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Stability Analysis for Yield and Maturity Traits in Coloured Sweet Pepper (*Capsicum annuum L. var. grossum Sendt.*)

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Abstract

The present investigation was carried out with fifteen coloured capsicum genotypes grown at three locations during Kharif 2018. Pooled analysis of variance over three environments revealed highly significant differences among genotypes for all the characters. The environment E1 was the most favourable environment for the expression of all traits. The pooled analysis of variance for stability revealed significant variation among genotypes for all traits. Environments (linear) component of variance was significant for all traits. The linear component of genotype × environment was also significant for all traits. The estimates of regression coefficients for fifteen genotypes ranged from 0.46 to 2.16 for days to first flowering, 0.56 to 1.43 for days to first fruit set, 0.18 to 1.76 for days to first harvest, -0.26 to 3.05 for number of fruits plant^{-1}, 0.24 to 1.91 for average fruit weight, 0.24 to 2.15 for average fruit yield plant-1 and 0.23 to 2.13 for fruit yield plot^{-1}.

Keywords: Sweet pepper; Stability; Yield; Maturity

Introduction

Sweet pepper is a versatile crop; it is mainly used in preparation of various products such as soups, stews, sausage, cheese, snacks, salad dressing, sauces, pizza, confectionaries, beverages etc. and to a limited extent canned, pickled or consumed as a fermented product which make it a major commodity in culinary industry. The consumption of sweet pepper is on the increase all over the world. It has become a multibillion dollar industry, as well as a part time hobby for home gardeners. Moreover the coloured bells command a higher market price and provide an alternate channel for this crop.

The genotype × environmental (G × E) interactions are major concern to plant breeders for developing improved cultivars. For a cultivar to be commercially successful, it must perform well across a range of environments in which the cultivar has to be grown. Among the different models proposed for estimating stability of genotypes by various workers Eberhart and Russel has been most extensively used to identify stable genotypes for important quantitative traits over environments in various crop species. Eberhart and Russel defined a stable genotype as one having high mean with a regression close to zero [1]. Accordingly, genotypes could be classified as, below average stable performing well only in favourable environments ($b_i > 1$). Above average stable adapted specifically to poor environments ($b_i < 1$) and average stable performing well in most of the environments ($b_i = 1$).

Materials and Methods

The present investigation was carried out to determine adaptive potential and phenotypic stability of fifteen coloured capsicum genotypes grown at three locations during Kharif 2018. The experiment was laid out in a completely randomized block design with three replications at each location. The observations recorded on various maturity and yield attributing traits were subjected to statistical and biometrical analysis and the results thus obtained are described as under.

Results and Discussion

Pooled analysis of variance over three environments revealed highly significant differences among genotypes for all the characters (Table 1). Mean sum of squares due to environments were significant for all the characters. Mean sum of squares due to genotype × environments were also significant for all characters.

The effect of environment in a stability analysis study is quantified through environmental index. The environmental indices for different traits are presented in Table 2. The present investigation revealed that the environment E_1 i.e. (Experimental Farm of Division of Vegetable Science, SKUAST-Kashmir, Shalimar) was the most favourable environment for the expression of all traits as indicated by the highest environmental index for number of fruits plant^{-1} (0.731), average fruit weight (3.325), fruit yield plant^{-1} (0.090) and fruit yield plot^{-1} (0.913) and lowest environmental index for days to first flowering (-0.895) and days to first harvest (-0.908). E_1 was also found to be favourable for expression of days to first fruit set (-0.339). The environment E_2 i.e., Vegetable Farm of Krishi Vigyan Kendra, Haran, Budgam was most favourable for expression of traits viz., days to first fruit set (-0.859). E_2 was also favourable for expression of various other traits like days to first flowering (-0.544), days to first harvest (-0.362), number of fruits plant^{-1} (0.018), average fruit weight (0.030), average fruit yield plant^{-1} (0.009) and average fruit yield plot^{-1} (0.002). The environment E_3 i.e., Regional Research Station and Faculty of Agriculture, Wadura was found to be unfavourable for expression of all traits. The influence of various environments as depicted by estimates of environmental indices was also reported by Tembhurne and Rao [2].

Mean squares of stability analysis in respect of various maturity and yield attributing traits under study are summarized in the Tables 3a and 3b. The pooled analysis of variance for stability of fifteen genotypes over three environments revealed significant variation

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Table 1: Mean squares of pooled environments for maturity and yield attributing traits in Coloured Capsicum (*Capsicumannuum* L. var. *grossum* Sendt.).

Source of variation	d.f	Days to first flowering	Days to first fruit set	Days to first harvest	Number of fruits plant^{-1}	Average fruit Weight (g)	Average fruit yield plant^{-1} (kg)	Average fruit yield plot^{-1} (kg)
Genotypes	14	27.832**	22.506**	21.077**	20.758**	908.508*	0.214**	21.755**
Environments	2	3.968*	36.192**	32.742**	171.540**	3712.613**	1.176**	119.460**
Genotype × Env.	28	2.855*	2.178*	3.610*	2.275*	373.908*	0.093*	7.390*
Error	112	1.235	1.260	1.277	1.779	206.528	0.058	5.952

Table 2: Environmental indices for various maturity and yield attributing traits in Coloured Capsicum (*Capsicum annuum* L. var. *grossum* Sendt.).

Character	Environmental index		
	E_1	E_2	E_3
Days to first flowering	-0.895	-0.544	1.439
Days to first fruit set	-0.339	-0.859	1.196
Days to first harvest	-0.908	-0.362	1.269
Number of fruits plant^{-1}	0.731	0.018	-0.749
Average fruit weight (g)	3.325	0.030	-3.355
Average fruit yield plant^{-1} (kg)	0.090	0.009	-0.099
Average fruit yield plot^{-1} (kg)	0.913	0.092	-1.005

Table 3a: Mean squares of stability analysis for maturity and yield attributing traits in Coloured Capsicum (*Capsicun annuum* L. var. *grossum* Sendt.).

Source of variation	d.f	Days to first flowering	Days to first fruit set	Days to first fruit harvest
Rep within Env.	6	0.814**	0.206	0.234
Genotypes	14	10.056**	9.988**	12.902**
Environment+ (genotype× Env.)	30	1.933**	1.270**	1.618**
Environments	2	23.742**	17.123**	19.243**
Genotype× Env.	28	0.375*	0.138*	0.359*
Environments (L)	1	47.485**	34.246**	38.486**
Genotype × Env. (L)	14	0.571*	0.143*	0.411*
Pooled Deviation	15	0.167	0.124	0.287*
Pooled Error	84	0.278	0.184	0.158
Total	44	4.518	4.044	5.208
* and ** significant at 5% and 1% respectively				

Table 3b: Mean squares of stability analysis for maturity and yield attributing traits in Coloured Capsicum (*Capsicum annuum* L. var. *grossum* Sendt.).

Source of variation	d.f	Number of fruits plant^{-1}	Average fruit weight (g)	Average fruit yield plant^{-1} (kg)	Average fruit yield plot^{-1} (kg)
Rep within Env.	6	0.454*	0.854	0.002	0.219
Genotypes	14	24.949**	1759.933**	0.304**	30.748**
Environment+ (genotype× Env.)	30	0.895**	17.096**	0.012**	1.221**
Environments	2	8.218**	167.355**	0.135**	13.893**
Genotype× Env.	28	0.372**	6.364*	0.003**	0.316**
Environments (L)	1	16.435**	334.710**	0.271**	27.785**
Genotype × Env. (L)	14	0.608**	7.117*	0.005**	0.487**
Pooled Deviation	15	0.128	5.236**	0.001	0.135
Pooled Error	84	0.243	1.157	0.001	0.128
Total	44	8.549	571.637	0.105	10.616
*and ** significant at 5% and 1% respectively					

among genotypes for all traits indicating the presence of large amount of variability in the material chosen for study. The mean sum of squares due to environments were significant for all traits indicating that environments selected to conduct the study were variable and influenced the expression of traits. Similar results have been reported by Tembhurne and Rao, Ummayiah et al., Spaldon et al. etc [2-4].

Environments (linear) component of variance was significant for all traits indicating that environmental effects were predictable. These results agree with the findings of Jyothi et al., Tembhurne and Rao, Ummiayah et al and Spaldon et al. [2-5]. The linear component of genotype × environment was also significant for all traits indicating the significant linear response of genotype to environmental changes for these traits. Non-significant effect of genotype × environment (linear) for rest of the traits indicated that the different genotypes did not differ genetically in their response to different environments. The linear component was found to be greater in magnitude than the corresponding non-linear component for almost all the traits suggesting that the performance of genotypes across environments could be predicted with greater precision for these traits. The pooled deviation was significant for days to first fruit harvest and average fruit weight indicating the important contribution of non-predictable component in respect of these traits. Similar results have been reported

by Srividhya and Ponnuswami, Tembhurne and Rao, Ummyiah et al., Spaldon et al. [2-4,6].

The genotypes exhibiting stability for different traits are given in Table 4a and 4b. In the present study, the estimates of regression coefficients for fifteen genotypes ranged from 0.46 to 2.16 for days to first flowering, 0.56 to 1.43 for days to first fruit set, 0.18 to 1.76 for days to first harvest, -0.26 to 3.05 for number of fruits plant^{-1}, 0.24 to 1.91 for average fruit weight, 0.24 to 2.15 for average fruit yield plant^{-1} and 0.23 to 2.13 for fruit yield plot^{-1}indicating that the genotypes possess different set of alleles for adaptation across environments.

Since early flowering is a desirable character in sweet pepper, the genotypes requiring less number of days to flowering as compared to the population mean would be desirable. Early flowering together with non-significant regression coefficient and non-significant deviation from regression indicating average stability were identified as SH-SP-2, SH-SP-4, SH-SP-5, SH-SP-14, SH-SP-15, SH-SP-16 and Nishat-1. The genotypes requiring less number of days for first flowering as compared with general mean together with significant but less than one regression coefficient together with non-significant deviation from regression would indicate above average stability. None of the genotypes exhibited above average stability. SH-SP-11 with regression coefficient value significantly greater than unity along with non-significant deviation from regression showed below average stability and was significantly adapted to favorable environments. The mean performance of both genotypes being greater than population mean was undesirable. Early fruit set is again a desirable trait. The genotypes exhibiting average stability were identified as SH-SP-4, SH-SP-14, SH-SP-15, SH-SP-16 and Nishat-1. Above average stability was exhibited by the genotypes SH-SP-2 though taking more number of days to first fruit set. Similarly, early fruit harvest is a desirable character. The genotypes showing average stability were identified as SH-SP-3, SH-SP-4, SH-SP-5, SH-SP-14, SH-SP-15 and Nishat-1. The genotypes SH-SP-9 and SH-SP-10 depicted unpredictable behavior with respect to days to first harvest. None of the genotypes exhibited above average stability.

The genotypes SH-SP-4, SH-SP-7, SH-SP-8, SH-SP-10, SH-SP-14,

Table 4a: Stability parameters for various maturity and yield attributing traits in Coloured Capsicum (*Capsicum annuum* L.var. *grossum* Sendt.).

S.No	Genotype	Days to first flowering			Days to first fruit set			Days to first fruit harvest		
		μ	Bi	S^2di	μ	Bi	S^2di	μ	Bi	S^2di
1	SH-SP-1	31.933	0.5	0.172	37.111	0.99	0.02	52.578	0.18	0.33
2	SH-SP-2	31.044	1.17	-0.303	39.422	0.65**	-0.19	54.378	1.42	-0.1
3	SH-SP-3	31.756	0.83	-0.07	37.378	0.56	-0.18	52.089	0.53	0.14
4	SH-SP-4	27.378	1.08	-0.317	33.9	1.43	-0.11	48.604	1.76	0.14
5	SH-SP-5	30	1.15	-0.31	36.6	1.01	-0.07	51.044	1.04	0.1
6	SH-SP-7	32.489	0.9	-0.119	37.422	1.07	0.08	53.311	0.56	-0.15
7	SH-SP-8	33.756	0.52	0.323	37.978	0.92	-0.18	54.733	1.36	-0.16
8	SH-SP-9	33.8	1.1	-0.121	37.978	0.73	-0.01	55.533	0.73	0.88*
9	SH-SP-10	32.822	1.24	0.159	38.044	0.85	0.32	52.244	0.83	0.58*
10	SH-SP-11	32.022	2.16**	-0.312	37.444	1.22	0.03	52.711	1.2	-0.13
11	SH-SP-12	33.133	0.46*	-0.313	38.333	0.81	-0.15	54.022	1.08	0.25
12	SH-SP-14	30.089	0.96	-0.311	34.422	1.16	-0.18	51.267	0.88	-0.15
13	SH-SP-15	30.267	0.59	-0.303	34.978	1.31	-0.12	51.267	1	0.25
14	SH-SP-16	28.956	1.07	-0.222	36.222	1.04	-0.07	52.356	1.14	-0.06
15	Nishat-1	30.178	1.25	-0.153	33.022	1.25	-0.12	49.089	1.29	-0.07
	Population mean	31.3	1		36.684	1		52.482	1	
	S.E	± 0.22	± 0.289		± 0.23	± 0.248		± 0.33	± 0.378	

Table 4b: Stability parameters for various maturity and yield attributing traits in Coloured Capsicum (*Capsicum annuum* L.var. *grossum* Sendt.).

S.No	Genotype	Days to first flowering			Days to first fruit set			Days to first fruit harvest		
		μ	Bi	S^2di	μ	Bi	S^2di	μ	Bi	S^2di
1	SH-SP-1	31.933	0.5	0.172	37.111	0.99	0.02	52.578	0.18	0.33
2	SH-SP-2	31.044	1.17	-0.303	39.422	0.65**	-0.19	54.378	1.42	-0.1
3	SH-SP-3	31.756	0.83	-0.07	37.378	0.56	-0.18	52.089	0.53	0.14
4	SH-SP-4	27.378	1.08	-0.317	33.9	1.43	-0.11	48.604	1.76	0.14
5	SH-SP-5	30	1.15	-0.31	36.6	1.01	-0.07	51.044	1.04	0.1
6	SH-SP-7	32.489	0.9	-0.119	37.422	1.07	0.08	53.311	0.56	-0.15
7	SH-SP-8	33.756	0.52	0.323	37.978	0.92	-0.18	54.733	1.36	-0.16
8	SH-SP-9	33.8	1.1	-0.121	37.978	0.73	-0.01	55.533	0.73	0.88*
9	SH-SP-10	32.822	1.24	0.159	38.044	0.85	0.32	52.244	0.83	0.58*
10	SH-SP-11	32.022	2.16**	-0.312	37.444	1.22	0.03	52.711	1.2	-0.13
11	SH-SP-12	33.133	0.46*	-0.313	38.333	0.81	-0.15	54.022	1.08	0.25
12	SH-SP-14	30.089	0.96	-0.311	34.422	1.16	-0.18	51.267	0.88	-0.15
13	SH-SP-15	30.267	0.59	-0.303	34.978	1.31	-0.12	51.267	1	0.25
14	SH-SP-16	28.956	1.07	-0.222	36.222	1.04	-0.07	52.356	1.14	-0.06
15	Nishat-1	30.178	1.25	-0.153	33.022	1.25	-0.12	49.089	1.29	-0.07
	Population mean	31.3	1		36.684	1		52.482	1	
	S.E	± 0.22	± 0.289		± 0.23	± 0.248		± 0.33	± 0.378	

Table 5: Stable genotypes of Coloured Capsicum (*Capsicum annuum* var. *grossum* Sendt.) with respect to different traits.

S.No	Traits	Genotypes showing average stability
1.	Days to first flowering	SH-SP-2, SH-SP-4, SH-SP-5, SH-SP-14, SH-SP-15, SH-SP-16, Nishat-1 (check)
2.	Days to first fruit set	SH-SP-4, SH-SP-14, SH-SP-15, SH-SP-16, Nishat-1 (check)
3.	Days to first harvest	SH-SP-3, SH-SP-4, SH-SP-5, SH-SP-14, SH-SP-15, Nishat-1 (check)
4.	Number of fruits plant^{-1}	SH-SP-4, SH-SP-7, SH-SP-8, SH-SP-10, SH-SP-14, SH-SP-16, Nishat-1(check)
5.	Average fruit weight (g)	SH-SP-2, SH-SP-12
6.	Average fruit yield plant^{-1} (kg)	SH-SP-1, SH-SP-7, SH-SP-14, SH-SP-16
7.	Average fruit yield plot^{-1} (kg)	SH-SP-1, SH-SP-7, SH-SP-8, SH-SP-14, SH-SP-16

Table 6: Stability of Coloured Capsicum (*Capsicum annuum* var. *grossum* Sendt.) with respect to different traits.

S.No	Genotypes	Traits for which genotypes show average stability
1.	SH-SP-1	Average fruit yield plant^{-1}, average fruit yield plot^{-1}
2.	SH-SP-2	Days to first flowering, average fruit weight
3.	SH-SP-3	Days to first harvest
4.	SH-SP-4	Days to first flowering, days to first fruit set, days to first harvest, number of fruits plant^{-1}
5.	SH-SP-5	Days to first flowering, days to first harvest
6.	SH-SP-7	Number of fruits plant^{-1}, average fruit yield plant^{-1} and average fruit yield plot^{-1}
7.	SH-SP-8	Number of fruits plant^{-1}, average fruit yield plot^{-1}
8.	SH-SP-9	-
9.	SH-SP-10	Number of fruits plant^{-1}
10.	SH-SP-11	-
11.	SH-SP-12	Average fruit weight
12.	SH-SP-14	Days to first flowering, days to first fruit set, days to first harvest, number of fruits plant^{-1}, average fruit yield plant^{-1}, average fruit yield plot^{-1}
13.	SH-SP-15	Days to first flowering, days to first fruit set, days to first harvest
14.	SH-SP-16	Days to first flowering, days to first fruit set, number of fruits plant^{-1}, average fruit yield plant^{-1}, average fruit yield plot^{-1}
15.	Nishat-1 (Check)	Days to first flowering, days to first fruit set, days to first harvest, number of fruits plant^{-1}

SH-SP-16 and Nishat-1 showed average stability for number of fruits plant^{-1}. The genotype SH-SP-1 showed above average stability. For average fruit weight only two genotypes SH-SP-2 and SP-12 exhibited average stability. The genotypes SH-SP-5, SH-SP-7, SH-SP-8, SH-SP-9 and SH-SP-15 showed unpredictable behavior as indicated by significant values of S^2di and prediction of stability was not reliable. For average fruit yield plant^{-1}, SH-SP-1, SH-SP-7, SH-SP-14 and SH-SP-16 showed average stability. Nishat-1 showed above average stability. SH-SP-8 showed significant deviation from regression indicating that prediction on stability of this genotype is not reliable. For average fruit yield plot^{-1}, SH-SP-1, SH-SP-7, SH-SP-8, SH-SP-14 and SH-SP-16 average stability. Nishat-1 showed above average stability. The stability of SH-SP-9 was not predictable.

As indicated by the stability parameters, the genotypes that were well adapted to all the environments Table 5 were SH-SP-2, SH-SP-4, SH-SP-5, SH-SP-14, SH-SP-15, SH-SP-16 and Nishat-1 for early flowering; SH-SP-4, SH-SP-14, SH-SP-15, SH-SP-16 and Nishat-1 for early fruit set; SH-SP-3, SH-SP-4, SH-SP-5, SH-SP-14, SH-SP-15 and Nishat-1 for early fruit harvest; SH-SP-4, SH-SP-7, SH-SP-8, SH-SP-10, SH-SP-14, SH-SP-16 and Nishat-1 for number of fruits plant^{-1}; SH-SP-2 and SH-SP-12 for average fruit weight; SH-SP-1, SH-SP-7, SH-SP-14 and SH-SP-16 for average fruit yield plant^{-1} and SH-SP-1, SH-P-7, SH-SP-8, SH-SP-14 and SH-SP-16 for fruit yield plot^{-1}. Similar results with respect to various traits have been reported by Srividhya and Ponnuswami, Ummyiah et al., Spaldon et al. [3,4,6].

The genotypes which show unpredictable behavior as depicted by significant deviation from regression irrespective of regression coefficient whether it is significant or not were SH-SP-9 and SH-SP-10 for days to first fruit harvest; SH-SP-5, SH-SP-7, SH-SP-8, SH-SP-9 and SH-SP-15 for average fruit weight; SH-SP-8 for fruit yield plant^{-1} and fruit yield plot^{-1}.

Table 6 depicts the total number of traits for which each genotype is stable. SH-SP-1 was found to be stable for average fruit yield plant^{-1} and average fruit yield plot^{-1}; SH-SP-2 was found to be stable for days to first flowering and average fruit weight; SH-SP-3 was found to be stable for days to first fruit harvest; SH-SP-4 was found to be stable for days to first flowering, days to first fruit set, days to first fruit harvest and number of fruits per plant; SH-SP-5 was found to be stable for days to first flowering and days to first fruit harvest; SH-SP-7 was found to be stable for number of fruits plant^{-1}, average fruit yield plant^{-1} and average fruit yield per plot; SH-SP-8 was found to be stable for number of fruits plant^{-1}; SH-SP-9 was not found to be stable for any trait under study; SH-SP-10 was found to be stable for number of fruits plant^{-1}; SH-SP-11 was not found to be stable for any trait under study; SH-SP-12 was found to be stable for average fruit weight; SH-SP-14 was found to be stable for days to first flowering, days to first fruit set, days to first fruit harvest, number of fruits plant^{-1}, average fruit yield plant^{-1} and average fruit yield plot^{-1}; SH-SP-15 was found to be stable for days to first flowering, days to first fruit set, days to first fruit harvest; SH-SP-16 was found to be stable for days to first flowering, days to first fruit set, days to first fruit harvest, number of fruits plant^{-1}, average fruit yield plant^{-1} and average fruit yield plot^{-1} and Check (Nishat-1) was found to be stable for days to first flowering, days to first fruit set, days to first fruit harvest and number of fruits plant^{-1}.

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