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Stability analysis in castor (*Ricinus communis* (L.)

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Abstract
The present investigation on G x E interactions and stability parameters in castor for seed yield per plant and ten other traits using L x T analysis involving nine parents, their resultant twenty crosses and two standard checks. Analysis of variance for stability revealed significant values for mean squares among the genotypes and environments (linear) for almost all the characters except seed volume per weight and oil content for environment indicated the variable nature of various entries and environments. The G x E interaction was significant for most of the characters when tested against both pooled error and pooled deviation, which indicated that different genotypes reacted differently to different environmental conditions. The top four hybrids *viz.,* Geeta x NAUCI 8, Geeta x NAUCI 9, NAUCP-1 x NAUCI 9 and SKP 72 x NAUCI 9 were the most promising and stable over environments for seed yield per plant.

Key words: Stability, G x E, Castor, Pooled deviation and Pooled error

INTRODUCTION

Castor (*Ricinus communis* L.) is one of the most important non-edible oilseed crops of India. Castor has 2n=20 chromosomes and belongs to the monospecific genus *Ricinus* of the *Euphorbiaceae* family. It has cross pollination up to the extent of 50 per cent. Because of its hardiness, castor plays an important role in the economy of arid and semi-arid regions of the country.

Castor is a perennial crop but grown as an annual crop for economic purposes. It has a wide range of adaptability in varying agro climatic conditions and soils. In India, castor is grown in the area of 7.70 lakh ha with a production of 11.27 lakh tonnes and productivity of 1520 kg per ha (Anonymous, 2019). Castor has the potential to become the premier oil crop for industrial oil production across the globe in agriculture. It is an ideal candidate for the production of high value, industrial oil feed stocks because of the varied oil content (48-60 %) of the seed. Castor is a highly polymorphic species; normally monoecious with pistillate flowers on the upper part and staminate flowers on the lower part of the raceme.

In a breeding programme, it is necessary to screen and develop stable genotypes, which perform more or less uniform under varying environmental conditions. Thus, knowledge of genotype x environment interaction helps the breeder to select high yielding and most adaptable varieties and hybrids.

MATERIALS AND METHODS

The present investigation was carried out in Castor (*Ricinus communis* L.) under three different locations of south Gujarat *viz.,* Pulses and Castor Research Station, Navsari, Regional Rice Research Station, Vyara and Hill Millet Research Station, Waghai during *Rabi,* 2018. The parental material comprised of four female parents (lines) *viz.,* SKP-84, Geeta, SKP 72, NAUCP-1, five male parents (tester) *viz.,* NAUCI-6, NAUCI-7, NAUCI-8, NAUCI-9, DCS-107. Data on 11 traits were recorded. The statistical analysis for genotype-environment interactions and stability parameters were worked out according to Eberhart and Russel (1966) for different characters under study. Consistent high performance together with

(i) the regression of each genotype in an experiment on environment index and (ii) a function of squared deviations from this regression would provide estimates of the desired stability parameters.

RESULT AND DISCUSSION

The main objective of the present investigation was to isolate the stable genotype over different environments for different traits under study. The analysis of variance revealed the existence of significant differences among genotypes for all the characters under all environments. Pooled analysis of variance over environments revealed a significant sum of squares due to hybrids x locations interaction for most of the characters except plant height, the number of effective branches per plant and seed volume per weight which indicated the performance of hybrids were not consistent over environments in all the traits **(Table 1)**. Conversely, the mean sum of squares due to parents x locations was found to be significant for the traits except for days to 50 per cent flowering, days to maturity, the number of nodes up to primary spike, effective length of the primary spike, seed volume per weight and 100 seed weight.

This indicated that parents reacted significantly in different environments for all characters except days to 50 per cent flowering, days to maturity, the number of nodes up to primary spike, effective length of the primary spike, seed volume per weight and 100 seed weight **(Table 2)**. The average performance of hybrids was different from that of parents in different environments for days to 50 per cent flowering and the number of effective branches per plant, which was evident from the significance of parents *vs.* hybrids x environment interaction for these characters. The mean squares due to G **×** E interactions were significant for all characters except the number of effective branches per plant and seed volume per weight. The significant G **×** E interactions indicated that the performance of genotypes was not consistent over the environments with respect to characters under study.

The stability analysis revealed highly significant differences for all the characters among the genotypes when tested against the pooled error and pooled deviation. The differences due to environments (E) component were highly significant for days to 50 per cent flowering, days to maturity, the number of nodes up to primary spike and seed yield per plant when tested against the pooled error and pooled deviation **(Table 3a)**. The environments + (genotypes x environments) interaction was observed to be significant for days to 50 per cent flowering, the number of nodes up to primary spike, effective length of the primary spike, the number of capsules on the primary spike, seed yield per plant and oil content when tested either against pooled error and pooled deviation.

Table 1. Analysis of variance (mean squares) for different traits in castor over pooled environment

Source of variance	d.f.	Days to 50 per cent flowering	Days to maturity	Plant height	Number of nodes up to primary spike	Effective length of primary spike	Number of capsules on primary spike	Number of effective branches per plant	Seed volume per weight	100 seed weight	Seed yield per plant	Oil content
Replication	2	25.70	62.91	760.51	23.74	404.98	186.42	6.75	19.88	84.73	1465.01	0.43
Environments (E)	2	293.06***	269.20**	651.66**	53.68**	207.87*	495.55**	9.21**	17.62	43.30*	6206.18**	10.37**
Replication x environments	4	5.67	17.94	16.88	1.30	4.17	54.72	0.03	50.95	1.48	22.37	3.28
Genotypes (G)	28	477.95**	1547.09**	2189.30**	77.52**	850.83**	2148.00**	47.20**	305.23**	84.72**	7123.77**	115.56**
Parents (P)	8	338.52**	394.00**	653.59**	44.91**	170.55**	458.14**	77.99*	135.18**	41.51**	7214.89**	29.01**
Hybrids (H)	19	539.26**	2111.16**	2915.28**	92.96**	970.55**	2963.34**	36.20**	385.14**	100.41**	6176.30**	44.15
Parents vs. Hybrids	1	428.35**	54.55	681.39*	5.15	4018.37**	175.57	10.07**	147.52*	132.28**	24396.78**	152.05**
Genotypes x Environments	56	33.00**	24.93**	194.51*	11.19**	96.43**	230.62**	1.44	15.18	32.20**	1194.85**	24.19**
Parents x Environments	16	18.26	17.12	431.97**	6.76	68.70	406.08**	3.10**	3.71	3.52	585.51*	40.87**
Hybrids x Environments	38	38.10**	28.99**	102.98	13.08**	111.41**	160.36*	0.73	19.04	45.37**	1508.98**	18.42**
(Parents vs. Hybrids) x Environments	2	54.19*	10.23	33.87	21.58	33.76	161.78	1.62*	33.27	11.30	101.24	0.32
Error	168	11.93	15.23	129.09	709.31	44.60	97.28	1.10	28.20	11.03	305.88	1.54
Total	260	68.82	184.65	372.20	3667.01	145.99	349.92	6.23	55.44	24.19	1281.53	18.35

*, ** Significant at 5 and 1 per cent probability levels, respectively

Table 2. Analysis of variance (mean sum of square) for phenotypic stability for different characters in castor

Source of variation	d.f.	Days to 50 per cent flowering	Days to maturity	Plant height	Number of nodes up to primary spike	Effective length of primary spike	Number of capsules on primary spike
Genotypes (G)	30	149.50**	485.50**	684.92**	25.57**	265.66**	673.45**
Environments (E)	2	99.59**	85.08**	230.56	16.88**	31.33	180.33
Env. + (Gen. x Env.)	62	13.19*	10.65	66.03	3.99**	66.29*	75.30**
G x E	60	10.30	8.17	60.54	3.56**	30.16*	71.80**
Environments (Linear)	1	199.19**	170.16**	461.13**	33.76**	132.59**	360.66**
G x E (Linear)	30	10.93	7.64	68.99	5.54**	37.01*	111.22**
Pooled deviation	31	9.37	8.41	50.43	1.53	22.56	31.34
Pooled error	180	3.87	4.90	45.92	1.34	15.27	31.14

Source of variation	d.f.	Number of effective branches per plant	Seed volume per weight	100 seed weight	Seed yield per plant	Oil content
Genotypes (G)	30	14.74**	98.23**	26.42**	2235.36**	35.20**+
Environments (E)	2	3.57	4.59	14.16	2299.09*	2.89
Env. + (Gen. x Env.)	62	0.56	5.20	10.18++	435.16**	7.41**
G x E	60	0.45	5.23	10.05++	373.03*	7.56**
Environments (Linear)	1	7.15**	9.17*	28.32**	4598.18**	5.78
G x E (Linear)	30	0.34	3.82	11.13	481.07*	10.04**
Pooled deviation	31	0.55	6.42	8.68++	256.44	4.90++
Pooled error	180	0.35	9.32	3.57	98.32	0.59

*, ** Significant at 5 and 1 per cent probability levels, respectively

The environment (linear) component was significant for all the traits when tested against both pooled error and pooled deviation except seed volume per weight for pooled error and oil content when tested against pooled deviation. A higher magnitude of mean squares due to environments (linear) indicated significant differences between environments for all the characters **(Table 3a)**. These results are in agreement with the earlier findings of Manivel and Hussain (2000) and Joshi *et al.* (2002).

The G x E interaction was significant for a number of nodes up to primary spike, the effective length of a primary spike, the number of capsules on the primary spike, seed yield per plant and oil content when tested against both pooled error and pooled deviation, while days to 50 per cent flowering and 100 seed weight when tested against pooled error. Similarly, G x E (linear) was significant for characters number of nodes up to primary spike, effective length of the primary spike, the number of capsules on primary spike, seed yield per plant and oil content when tested against pooled deviation as well as pooled error. This suggested that the performance of genotypes over environments could be predicted reasonably for these traits. The non-linear component of G x E interactions was significant for most of the characters except plant height, the number of nodes up to primary spike, the number of capsules on primary spike and seed volume per weight **(Table 3b)**. Similar findings were recorded by Mandal and Dana (1994) for seed yield per plant, by Manivel and Hussain (2000) for days to 50 % flowering and oil content, by Joshi *et al.* (2002) for plant height and the number of capsules on the primary spike, by Joshi *et al.* (2002) for the number of nodes up to primary spike and 100-seed weight, by Kumari *et al.* (2003) for days to 50 per cent flowering and effective branches per plant and by Solanki and Joshi (2003) for the number of capsules on the primary spike and 100-seed weight and Chaudhary *et al.* (2019). Various scientists reported that both linear and nonlinear components of G x E were significant for most of the traits among the traits studied Joshi *et al.* (2002), Kumari *et al.* (2003), Solanki and Joshi (2003), Patel *et al.* (2015), Patel and Patel (2015) and Aher *et al.* (2016). Simultaneous consideration of the mean (X), regression coefficient (bi) and deviation from regression (S^2di) of the

Table 3a. Stability parameters for days to 50 per cent flowering, number of nodes up to primary spike and effective length of primary spike in castor

S. No.	Genotypes	Days to 50 per cent flowering			Number of nodes up to primary spike			Effective length of primary spike		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1	SKP 84	73.67	1.51	-1.05	20.22	-0.26	-0.07	57.93	2.94	-14.08
2	Geeta	63.44	2.74	-2.00	16.33	0.43	-0.06	63.09	2.52	-10.58
3	SKP 72	69.78	2.00	-3.12	15.89	-3.05	-1.26	53.07	0.86	75.98
4	NAUCP-1	66.11	0.83	-1.15	14.11	1.86	0.67	51.27	-3.68	3.61
5	NAUCI 6	60.55	1.83	-3.23	15.00	2.51*	-1.40	52.24	1.51	-8.51
6	DCS 107	73.78	1.16	-3.37	14.22	-0.09	-1.12	59.21	-3.69	-2.13
7	NAUCI 7	63.00	2.63	0.39	17.89	2.86	-0.93	51.69	0.98	-7.03
8	NAUCI 8	66.22	0.81	49.22**	19.89	0.94	-1.40	50.22	1.56	1.27
9	NAUCI 9	79.22	1.09	3.17	18.78	-1.24	-0.78	55.89	0.85	-13.62
10	SKP 84 x NAUCI 6	58.78	2.26	-1.20	19.44	-0.94*	-1.40	56.57	-0.72	1.90
11	SKP 84 x DCS 107	73.78	1.45	-2.94	15.33	-1.32	-0.42	54.49	-1.09	-9.06
12	SKP 84 x NAUCI 7	66.89	1.36	-3.00	17.33	0.45	0.37	59.58	3.29	-14.63
13	SKP 84 x NAUCI 8	61.11	1.98	13.66*	16.55	1.53	-1.22	62.53	-1.71	11.55
14	SKP 84 x NAUCI 9	80.22	0.24	19.79*	16.44	-0.19	-0.26	63.61	11.58	87.56
15	Geeta x NAUCI 6	58.44	1.85	37.77**	15.55	3.60	-1.24	77.04	-3.19	48.73
16	Geeta x DCS 107	70.55	0.10	0.75	19.22	3.90	0.29	76.09	3.64	-14.58
17	Geeta x NAUCI 7	71.55	-0.94**	-3.92	20.00	-0.14	-0.76	71.32	-0.71	-0.70
18	Geeta x NAUCI 8	65.00	3.44	8.14	21.22	2.57	-0.31	73.36	3.38	-14.51
19	Geeta x NAUCI 9	66.78	3.12	17.85*	23.44	0.24	0.38	78.03	1.97	-9.75
20	SKP 72 x NAUCI 6	76.00	-0.11	-1.11	13.88	1.95	8.98**	64.28	2.87	-15.16
21	SKP 72 x DCS 107	80.00	0.77	8.50	13.89	0.77	1.79	46.19	-2.00	0.30
22	SKP 72 x NAUCI 7	79.55	-2.55	7.53	11.33	-0.90	0.60	52.22	1.70	74.88
23	SKP 72 x NAUCI 8	82.67	-0.93	-0.78	13.78	0.98	-1.27	63.82	-0.05	-12.71
24	SKP 72 x NAUCI 9	82.89	1.17	-2.84	14.22	-1.86	0.67	61.40	3.90	-8.19
25	NAUCP-1 x NAUCI 6	65.67	0.81	3.44	15.22	2.70	-0.40	62.02	1.65	68.05*
26	NAUCP-1 x DCS 107	71.44	1.00	16.82*	15.44	0.24	0.38	68.63	-0.81	-7.26
27	NAUCP-1 x NAUCI 7	78.33	-1.15	2.46	11.89	-0.38	3.18	42.40	1.99	37.65
28	NAUCP-1 x NAUCI 8	66.78	1.35	19.08*	17.67	7.70	2.18	56.34	3.73	18.98
29	NAUCP-1 x NAUCI 9	67.33	-0.15	-2.51	20.55	5.97	0.24	78.83	0.63	-14.42
30	GNCH-1	67.44	0.82	-3.77	19.67	-0.74	-1.33	61.13	0.42	-12.64
31	GCH-8	70.00	0.48	-3.85	19.33	0.88	-0.25	63.94	-0.06	-15.08
	General Mean	70.33		16.72		60.81				

*, ** Significant at 5 and 1 per cent probability levels, respectively for unit regression test (bi=1) and (S^2d_i=0)

individual genotypes for seed yield showed that among the parents, Geeta (154.3) and NAUCI 8 (169.9) recorded average seed yield and average stability as the regression was not differing from unity, and deviation from regression was also non-significant. Whereas, the highest yielding parent NAUCI 9 had a regression coefficient greater than unity and deviation from regression was nonsignificant, indicating its stable performance in **Table 3a and Table 3b.**

The high yielding parent Geeta was stable for the characters like days to 50 per cent flowering, the number of nodes up to primary spike, effective length of the primary spike, 100 seed weight and seed yield per plant. This parent also has a high *per se* performance for all these characters. The high yielding parent NAUCI 9 had higher mean values for an effective length of primary spike number of capsules on the primary spike and 100 seed weight with above average responsiveness as indicated

Table 3b. Stability parameters for number of nodes up to primary spike, effective length of primary spike and number of capsules on primary spike in castor

S. No.	Genotypes	Number of capsules on primary spike			100 seed weight			Seed yield per plant			Oil content		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1	SKP 84	82.22	4.39	-20.61	30.26	-0.34	-3.27	136.7	0.44*	-100.1	43.57	0.58	-0.11
2	Geeta	77.56	9.75	8.71	33.07	1.49	-3.69	154.3	1.39	-98.8	47.03	-3.07	0.59
3	SKP 72	69.78	3.59	325.25	29.07	1.59	-1.10	83.2	0.66	-9.6	42.70	-12.15	0.77
4	NAUCP-1	78.67	-4.02	-29.23	32.17	-0.52*	-3.73	124.2	-0.59	4.1	43.49	23.57	10.08**
5	NAUCI 6	65.78	2.31	-28.09	33.28	-0.02	-2.64	143.0	0.38	-17.9	47.73	-2.27	7.68*
6	DCS 107	71.56	-3.30	-18.06	30.41	-0.99	-0.47	151.8	-1.31	-88.8	47.02	3.45	-0.57
7	NAUCI 7	71.11	1.82	-24.93	28.62	0.74	-1.68	111.6	1.37	180.1	45.06	-3.23	23.99**
8	NAUCI 8	77.78	0.40	-8.47	30.61	-0.89	-2.20	169.9	2.96	127.8	45.87	10.60	0.94
9	NAUCI 9	89.00	1.55	108.00	35.13	1.21	-3.57	170.0	2.41	76.2	46.04	-8.25	-0.37
10	SKP 84 x NAUCI 6	91.11	2.65	100.69*	33.28	0.93	-2.46	146.4	1.17	377.6*	44.05	-6.19	20.73**
11	SKP 84 x DCS 107	68.89	-2.49	-22.12	30.20	0.36	-3.42	153.3	-0.63	185.7	47.74	-1.95	2.09*
12	SKP 84 x NAUCI 7	85.67	1.86	-31.06	31.92	0.21	0.45	136.2	2.94	114.7	43.13	2.19	12.06**
13	SKP 84 x NAUCI 8	118.67	-0.28	-30.05	30.32	-0.44	-0.28	176.6	0.54	-20.1	44.40	3.55	23.69**
14	SKP 84 x NAUCI 9	97.22	3.05*	-31.12	34.57	1.84	-3.35	182.1	2.93*	-97.6	46.59	0.82	1.49
15	Geeta x NAUCI 6	58.67	-1.11	-22.58	30.91	7.13	0.64	189.4	1.65	927.1**	50.68	-2.90	1.12
16	Geeta x DCS 107	86.78	0.82	-22.94	36.91	6.51*	0.99	124.2	1.07	1082.2**	48.15	4.40	2.91*
17	Geeta x NAUCI 7	66.78	-1.82*	-31.05	27.44	-1.82*	-3.73	143.8	-0.58	-59.6	37.65	3.33	1.55
18	Geeta x NAUCI 8	88.89	6.38	-19.45	37.60	0.95	-0.03	194.6	1.54	47.8	48.04	0.93	8.35**
19	Geeta x NAUCI 9	96.89	4.21	54.02	40.81	-1.04	0.05	194.6	2.61	-26.4	50.74	0.72	-0.58
20	SKP 72 x NAUCI 6	58.22	2.42*	-31.11	30.16	7.19	0.91	125.0	0.45	-23.0	40.39	-0.52	9.11**
21	SKP 72 x DCS 107	51.11	-2.77*	-30.16	32.02	-3.80	0.42	151.3	-1.30	2.3	45.99	-5.19	2.53*
22	SKP 72 x NAUCI 7	49.22	-2.43	2.87	32.61	7.98	0.46	108.9	1.40	316.1*	42.10	-12.99	5.47**
23	SKP 72 x NAUCI 8	79.67	0.68	4.22	29.47	2.44	0.21	158.0	2.70	1833.07**	46.12	-5.51	-0.09
24	SKP 72 x NAUCI 9	65.78	1.33	-29.49	30.71	6.35	0.98	194.6	0.99	-94.9	49.50	-7.49	-0.04
25	NAUCP-1 x NAUCI 6	65.22	-4.53	-20.31	33.08	-6.04	0.96	145.8	-1.45	518.4*	44.22	16.63*	-0.58
26	NAUCP-1 x DCS 107	79.44	0.12	-30.74	38.78	-6.60	0.93	163.3	-0.74	78.5	47.58	0.07	-0.06
27	NAUCP-1 x NAUCI 7	62.67	3.15	-23.31	32.60	4.41	0.32	136.2	-0.09	-62.9	36.42	-1.73	2.02*
28	NAUCP-1 x NAUCI 8	91.67	1.44	-31.11	32.62	1.28	-3.02	183.3	-0.82	-94.5	50.84	1.68	0.16
29	NAUCP-1 x NAUCI 9	91.67	2.49	0.75	32.79	2.60	0.11	176.2	1.20	-99.1	47.81	7.74	-0.34
30	GNCH-1	70.56	0.86	-30.51	32.81	0.07	-3.70	156.1	1.43	-59.1	46.33	0.00*	-0.60
31	GCH-8	73.78	1.44	-31.04	33.20	0.68	-2.70	166.4	1.14	-97.7	47.67	-1.80	-0.54
	General mean	77.16			32.46			152.72			45.54		

*, ** Significant at 5 and 1 per cent probability levels, respectively for unit regression test (bi=1) and (S^2d_i=0)

by non-significant deviations from regression with more than unit regression coefficient. The parent, NAUCI 8 displayed high *per se* performance for days to 50 per cent flowering, the number of capsules on primary spike and seed yield per plant. This parent exhibited the highest days to 50 per cent flowering and the number of capsules on primary spike with below unit regression but was stable over environments and perfect prediction would be rather easy. In the case of hybrids, most of the hybrids showed better performance than their corresponding parents. Comparatively the best five stable hybrids *viz.,* Geeta x NAUCI 8, Geeta x NAUCI 9, SKP 72 x NAUCI 9, NAUCP-1 x NAUCI 9 and SKP 84 x NAUCI 9 had high seed yield per plant and high stability for other some characters with non-significant S^2d_i value.

In general, the hybrids found stable for seed yield per plant also depicted stability in respect of one or more yield component traits like number of nodes up to primary spike, effective length of primary spike, the number of capsules on primary spike and 100 seed weight. This indicated that the stability of various component traits might be responsible for the observed stability of different hybrids for seed yield. Grafius (1956) also has a similar opinion that the stability of seed yield might be due to the stability of various yield components. Phenotypic stability of various component traits reflecting into yield stability was also reported by various workers *viz*., Manivel and Hussain (2000), Solanki and Joshi (2000), Joshi *et al.* (2002c), Joshi *et al.* (2002), Kumari *et al*. (2003), Solanki and Joshi (2003), Patel et al. (2015), Aher *et al.* (2016), Chaudhary *et al*. (2019).

The estimated environmental index for seven different characters in castor is presented in **Table 4**. The environmental index was observed to be congenial for the number of nodes up to primary spike and oil content at Vyara (location-II) while, it was favourable for days to 50 per cent flowering, effective length of primary spike, the number of capsule on primary spike, 100 seed weight

Table 4. Estimation of environmental index for various characters under different environments in castor

S. No.	Characters	Environmental index		
		Navsari (L-I)	Vyara (L-II)	Waghai (L-III)
1	Days to 50% flowering	-1.90	1.66	0.25
2	Number of nodes up to primary spike	0.80	-0.65	-0.15
3	Effective length of primary spike	1.52	-1.39	-0.13
4	Number of capsules on primary spike	2.66	-2.05	-0.60
5	100 seed weight	0.61	-0.73	0.12
6	Seed yield per plant	7.65	-9.33	1.67
7	Oil content	-0.34	0.28	0.08

Table 5. Character-wise lists of parents and hybrids for general and specific environments in castor

S. No.	Character	Genotypes with general adaptability (most stable)		Specific adaptability to favourable environment		Specific adaptability to poor environment	
		Parents	Hybrids	Parents	Hybrids	Parents	Hybrids
1	Days to 50 per cent flowering	SKP 84 DCS 107	SKP 84 x DCS 107 SKP 84 x NAUCI 7 SKP 72 x NAUCI 9	NAUCP-1	NAUCP-1 x NAUCI 6	-	-
2	Number of nodes up to primary spike	NAUCI 8 NAUCP-1	Geeta x NAUCI 8 SKP 84 x NAUCI 8 SKP 72 x NAUCI 8	Geeta	SKP 84 x NAUCI 7 SKP 84 x NAUCI 6	NAUCI 6	
3	Effective length of primary spike	Geeta NAUCI 6 NAUCI 7	Geeta x NAUCI 9 SKP 72 x NAUCI 6 NAUCP-1 x NAUCI 7	SKP 72 NAUCI 9	NAUCP-1 x NAUCI 9 SKP 72 x NAUCI 7	_	_
4	Number of capsules on primary spike	NAUCI 7 NAUCI 9	SKP 84 x NAUCI 7 SKP 84 x NAUCI 9 SKP 72 x NAUCI 6 NAUCP-1 x NAUCI 9 NAUCP-1 x NAUCI 8	NAUCI 8	Geeta x DCS 107 SKP 72 x NAUCI 8		Geeta x NAUCI 7
5	100 seed weight	Geeta NAUCI 9 SKP 72	Geeta x NAUCI 8 SKP 84 x NAUCI 9 NAUCP-1 x NAUCI 8 NAUCP-1 x NAUCI 9	NAUCI 7	SKP 84 x NAUCI 6 SKP 84 x NAUCI 7	NAUCP-1	Geeta x NAUCI 7
6	Seed yield per plant	Geeta NAUCI 8 NAUCI 9 SKP 84	SKP 84 x NAUCI 8 SKP 84 x NAUCI 9 Geeta x NAUCI 8 Geeta x NAUCI 9 NAUCP-1 x NAUCI 9	NAUCI 6 SKP 72	SKP 72 x NAUCI 6 SKP 72 x NAUCI 9	_	_
7	Oil content	-	NAUCP-1 x NAUCI 8 Geeta x NAUCI 9	SKP 84	SKP 84 x NAUCI 9	_	_

and seed yield per plant at Navsari (location-I). In general, the environment Navsari (E_1) was found to be the most favourable for seed yield and other related traits.

The stability of genotypes revealed that none of the parents and hybrids was found to be ideal for better as well as poor environmental conditions for all the characters (**Table 5**). One hybrid adapted in a favourable (better condition) environment for days to 50 per cent flowering and oil content. Two hybrids adapted in favourable for a number of nodes up to primary spike, effective length of primary spike, the number of capsules on primary spike, 100 seed weight and seed yield per plant. Hence, it would be advantageous to exploit high yielding and stable hybrids such as Geeta x NAUCI 8 and SKP 72 x NAUCI 9 in a future breeding programme.

Estimates of environmental indices revealed that Navsari location was favourable for most of the yield contributing characters followed by Waghai and Vyara. Among the parents, Geeta and NAUCI 9 and among hybrids, Geeta x NAUCI 8, SKP 72 x NAUCI 9 and NAUCP-1 x NAUCI 9 were found average stable over environments for seed yield with one or more yield contributing characters.

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