IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 8, Issue 6 Ver. II (Jun. 2015), PP. 68-72
www.iosrjournals.org

Gene - Environment Interaction and Stability Analysis for Yield and Yield Determinant Traits in Castor (Ricinus Communis L)

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Abstract: *A field study was conducted at Sardarkrushinagar in North Gujarat during crop season kharif 2012 to know the existence of genotype x environment interaction and stability for yield and yield attributes in three different environments. The experiment was laid out in a randomized complete block design replicated thrice. Stability parameters that are useful tools for identification of genotypes with specific and wide adaptations and contrasting role played by genotype, environments and interaction in varied environments were considered and analyzed. Pooled Analysis of variance over three environments revealed the genotypic variances were highly significant for all the characters including seed yield per plant which indicates considerable genetic variability was present in the population. The three genotypes viz., GCH 4, GCH 6, GCH 7 and parental lines viz., Geeta, 48-1 and VP 1 were found stable across environments. These parental lines may be used in development of population or hybrids in further breeding programme.*

Keywords: *Stability analysis, G x E interaction, grain yield*

I. Introduction

Castor [Ricinus communis (L.)] is an important non-edible oil seed crop of arid and semi-arid regions of India, which belongs to the genus Ricinus of Euphorbiaceae family. The castor possesses 2n = 20 chromosome numbers. Its monoecious nature favours cross-pollination up to the extent of 50 per cent. The crop has cultivated in many tropical and subtropical regions of the world (Govaerts et al., 2000). The release of first hybrid GCH-3 based on exotic pistillate line TSP-10R in Gujarat during year 1968 attracted the attention of breeders to utilize the heterosis on commercial scale. Subsequently, heterosis breeding programme was geared up in Gujarat and as a result, seven hybrids viz., GCH-3 (1968), GAUCH-1 (1973), GCH-2 (1983), GCH-4 (1986), GCH -5 (1995), GCH-6 (1999) and GCH-7 (2006) were released periodically for commercial cultivation with a yield potential of over 5 tones/ha under irrigated conditions which based on versatile pistillate lines VP-1 and SKP-84 possesses S-type female sex mechanism.

In varying environments it may be expected that the interaction of genotype with environment will also be varying and ample. As a result one cultivar may have the highest yield in one environment, while a second cultivar may excel in others. This necessitated the study of genotypes by environment interaction to know the magnitude of interactions in the selection of genotypes across several environments besides calculating the average performance of the genotypes under evaluation. . The plant breeder is always interested in the stability of performance for the characters which are of economically important. The desirable hybrids should have low genotype x environment interactions for important characters, so as to get desirable performance of hybrids over wide range of environmental conditions. Genotype x environment interactions are of common occurrence and often creates manifold difficulties in interpreting results and thus hamper the progress of breeding programmes aiming at further genetic improvement in crop plants. Therefore, the study was undertaken to evaluate the stability and adaptability of sixteen genotypes of castor in varying environments.

II. Materials And Methods

Sixteen genotypes comprising ten parents and six hybrids (F_1) of castor were selected for study. Ten parents named VP-1, Geeta, JP 65, SKP 84, VI 9, JI 35, 48-1, SH 72, JI 96 and SKI 215 whereas, six hybrids (F_1) GAUCH 1, GCH 2, GCH 4, GCH 5, GCH 6 and GCH 7 were used for investigation. The field experiment was conducted at Main Castor and Mustard Research Station and Centre for Watershed management, participatory research and rural engineering, Sardarkrushinagar Dantiwada Agricultural University during kharif 12 keeping distance between rows at 90 cm and 120 cm in rainfed and irrigated condition respectively, whereas; between plants within row 60 cm distance was maintained in both the growing conditions. Experiment was laid out in Randomized Complete Block Design with three replications. The detail of location and date of sowing is narrated in Table 1. The various quantitative traits viz., days to flowering, days to maturity, plant height (cm),

total length of primary raceme (cm), number of nodes up to primary raceme, number of capsules on primary raceme and seed yield per plant (g) were included for study. Analysis of variance was performed and stability parameters were completed following the model proposed by Eberhart and Russell (1966). The type of stability was decided on regression coefficient (b_i) and mean values (Finaly and Wilkinson 1963).

Table 1. Details of environments.

Sr.No.	Location and condition	Environments	Date of sowing
1.	Centre for Watershed management, participatory research and rural engineering, S. D. Agricultural University, Sardarkrushinagar (Rainfed)	E I	16th July 2012
2.	Main Castor and Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar (Early sown irrigated)	E II	18th July 2012
3.	Main Castor and Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar (Timely irrigated)	E III	20stAugust 2012

III. Results And Discussion

The Analysis of variance for individual environments revealed highly significant mean squares due to genotypes for all the characters indicating the presence of genetic variation for different characters in the population (Table 2). While pooled analysis of variance revealed the genotypic variances were highly significant for all the characters. The environmental variance was highly significant for all the characters indicating presence of variation in the environments selected for the study. The variance due to G x E interaction was also highly significant for all the traits (Table 3).

The analysis of variance for stability of different characters, as per Eberhart and Russell (1966) model is given in Table 4. The mean squares due to genotypes, environments, genotype x environment, environment (linear) and genotype x environment (linear) were tested against pooled deviation. The pooled deviation was tested against pooled error. The significant mean sum of squares due to genotypes, environments and environment (linear) for all characters were observed when tested against pooled deviation.

The mean squares due to G x E interactions were significant for days to maturity, total length of primary raceme, number of nodes up to primary raceme, number of capsules on primary raceme and seed yield per plant which indicate differential response of genotypes in varying environments for these traits. The mean sum of square due to environment and environment (linear) was found highly significant for all the characters (Table 4), which revealed that differences due to environments were real and thus, the creation of environments was fully justified.

The mean sum of squares due to pooled deviation were significant when tested against pooled error for days to flowering, days to maturity, plant height, total length of primary raceme, number of nodes up to primary raceme, number of capsules on primary raceme and seed yield per plant(Table 4). This suggested the involvement of non-linear components of genotype x environment interaction for differences in the stability of the genotypes and also signifies the involvement of non-additive gene action for these traits. Both G x E (linear) and pooled deviations were significant for days to maturity, total length of primary raceme, number of nodes up to primary raceme, number of capsules on primary raceme and seed yield per plant, which indicated the involvement of both linear and non-linear components towards genotype x environment interaction for these traits.

Stability parameters were worked out for all the characters except days to flowering and plant height as analysis of variance for stability of these two traits showed absence of genotype x environment interaction.

For days to maturity, a perusal of the data revealed that regression coefficient (bi) was significant for three genotypes (GAUCH 1, GCH 2, and SH 72), indicating responsiveness of these genotypes to environmental changes. Regression coefficient however, did not deviate significantly from unity for 13 genotypes. This indicated average sensitivity of these genotypes towards environmental variation.

Ten genotypes viz., GCH 2, GCH 4, GCH 5, GCH 7, Geeta, SKP 84, VI 9, 48-1, SH 72 and SKI 215 had showed higher mean of days to maturity than grand mean (142.05) except GCH 2, Geeta and VI 9. all the genotypes recorded not significant unit regression ($b_i = 1$) and non linear deviation from regression ($S^2d_i = 0$) which showed that these genotypes could be considered stable over a range of environments. One genotype SH 72 had above average response and high stability in better environments as is evident from their significant linear regression (bi > 1) and non-significant deviation from regression (S^2d_i).

The perusal of the stability parameters of the trait revealed that the genotypes, GCH 7, Geeta, JP 65, SKP 84, VI 9, 48-1, SH 72, JI 96 and SKI 215 gave the highest number of nodes up to primary raceme, out of this, Geeta, JP 65, SKP 84, 48-1 and JI 96 genotypes exhibited non-significant regression coefficient (b_i) and non-significant deviation from regression (S^2d_i), indicating stability of genotypes over environments.

Three genotypes viz., Geeta, JP 65 and SH 72 showed regression coefficient greater than unity ($b_i > 1$) and non-significant deviation from linear regression. Therefore, these genotype was considered as better for favourable environments. For number of nodes up to primary raceme based on unit regression and least

deviation from regression, five genotypes were found stable. These genotypes may be considered superior under varying environments. The genotypes Geeta, JP 65, SKP 84, 48-1 and JI 96 were found to be ideally stable for this trait. One genotype SH 72 registered higher mean of this trait, significant linear regression ($b_i > 1$) and non-significant S^2d_i. Therefore, it was considered as better for favourable environments. Three genotypes (SKP 84, 48-1 and JI 96) had higher mean, non-significant S^2d_i and regression coefficient less than one ($b_i < 1$). Therefore, it could be considered as better favourable for poor environments. Similar type of results were also reported by Joshi et al.(2002a) and Thakkar et al. (2010) and Patel et al.(2011)

Eight genotypes recorded higher mean number of capsules on primary raceme than the general mean (61.26), out of all these genotypes GCH 2, SKP 84, 48-1 and SH 72 had unit regression (b_i) with non-significant deviation from regression (S^2d_i) indicating stability of genotypes over environments. The performance of GCH 5, VI 9 and SKI 215 showed significant deviation from linear regression for these genotypes.

Stability parameters of 16 genotypes for number of capsules on primary raceme showed that 4 genotypes were ideal for varying environments. The genotypes were GCH 2, SKP 84, 48-1 and SH 72. One genotype SKP 84 registered higher mean number of capsules on primary raceme, non-significant deviation from regression (S^2d_i) and regression coefficient less than one ($b_i < 1$). Therefore, this genotype was considered as suitable for better under poor environments. Seven genotypes viz., GCH 2, GCH 7, Geeta, JP 65, 48-1, SH 72 and JI 96 registered higher mean, non-significant deviation from linear regression (S^2d_i) and regression coefficient greater than one ($b_i > 1$). Therefore, these genotypes were considered as suitable for favourable environments only. Similar type of result also reported by Manivel and Hussain (2001), Joshi et al. (2002a) and Thakkar et al. (2010).

Stability parameters analysis for seed yield per plant revealed that thirteen genotypes (GAUCH 1, GCH 2, GCH 4, GCH 6, GCH 7, VP 1, Geeta, JI 65, SKP 84, JI 35, 48-1, SH 72 and JI 96) showed non-significant deviation from regression. For regression coefficient ten genotypes showed non-significant unity for regression (Table 5).The nine genotypes viz., GCH 2, GCH 4, GCH 5, GCH 6, GCH 7, Geeta, 48-1, SH 72 and JI 96 depicted above average performance. Among nine genotypes, five genotypes viz., GCH 4, GCH 6, GCH 7, Geeta and 48-1 exhibited unit regression (b_i) and non-significant deviation from regression (S^2d_i). Two genotypes viz., GCH 2 and JI 96 depicted significant regression coefficient ($b_i > 1$) and non-significant deviation from regression (S^2d_i). Based on higher mean performance, unit regression and least deviation from regression five genotypes were found stable under varying environments. The genotypes GCH 4, GCH 6, GCH 7, Geeta and 48-1 were found to be ideally stable for seed yield per plant. Genotypes viz., GCH 2, GCH 4, GCH 7, Geeta, 48-1 and JI 96 registered higher mean of seed yield per plant, non-significant deviation from linear regression (S^2d_i) and regression coefficient greater than one ($b_i > 1$). Therefore, these genotypes were considered as better for favourable environments. Two genotypes (GCH 6 and SH 72) had higher mean, non-significant deviation from linear regression (S^2d_i) and regression coefficient less than one ($b_i < 1$) (Table 5). Therefore, these genotypes were considered as ideal genotypes for poor environments. These results were in accordance as reported by Manivel and Hussain (2001), Joshi et al. (2002), Kumari et al. (2003), Thakkar et al. (2010) and Patel et al (2011)

For total length of primary raceme based on unit regression and least deviation from regression, six genotypes were found stable. These genotypes may be considered superior under varying environments. The genotypes GCH 4, GCH 5, GCH 7, SKP 84, JI 96 and SKI 215 were found to be ideally stable for this trait. Genotypes viz., GCH 2, GCH 4, GCH 5, VI 9, JI 96 and SKI 215 registered higher mean of total length of primary raceme, non-significant S^2d_i and $b_i > 1$. Therefore, these genotypes may be performed better in superior/ favourable environmental conditions. The two genotypes (GCH 7 and SKP 84) had higher mean, non-significant deviation from regression (S^2d_i) and regression coefficient lees than one(Table 5). Therefore, it was considered as favourable for poor environments and widely adapted. These results are in accordance as reported by Manivel and Hussain (2001), Joshi et al. (2002a) and Thakkar et al. (2010).

Conclusion : From the present investigation it is concluded that the creation of environments was fully justified on the basis of significant result due to environment and environment (linear). Among castor promising genotypes that identified superior performance, genotypes GCH 4, GCH 6, GCH 7 and parental lines viz., Geeta, 48-1 and VP 1 were stable for two or more stability parameters and combination with high seed yield potential.

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Table 2. Analysis of variance (Mean square) for individual environment

Sources of variation	d.f	Days to flowering	Days to maturity	Plant height (cm)	Total length of primary raceme(cm)	Number of nodes up to primary raceme	Number of capsules on primary raceme	Seed yield per plant (g)
ENVIRONMENT I								
Replication	2	21.40	38.08	3.43	3.10	1.22	5.33	4.53
Genotype	15	656.82**	906.02**	1967.11**	245.48**	26.21**	591.90**	1729.20**
Error	30	7.29	12.88	10.43	4.94	1.08	3.06	36.02
ENVIRONMENT II								
Replication	2	26.52	2.02	140.43	5.82	0.37	22.10	338.00
Genotype	15	398.39**	562.57**	4572.62**	285.92**	69.74**	1939.23**	10298.88**
Error	30	13.90	34.38	59.49	5.38	1.47	17.01	140.73
ENVIRONMENT III								
Replication	2	2.31	12.27	35.55	6.95	1.76	33.83	103.73
Genotype	15	132.04**	343.02**	2438.30**	211.30**	7.80**	2025.17**	11624.61**
Error	30	11.60	18.74	58.17	7.79	0.55	23.10	220.27

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

Table. 3 Pooled analysis of variance (mean square) over environment for different characters in castor.

Sources of variation	d.f	Days to flowering	Days to maturity	Plant height (cm)	Total length of primary raceme(cm)	Number of nodes up to primary raceme	Number of capsules on primary raceme	Seed yield per plant (g)
Genotype	15	618.04**	577.87**	6763.16**	473.43**	56.56**	3682.29**	14763.14**
Environment	2	1722.53**	13889.87**	34611.94**	7472.07**	72.35**	45705.05**	217141.70**
G x E	30	284.61**	616.87**	1107.43**	134.64**	23.59**	437.01**	4444.77**
Pooled error	90	10.93	21.99	42.70	6.04	1.03	14.39	132.34

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

Table 4. Analysis of Variance (mean squares) for stability for various traits in castor

Sources of variation	d.f	Days to flowering	Days to maturity	Plant height (cm)	Total length of primary raceme(cm)	Number of nodes up to primary raceme	Number of capsules on primary raceme	Seed yield per plant (g)
Genotype	15	206.01*	192.62*	2254.39**	157.81**	18.85**	1227.43**	4921.05**
Environment	2	574.18**	4629.90**	11537.34**	2490.68**	24.12**	15235.01**	72380.67**
G x E	30	94.87	205.63*	369.14	44.88**	7.86*	145.67**	1481.58**
E + (G x E)	32	124.83*	482.14**	1067.16**	197.74**	8.88**	1088.75**	5912.77**
Environment (Linear)	1	1148.35**	9259.95**	23074.60**	4981.37**	48.23**	30470.03**	144761.11**
Genotype x Environment (Linear)	15	122.49	327.85**	404.75	76.72**	12.41**	257.05**	2544.43**
Pooled deviation	16	63.04**	78.18**	312.69**	12.23*	3.11**	32.15*	392.58**
Pooled error	90	10.93	21.99	42.70	6.04	1.03	14.39	132.34

***, ** Significant against pooled deviation mean square at 5 and 1 per cent level of significance, respectively.**

Table 5. Stability parameters of different genotypes for different traits in castor.

Sr. No.	Genotypes	Days to flowering			Days to maturity			Plant height (cm)			Total length of primary raceme(cm)		
		Mean	b_i	$S^2 d_i$	Mean	b_i	$S^2 d_i$	Mean	b_i	$S^2 d_i$	Mean	b_i	$S^2 d_i$
1.	GAUCH 1	63.89	0.17	-3.52	125.89	-0.10**	61.92	77.40	0.74	56.28	38.33	0.80	17.30
2.	GCH 2	66.67	0.01	25.91	147.33	-0.15**	89.26*	98.29	0.86	-14.03	45.51	1.57*	-0.51
3.	GCH 4	71.56	1.24	25.95	144.44	0.48	-6.98	87.93	0.99	385.97**	46.24	1.36	3.38
4.	GCH 5	75.00	2.07	9.41	143.33	0.83	-0.06	133.89	1.46	43.11	48.07	1.41	-1.97
5.	GCH 6	81.44	1.60	50.86*	138.56	0.60	-4.71	109.00	0.01	112.11	42.38	0.05**	8.86
6.	GCH 7	76.11	0.47	13.58	158.22	0.63	35.19	136.47	0.90	399.41**	50.11	0.92	5.54
7.	VP 1	64.44	0.47	187.85**	137.89	1.75	27.72	68.04	0.59	170.78*	40.84	1.06	12.49
8.	GEETA	84.89	1.44	1.62	144.44	0.82	160.44**	123.69	1.62	198.62*	38.80	0.87	6.95
9.	JP 65	75.89	-1.38*	-2.52	133.22	0.41	79.80*	116.82	2.01*	722.33**	41.13	1.22	28.69*
10.	SKP 84	74.22	1.70	6.55	148.00	1.40	57.18	92.93	1.03	26.64	44.69	0.84	13.70
11.	VI 9	76.33	-1.48*	246.28**	145.00	0.25	494.65**	91.56	1.24	-5.64	49.18	2.13**	-1.87
12.	JI 35	79.78	3.78*	-1.11	138.33	1.95	88.16*	72.13	0.03	-13.98	28.31	0.39**	7.25
13.	48-1	87.11	1.85	233.13**	147.00	1.82	30.83	147.93	1.50	590.22**	37.38	0.90	12.46
14.	SH 72	87.89	0.79	15.68	143.67	2.17**	30.41	150.84	0.78	51.42	62.13	0.40**	51.64**
15.	JI 96	84.56	1.45	36.31	129.11	1.36	-3.17	142.53	1.21	866.11**	44.60	1.05	-1.10
16.	SKI 215	90.67	1.82	104.44**	148.33	1.78	-7.09	100.29	1.05	1186.05**	45.22	1.02	0.64
Mean		77.53			142.05			109.36			43.93		
S.Em. ±		5.61			6.25			12.50			2.47		

Table 5 continued

Sr. No.	Genotypes	Number of nodes up to primary raceme			Number of capsules on primary raceme			Seed yield per plant (g)		
		Mean	**b_i**	**$S^2 d_i$**	**Mean**	**b_i**	**$S^2 d_i$**	**Mean**	**b_i**	**$S^2 d_i$**
1.	GAUCH 1	13.71	-0.14	1.95	55.29	0.96	-4.79	124.07	0.87	-35.57
2.	GCH 2	15.24	-0.03	0.77	61.80	1.08	1.46	201.23	1.74**	45.98
3.	GCH 4	14.07	-0.02	12.48**	51.33	0.93	-2.33	155.37	1.14	-23.50
4.	GCH 5	17.62	0.36	-0.34	75.27	1.47**	118.08**	228.63	2.17	500.19*
5.	GCH 6	15.33	-0.02	-0.27	46.80	0.35**	7.42	180.41	0.64	-43.86
6.	GCH 7	21.16	1.51	4.34*	71.80	1.30*	13.41	189.27	1.18	-24.18
7.	VP 1	15.69	-2.59**	-0.34	44.44	0.89	-3.47	77.57	0.26**	2.50
8.	GEETA	19.24	1.42	0.23	72.58	1.30*	0.75	173.27	1.42	-8.63
9.	JP 65	18.51	2.62	1.76	82.71	1.60**	4.43	125.11	0.77	-24.15
10.	SKP 84	18.96	0.41	0.99	68.53	0.76	-2.15	89.33	0.36**	-25.02
11.	VI 9	20.40	6.59**	11.89**	40.56	0.57**	85.20*	122.59	0.32**	-44.10
12.	JI 35	15.22	-0.83	4.76*	33.09	0.46**	31.85	132.10	1.01	-22.38
13.	48-1	21.13	0.80	1.13	62.36	1.25	-4.48	169.28	1.10	-20.11
14.	SH 72	19.76	3.34*	0.36	115.42	1.26	0.70	161.49	0.54*	-44.12
15.	JI 96	19.51	0.86	4.85	56.44	1.16	-4.72	175.27	1.50*	2.25
16.	SKI 215	18.16	1.74	-0.34*	41.71	0.64*	196.32**	129.91	0.97	5340.23**
Mean		17.73			61.26			152.18		
S.Em. ±		1.25			4.01			14.01		

**** Significant at P = 0.01; * Significant at P = 0.05; ASN = Arcsine transformed value,**

Table 6. Performance of promising parents and hybrids for stability of sex expression in castor.

Genotypes	Per cent pistillate whorls on primary raceme	Per cent pistillate whorls on secondary raceme	Per cent pistillate whorls on tertiary raceme
GAUCH 1	US	US	US
GCH 2	US	US	US
GCH 4	US	US	US
GCH 5	S	US	US
GCH 6	US	US	US
GCH 7	US	US	US
VP 1	S	S	S
GEETA	US	US	US
JP 65	S	S	S
SKP 84	S	S	S
VI 9	US	US	US
JI 35	US	US	US
48-1	S	S	S
SH 72	US	US	US
JI 96	US	US	US
SKI 215	US	S	US

S = Stable; US = Unstable