.33
LSFH 35 ©	60.44	1.59	1.42*	90.89	1.10	-0.72	150.70	1.05	-9.80	16.69	1.38	-0.23

Table 5. Estimation of stability parameters in sunflower hybrids and parents for seed filling percentage, oil content, hull content and volume weight under three environments

Genotype	Oil content			Hull content			Volume weight			Seed yield		
	μ	b	S²di	μ	b	S²di	μ	b	S²di	μ	b	S²di
1 x 1	30.14	6.033	-0.89	32.15	-2.26	32.16**	35.59	-0.68	0.1733	40.40	1.26	53.28**
1 x 2	38.41	3.253	5.08*	26.27	-0.85	0.38	28.89	2.97	16.74**	37.08	1.46	57.05**
1 x 3	28.32	12.905	4.68**	31.65	-1.69	3.39	28.35	4.72	60.25**	42.94	2.19	248.51**
1 x 4	30.11	-18.244	-0.46	32.46	10.42	65.24**	32.78	-0.26	21.87**	43.00	-0.29	235.39**

1 x 5	29.39	3.294	-1.0	31.75	3.72	1.62	34.71	2.21	-0.85	51.89	2.07	14.04
1 x 6	36.27	7.248	1.64	30.23	8.57	26.40**	28.03	2.40	2.28	32.37	1.81	-3.06
1 x 7	34.01	0.163	-1.01	30.11	-6.68	9.64**	32.11	-3.00	16.74**	46.07	-0.39	311.48**
1 x 8	33.04	-5.568	-0.91	31.25	8.33	9.63**	28.52	4.56	2.80	33.99	0.15	15.81
1 x 9	35.47	-2.301	28.60**	29.66	-8.58*	-1.20	34.39	1.18	2.51	44.20	0.43	116.96**
1 x 10	33.54	0.133	0.51	33.02	-5.64	124.49**	26.39	4.53	3.40*	38.49	2.38	4.92
2 x 1	37.25	-8.103*	-0.97	28.22	-1.36	7.19**	32.91	0.55	7.09**	49.83	0.12	98.66**
2 x 2	39.49	-2.047	-0.77	27.02	5.85	-1.05	27.48	4.11	2.71	36.41	1.96	72.63**
2 x 3	32.14	7.074	84.57**	32.83	-2.92	-0.26	31.04	3.36*	-1.06	39.53	1.39	423.76**
2 x 4	36.95	-4.331	3.62*	27.30	8.25	2.02	29.25	2.98	9.69**	50.92	1.27	81.17**
2 x 5	35.21	5.59	-0.46	29.4	-7.44	16.53**	33.83	0.95	-0.83	50.29	1.31	-6.83
2 x 6	39.12	-2.295	0.31	25.41	1.22	-0.03	31.73	5.26	-0.20	45.83	2.12	59.11**
2 x 7	36.67	-3.528	2.38	30.52	-0.85	17.53**	30.93	2.48	14.16**	52.68	0.69	33.14**
2 x 8	31.55	8.909	0.00	33.93	-2.94	5.65*	30.53	3.09	5.86*	43.48	0.26	5.04
2 x 9	38.98	-4.939	-0.58	26.06	13.82*	-0.99	34.3	-0.70	0.82	47.59	1.09	37.44**
2 x 10	34.36	-30.586	11.48**	34.49	2.03	34.72**	26.02	2.84	35.66**	36.80	-0.58	245.08**
3 x 1	31.32	12.14	12.28**	28.66	3.57	12.17**	34.21	2.58	7.91**	58.51	1.57	9.18
3 x 2	38.31	-4.392	0.64	27.74	2.20	-0.97	31.54	1.78	0.48	47.68	2.44	-4.70
3 x 3	34.73	5.869	1.89	31.76	11.49	36.25**	32.37	3.29	3.40*	48.26	3.32*	-6.99
3 x 4	37.28	-2.152*	-1.01	30.00	-2.25	9.47**	33.73	0.46	-1.03	58.18	0.32	-3.34
3 x 5	36.12	-0.742	1.62	29.67	-0.12	20.84**	35.1	-0.34	-0.98	61.50	2.20	4.17
3 x 6	38.13	11.708	2.56	25.84	0.35	3.93*	27.53	-4.68	4.34*	44.76	1.97	55.15**
3 x 7	35.09	2.239	13.38**	28.95	1.17	6.65**	34.42	0.35	-0.56	53.35	1.59	11.23
3 x 8	32.34	8.078	1.11	32.23	1.51	1.98	32.37	2.48	-1.05	52.02	2.21	13.06
3 x 9	37.58	1.11	0.782	27.39	-0.015	1.73	35.28	2.38*	-1.091	62.71	1.12	-6.62
3 x 10	32.06	14.18	31.01**	30.77	-12.15	-0.52	31.68	1.33	0.369	52.94	1.42	-6.49
4 x 1	34.22	0.984	2.83	25.64	-0.53	-0.67	35.13	0.69	-0.36	62.67	1.16	-6.08
4 x 2	39.62	-0.455	-0.89	24.73	-0.20	-0.14	30.65	-0.40	-0.93	38.08	0.24	327.96**
4 x 3	34.66	9.738	0.36	32.60	9.56	23.78**	30.06	-0.59*	-1.09	42.58	1.87	97.57**
4 x 4	33.79	3.842	44.08**	31.24	-2.78	72.27**	34.43	1.18	2.76	53.75	0.68	35.37**
4 x 5	36.72	1.147	-0.80	28.91	1.13	-0.17	37.04	-0.28	1.63	63.55	1.12	-1.60

4 x 6	37.92	2.041	2.38	25.78	-3.34	-0.83	27.96	-2.13	21.96**	47.31	2.32	22.56**
4 x 7	34.68	3.474	-0.92	30.16	-3.60	27.89**	36.04	1.53*	-1.09	63.07	1.27	-6.62
4 x 8	34.86	6.068	8.89**	33.71	9.27	42.55**	33.02	2.12	-0.58	52.97	0.48	67.18**
4 x 9	37.16	-3.822	-0.97	28.63	2.90	3.05	34.47	2.33	-1.06	56.35	2.12	-0.66
4 x 10	36.69	-0.534	-0.31	31.99	6.24	28.30**	32.74	-0.43	-0.69	44.89	-0.19	318.79**
PET 2-7-1B	32.15	1.33	0.10	29.60	4.90	0.03	31.16	-2.37	-0.91	28.62	-0.15	-6.34
PET 89-1B	30.31	3.08	0.22	29.63	4.05	0.93	28.95	1.81	9.05**	33.85	1.23	1.97
ARM 249B	29.99	2.21	-0.95	27.83	11	31.78**	29.5	-0.82	-0.70	33.93	0.51	0.86
CMS 234B	31.28	1.64	0.75	30.22	2.86	-0.89	32.11	-1.08*	-1.08	37.17	0.91	0.61
R 16	30.74	-1.24	1.29	30.15	-1.97	11.02**	30.96	1.13	0.29	38.87	-1.02	-3.49
6D-1R	34.78	3.51	-0.78	29.88	0.03	-1.13	28.59	-1.33	1.40	28.74	0.96	120.21
RHA 1-1	30.60	5.85*	-1.00	30.95	2.95	5.99*	28.98	0.22	0.25	32.84	-0.10	200.87**
R-271-1	33.58	1.94	7.77**	29.98	3.72	1.39	31.43	-0.51	2.10	30.27	0.61	11.02
RHA 138-2	29.94	-5.56	0.87	31.58	2.97	2.69	30.44	-2.39	0.09	37.26	0.85	79.80**
EC-601924	35.12	5.13	-0.44	32.29	-5.45	3.40	26.26	-0.09	4.46**	29.34	0.76	87.56**
EC-601957	30.79	9.078	5.19**	33.12	-6.02*	-1.15	28.82	2.28	22.75**	31.39	0.14	-2.30
EC-623016	31.05	7.456	-0.29	31.70	-0.56	96.40**	28.93	0.26	0.28	35.37	1.73	106.74**
EC-623023	30.38	3.491	-0.98	30.85	-10.2	-0.24	31.17	2.07	-1.06	36.10	0.20	0.81
IC-294064	30.93	-5.711	6.37**	30.55	6.49	44.98**	28.09	-1.4	10.07	30.38	0.35	220.53
LSFH 171 ©	35.34	0.854	-0.93	30.86	-1.39	-0.6	31.58	0.11	-0.60	46.51	1.36	-6.84
LSFH 35 ©	32.92	2.331	-1.02	32.26	-3.91	-0.88	32.4	0.83	-0.09	45.19	1.25	-6.89

Table 6. Stable hybrids identified on the basis of high mean for seed yield along with stability of component traits.

Hybrids	Seed yield (g)	Stable for component traits
CMS 234A x RHA 138-2	63.55	DF^{++}, PH, HD, BY^{+}, HI^{+}, Oil, H, VW $^{++}$
CMS 234A x EC 601957	63.07	DF^{++}, DM^{++}, PH, HD, Oil^{+}, VW^{+}, TW^{++}, BY^{+}, HI^{++}
CMS 234A x R 16	62.67	DH^{++}, HD, SFP, Oil H^{++}, VW^{++}, TW^{++}, BY^{+}
ARM 249A x EC 623023	62.17	DF^{+}, DM^{++}, PH, HD^{++}, SFP, Oil H^{++}, BY^{+}, HI^{+}

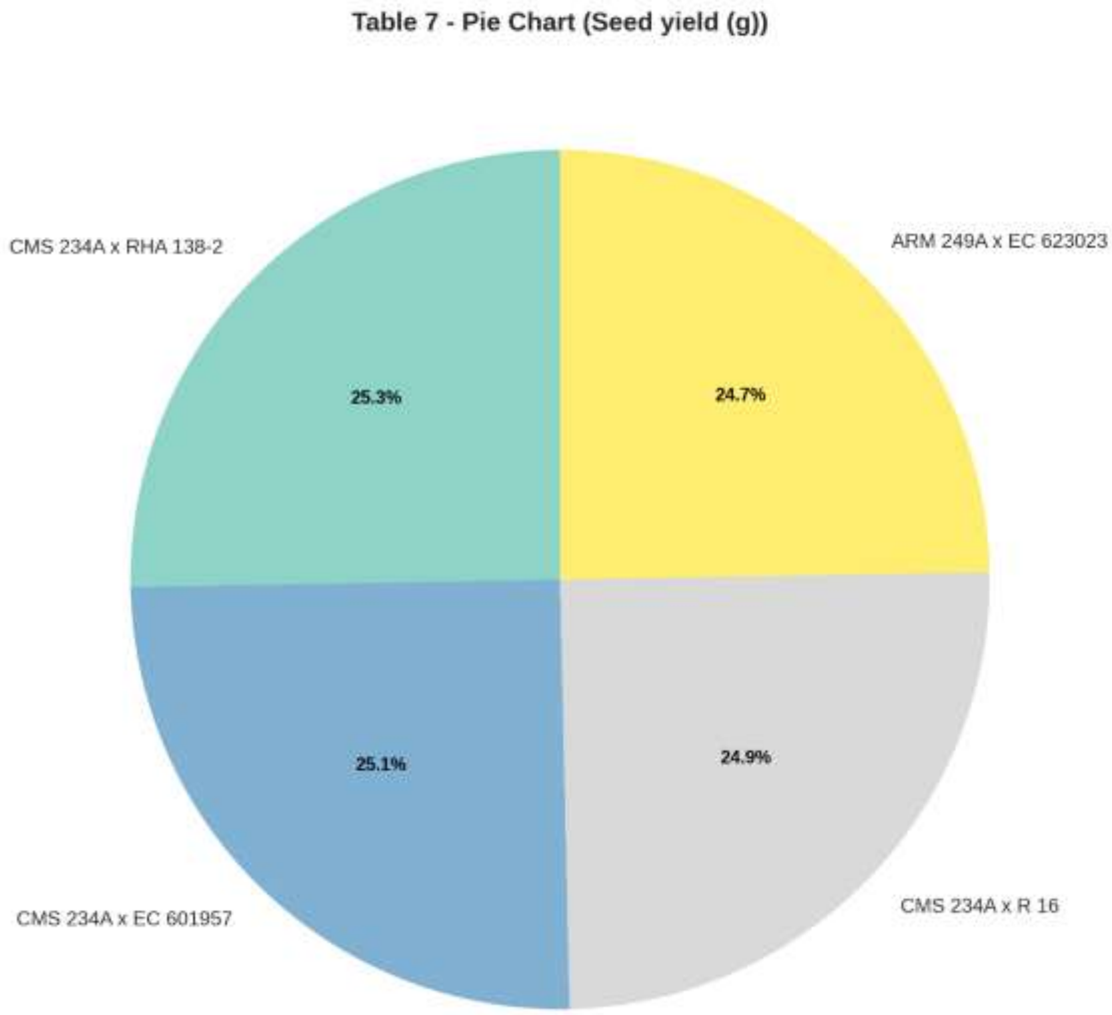


Figure: Pie Chart for Table 7

+ Better for favorable environment, ++ Better for unfavorable environment

DF=Days to 50% flowering, DM= Days to maturity, PH= Plant height, HD= Head diameter, SFP= Seed filling percentage, Oil= Oil content, H= Hull content, VW= Volume weight, TW= Test weight, BY= Biological yield, HI= Harvest index

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