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Stability analysis in chilli (*Capsicum annuum* L.) for yield and yield attributing traits

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Abstract

Chilli, an important vegetable crop in India, is sensitive to environmental variations and climate change. An investigation was carried out to assess the stability of 25 test hybrids along with three commercial checks across different locations. Pooled analysis of variance showed the presence of significant genetic variability among the hybrids for all the characters studied. Variance due to hybrid × environment interaction was non-significant for all the characters except green fruit yield plant^{-1}. Considering all the stability parameters, CMS10A x Byadgikaddi for fruit weight and fruit width, CMS10A × Gouribidanur for green fruit yield plant^{-1}, CMS10A x LCA 206 for red fruit yield plant^{-1} and CMS8A x Byadgidabbi for number of fruits exhibited below average stability and these were specifically adopted to unfavorable locations. The test Hybrids, CMS6A × Tiwari for the character average fruit weight, CMS9A × LCA 206 for the character fruit width were well adopted to all environments. CMS10A × Gouribidanur proved to be the best yielding genotype among 25 test hybrids, having higher yield level than the check and were also stable for most of the characters as evident from their non-significant s^2di values.

Key words: *Capsicum annuum* L., stability, genotype × environments, fruit yield.

Introduction

Chilli (*Capsicum annuum* L.) is one of the most important solanaceous vegetable crops grown for various uses of its fruits both in green and ripe stages. It is the second largest commodity after black pepper (*Piper nigrum* L.) in the international spice trade. Chilli has its unique place in Asian diet as a spice as well as vegetable. The area under chilli in India is about 0.79 million ha with annual production of 13.04 m tones and productivity of 1.74 tonnes ha^{-1} (Anon, 2014). Chilli, being sensitive to environmental variations exhibits large fluctuations in yield. Phenotypically stable genotypes (varieties/ hybrids) are of great importance, because environmental condition varies from season to season. Phenotypic expression of the genotype is variable when grown in different environments. It is observed that G × E interaction is widely present and contributes substantially to the non-realization of expected gain from selection (Comstock and Moll, 1963).

Partitioning of growing environments to reduce genotype x environment (G x E) interaction is challenging especially in regions where climatic variation is large. Therefore, evaluation of cultivars by stability parameters across multi-environments is important to identify the consistent performing and high yielding cultivars (Gurung *et. al.,* 2012). Stable genotypes are particularly of great importance in chilli growing areas of Karnataka, where the crop is grown in varied environmental conditions. It is difficult to expect a hybrid to be stable in its performance from one environment to another, because of uncertain magnitude and distribution of rainfall. Multi environmental testing of genotypes provides an opportunity to plant breeders to identify the adaptability of a genotype to a particular environment and also stability of the genotypes over different environments. Although a number of varieties have been recommended for cultivation, yet the information on stability is lacking across agro-climate conditions of south Karnataka. Hence, the present investigation was carried out to identify high yielding stable genotypes of Chilli for cultivation at this region through stability analysis.

Materials and methods

Five lines were crossed with five testers in Line x Tester mating design to developed twenty-five F_1s (Table 1). The 25 crosses so synthesised and three commercial checks *viz.*, KBCH-1, Arka Haritha and Arka Meghana were evaluated during *kharif* 2014 at three different environments *viz.*, experimental plots of Balajigapade (Chikkaballapur), Department of Horticulture, 'K' block and Department of Genetics and Plant Breeding (GPB), University of Agricultural sciences (UAS), Gandhi Krishi

Table 1. List of test hybrids and check hybrids used for experiment

SI.No	Hybrids	SI.No	Hybrids
1	CMS6A × Gouribidanur	15	CMS 8A × LCA 206
2	CMS 6A × Tiwari	16	CMS 9A × Gouribidanur
3	CMS 6A × Byadgi kaddi	17	CMS 9A × Tiwari
4	CMS 6A × Byadgi dabbi	18	CMS 9A × Byadgi kaddi
5	CMS 6A × LCA 206	19	CMS 9A × Byadgi dabbi
6	CMS 7A × Gouribidanur	20	CMS 9A × LCA 206
7	CMS 7A × Tiwari	21	CMS 10A × Gouribidanur
8	CMS 7A × Byadgi kaddi	22	CMS 10A × Tiwari
9	CMS 7A × Byadgi dabbi	23	CMS 10A × Byadgi kaddi
10	CMS 7A ×LCA 206	24	CMS 10A × Byadgi dabbi
11	CMS 8A × Gouribidanur	25	CMS 10A × LCA 206
12	CMS 8A × Tiwari	26	KBCH-1
13	CMS 8A × Byadgi kaddi	27	Arka Haritha
14	CMS 8A × Byadgi dabbi	28	Arka Meghana

Table 2. ANOVA for fruit yield and its component traits

Source of variance	df	Green fruit yield plant^{-1} (g)	Red fruit yield plant^{-1} (g)	Fruits plant^{-1}	Average fruit length (cm)	Average fruit weight (g)	Average fruit width (cm)
Rep within environment	3	8031.33	59.58	774.30	0.02	0.24	0.008
Hybrids	27	30430.24**	1611.30*	2463.41 **	10.35**	3.46**	0.06**
Environment + (Hybrids x Environment)	56	15450.02	1222.39	711.52	0.86	0.13	0.01**
Environments	2	43692.14*	9656.72**	3635.90 **	4.82**	1.05**	0.19**
Hybrids x Environment	54	14404.01	910.01	603.21	0.71	0.10	0.003
Environments (Lin.)	1	87384.30**	19313.44**	7271.78**	9.65**	2.11 **	0.39**
Hybrids x Environment (Lin.)	27	19646.98*	936.94	768.27	0.66	0.03	0.002
Pooled Deviation	28	8833.87**	851.53**	422.50**	0.74***	0.16**	0.003
Pooled Error	81	770.34	48.74	66.13	0.046	0.01	0.003

* Significant @P = 0.05 and ** Significant @P = 0.01

Vignana Kendra (GKVK), Bengaluru. The experiments were laid out in Randomized Complete Block Design (RCBD) with two replications. Each genotype was grown in a single row of five-meter length consisting of 12 plants per row with a spacing of 0.40 m between plants within a row and 0.75 meter between rows. All the recommended package of practices was followed to grow the good crop.

Five plants were tagged randomly in each plot leaving border plants and the observations recorded during the course of investigation were green fruit yield plant^{-1}(g), red fruit yield plant^{-1} (g), fruits plant^{-1}, average fruit length (cm), average fruit weight (g), fruit width (cm). Genotypes were assessed for stability of performance over environments in accordance with method described by Eberhart and Russel (1966).

Results

Pooled analysis of variance (Table 2) showed that the mean sum of squares due to hybrids and environments for all the characters *viz.,* green fruit yield plant^{-1}(g), red fruit yield plant^{-1}(g), fruits plant^{-1}, average fruit length (cm), average fruit weight (g), fruit

Table 3a. Stability parameters for green fruit yield, red fruit yield and number of fruits plant^{-1}

Hybrids	Green fruit yield plant^{-1} (g)			Red fruit yield plant^{-1} (g)			Number of fruits plant^{-1}		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
CMS6A × Gouribidanur	532.4	-3.27**	-1026.91	140.1	2.996	653.47**	92.12	-0.88*	-89.25
CMS 6A × Tiwari	461.3	-4.83**	-1023.68	71.76	0.383	-37.62	47.23	-0.13**	-91.37
CMS 6A × Byadgikaddi	390.2	-0.55**	-1029.58	70.96	1.726	184.14*	67.26	-0.39*	-90.98
CMS 6A × Byadgidabbi	316.7	-0.001**	-1029.66	88.6	0.00**	-49.13	73.39	-0.64*	-90.26
CMS 6A × LCA 206	295.7	0.07	-973.17	109.01	-0.637	6849.29**	52.68	0.39	108.24
CMS 7A × Gouribidanur	351.6	4.23**	-1025.08	102.47	0.153*	-47.3	91.31	3.1	-64.5
CMS 7A × Tiwari	386.2	-0.57**	-1029.58	76.21	0.856	8.25	92.67	3.12	-64.07
CMS 7A × Byadgikaddi	647.4	-3.67**	-1026.2	120.37	2.411	405.80**	110.5	-1.83*	-82.03
CMS 7A × Byadgidabbi	357.2	3.24**	-1026.96	87.01	0.971	24.62	106.63	3.58	-55.402
CMS 7A × LCA 206	380.6	1.44	3864.91*	82.48	1.122	1971.47**	96.33	2.72	525.09*
CMS 8A × Gouribidanur	570.9	2.54	13556.61**	93.96	-0.306	1.3105*	144.37	1.83	3406.79**
CMS 8A × Tiwari	294.9	1.53	11451.01**	76.44	0.357	1297.70**	67.9	1.01	1008.80**
CMS 8A × Byadgikaddi	295.8	4.02**	-1025.51	123.14	2.533	453.05**	64.68	1.63	-83.98
CMS 8A × Byadgidabbi	333.6	3.61**	-1026.32	91.7	2.129	305.72**	91.04	1.51	-84.97
CMS 8A × LCA 206	414	2.91	3968.93*	82.48	1.122	1971.47**	96.33	2.72	525.09*
CMS 9A × Gouribidanur	381	-0.49	72802.22**	84.17	1.412	288.05*	78.27	-0.78	2140.86**
CMS 9A × Tiwari	263.7	0.73*	-1029.52	90.45	2.435	414.85**	63.07	0.02**	-91.42
CMS 9A × Byadgikaddi	472	0.04**	-1029.66	59.61	-0.532	-26.99	63.47	1.09	-88.08
CMS 9A × Byadgidabbi	316.7	-0.001**	-1029.66	59.06	2.61	484.12**	73.39	-0.64*	-90.26
CMS 9A × LCA 206	341.6	2.98	430.26	85.44	2.012	2231.76**	82.35	3.13*	-89.65
CMS 10A × Gouribidanur	458.6	0.78	-768.92	101.76	-0.829	4381.55**	116.91	-1.3	1462.01**
CMS 10A × Tiwari	453.4	4.36	1918.15	123.14	0.883	146.78*	149.27	3.17	822.37**
CMS 10A × Byadgikaddi	295.8	4.02**	-1025.51	123.14	2.533	453.05**	64.68	1.63	-83.98
CMS 10A × Byadgidabbi	226.7	-1.36**	-1029.19	64.39	1.565	142.48	71.97	-1.42*	-85.74
CMS 10A × LCA 206	490.1	4.59	13426.03**	113.41	1.078	-43.65	145.82	3.47	841.19**
KBCH-1	487.1	1.39	-989.11	121.63	-0.361	78.44	115.96	0.38	-75.05
ArkaHaritha	307.9	1.12	11006.17**	93.04	- 0.125**	-48.97	69.51	2.26	-80.91
ArkaMeghana	287.9	-0.9	4237.83*	141.41	-0.501	-26.37	42.63	-0.79*	-88.43
Mean	386.1			95.62			86.85		
SEm ±	66.5			20.63			14.53		

* Significant @ P= 0.05 **significant @ P= 0.01

Table 3b. Stability parameters for fruits length, weight and width

Hybrids	Fruit length (cm)			Fruit weight (g)			Fruit width (cm)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
CMS6A × Gouribidanur	9.78	0.21	0.27**	4.74	1.45	-0.01	1.26	1.03	-0.003
CMS 6A × Tiwari	10.17	0.21	0.27**	5.05	0.99	-0.01	1.36	1.03	-0.003
CMS 6A × Byadgikaddi	11.69	0.21	0.27**	5.57	1.33	-0.01	1.37	1.03	-0.003
CMS 6A × Byadgidabbi	14.19	0.21	0.27**	4.57	1.33	-0.01	1.08	1.03	-0.003
CMS 6A × LCA 206	9.76	0.00**	-0.04	3.38	0.00**	-0.01	1.07	0.00**	-0.003
CMS 7A × Gouribidanur	9.27	0.21	0.27**	3.81	1.33	-0.01	1.07	1.03	-0.003
CMS 7A × Tiwari	8.86	0.21	0.27**	2.57	0.47	-0.01	1.11	1.03	-0.003
CMS 7A × Byadgikaddi	13.23	-0.97	6.38**	5.66	-0.44	-0.01	1.21	1.13	-0.003
CMS 7A × Byadgidabbi	13.51	0.21	0.27**	3.00	1.22	-0.01	0.98	1.03	-0.003
CMS 7A × LCA 206	11.13	3.58	1.54***	4.17	0.23	0.44**	1.07	0.88	-0.002
CMS 8A × Gouribidanur	9.44	1.18	-0.04	4.32	0.25	0.66**	1.18	-0.1	0.07**
CMS 8A × Tiwari	10.25	2.5	0.41**	4.34	0.7	0.38**	1.14	0.78	-0.0007
CMS 8A × Byadgikaddi	10.64	0.21	0.27**	5.32	1.04	-0.01	1.22	1.03	-0.003
CMS 8A × Byadgidabbi	12.39	0.21	0.27**	4.18	1.27	-0.01	1.02	1.03	-0.003
CMS 8A × LCA 206	11.13	3.58	1.54**	4.17	0.23	0.44	1.06	0.88	-0.002
CMS 9A × Gouribidanur	10.47	4.13	2.39**	4.71	1.28	-0.01	1.22	1.56	0.01*
CMS 9A × Tiwari	8.62	0.21	0.27**	4.34	1.45	-0.008	1.23	1.03	-0.003
CMS 9A × Byadgikaddi	11.75	0.21	0.27**	5.72	1.56	-0.007	1.29	1.03	-0.003
CMS 9A × Byadgidabbi	14.19	0.21	0.27**	4.57	1.33	-0.01	1.08	1.03	-0.003
CMS 9A × LCA 206	10.33	1.25*	-0.04	3.68	1.11	0.032	1.11	1.01	-0.003
CMS 10A × Gouribidanur	10.14	3.08	0.93**	4.23	2.73	2.02**	0.95	1.04	-0.003
CMS 10A × Tiwari	9.79	2.19	0.21*	3.02	1.66	0.20**	0.96	1.13	-0.002
CMS 10A × Byadgikaddi	10.64	0.21	0.27**	5.32	1.04	-0.01	1.22	1.03	-0.003
CMS 10A × Byadgidabbi	13.59	0.21	0.27**	2.82	1.27	-0.01	0.69	1.03	-0.003
CMS 10A × LCA 206	11	3.3	1.19**	3.44	1.09	0.03	0.93	0.93	-0.003
KBCH-1	6.92	0.39	0.52**	4.27	1.32	-0.01	0.95	1.3	-0.003
ArkaHaritha	8.97	0.84	0.36**	3.57	0.42	0.05	0.96	2.34	-0.003
ArkaMeghana	7.77	-0.12	0.26*	7.67	0.22	-0.01	1.23	0.59	-0.003
Mean	10.7			4.36			1.11		
SEm ±	0.6			0.28			0.04		

* significant @ P= 0.05 **significant @ P= 0.01

width (cm) were highly significant. Further, it could be observed that variance due to hybrid × environment interaction was non-significant for all the characters except green fruit yield plant^{-1}. MSS due to hybrids x environment (linear) was non-significant for all the characters under study except green fruit yield plant^{-1}. However, variance due to pooled deviation was significant for all the productive traits across three environments.

Table 4. List of hybrid with good performance based on stability parameters for yield components.

Stability parameter	High Responsive hybrids
Green fruit yield plant^{-1}	CMS 10A × Gouribidanur
Red fruit yield plant^{-1}	CMS 10A× LCA206
Number of fruits plant^{-1}	CMS 7A × Gouribidanur, CMS 7A × Tiwari, CMS 7A × Byadgidabbi and CMS 8A × Byadgidabbi
Average fruit length (cm)	8A × Gouribidanur
Average fruit weight (g)	CMS 6A× Gouribidanur, CMS 6A× Tiwari, CMS 6A× Byadgikaddi, CMS 6A× Byadgidabbi, CMS 8A× Byadgikaddi, CMS 9A× Gouribidanur, CMS 9A× Byadgikaddi, CMS 9A× Byadgidabbi and CMS 10A× Byadgikaddi.

Stability parameters: The test hybrid, CMS10A x Byadgikaddi exhibited higher mean with unit regression co-efficient (b_i>1) and the deviation non-significantly different from zero (S^2_{di} = 0) for average fruit weight and fruit width (Table 3b). Similarly, the hybrid, CMS10A × Gouribidanur for green fruit yield plant^{-1}, CMS10A x LCA 206 for red fruit yield plant^{-1} and CMS8A x Byadgidabbi for number of fruits exhibited high mean with unit regression co-efficient (b_i>1) and the deviation non-significantly different from zero (S^2_{di} = 0) (Table 3a). Chowdhury *et al.* (2001), Senapati and Sarkar (2002), Nehru *et al.* (2003) and Tembhurne and Rao (2013) also obtained similar results for investigating characters. The test hybrids, CMS 6A × Tiwari for the character average fruit weight and CMS 9A × LCA 206 for the character fruit width were exhibited nearer to unit regression co-efficient and non-significant deviation from regression. Further, CMS10A × Gouribidanur has higher yield level than the check and unit regression coefficient for most of the characters under study.

Discussion

Pooled ANOVA revealed the presence of significant genetic variability among the genotypes. Significant environment mean square indicated that the differential effect of environment affected the performance of the genotypes. Significance of variance due to hybrids x environment (linear) was evident for green fruit yield plant^{-1} while it was non-significant for all other productive traits across three environments thus indicating that the hybrids responded differently to change in environments. Hence, more testing sites are needed or the environments in locations need to be controlled (Gill *et al.,* 1984). Further, variances due to pooled deviation was significant for all the productive traits across three environments thus indicating that the unpredictable partition formed the major part of G x E interaction that the genotypes tested differed considerably in their stability for the characters.

According to Eberhart and Russell (1966) model, a genotype is considered stable in performance if it has high mean performance, unit regression coefficient, and least deviation from regression. Cultivar with a regression value above one is considered unstable with higher sensitivity to environmental change. It is good for specific adaptation in high yielding environment. Regression coefficient below one indicates that the cultivar is relatively stable with greater resistance to environmental change.

Among the hybrids, CMS10A x Byadgikaddi specifically adapted to unfavorable environment for the productive traits *viz.*, average fruit weight and fruit width. Similarly, CMS10A × Gouribidanur for green fruit yield plant^{-1}, CMS10A x LCA 206 for red fruit yield plant^{-1} and CMS8A x Byadgidabbi for number of fruits were having below average stability hence, specifically adapted to unfavorable locations for the respective traits. The test hybrids, CMS 6A × Tiwari (for average fruit weight) and CMS 9A × LCA 206 (for fruit width) were adapted to all environments for respective traits (Table 3b). But, CMS10A × Byadagidabbi was poorly adopted to all the environments for the productive traits *viz.*, red fruit yield, average fruits per plant. The hybrid, CMS 10A × LCA 206 for green fruit yield, red fruit yield, average fruits per plant and average fruits length and CMS10A × Gouribidanur for green fruit yield, red fruit yield and average fruits per plant were specifically adapted to favorable and unfavorable environments, respectively.

CMS10A × Gouribidanur proved to be the best yielding genotype among 25 test hybrids and it was stable for most of the characters as evident from their non-significant s^2di values (Table 3).

The stability analysis study revealed that, additive environmental variance was of considerable magnitude as indicated by the significance of variance due to environment at différent locations. Among the three locations studied the 'K' block, Department of Genetics and Plant Breeding (GPB) (E_3) was found to be the most suitable location for most of the characters especially to obtain yield and its component traits. The present investigation revealed that the test hybrid CMS10A × Gouribidanur was found promising and highly adaptable across different environments.

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