Electronic Journal of Plant Breeding, 7(4): 830-837 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00112.5

Research Article

Genotype x environment interactions and stability analysis for seed yield and yield attributing characters in castor (*Ricinus communis* L.)

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(Received:19 Oct 2015; Accepted:15Dec 2015)

Abstract

The forty six genotypes including 36 hybrids, 9 parents and GCH-7 as commercial check were evaluated for stability in three environments (sowing dates and spacing) at RRS, AAU, Anand. The partitioning of G x E interaction indicated that substantial portion of G x E interaction was linear for seed yield per plant, number of secondary spikes per plant, number of tertiary spikes per plant, total number of capsules per plant, total length of primary raceme and oil content. Both linear and nonlinear components were equally important for these characters. The study of the stability parameters revealed that parent ANDCP-06-07 as well as hybrids ANDCP-08-01 x JP-65, ANDCP-06-07 x ACP-1-06-07, ANDCP-06-07 x DPC-9, VP-1 x DPC-9 and DPC-9 x ANDCP-06-07-1 had average stability and wider adaptability for seed yield per plant; whereas, parents ACP-1-06-07, SKP-84, ANDCP-06-07-1 and hybrid ACP-1-06-07 x JP-65 had above average stability (bi < 1) and well adapted to poor environment, similarly hybrids ANDCP-08-01 x ANDCP-06-07-1, ACP-06-07-1 x DPC-9, GCH-7 (Check) had below average stability (bi > 1) and specifically adapted to favorable environment. None of the parents or hybrids was found consistently stable for all the characters in any environment.

Key words

Castor, genotype x environment interaction, seed yield per plant, stability

Introduction

The stability parameters provide information about adaptability of genotypes, and their stability over a wide range of agro-climatic conditions. If adaptability in real sense is an inherited phenomenon then preliminary evaluation can be made to identify the stable genotypes, and their cross combinations subjected to further testing. Generally multilocation trials are conducted for the several years to find out stability. However, economy could be exercised by manipulating agronomic differentials like sowing dates, plant geometry, doses of fertilizer, irrigations etc. at a single sowing location and season. According to Allard and Bradshaw (1964), a genotype which can adjust its genotypic or phenotypic state in response to transient fluctuations in environments, in such a way that it gives high and stable economic returns over the time and space, can be termed as “well-buffered’ or “highly buffered” genotype.

A knowledge regarding nature and relative magnitude of genotypes x environments interaction is important in making decisions concerning breeding methods, selection programme and testing procedures in crop plants (Baker, 1969). Sprague (1966) opined that the possibility of reducing genotypes x environments (G X E) interaction in field experiments is questionable, despite knowledge of the factors responsible for such interactions. The breeders have long been aware of the problems of differential responses of genotypes, when tested under different environments; however, they were unable to quantify the same and modified their methodology. This was largely due to the problem of their inability to define and measure the adaptability and/ or the complexities of environments. The present study was undertaken to identify stable pistillate x pistillate hybrids and their parents for seed yield and component characters. The importance of G X E interaction and stability parameters in F_1 generation is that the F_1s, which are stable in varied environments, are likely to produce stable segregants in succeeding generations, and those may be looked for selection of desirable genotypes, and such F_1 may show stability when recommended as hybrid for commercial cultivation.

Materials and Methods

In this study, nine genetically diverse pistillate lines *viz*. ANDCP-08-01, ANDCP-06-07, ACP-1-06-07, SKP-84, VP-1, DPC-9, JP-65, ANDCP-06-07-1 and ANDCP-06-07-2 were crossed in half diallel mating fashion and the resulting 46 genotypes (36 hybrids + 9 parents + GCH-7 as check) were included as experimental materials. They were grown in Randomized Complete Block Design with three replications in three environments *viz*., E1 (Late *kharif* – Second week of September; 120 x 60 cm^2), E2 (*Autumn* - Second week of October; 90 x 60 cm^2) and E3 (*Rabi*- First week of November; 90 x 45 cm^2). The investigation was carried out at Regional Research Station, Anand Agricultural University, Anand during 2012-13. All recommended package of practices were followed for good crop stand and growth. Five competitive plants in each replication were randomly selected for recording seed yield per plant, oil content, total length of primary raceme, number of secondary spikes per plant, number of tertiary spikes per plant and total number of capsules per plant. For estimation of stability the data were analysed as per the method suggested by Eberhart and Russell (1966).

Results and Discussion

The pooled analysis over three environments revealed significant differences among the hybrids for seed yield per plant, oil content, total length of primary raceme, number of secondary spikes per plant, number of tertiary spikes per plant and total number of capsules per plant (Table 1). Highly significant values of mean square due to environments (linear) for all the characters indicated that environments differed considerably among different sowing dates. Similar observations were also reported by Solanki and Joshi (2003), Kumari *et al*. (2003), Patel and Pathak (2006), Chaudhari (2006) and Patel (2009). The mean square values due to G X E (linear) and G X E (pooled deviation) were found to be significant for the all the characters except oil content. Significant G x E interactions (linear) for seed yield per plant were earlier reported by Solanki and Joshi (2003), Sasidharan (2005), Chaudhari (2006) and Patel (2009). When both linear and non-linear (pooled deviation) components of G X E interaction are significant, the magnitude of both the components need to be considered, and greater magnitude of linear component [G X E (L)* > G X E (NL)*] suggests the possibility for prediction of performance of genotypes over environments. Accordingly, three kinds of linear responses (b_i) *viz.*, b_i<1, b_i=1 and b_i>1 have been considered, and interpreted as b_i=1, average stability and widely adaptable to different environments; b_i>1 and significant, below average stability, increasing sensitivity to environmental changes and well adapted to favorable environment and b_i<1 and significant, above average stability, greater tolerance to environmental changes; thereby genotype would have specific adaptability to poor environment (Table 2).

The estimate of mean performance (x), regression coefficient (bi) and deviation from regression (S^2di) presented in Table 3 to 5. For seed cotton yield per plant out of 46 genotypes, 26 genotypes had non-significant deviation from linear regression, and 22 genotypes had higher seed yield per plant than respective mean and among them, 13 genotypes were identified as well adapted to different environments (Table 2).

Among the parental genotypes, for seed yield per plant ANDCP-06-07 had average stability (M=174.98; b_i=0.23**, S^2d_i=167.80), suggesting it as widely adapted to all the environments. Parents ACP-1-06-07 (M=169.62; b_i=0.51**@@, S^2d_i=-194.79), SKP-84 (M=195.21; b_i=0.78**@@, S^2d_i=-436.59) and ANDCP-06-07-1 (M=193.29; b_i=0.71**@, S^2d_i=-320.66) had above average stability, thereby specifically adapted to poor environment. Among the hybrids, ANDCP-08-01 x JP-65 (M=366.42; b_i=0.93**, S^2d_i=-335.58), ANDCP-06-07 x ACP-1-06-07 (M=264.05; b_i=0.95**, S^2d_i=-435.09), ANDCP-06-07 x DPC-9 (M=308.72; b_i=1.51**, S^2d_i=319.95), VP-1 x DPC-9 (M=305.38; b_i=1.32**, S^2d_i=276.35) and DPC-9 x ANDCP-06-07-1 (M=302.89; b_i=1.23**, S^2d_i=618.40) were found stable and widely adapted to all the environments, while hybrids ANDCP-08-01 x ANDCP-06-07-1 (M=262.16; b_i=2.10**@@, S^2d_i=365.54), ACP-06-07-1 x DPC-9 (M=329.93; b_i=2.14**@@, S^2d_i=-381.82) and conventional hybrid GCH-7 (M=358.64; b_i=3.16**@@, S^2d_i=234.71) had below average stability, thereby well adapted to favorable environment. On the other hand, hybrid ACP-1-06-07 x JP-65 (M=297.50; b_i=0.29@@, S^2d_i=-230.42) had above average stability, and specifically adapted to unfavorable or poor environment. (Table 2 & 3).

For the character oil content, none of the pistillate parents could be considered as stable and widely adapted, while parents ANDCP-08-01, ANDCP-06-07-1 and ANDCP-06-07-2 had below average stability, thereby specifically adapted to favorable environment. The parents ANDCP-06-07, VP-1 and DPC-9 had above average stability suggesting them as well adapted to poor environment. Among the hybrids, ANDCP-08-01 x ANDCP-06-07-1, ANDCP-06-07 x DPC-9, ANDCP-06-07 x JP-65, ACP-1-06-07 x DPC-9 and VP-1 x DPC-9 had average stability; while, hybrids VP-1 x ANDCP-06-07-1 and JP-65 x ANDCP-06-07-1 had below average stability thereby specifically adapted to favorable environment, and the hybrids ANDCP-08-01 x DPC-9, ANDCP-08-01 x JP-65, ANDCP-06-07 x ANDCP-06-07-1, ANDCP-06-07 x ANDCP-06-07-2, SKP-84 x DPC-9, DPC-9 x ANDCP-06-07-1, DPC-9 x ANDCP-06-07-2 and GCH-7 (Commercial

DOI: 10.5958/0975-928X.2016.00112.5

hybrid) had above average stability, hence specifically adapted to poor environment.

The larger length of primary raceme, number of secondary spikes per plant, number of tertiary spikes per plant, total number of capsules per plant are major yield contributing characters and hence, estimation of stability for these characters were also done and furnished in table 4 and 5. For the characters total length of primary raceme and number of secondary spikes per plant, none of the genotype had average stability. Whereas, for number of tertiary spikes per plant one parent (VP-1) and two hybrids (SKP-84 x JP-65 and JP-65 x ANDCP-06-07-1) had average stability and would have well adaptation to array of environments (Table 2 to 5).

In case of total number of capsule per plant two pistillate parents (SKP-84and VP-1) and five hybrids (ANDCP-08-01 x JP-65, ANDCP-06-07 xACP-1-06-07, SKP-84 x DPC-9, VP-1 x DPC-9 and DPC-9 x ANDCP-06-07-1) had found average stable. While, hybrids ANDCP-08-01 x ANDCP-06-07-1, ANDCP-06-07 x DPC-9, ACP-1-06-07 x DPC-9, ACP-1-06-07 xANDCP-06-07-1 and SKP-84 x ANDCP-06-07-2 had below average stability (Table 2 to 5).

From present study, it was revealed that none of the parents or hybrids was found consistently stable for all the characters in any environment. As the seed yield per plant is important character in stability point of view, the perusal of results for this character indicated that parent ANDCP-06-07 as well as hybrids ANDCP-08-01 x JP-65, ANDCP-06-07 x ACP-1-06-07, ANDCP-06-07 x DPC-9, VP-1 x DPC-9 and DPC-9 x ANDCP-06-07-1 had average stability and wider adaptability; whereas, parents ACP-1-06-07, SKP-84, ANDCP-06-07-1 and hybrid ACP-1-06-07 x JP-65 had above average stability (bi < 1) and well adapted to poor environment, similarly hybrids ANDCP-08-01 x ANDCP-06-07-1, ACP-06-07-1 x DPC-9, GCH-7 (Check) had below average stability (bi > 1) and specifically adapted to favorable environment.

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 DOI: 10.5958/0975-928X.2016.00112.5

Table 1. Analysis of variance for phenotypic stability for different characters in castor

Source	df	Seed yield per plant		Oil content		Total length of primary raceme		Number of secondary spikes / plant		Number of tertiary spikes / plant		Total number of capsules / plant	
Rep. within Env.	6	497.99		1.60	## **	62.18	**	0.37	NS	0.54	**	1594.49	NS
Genotypes (G)	45	16320.82	@@ ## **	7.88	@@ ## **	229.11	@@ ## **	2.19	@@ ## **	3.68	@@ ## **	20869.43	@@ ## **
Environments (E)	2	219969.50	@@ ## **	155.95	@@ ## **	327.28	@@ ## **	21.90	@@ ## **	55.15	@@ ## **	377651.10	@@ ## **
G x E.	90	4846.68	**	0.75	## **	53.96	**	0.74	# **	1.18	## **	7224.67	**
E + (G x E)	92	9523.26	## **	4.12	## **	59.90	**	1.20	## **	2.35	## **	15277.43	## **
E (Lin)	1	439939.10	## **	311.90	## **	654.57	## **	43.81	## **	110.31	## **	755302.30	## **
G x E (Lin)	45	6019.57	# **	1.44	## **	54.92	**	0.99	## **	1.88	## **	8826.48	**
Pooled Deviation	46	3593.92	**	0.06		51.84	**	0.47	**	0.46	**	5500.63	**
Pooled Error	270	457.15		0.43		15.90		0.22		0.10		777.05	
Total		11756.04						1.52		2.79		17114.21	

@, @@ Significant tested against genotypes x environments (Gx E) at 0.05 and 0.01 levels of probability, respectively.
 # ## Significant tested against pooled deviation at 0.05 and 0.01 levels of probability, respectively.
, * Significant tested against pooled error at 0.05 and 0.01 levels of probability, respectively

Table 2. List of stable genotypes over environment for yield and yield contributing characters

Sl. No.	Stability	Seed yield per plant	Oil content	Total length of primary raceme
	PARENTS			
1	**Average stability** (Mean<parental mean; b_i=0 significant and b_i=1 NS; S^2d_i=0 NS) Widely adapted to all the environments	ANDCP-06-07	-	-
2	**Below average stability** (Mean>parental mean; b_i=0 significant; b_i=1 significant and b_i>1.00; S^2d_i=0 NS) Specifically adapted to favourable environment	-	ANDCP-08-01, ANDCP-06-07-1 ANDCP-06-07-2	SKP-84
3	**Above average stability** (Mean>parental mean; b_i=0 significant; b_i=1 significant and b_i<1.00; S^2d_i=0 NS) Specifically adapted to poor environment	ACP-1-06-07, SKP-84 ANDCP-06-07-1	ANDCP-06-07, VP-1 DPC-9	ANDCP-06-07-1
	HYBRIDS			
1	**Average stability** (Mean<parental mean; b_i=0 significant and b_i=1 NS; S^2d_i=0 NS) Widely adapted to all the environments	ANDCP-08-01 x JP-65, ANDCP-06-07 x ACP-1-06-07, ANDCP-06-07 x DPC-9, VP-1 x DPC-9, DPC-9 x ANDCP-06-07-1	ANDCP-08-01 x ANDCP-06-07-1, ANDCP-06-07 x DPC-9, ANDCP-06-07 x JP-65, ACP-1-06-07 x DPC-9, VP-1 x DPC-9	-
2	**Below average stability** (Mean>parental mean; b_i=0 significant; b_i=1 significant and b_i>1.00; S^2d_i=0 NS) Specifically adapted to favourable environment	ANDCP-08-01 x ANDCP-06-07-1, ACP-06-07-1 x DPC-9, GCH-7 (Check)	VP-1 x ANDCP-06-07-1 JP-65 x ANDCP-06-07-1	ANDCP-06-07 x JP-65, JP-65 x ANDCP-06-07-1
3	**Above average stability** (Mean>parental mean; b_i=0 significant; b_i=1 significant and b_i<1.00; S^2d_i=0 NS) Specifically adapted to poor environment	ACP-1-06-07 x JP-65	ANDCP-08-01 x DPC-9, ANDCP-08-01 x JP-65, ANDCP-06-07 x ANDCP-06-07-1, ANDCP-06-07 x ANDCP-06-07-2, SKP-84 x DPC-9, DPC-9 x ANDCP-06-07-1, DPC-9 x ANDCP-06-07-2, GCH-7 (Check)	ACP-1-06-07 x DPC-9

Electronic Journal of Plant Breeding, 7(4): 830-837 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00112.5

Table 2. Contd...

Sl. No.	Stability	Number of secondary spikes per plant	Number of tertiary spikes per plant	Total number of capsules per plant
	PARENTS			
1	**Average stability** (Mean<parental mean; b_i=0 significant and b_i=1 NS; S^2d_i=0 NS)Widely adapted to all the environments	-	VP-1	SKP-84 VP-1
2	**Below average stability** (Mean>parental mean; b_i=0 significant; b_i=1 significant and b_i>1.00; S^2d_i=0 NS) Specifically adapted to favourable environment	ANDCP-06-07, VP-1 DPC-9	ANDCP-06-07-1	-
3	**Above average stability** (Mean>parental mean; b_i=0 significant; b_i=1 significant and b_i<1.00; S^2d_i=0 NS) Specifically adapted to poor environment	-	ANDCP-08-01	-
	HYBRIDS			
1	**Average stability** (Mean<parental mean; b_i=0 significant and b_i=1 NS; S^2d_i=0 NS) Widely adapted to all the environments	-	SKP-84 x JP-65 JP-65 x ANDCP-06-07-1	ANDCP-08-01 x JP-65, ANDCP-06-07 x ACP-1-06-07, SKP-84 x DPC-9, VP-1 x DPC-9, DPC-9 x ANDCP-06-07-1
2	**Below average stability** (Mean>parental mean; b_i=0 significant; b_i=1 significant and b_i>1.00; S^2d_i=0 NS) Specifically adapted to favourable environment	ANDCP-08-01 x DPC-9 SKP-84 x JP-65	ANDCP-08-01 x DPC-9, ANDCP-08-01 x ANDCP-06-07-1, ANDCP-06-07 x JP-65, SKP-84 x VP-1, SKP-84 x DPC-9, VP-1 x ANDCP-06-07-2, DPC-9 x ANDCP-06-07-1	ANDCP-08-01 x ANDCP-06-07-1, ANDCP-06-07 x DPC-9, ACP-1-06-07 x DPC-9, ACP-1-06-07 x ANDCP-06-07-1, SKP-84 x ANDCP-06-07-2
3	**Above average stability** (Mean>parental mean; b_i=0 significant; b_i=1 significant and b_i<1.00; S^2d_i=0 NS) Specifically adapted to poor environment	ANDCP-08-01 x JP-65 VP-1 x JP-65	ANDCP-08-01 x JP-65, ANDCP-06-07 x SKP-84, ACP-1-06-07 x VP-1, VP-1 x ANDCP-06-07-1, DPC-9 x JP-65	-

Table 3. Stability parameters for seed yield per plant and oil content

Sl. No.	Parents / Crosses	Code	Seed yield per plant			Oil content		
			Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1	ANDCP-08-01	P1	116.79	0.84 **@	-410.73	47.02	1.25 **@@	-0.43
2	ANDCP-06-07	P2	174.98	0.23 **	167.80	45.95	0.56 **@@	-0.38
3	ACP-1-06-07	P3	169.62	0.51 **@@	-194.79	44.99	2.07 **@@	-0.38
4	SKP-84	P4	195.21	0.78 **@@	-436.59	45.03	1.16 **@@	-0.43
5	VP-1	P5	196.18	1.27 *	2384.78 #	45.48	0.79 **@@	-0.42
6	DPC-9	P6	128.72	-0.04	5944.63 #	45.72	-0.03 @@	-0.42
7	JP-65	P7	135.49	-0.53	25133.88 #	40.58	2.31 **@@	-0.41
8	ANDCP-06-07-1	P8	193.29	0.71 **@	-320.66	46.92	1.46 **@@	-0.42
9	ANDCP-06-07-2	P9	167.75	0.53	3412.96 #	46.79	1.42 **@@	-0.44
	Parental Mean		**164.22**			**45.39**		
10	ANDCP-08-01 **x** ANDCP-06-07	P1 x P2	211.90	1.09 *	2123.99 #	46.85	0.76 **	-0.22
11	ANDCP-08-01 **x** ACP-1-06-07	P1 x P3	208.51	0.38 @	319.31	46.37	1.35 **@@	-0.43
12	ANDCP-08-01 **x** SKP-84	P1 x P4	197.41	0.08	5723.93 #	45.76	0.96 **	-0.32
13	ANDCP-08-01 **x** VP-1	P1 x P5	203.90	-0.06	4967.29 #	46.65	1.09 **@@	-0.44
14	ANDCP-08-01 **x** DPC-9	P1 x P6	223.87	1.38	5516.22 #	47.95	0.72 **@@	-0.43
15	ANDCP-08-01 **x** JP-65	P1 x P7	366.42	0.93 **	-335.58	47.34	0.62 **@@	-0.43
16	ANDCP-08-01 **x** ANDCP-06-07-1	P1 x P8	262.16	2.10 **@@	365.54	47.28	0.98 **	-0.40
17	ANDCP-08-01 **x** ANDCP-06-07-2	P1 x P9	221.82	1.36	5928.43 #	45.93	1.10 **	-0.34
18	ANDCP-06-07 **x** ACP-1-06-07	P2 x P3	264.05	0.95 **	-435.09	46.92	0.92 **	-0.30
19	ANDCP-06-07 **x** SKP-84	P2 x P4	210.51	0.13 @@	570.35	46.90	0.83 **@@	-0.42
20	ANDCP-06-07 **x** VP-1	P2 x P5	172.55	0.11 @	1040.92	46.56	0.67 **@@	-0.40
21	ANDCP-06-07 **x** DPC-9	P2 x P6	308.72	1.51 **	319.95	49.95	1.15 **	-0.37
22	ANDCP-06-07 **x** JP-65	P2 x P7	371.17	1.32	4116.71 #	47.23	1.22 **	-0.33
23	ANDCP-06-07 **x** ANDCP-06-07-1	P2 x P8	128.64	0.22 *@@	-338.168	47.91	0.83 **@@	-0.40
24	ANDCP-06-07 **x** ANDCP-06-07-2	P2 x P9	172.32	0.69	1003.87	47.04	0.86 **@@	-0.43
25	ACP-1-06-07 **x** SKP-84	P3 x P4	211.85	0.17	11997.35 #	45.46	1.10 **	-0.18
26	ACP-1-06-07 **x** VP-1	P3 x P5	209.41	1.25 **	455.32	46.29	1.03 **	-0.42
27	ACP-1-06-07 **x** DPC-9	P3 x P6	329.93	2.14 **@@	-381.82	49.47	0.80 **	-0.37
28	ACP-1-06-07 **x** JP-65	P3 x P7	297.50	0.29 @@	-230.42	46.02	1.63 **@@	-0.44
29	ACP-1-06-07 **x** ANDCP-06-07-1	P3 x P8	240.61	1.78 **@@	-444.48	46.89	1.07 **@@	-0.44
30	ACP-1-06-07 **x** ANDCP-06-07-2	P3 x P9	172.29	0.82 **	-353.26	46.40	0.83 **	-0.26
31	SKP-84 **x** VP-1	P4 x P5	204.30	1.10 **	552.41	45.83	0.76 **@@	-0.42
32	SKP-84 **x** DPC-9	P4 x P6	355.28	0.69	5058.24 #	48.97	0.48 **@@	-0.35
33	SKP-84 **x** JP-65	P4 x P7	410.35	2.19 *	8714.75 #	45.77	0.95 **	-0.38
34	SKP-84 **x** ANDCP-06-07-1	P4 x P8	231.31	1.57 **@@	-216.99	46.56	0.78 **	-0.34
35	SKP-84 **x** ANDCP-06-07-2	P4 x P9	245.62	1.51 **@@	-156.38	46.30	0.42 **@@	-0.29
36	VP-1 **x** DPC-9	P5 x P6	305.38	1.32 **	276.35	49.12	1.05 **	0.01
37	VP-1 **x** JP-65	P5 x P7	317.71	2.07 **	3304.86 #	44.78	1.38 **@@	-0.42
38	VP-1 **x** ANDCP-06-07-1	P5 x P8	219.79	0.46	3580.15 #	47.02	1.14 **@@	-0.42
39	VP-1 **x** ANDCP-06-07-2	P5 x P9	182.96	0.63 **@@	-264.62	45.96	0.87 **@	-0.41
40	DPC-9 **x** JP-65	P6 x P7	234.49	0.64	22812.66 #	43.95	0.74 **@@	-0.43
41	DPC-9 **x** ANDCP-06-07-1	P6 x P8	302.89	1.23 **	618.40	50.19	0.20 **@@	-0.42
42	DPC-9 **x** ANDCP-06-07-2	P6 x P9	291.65	2.22 **	5699.24 #	49.41	0.53 **@@	-0.37
43	JP-65 **x** ANDCP-06-07-1	P7 x P8	368.75	2.52 **	7211.79 #	47.28	1.95 **@@	-0.34
44	JP-65 **x** ANDCP-06-07-2	P7 x P9	319.18	1.74 **	3020.55 #	46.70	1.62 **@@	-0.37
45	ANDCP-06-07-1 **x** ANDCP-06-07-2	P8 x P9	238.05	0.04	6236.23 #	46.44	1.37 **@	-0.24
46	GCH-7	Check	358.64	3.16 **@@	234.71	47.68	0.27 **@@	-0.44
	Hybrids Mean		**258.70**			**47.00**		

*, ** Significant at 0.05 and 0.01 percent level, respectively when H_0: b=0
@, @@ Significant at 0.05 and 0.01 percent level respectively, when H_0: b=1
Significant at 0.05 percent level

DOI: 10.5958/0975-928X.2016.00112.5

Table 4. Stability parameters for total length of primary raceme and number of secondary spikes per plant

S.No	Parents / Crosses	Code	Total length of primary raceme					No. of secondary spikes per plant				
			Mean	**b_i**		**S^2d_i**		**Mean**	**b_i**		**S^2d_i**	
1	ANDCP-08-01	P1	61.53	0.32		52.12	#	4.76	1.32	**	-0.00	
2	ANDCP-06-07	P2	70.00	3.85	**@@	-12.71		4.96	1.39	**@	-0.19	
3	ACP-1-06-07	P3	99.69	-0.72		106.84	#	4.16	0.97	**	-0.19	
4	SKP-84	P4	78.49	5.21	**@@	-15.86		4.40	-0.29		1.26	#
5	VP-1	P5	70.84	-1.16		54.25	#	5.00	2.25	**@@	-0.19	
6	DPC-9	P6	55.53	-0.03		-1.03		5.64	3.42	**@@	0.40	
7	JP-65	P7	67.82	0.37		86.98	#	6.42	2.40		4.40	#
8	ANDCP-06-07-1	P8	74.62	-1.53	**@@	-15.91		4.73	-0.20	@@	-0.15	
9	ANDCP-06-07-2	P9	69.29	2.52	**@	-9.94		4.40	2.08	**@@	-0.19	
	Parental Mean		**71.98**					**4.94**				
10	ANDCP-08-01 **x** ANDCP-06-07	P1 x P2	74.38	0.55		-13.99		4.73	1.16	**	-0.21	
11	ANDCP-08-01 **x** ACP-1-06-07	P1 x P3	82.87	2.12		302.24	#	4.98	0.00	@	0.00	
12	ANDCP-08-01 **x** SKP-84	P1 x P4	77.53	2.34	**@	-10.73		5.04	0.02	@@	-0.14	
13	ANDCP-08-01 **x** VP-1	P1 x P5	74.76	1.29		66.61	#	5.49	0.72		0.08	
14	ANDCP-08-01 **x** DPC-9	P1 x P6	76.27	1.54		-4.70		5.42	2.24	**@@	-0.19	
15	ANDCP-08-01 **x** JP-65	P1 x P7	85.04	-3.77	@	53.90	#	6.22	0.69	**@@	-0.21	
16	ANDCP-08-01 **x** ANDCP-06-07-1	P1 x P8	78.91	1.27	**@	-15.68		5.60	0.20	@@	-0.15	
17	ANDCP-08-01 **x** ANDCP-06-07-2	P1 x P9	82.02	1.69		0.12		4.36	0.08		0.04	
18	ANDCP-06-07 **x** ACP-1-06-07	P2 x P3	88.67	2.43		123.62	#	3.96	1.69	**@@	-0.17	
19	ANDCP-06-07 **x** SKP-84	P2 x P4	75.73	2.85		87.48	#	3.84	1.10	**	-0.02	
20	ANDCP-06-07 **x** VP-1	P2 x P5	73.40	1.95		112.04	#	4.78	1.32	**@@	-0.22	
21	ANDCP-06-07 **x** DPC-9	P2 x P6	74.62	2.37	**@@	-14.52		4.58	1.63	**@@	-0.17	
22	ANDCP-06-07 **x** JP-65	P2 x P7	84.89	3.95	**@@	-13.82		6.36	-2.01	@	1.72	#
23	ANDCP-06-07 **x** ANDCP-06-07-1	P2 x P8	70.62	3.16	**@	-1.83		4.33	0.85	**	-0.21	
24	ANDCP-06-07 **x** ANDCP-06-07-2	P2 x P9	79.20	2.94		29.75		4.09	0.58		0.90	#
25	ACP-1-06-07 **x** SKP-84	P3 x P4	99.13	-0.84		36.64		4.60	-1.28	**@@	0.15	
26	ACP-1-06-07 **x** VP-1	P3 x P5	88.07	1.00		47.38	#	5.31	1.37	**	-0.11	
27	ACP-1-06-07 **x** DPC-9	P3 x P6	81.02	-0.90	**@@	-15.42		5.00	0.27	*@@	-0.21	
28	ACP-1-06-07 **x** JP-65	P3 x P7	90.93	-0.89	@	-4.58		5.73	1.24		0.75	#
29	ACP-1-06-07 **x** ANDCP-06-07-1	P3 x P8	92.98	2.35		150.41	#	4.76	0.20		0.47	
30	ACP-1-06-07 **x** ANDCP-06-07-2	P3 x P9	87.76	-0.38	@@	-14.46		4.44	1.48	*	0.27	
31	SKP-84 **x** VP-1	P4 x P5	79.47	0.68		97.47	#	5.33	1.72		1.28	#
32	SKP-84 **x** DPC-9	P4 x P6	79.69	0.51		-11.78		6.38	0.51		0.95	#
33	SKP-84 **x** JP-65	P4 x P7	91.56	0.48		115.19	#	7.42	1.65	**@@	-0.18	
34	SKP-84 **x** ANDCP-06-07-1	P4 x P8	82.58	3.24		73.68	#	5.36	0.70		0.39	
35	SKP-84 **x** ANDCP-06-07-2	P4 x P9	76.73	2.05	**	-8.55		5.38	1.54		0.91	#
36	VP-1 **x** DPC-9	P5 x P6	80.56	0.61		15.95		6.38	0.24	@@	-0.20	
37	VP-1 **x** JP-65	P5 x P7	80.73	0.54		-11.81		5.62	-0.23	**@@	-0.22	
38	VP-1 **x** ANDCP-06-07-1	P5 x P8	68.78	-2.74		57.08	#	5.02	1.54	**@@	-0.22	
39	VP-1 **x** ANDCP-06-07-2	P5 x P9	69.49	-3.36	@	47.67	#	5.24	2.61	*	0.79	#
40	DPC-9 **x** JP-65	P6 x P7	82.33	0.44		-9.15		5.67	0.75	**@@	-0.22	
41	DPC-9 **x** ANDCP-06-07-1	P6 x P8	77.80	2.05	**@@	-15.89		5.67	0.55		-0.05	
42	DPC-9 **x** ANDCP-06-07-2	P6 x P9	75.22	-2.39	**@@	-4.24		5.56	2.85	**@@	-0.10	
43	JP-65 **x** ANDCP-06-07-1	P7 x P8	83.51	4.05	**@	16.66		6.40	1.28	**	-0.18	
44	JP-65 **x** ANDCP-06-07-2	P7 x P9	83.49	1.41		137.15	#	5.89	1.75		1.09	#
45	ANDCP-06-07-1 **x** ANDCP-06-07-2	P8 x P9	72.09	1.73		0.54		5.07	0.49		0.21	
46	GCH-7	Check	79.24	0.87		8.72		7.84	1.11	*	-0.10	
	Hybrids Mean		**80.60**					**5.35**				

*, ** Significant at 0.05 and 0.01 percent level, respectively when H_0: b=0

@, @@ Significant at 0.05 and 0.01 percent level respectively, when H_0: b=1

Significant at 0.05 percent level

Electronic Journal of Plant Breeding, 7(4): 830-837 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00112.5

Table 5. Stability parameters for number of tertiary spikes per plant and total number of capsules per plant

S.No.	Parents / Crosses	Code	Number of tertiary spikes per plant			Total number of capsules per plant		
			Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1	ANDCP-08-01	P1	3.87	0.61 **@@	-0.08	138.22	0.72 **@@	-774.82
2	ANDCP-06-07	P2	2.87	0.74 **@@	-0.09	233.60	0.16 @@	320.63
3	ACP-1-06-07	P3	2.58	0.49 **@@	-0.10	215.36	0.24 @@	-378.43
4	SKP-84	P4	4.02	0.13 @@	-0.01	242.08	0.77 **	-475.06
5	VP-1	P5	4.33	0.87 **	-0.09	242.41	1.06 *	3611.78
6	DPC-9	P6	3.56	-0.23 @@	0.10	168.50	0.01	9298.03 #
7	JP-65	P7	6.09	-2.07	8.83 #	182.23	-0.63	45061.70 #
8	ANDCP-06-07-1	P8	3.87	1.59 **@@	-0.08	271.08	1.11 *	2400.10 #
9	ANDCP-06-07-2	P9	3.13	1.00	3.75 #	231.90	0.76	4516.22 #
	Parental Mean		**3.81**			**213.93**		
10	ANDCP-08-01 **x** ANDCP-06-07	P1 x P2	3.84	1.91 **@@	-0.01	254.60	1.25 *	3983.06 #
11	ANDCP-08-01 **x** ACP-1-06-07	P1 x P3	4.60	1.33 **@@	-0.10	233.53	0.40 *@@	-140.99
12	ANDCP-08-01 **x** SKP-84	P1 x P4	3.53	0.91 **@@	-0.10	228.87	0.28	7636.99 #
13	ANDCP-08-01 **x** VP-1	P1 x P5	4.64	0.16 @@	-0.02	238.15	-0.10	7313.07 #
14	ANDCP-08-01 **x** DPC-9	P1 x P6	5.09	1.37 **@@	-0.10	254.98	1.21	9214.58 #
15	ANDCP-08-01 **x** JP-65	P1 x P7	5.33	0.66 **@@	-0.09	391.43	0.86 **	372.97
16	ANDCP-08-01 **x** ANDCP-06-07-1	P1 x P8	5.04	1.04 **@@	-0.10	323.79	2.09 **@@	-434.93
17	ANDCP-08-01 **x** ANDCP-06-07-2	P1 x P9	3.09	1.14 **@	-0.07	274.32	1.42	8612.55 #
18	ANDCP-06-07 **x** ACP-1-06-07	P2 x P3	3.47	1.02 **	-0.10	324.27	0.96 **	-681.17
19	ANDCP-06-07 **x** SKP-84	P2 x P4	5.56	0.33 *@@	-0.05	256.87	0.20	2565.63 #
20	ANDCP-06-07 **x** VP-1	P2 x P5	5.47	-0.09 @@	0.20	213.19	0.11 @	1861.12 #
21	ANDCP-06-07 **x** DPC-9	P2 x P6	3.58	1.02 **	-0.09	356.70	1.37 **@	-630.50
22	ANDCP-06-07 **x** JP-65	P2 x P7	6.33	2.53 **@@	0.01	462.28	1.26	8215.85 #
23	ANDCP-06-07 **x** ANDCP-06-07-1	P2 x P8	4.22	1.82 **@@	0.00	187.27	0.35 @@	7.18
24	ANDCP-06-07 **x** ANDCP-06-07-2	P2 x P9	4.00	1.44 **@@	-0.10	25.55	0.73	3812.15 #
25	ACP-1-06-07 **x** SKP-84	P3 x P4	3.82	1.22 **@@	-0.10	215.70	0.38	4756.70 #
26	ACP-1-06-07 **x** VP-1	P3 x P5	5.56	0.53 **@@	-0.10	263.61	1.11 **	1246.03
27	ACP-1-06-07 **x** DPC-9	P3 x P6	4.49	0.59 **@@	-0.09	376.19	1.84 **@@	-767.17
28	ACP-1-06-07 **x** JP-65	P3 x P7	3.62	0.94 **@@	-0.10	343.36	0.18 @@	-588.58
29	ACP-1-06-07 **x** ANDCP-06-07-1	P3 x P8	3.80	1.47 **@@	-0.05	314.11	2.10 **@@	-777.05
30	ACP-1-06-07 **x** ANDCP-06-07-2	P3 x P9	3.84	1.51 **@@	-0.10	209.65	0.79 **	-393.60
31	SKP-84 **x** VP-1	P4 x P5	5.13	1.14 **@@	-0.09	254.15	1.23 **	969.73
32	SKP-84 **x** DPC-9	P4 x P6	5.38	2.17 **@@	0.08	409.29	1.08 **	2021.79
33	SKP-84 **x** JP-65	P4 x P7	6.36	0.92 **	-0.08	494.37	1.87	18529.48 #
34	SKP-84 **x** ANDCP-06-07-1	P4 x P8	3.18	2.82 **@@	0.47 #	302.96	1.63 **@@	-675.95
35	SKP-84 **x** ANDCP-06-07-2	P4 x P9	4.56	1.47 **@@	-0.10	326.19	1.68 **@@	331.64
36	VP-1 **x** DPC-9	P5 x P6	4.13	0.39 **@@	-0.09	335.50	1.02 **	452.72
37	VP-1 **x** JP-65	P5 x P7	4.36	1.27 **@@	-0.10	379.58	1.82 **	2804.41 #
38	VP-1 **x** ANDCP-06-07-1	P5 x P8	4.93	0.71 **@@	-0.09	291.69	0.63	2887.65 #
39	VP-1 **x** ANDCP-06-07-2	P5 x P9	5.84	1.93 **@@	-0.09	253.74	0.94 **	-280.58
40	DPC-9 **x** JP-65	P6 x P7	5.56	0.32 **@@	-0.08	251.27	0.63	23204.07 #
41	DPC-9 **x** ANDCP-06-07-1	P6 x P8	4.87	1.54 **@@	-0.09	343.38	1.04 **	979.41
42	DPC-9 **x** ANDCP-06-07-2	P6 x P9	6.51	-0.39 @@	0.24	355.09	2.34 **	8359.92 #
43	JP-65 **x** ANDCP-06-07-1	P7 x P8	5.51	0.99 **	-0.10	463.65	2.47 **	12453.40 #
44	JP-65 **x** ANDCP-06-07-2	P7 x P9	4.71	2.92 *	4.63 #	410.45	1.58 **	3629.71 #
45	ANDCP-06-07-1 **x** ANDCP-06-07-2	P8 x P9	3.49	1.99 **@@	-0.05	327.04	0.30	18918.35 #
46	GCH-7	Check	7.84	-0.17	1.22 #	424.21	2.72 **@@	3874.92 #
	Hybrids Mean		**4.74**			**307.32**		

*, ** Significant at 0.05 and 0.01 percent level, respectively when H_0: b=0
@, @@ Significant at 0.05 and 0.01 percent level respectively, when H_0: b=1
Significant at 0.05 percent level