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Stability of Single and Three-Way Cross Hybrids for Seed Yield and Other Important Agronomic Traits in Sunflower (*Helianthus annuus* L.)

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Abstract: A stability analysis was carried out using nine single crosses and fifteen diverse three-way crosses for nine traits across three locations *viz*., Dharwad, Annigeri and Raichur during *Kharif* 2006. The analysis of variance for stability revealed significant differences among the hybrids for all the characters except head diameter and 100 seed weight. The additive environmental variance found to be of considerable magnitude as indicated by the significance of variance due to environment (linear) for all the characters thus implying that no simple relationship existed between genotypes and the environment. The single cross hybrids CMS 17 A x RHA-95-C-1 and DCMS 51 A x RHA-6D-1 excelled in their mean performance for seed yield however, two three-way hybrids CMS 234 A x DSI-2 x RHA-6D-1 and DCMS 51 A x DSI-1017 x RHA-6D-1 regarded as the best for high seed yield besides well adaptability. Diversification of leading single cross hybrids such as RSFH-1, KBSH-44, KBSH-1 and DCMS 51 A with inbreds DSI-2 and DSI-1017 and consequent their three way crosses excelled in performance for a majority of the traits such as head diameter, number of filled seeds per head, 100 seed weight and seed yield per plant.

Keywords: stability, G x E interaction, regression coefficient, single cross hybrids, THREE-way cross hybrids

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Introduction

Sunflower (*Helianthus annuus* L.), a member of the family of Asteraceae is native to the southern part of the USA and Mexico. It is a rich source of edible oil (40 to 52 %). In India, large scale cultivation of sunflower started in the year 1972 with the introduction of high yielding Russian populations VNIIMK 8931 (EC.68413), Peredovik (EC.68414) and Armavirskii (EC.68415) which upgraded its importance later as an oilseed crop. The discovery of cytoplasmic male sterility by Leclercq (1969) became a landmark in the development of commercial hybrids. In India, the development and release of first ever sunflower hybrid BSH-1 using male sterility systems by Seetharam *et al.* (1980) gave a fillip and renewed interest in the crop. In India sunflower is grown over an area of 5.20 lakh hectares with a production of 3.35 lakh tonnes (Anonymous, 2017). The crop is mainly grown in Karnataka, Maharashtra, Andhra Pradesh, Telangana and it is upcoming in North Eastern states like Odisha, West Benagal, Bihar and Karnataka alone accounting for nearly 50 per cent of the area and production.

Yield potential and agronomic uniformity of the hybrids is the reason behind the steady replacement of populations. The hybrids synthesized and released presently in the country for commercial cultivation are Single Cross (SC) hybrids, where uniformity is a distinct advantage. Besides, hybrids are proven to be more self-fertile, resulting in increased seed set and seed filling. Hybrids are fertilizer responsive and are fairly tolerant to major foliar diseases (Sindagi *et al.*, 1979; Seetharam, 1981). However, the recent foregoing breeding knowledge reveals that seed yield of single cross hybrids have become fairly stagnant over the years and to break yield plateau new methods have been adopted. Among the different methods adopted, synthesis of three-way hybrids and their evaluation is of considerable interest (Jayalaxmi and Narendra, 2004) The three-way hybrids proved useful in sorghum (Walsh and Atkins, 1973). These three-way cross hybrids offers both individual and population buffering, while single cross hybrids have only the individual buffering (Allard and Bradshaw, 1964). The production of three-way crosses in the present study is based mainly on the diversification of genetic makeup of leading public sector hybrids like KBSH-1, KBSH-44 and RSFH-1, besides some of the promising single crosses chosen from line x tester analysis. In the present study, an attempt has been made to study the potentiality of three-way cross hybrids as against single cross hybrids and also their stability of performance for seed yield across locations.

Material and methods

Fifteen three-way cross hybrids along with eight single crosses (including public sector hybrids KBSH 1, KBSH 44, RSFH 1 and DRSH1 and one private sector hybrid SB 275 as checks) were evaluated at three locations representing different agro-climatic zones of 2,3 and 8 of Northern Karnataka *viz*., Dharwad, Annigeri and Raichur, respectively during *Kharif* 2006 in a randomized block design with three replications. The three-way and single cross hybrids were treated as separate entities and randomization was done in each entity independently using random number table. Each entry was raised in three rows plot of three metres length with a spacing of 60 cm between rows and 30 cm between plants within the row in all the three locations. Recommended agronomic practices were followed to raise a good crop. Observations were recorded from 10 competitive plants on days to flowering, plant height, head diameter, 100 seed weight, number of filled seeds per head, volume weight, hull content, oil content and seed yield per plant for each entry and the stability analysis was carried out following the procedure as suggested by Eberhart and Russell (1966).

Results and discussion

The two-way analysis of variance (Table 1) revealed that the mean squares due to genotype x environmental interactions were significant for all the characters suggesting the varying response of the genotypes to different environments, when tested against pooled error. The mean squares due to environments observed to be significant for all the characters, indicating that considerable G x E interactions operate in sunflower (Shinde *et al*., 1992; Halaswamy, 1998; Goud and Sarala, 2004).

Further, the analysis of variance for stability (Table 2) also revealed that significant differences exist among the hybrids for all the characters except head diameter and 100 seed weight. The additive environmental variance found to be of considerable magnitude as indicated by the significance of variance due to environments (linear) for all the characters. The mean squares due to pooled deviations found significant for all the characters but not the mean squares due to genotype x environment (linear) except for oil content, thus implying that there is no simple relationship exist between genotypes and the environments and therefore, it is rather difficult to predict the performance of the genotypes across environments (Mohan Rao *et al*., 2004). For oil content both genotype x environment linear (Laishram and Singh, 1997; Mohan Rao *et al*., 2004) as well as pooled deviations found significant indicating that part of the variation in the

Table 1: Analysis of variance in respect of yield and yield attributes in sunflower (*Helianthus annuus* L.)

Source of variation	D.f	Mean Squares								
		Days to 50 % flowering	Plant height (cm)	Head diameter (cm)	100 Seed weight (g)	Number of filled seeds per head	Volume weight (g/ 100 cc)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
Genotypes (g)	23	28.640**	442.262**	1.202	0.259**	2795.437**	26.856**	42.848**	14.657**	50.845*
Environment (e-1)	2	77.687**	39,607.317**	158.187**	3.014**	254,248.280**	954.970**	31.265	110.204**	7227.847**
Genotypes x Environment (g x e)	46	3.146**	95.296**	0.777**	0.095**	1178.470**	6.729**	14.315**	2.559**	25.179**
Pooled error	138	0.775	7.131	0.115	0.014	252.058	0.838	0.766	0.144	6.750

*Significant at 5 % level
**Significant at 1 % level

Table 2: Analysis of variance for Stability (Eberhart and Russell, 1966) for seed yield and yield attributes in sunflower (*Helianthus annuus* L.)

Source of variation	D.f	Mean Squares								
		Days to 50 % flowering	Plant height (cm)	Head diameter (cm)	100 Seed weight (g)	Number of filled seeds per head	Volume weight (g/ 100 cc)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
Genotypes (g)	23	28.640**	442.262**	1.202	0.259	2795.437**	26.856**	42.848**	14.657**	50.845**
Environment (e-1)	2	77.687**	39,607.317**	158.187**	3.014**	254,248.280**	954.970**	31.265	110.204**	7227.847**
Genotypes x Environment (g x e)	46	3.146	95.296	0.777	0.095	1178.470	6.729	14.315	2.559*	25.179
Environment + (g x e)	48	6.252	1741.630	7.336	0.217	11,723.045	46.239	15.021	7.044	325.290
Environment (Linear)	1	155.408**	79,214.268**	316.376**	6.029**	508,496.770**	1909.933**	62.522**	220.414**	14,455.680**
Genotype x Environment (Linear)	23	3.640	111.829	0.824	0.099	1500.345	5.901	15.242	4.002	31.220
Pooled deviation	24	2.540**	75.496**	0.700**	0.088**	820.894**	7.242**	12.831**	1.069**	18.341**
Pooled error	138	0.775	7.131	0.115	0.014	252.058	0.838	0.766	0.144	6.750

*Significant at 5 % level
**Significant at 1 % level

performance of genotypes is predictable (Eberhart and Russell, 1966). The more pronounced linearity of this character could largely be explained by differences in regression slopes. This obviously means that accurate prediction of the phenotypic performance of the genotype is possible.

The crop breeders are interested in developing hybrids with high seed yield potential coupled with better stability over a wide range of environments, whether it is a single or three-way cross hybrid. Almost all the single crosses RSFH-1, KBSH-1, KBSH-44 and DCMS 51 A based hybrids in the present investigation excelled in their performance over environments for seed yield per plant and well adapted to the range of environments as they have shown b_i near to unity with non-significant s^2d_i values (Table 3; Figure 1). This is obvious that the check hybrids have been tested across locations before they were considered for release. Among the different hybrids evaluated the single cross hybrids CMS 17 A x RHA-95-C-1 (KBSH 44) excelled in its mean yield followed by DCMS 51 A x R-64 and CMS 103 A x R-64 (RSFH 1) indicating the superiority of single crosses over three way crosses. Among three-way hybrids, CMS 234 A x DSI-2 x RHA-6D-1 (46.29 g) and DCMS 51 A x DSI-1017 x RHA-6D-1 (46.26 g) exhibited high mean seed yield as well as better adaptability. The three-way crosses which have been synthesized from corresponding single cross hybrids by crossing with an unrelated inbred as the second parent, however, were lower in their mean *per se* performance across locations but they were as stable as single cross hybrids. The possible reason for greater stability in three-way hybrids is attributed to broadening of the genetic base enabling to possess better population buffering to overcome adverse environmental conditions. Similar findings have been reported by Vranceanu and Stonescu (1979), Sindagi *et al.* (1979), Giriraj *et al.* (1988), Naresh (1993) and Halaswamy (1998). However, a majority of the three-way crosses found to be inferior in seed yield over their corresponding single crosses despite on par excellence in their stability. The lower yield potential of three-way hybrids can be attributed to consequent reduction in level of heterozygosity with increase in heterogeneity compared to corresponding single cross hybrids (Kide *et al.*, 1985). The reduction in level of heterozygosity perhaps might be the reason for non superiority of three way crosses to out yield single crosses although heterogeneity confirmed the relative stability to them (Walsh and Atkins, 1973). Since uniformity of the sunflower hybrid is a necessity, the three way hybrids developed and released earlier by some private sector have not become so popular and been out of cultivation. Nevertheless, attempts can be made exhaustively to maintain morphological uniformity by including suitable parents in three way crosses to confer better stability for seed yield and also resistance to different biotic and abiotic stresses over single crosses.

Table 3: Stability parameters of single and three-way crosses in sunflower (*Helianthus annuus* L.)

S.No.	Hybrids	Days to 50 % flowering			Plant height (cm)			Head diameter (cm)		
		Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i
1	**CMS 103 A x R-64 (RSFH-1)**	60.67	2.45	0.93	149.64	0.77	44.06**	13.84	1.07	0.61*
2	CMS 103 A x DSI-1 x R-64	57.67	0.73	8.42**	160.75	0.98	26.92*	12.63	1.05	−0.08
3	CMS 103 A x DSI-2 x R-64	63.83	1.15	0.77	159.69	0.98	94.61**	14.72	1.31	2.34**
4	CMS 103 A x DSI-1005 x R-64	60.94	0.45	4.25*	144.07	0.96	8.71	12.95	0.92	2.59**
5	CMS 103 A xDSI-1017 x R-64	61.56	1.06	−0.67	147.56	0.96	35.95*	13.28	1.17	−0.11
6	**CMS 17 A x RHA-95-C-1 (KBSH-44)**	61.72	2.34	5.15**	175.15	1.10	32.73*	13.83	0.90	−0.06
7	CMS 17 A x DSI-1 x RHA-95-C-1	58.11	1.39	0.20	167.16	1.25	96.29**	12.64	0.85	0.50*
8	CMS 17 A x DSI-2 x RHA-95-C-1	58.83	1.12	−0.77	161.26	1.18	29.78*	13.12	1.20	1.82**
9	CMS 17 A x DSI-1005 x RHA- 95-C-1	57.89	0.84	2.05	152.30	0.97	12.37	12.94	0.94	0.14
10	CMS17 A x DSI-1017 x RHA- 95-C-1	59.22	1.14	1.12	162.58	1.01	36.36*	13.30	1.00	0.07
11	**CMS 234 A x RHA-6D-1 (KBSH-1)**	58.72	1.04	−0.26	165.73	1.03	−6.63	12.80	0.43	0.15
12	CMS 234 A x DSI-2 x RHA-6D-1	60.50	0.45	−0.57	173.00	1.06	−6.61	13.27	1.06	−0.09
13	CMS 234 A x DSI-1017x RHA-6D-1	58.67	2.28	2.69*	167.02	0.89	15.00	13.23	1.14	0.01
14	**CMS 4546 A x R-298**	51.50	0.83	−0.68	143.91	0.81	253.93**	11.86	0.84	0.43
15	CMS 4546 A x DSI-1017 x R-298	50.89	1.18	−0.45	151.64	0.61	49.67**	12.93	0.54	−0.04
16	**DCMS 51 A x RHA-6D-1**	61.83	0.74	−0.20	178.90	1.38	85.72**	13.24	1.08	−0.07
17	DCMS 51 A x DSI-1017 x RHA-6D-1	59.22	1.48	−0.70	169.63	0.72	1.28	14.33	1.46	−0.09
18	**DCMS 51 A x RHA-95-C-1**	61.28	0.96	0.75	186.79	1.23	11.37	13.35	1.08	0.16
19	DCMS 51 A x DSI-1017 x RHA-95-C-1	61.00	−1.17	16.34**	162.93	0.86	212.03**	12.96	0.86	−0.09
20	**DCMS 51 A x R-64**	63.94	1.00	3.39*	176.61	1.22	335.58**	14.28	1.10	−0.03
21	DCMS 51 A x DSI-1017x R-64	61.39	0.36	−0.70	161.37	1.06	−5.52	13.87	1.02	0.49*

(*continued*)

Table 3: (*continued*)

22	**DCMS 51 A x RHA-271**	59.06	0.03	0.90	179.63	1.13	−4.16	13.27	0.88	5.37**
23	DCMS 51 A x DSI-1017 x RHA-271	58.83	1.15	0.77	154.93	1.05	219.28**	13.95	1.48	0.03
24	GK-2002	57.28	0.99	−0.37	145.23	0.99	62.06**	13.70	0.62	−0.04
S.No.	**Hybrids**	**100 seed weight**			**Number of filled seeds per head**			**Volume weight (g/100 cc)**		
		Mean	**b_i**	**s^2d_i**	**Mean**	**b_i**	**s^2d_i**	**Mean**	**b_i**	**s^2d_i**
1	**CMS 103 A x R-64 (RSFH-1)**	4.86	0.30	−0.01	232.30	0.82	−203.22	35.94	0.37	−0.59
2	CMS 103 A x DSI-1 x R-64	4.9	1.36	−0.01	207.95	1.24	−239.78	37.32	0.83	0.12
3	CMS 103 A x DSI-2 x R-64	5.41	0.71	0.01	242.73	0.98	−214.05	32.30	0.84	−0.48
4	CMS 103 A x DSI-1005 x R-64	4.67	1.14	0.07**	172.53	0.67	−174.02	33.66	0.86	6.84**
5	CMS 103 A xDSI-1017 x R-64	4.59	0.63	−0.01	179.26	0.73	−223.17	34.90	0.75	16.77**
6	**CMS 17 A x RHA-95-C-1 (KBSH-44)**	5.59	2.30	0.34**	288.13	1.38	1013.55*	43.12	0.77	21.36**
7	CMS 17 A x DSI-1 x RHA-95-C-1	4.90	0.65	−0.01	213.57	0.96	525.33	41.06	1.23	−0.77
8	CMS 17 A x DSI-2 x RHA-95-C-1	4.75	2.37	0.17**	217.30	1.55	2117.36**	38.81	1.32	1.51
9	CMS 17 A x DSI-1005 x RHA- 95-C-1	4.81	0.90	0.00	204.97	1.17	−187.66	41.46	0.86	−0.65
10	CMS17 A x DSI-1017 x RHA- 95-C-1	4.92	0.83	0.24**	227.77	1.37	750.46*	40.20	1.21	−0.61
11	**CMS 234 A x RHA-6D-1 (KBSH-1)**	4.93	1.72	0.05*	228.70	1.19	−156.81	41.69	1.03	5.47**
12	CMS 234 A x DSI-2 x RHA-6D-1	5.14	1.36	−0.01	259.01	1.07	1907.86**	41.58	0.84	1.34
13	CMS 234 A x DSI-1017x RHA-6D-1	4.76	1.66	0.07**	198.03	1.32	718.11	40.25	1.20	3.74*
14	**CMS 4546 A x R-298**	4.58	1.29	0.09**	176.23	0.72	410.95	36.48	0.61	24.01**
15	CMS 4546 A x DSI-1017 x R-298	4.58	0.44	0.14**	168.85	0.70	−69.45	37.26	1.20	1.13
16	**DCMS 51 A x RHA-6D-1**	5.29	0.00	−0.01	252.04	0.49	766.85	40.96	0.95	−0.83
17	DCMS 51 A x DSI-1017 x RHA-6D-1	5.12	0.75	0.00	240.01	1.03	305.02	40.90	1.15	2.81*

(*continued*)

Table 3: (*continued*)

18	**DCMS 51 A x RHA-95-C-1**	5.28	1.29	0.03*	248.21	1.03	240.80	40.19	1.02	−0.18
19	DCMS 51 A x DSI-1017 x RHA-95-C-1	4.81	0.53	0.08**	210.39	1.00	942.95*	39.26	1.26	2.55*
20	**DCMS 51 A x R-64**	5.10	0.53	0.26**	213.89	0.74	175.38	37.68	0.70	21.29**
21	DCMS 51 A x DSI-1017x R-64	4.91	0.29	−0.01	214.86	0.71	−168.69	32.75	1.60	32.97**
22	**DCMS 51 A x RHA-271**	4.38	1.72	−0.01	205.12	1.09	−242.55	39.13	1.04	2.61*
23	DCMS 51 A x DSI-1017 x RHA-271	4.54	0.44	0.23**	191.03	1.03	−247.24	37.66	1.32	13.45**
24	GK-2002	4.85	0.78	0.06**	261.28	1.02	5904.06**	40.75	1.03	−0.15
S.No.	**Hybrids**	**Hull content**			**Oil content**			**Seed yield per plant**		
		Mean	**b_i**	**s^2d_i**	**Mean**	**b_i**	**s^2d_i**	**Mean**	**b_i**	**s^2d_i**
1	**CMS 103 A x R-64 (RSFH-1)**	31.32	−3.66	0.02	38.30	0.14	0.13	47.56	0.93	−3.14
2	CMS 103 A x DSI-1 x R-64	26.25	0.82	8.60**	37.67	1.06	−0.07	41.06	1.22	−6.51
3	CMS 103 A x DSI-2 x R-64	26.72	3.81	59.79**	38.57	1.3	0.86*	44.37	0.93	−0.65
4	CMS 103 A x DSI-1005 x R-64	25.55	2.29	8.06**	36.77	1.2	1.80**	36.29	0.66*	−6.66
5	CMS 103 A xDSI-1017 x R-64	27.47	1.14	7.91**	37.12	0.71	1.33**	38.59	0.82	−6.05
6	**CMS 17 A x RHA-95-C-1 (KBSH-44)**	32.56	5.24	1.23	34.52	1.1	−0.12	49.70	1.02	4.97
7	CMS 17 A x DSI-1 x RHA-95-C-1	35.31	3.57	83.76**	37.19	1.51	−0.1	43.01	1.03	29.86*
8	CMS 17 A x DSI-2 x RHA-95-C-1	33.92	1.34	−0.43	36.61	2.41	0.67*	42.88	1.36	26.81*
9	CMS 17 A x DSI-1005 x RHA- 95-C-1	34.12	0.64	1.45	34.23	1.96	8.49**	41.21	1.22	−4.88
10	CMS17 A x DSI-1017 x RHA- 95-C-1	35.87	0.62	−0.74	35.92	1.55	0.50*	45.24	1.43	2.44
11	**CMS 234 A x RHA-6D-1 (KBSH-1)**	27.54	2.9	16.57**	40.08	0.78	0.05	44.92	1.05	−5.72
12	CMS 234 A x DSI-2 x RHA-6D-1	26.38	−1.28	−0.64	40.75	0.58	1.78**	46.29	1.03	−2.38
13	CMS 234 A x DSI-1017x RHA-6D-1	24.16	−3.66	−0.09	40.50	0.69	0.48*	39.76	1.28	8.03

(*continued*)

Table 3: (*continued*)

14	**CMS 4546 A x R-298**	34.04	2.72	22.10**	34.20	1.07	0.38	37.52	0.71	8.80
15	CMS 4546 A x DSI-1017 x R-298	35.83	3.40*	−0.73	36.80	0.39	0.51*	36.38	0.82*	−6.64
16	**DCMS 51 A x RHA-6D-1**	30.56	−0.14	25.54**	40.56	1.42	−0.02	47.64	0.55	34.61*
17	DCMS 51 A x DSI-1017 x RHA-6D-1	27.62	4.07	30.02**	41.42	0.02	1.14**	46.26	1.04	8.91
18	**DCMS 51 A x RHA-95-C-1**	30.32	−1.99	7.32**	39.78	1.04	−0.14	46.11	0.89	−2.06
19	DCMS 51 A x DSI-1017 x RHA-95-C-1	27.25	−0.44	−0.76	39.35	0.83	0.06	43.19	1.15	15.83
20	**DCMS 51 A x R-64**	25.57	3.21	5.24**	41.00	0.18	0.21	41.62	0.74*	−6.55
21	DCMS 51 A x DSI-1017x R-64	26.91	0.26	13.50**	39.47	−0.46	0.45*	43.54	0.79	0.31
22	**DCMS 51 A x RHA-271**	25.02	0.71	1.60	38.55	1.84	−0.12	45.11	1.06	−4.91
23	DCMS 51 A x DSI-1017 x RHA-271	28.32	0.87	0.97	35.48	1.26	0.61*	41.51	1.25	4.02
24	GK-2002	31.95	−2.42*	−0.74	39.20	1.41	3.32**	53.05	1.03	189.76**

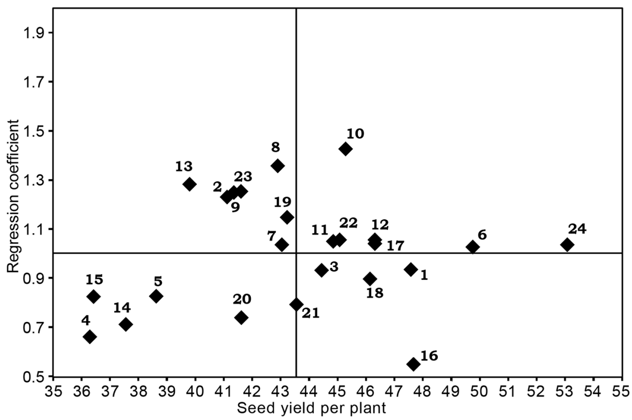

Figure 1: Relation of seed yield per plant with stability.

The mean oil content of the hybrids found to vary from location to location (Giriraj and Virupakshappa, 1992; Panduranga, 2000; Bharathi, 2000) and out of three environments, the environment at Dharwad and Raichur observed to be favorable for high oil content, although the latter found unfavourable for realizing higher seed yield. Both single and three-way of almost all the leading hybrids did not vary much for oil content except DSI- 1 and DSI-2 based three-way hybrids of KBSH-44 recording high oil content, indicating that diversification has an added value in increasing oil content. Further, in a majority of the cases the three-way crosses have shown greater instability in expression of oil content as revealed by significant s^2d_i deviations, irrespective of the b_i value being considered (Figure 2). The three-way crosses CMS 234 A x DSI-2 x RHA-6D-1 and DCMS 51 A x DSI-1017 x RHA-6D-1 also possessed higher oil content but both appeared to be unstable over environments.

As regards to hull content, three-way crosses have shown lesser hull content, in general, compared to other single crosses. However, the exceptions have been in three-way of KBSH-44, CMS 4546 A x R 298 and DCMS 51 A x RHA-271 where high hull content is being noticed. The highest mean hull content has been noticed in both single and three-way crosses of KBSH-44, which is in fact known for its high hull proportion and low oil content. Although, the hybrids have shown relative stability in terms of mean hull content across locations, a greater instability in expression of hull content is evident due to significant deviations from regression coefficient (s^2d_i).

Irrespective of single or three-way crosses, KBSH-44, KBSH-1 and DCMS 51 A based hybrids recorded better volume weight among which KBSH-44 is leading

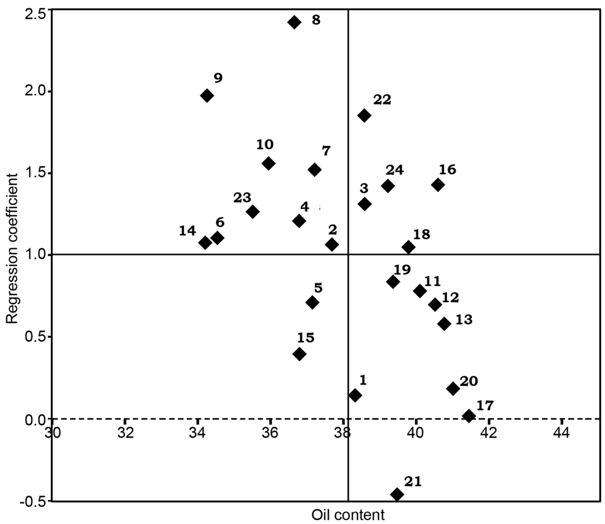

Figure 2: Relation of oil content with stability.

across the locations followed by KBSH-1. The single cross hybrids KBSH-44, KBSH-1, DSH-1, DCMS 51 A x R-64 appeared to be unstable in expression for volume weight in view of significant s^2d_i and the above findings are in conformity with the earlier reports of Laxman and Kallennawar (1999) and Bharathi (2000). The three-way hybrids CMS 17 A x DSI-1005 x RHA-95-C-1, CMS 234 A x DSI-2 x RHA-6D-1 found suitable to all the environments with well adaptability besides high mean value.

For number of filled seeds per plant, KBSH-44 followed by DCMS 51 A x RHA-6D-1 and DCMS 51 A x RHA-95-C-1 shown the highest mean across locations. The fluctuating environments, however, had a bearing on the stability of KBSH-44 and two of its three-way hybrids (DSI-2 and DSI-1017 based) profoundly than RSFH-1 and three-way crosses, so also CMS 4546 A x R 298 and DCMS 51 A based hybrids in which s^2d_i found significant.

The mean seed weight across locations did not vary much between single and three-way crosses except in case of KBSH-44 and its three-way hybrids. The single and three-way crosses of KBSH-44, KBSH-1, CMS 4546 A x R 298 and DCMS 51 A x RHA-95-C-1 hybrids found to have significant s^2d_i, thus can be considered as unstable. The three-way crosses CMS 103 A x DSI-2 x R-64, CMS 234 A x DSI-2 x RHA-6D-1 and DCMS 51 A x DSI-1017 x RHA-6D-1 have shown high value for test weight and also well suited to all the three environments.

Looking to the size of the head, three-way hybrid DCMS 51 A x DSI-1017 x RHA-6D-1 excelled all other single and three-way hybrids with well adaptability to all the environments as revealed by non-significant b_i and s^2d_i values. The three-way hybrids of KBSH-1 excelled its originating single cross hybrid for size of the head besides well adaptability. But the situation is quite reverse in case of KBSH-44 three-way hybrids where majority of them found poorly adapted to all the environments with average stability.

As for plant height is concerned the hybrid DCMS 51 A x RHA-95-C-1 appeared to be the tallest. Most of the single and three-way hybrids have shown significant s^2d_i values indicating that plant height is highly sensitive to environmental fluctuations. All the three-way hybrids of KBSH-44 appeared to be shorter than its single cross, irrespective of the additional parent used. While the situation is quite different in respect of KBSH-1, where the three way hybrids CMS 234 A x DSI-1017 x RHA-6D-1, CMS 234 A x RHA-6D-1, DCMS 51 A x DSI-1017 x RHA-6D-1 were well adapted but medium in stature for plant height.

Addition of second parent enhanced flowering time in three-way hybrids corresponding to single cross hybrids. CMS 4546 x R-298 and its three-way with DSI-1017 as additional parent flowered earlier than all other hybrids besides better adaptability.

From the foregoing discussions, it can be concluded that the favorable environments for most of the economic traits observed to be Dharwad followed by Annigeri and Raichur under *Kharif* conditions. The single cross hybrids CMS 17 A x RHA 95-C-1, DCMS 51 A x RHA-6D-1 excelled in mean performance for seed yield per plant. However, two three-way hybrids CMS 234 A x DSI-2 x RHA-6D-1, DCMS 51 A x DSI-1017 x RHA-6D-1 rated as the best for high seed yield per plant and also found to be stable for 100 seed weight, volume weight, head diameter and number of filled seeds per head. Thus, these hybrids need a large scale evaluation to confirm the results of the present study. Among single cross hybrids, KBSH-1 performed better across environments for days to 50 per cent flowering, plant height, oil content and seed yield per plant. But the economics of cost of production and the time period required proves attention towards single cross hybrids.

References

Allard, R.W., Bradshaw, A.D., 1964. Implication of genotype-environmental interaction in applied plant breeding. Crop Science 4: 503–505.

Anonymous, 2017, Director's report, Annual group meeting on Sunflower held at CCS Haryana Agricultural University, Hisar, April 20–22, 2017.

Bharathi, 2000, Stability analysis of few promising sunflower hybrids over seasons. *M.Sc. (Agri.) Thesis*, Univ. Agic. Sci. Bangalore (India).

Eberhart, S.A., Russell, R.A., 1966. Stability parameters for comparing varieties. Crop Science 6: 36–40.

Giriraj, K., Shantha, R., Hiremath and Seenappa, K., 1988, Stability of sunflower genotypes for seed yield. *XII. Intl. Conf. Novisa*, Yogoslavia.

Giriraj, K., Virupakshappa, K., 1992, Heterotic effect for seed yield and component characters in sunflower over seasons. *Proc. Of 13th Int. Sunflower Conf. Pisa*, Italy, 8–10th September.

Goud, I.S., Sarala, B.S., 2004. Stability for seed and oil yield in promising sunflower, (*Helianthus annuus* L.) hybrids under irrigated conditions in Northern parts of Karnataka. Journal Oilseeds Researcher 21(2): 329–330.

Halaswamy, B.H., 1998, Analysis of three-way and single cross hybrids for stability and seed production potentiality in sunflower (*Helianthus annuus* L.). *Ph.D. Thesis*, Univ. Agic. Sci. Dharwad (India).

Jayalaxmi, V., Narendra, B., 2004. Evaluation of three way hybrids in sunflower. Journal Oilseeds Researcher 21(1): 152.

Kide, B.R., Bhale, N.L., Borikar, S.T., 1985. Study of heterosis in three-way crosses in sorghum. Indian Journal Genetics 452(2): 203–208.

Laishram, J.M., Singh, N.N., 1997. Phenotypic stability for quantitative characters in sunflower (*Helianthus annuus* L.) in Manipur. Indian Journal Genetics and Plant Breeder 57: 174–179.

Laxman, S., Kallennawar, 1999, Stability analysis of experimental hybrids for seed yield and its component characters in sunflower. *M.Sc. (Agri.) Thesis*, Abstracts.

Leclercq, P., 1969. Line sterile cytoplasmique chezk tournesol. Annals Amelior Planta 12: 99–106.

Naresh, R., 1993, Production and evaluation of three-way cross hybrids in sunflower (*Helianthus annuus* L.). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci. Bangalore (India).

Panduranga, Y.K., 2000, Stability studies in new sunflower (*Helianthus annus* L.) hybrids under different agro-climatic conditions. *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci. Bangalore.

Rao, M., Reddy, G.L., Kulkarni, R.S., Reddy, S.S.L., Ramesh, S., 2004. Stability analysis of sunflower hybrids through non-parametric model. Helia 27(41): 59–66.

Seetharam, A., 1981. Sunflower cultivation. Indian Fmg 25: 1–4.

Seetharam, A., Giriraj, K., Kusuma Kumari, P., 1980. Phenotypic stability of seed yield in sunflower hybrids. Indian Journal Genetics Plant Breeder 40: 102–104.

Shinde, R.M., Pawar, B.B., Dumbre, A.D., 1992. Stability of yield and yield components in sunflower. Journal Maharashtra Agricultural University 17(1): 135–136.

Sindagi, S.S., Kulkarni, R.S., Seetharam, A., 1979. Line x tester analysis of the combining ability in sunflower (*Helianthus annuus* L.). Sunflower News Letter 3(2): 11–12.

Vranceanu, A.V., Stoenescu, F.M., 1979. Expression of heterosis in single, three way and double sunflower hybrids. Fundulea 44: 29–36.

Walsh, E.J., Atkins, R.E., 1973. Performance and within variability of three-way and single crosses of grain sorghum. Crop Science 13: 267–271.