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Genotype × Environment Interaction and Stability Analysis in Basmati Rice (*Oryza sativa* L.) Genotypes

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ABSTRACT

Background: Basmati rice is an important cereal crop occupying a unique position in Indian agriculture. More than 90% of global rice is produced and consumed in Asia and plays a crucial role in the entry of mineral nutrients into the food chain. Identification of stable genotypes is of great significance because the environmental conditions vary from season to season and year to year.

Methods: Thirty six Basmati rice genotypes were evaluated in four production environments during *kharif* 2016 and *kharif* 2017 at two locations Kaul and Uchani to study the G × E interaction for milling, appearance, cooking and eating quality parameters. The genotypes were grown in randomized block design with three replications.

Result: Based on the stability analysis of Eberhart and Russell model, genotypes *viz*., Haryana Mahak 1, Pusa 1826-12-271-4 and HKR 06-434 were found stable across the environments for milling%, grain length before cooking and length breadth ratio before cooking, respectively.

Key words: Basmati, G × E interaction, Rice, Stability, Quality.

INTRODUCTION

Rice is the source of more than 20% of total calorie intake for more than half of the world population. Global production of rice was 782 million tons from 167.1 million ha with average productivity of 4.68 t/ha (FAOSTAT, 2020). Increasing food demand due to continuously growing populations which is predicted to reach 9.73 million by 2050 (Worldometer, 2020) and declining water resources are becoming big challenges for rice production in Asia. Traditionally rice is cultivated in puddled soil and constantly standing water. Puddling is helpful in reducing water losses due to percolation, control weeds germination and increase nutrient availability (Surendra *et al.,* 2001). However, puddling and transplanting demands huge inputs of water and labor which are becoming increasingly scarce and expensive making rice production less profitable. With decreasing availability of water, rice cultivation may be switched towards novel resource saving technologies such system of rice intensification (SRI) and direct seeded rice (DSR).

The SRI consists of transplanting of single seedling per hill of 8-12 days old in a square fashion of 25 × 25 cm^2 within 15-30 min after removal from the nursery at a shallow depth, keeping paddy soil moist but not continuously saturated, controlling weeds with frequent weeding by a mechanical hand weeder and applying organic fertilizers with chemical fertilizers (Uphoff, 2007). The puddled paddy soil is kept moist but not consistently saturated so that mainly aerobic soil conditions prevail. The advantage of this methods includes up to 50% water saving, 20-100% increase in yield and up to 90% decrease in seed rate (Duttarganvi *et al.,* 2014).

In direct seeded rice, seeds are directly sown in the field instead of transplanting seedlings. DSR avoids three basic operations in *i.e.* puddling, transplanting and standing water throughout the season. This method saves around 30% of water 11.2% of labor cost (Akhgari and Kaviani, 2011). Owing to water and labor shortage (Pandey and Velasco, 1999) and soil degradation under intensive TPR (Sinha *et al.,* 1998) farmers are inkling to adopt DSR. The area under DSR is increasing as it is more productive and profitable to compensate the production costs.

Plant growth, yield and quality traits are greatly influenced by environmental fluctuations due to significant genotype and environment interaction (Reddy *et al.,* 2011). The performance of some genotypes vary under different production environments and show a range from low to high interaction with the environments. A genotype with high yielding ability, better grain quality and stable performance over the environments is of great importance for enhancing the productivity of Basmati rice. Identification of genotypes that interact least with the fluctuating environment is advisable to attain consistent yield. Therefore, knowledge of G × E interaction helps in the selection the stable

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and high yielding genotypes (Ahmad and Ansari, 2014; Kesh *et al.,* 2018). Keeping in view the above facts, the present study was planned to identify the high yielder and stable genotypes under different crop establishment methods using Eberhart and Russell (1966) model.

Table 1: List of Basmati rice genotypes used in the study.

Sr. no.	Genotypes
1	Pusa Basmati 1121
2	Pusa Basmati 1509
3	Pusa Sugandh 2
4	Pusa Sugandh 3
5	Pusa Sugandh 5
6	Pusa Basmati 6
7	Pusa Basmati 1
8	Improved Pusa Basmati 1
9	HKR 98-476
10	HKR 03-408
11	HKR 06-434
12	HKR 06-443
13	HKR 06-487
14	HKR 06-417
15	HKR 08-425
16	Haryana Mahak 1
17	Haryana Basmati 1
18	Taraori Basmati
19	Super Basmati
20	CSR-30
21	Basmati 370
22	Pusa 1826-12-271-4
23	CSR TPB-1
24	Pusa 6295-2
25	Pusa 1734-8-3-85
26	HKR -11-509
27	Pusa 1475-03-42-45-119-1
28	SJR-70-3-2
29	HKR 11-447
30	HUBR-16
31	PAU-6297-1
32	UPR-386-9-1-1
33	Pusa 1656-10-705
34	Pusa 1637-2-8-20-5
35	Pusa 1884-3-9-175
36	Pusa 1884-9-12-14

MATERIALS AND METHODS

The thirty six genotypes (Table 1) were planted in a randomized block design (RBD) in three replications under four different environments namely conventional transplanted rice (TPR),system of rice intensification (SRI), direct seeded rice (DSR) and chemical free cultivation (CFC) for two years *Kharif* 2016 and *Kharif* 2017 at two locations Kaul (Kaithal) and Uchani (Karnal). Plot size of 5 row of 1m length was prepared. In SRI system seed rate of 5 kg/ha, 15days old one seedling per hill with spacing of 25 × 25 cm^2 and irrigation at 5 days interval up to 90-100 days after transplanting (DAT) were practiced. In DSR system, pre-germinated seeds were dibbled in puddled soil surface. Irrigation was applied at an interval of 6-7 days when hair cracks developed on the surface. In TPR and CFC system, 27 days old 2-3 seedlings per hill spaced at 15 × 20 cm^2 were transplanted. The inorganic fertilization was applied in TPR while in CFC organic fertilization of farm yard manure and vermicomposting was applied. Irrigation was applied at 3 days interval up to 90-100 DAT under both TPR and CFC production environments. Seed rate in TPR, DSR and CFC was 20 kg/ha. Hulling %, milling % and head rice recovery % was measured according to the methods of Khush *et al.,* (1979). Amylose content value was measured as per the protocol suggested by (Juliano, 1971). Length and breadth of the grain before cooking was recorded on ten randomly selected polished grains in mm using graph paper sheet. The L/B ratio was calculated using the following formula of Murthy and Govindaswamy (1967). The Eberhart and Russell (1966) model of stability was used to determine the stability parameters for different quality traits. Eberhart and Russell (1966) model estimates regression and mean square for deviation from regression as indices of a stable genotype. A Genotype with high mean value, unit regression coefficient and deviation not significantly differing from zero (S^2di =0) was taken as stable. The mean sum of squares due to genotypes, environments, G × E interaction, environment (linear) and G × E (linear) was tested against pooled deviation. If pooled deviation is non-significant, all these components were tested against pooled error. Mean sum of squares due to pooled deviations were tested against pooled error. The t-test based on the standard error of regression value was used to test significant deviation from unity while F-test was employed to test the significance of deviation from regression.

Table 2: Pooled analysis of variance over 16 environments for different traits in rice.

Source	df	H%	M%	HRR%	GLBC	GBBC	LBBC	AC
Genotype	35	11.79**	22.73**	67.25**	3.84**	0.0511	1.232**	9.970**
Environment	15	4.85**	5.84**	6.31**	0.45**	0.0107	0.027**	13.615**
Gen. × Env.	525	1.65**	2.37**	2.57**	0.009*	0.0006	0.005**	0.797**
Env. + Gen. × Env.	540	1.74**	2.48*	2.70*	0.022**	0.001	0.006**	1.153**
Env. (Linear)	1	72.77**	87.63**	94.60**	6.789	0.160	0.408**	204.223**
Env. × Gen. (Lin.)	35	3.84**	4.47**	4.59**	0.030**	0.004	0.034**	1.848**
Pooled deviation	504	1.46**	2.14**	2.33*	0.008*	0.000	0.003*	0.702*
Pooled error	1120	0.57	0.85	1.43	0.008	0.0008	0.002	0.38

RESULTS AND DISCUSSION

Pooled analysis of variance

The results of pooled analysis of variance for stability as devised by Eberhart and Russell (1966) showed that genotypes, environments and genotype × environment interaction were significantly different for all the characters except grain breadth before cooking indicating that genotypes are rich in variation for various characters, micro environments created through production systems were different from each other and genotype × environment interaction components showed wide differential behavior of genotypes under changing environments (Table 2). Mean sum of squares due to environments + (genotypes × environments) were highly significant for all the characters except grain breadth before cooking suggesting the distinct nature of environments and genotype × environment interaction on phenotypic expression and significance of environment (linear) component indicated that the genotypes responded linearly for most of the characters under study. Significance for mean squares for genotype × environments (linear) indicates variation in the performance of genotype is due to the regression of genotypes on environments. The findings of Kulkarni *et al.* (2015), Meena *et al.* (2016), Pandey *et al.* (2020) and Kesh *et al.* (2021) were in accordance with the present results.

Table 3: Stability parameters for H% and M% and HRR% across the environments.

Genotypes	H %			M %			HRR %		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
Basmati 370	78.60	-1.29	0.61	68.49	-1.22	0.11	53.00	-1.32	-0.38
CSR-30	77.95	0.67	1.63**	66.80	-0.36	2.99**	56.82	-0.12	3.17**
CSR TPB-1	77.68	0.25	1.67**	66.35	-0.05	2.45**	53.67	0.27	1.41
Haryana Basmati 1	80.05	-0.92	1.16**	69.89	-1.53	0.44	56.68	-0.85	1.12
Haryana Mahak 1	78.09	0.37	0.13	68.47	0.84	-0.08	54.94	0.91	-0.76
HKR -11-509	79.38	1.50	2.10**	68.57	3.06**	2.29**	54.40	2.61	2.84**
HKR 03-408	79.31	-0.60	0.98	67.17	1.30	3.46**	55.80	1.20	3.80**
HKR 08-417	77.73	0.20	1.96**	66.74	0.79	2.85**	52.26	1.16	2.25
HKR 06-434	77.98	-0.81	1.64**	67.04	-1.17	3.77**	55.81	-0.81	2.95**
HKR 06-443	77.06	-0.39	0.74	67.00	0.10	-0.12	55.60	0.26	-0.66
HKR 06-487	79.22	0.00	1.72**	67.87	0.44	3.00**	53.98	0.70	2.70**
HKR 08-425	77.62	1.56	1.20**	67.00	2.44	4.27**	54.71	1.16	1.57
HKR 11-447	79.62	1.54	2.35**	68.87	0.53	3.24**	55.64	0.72	1.97
HKR 98-476	79.40	3.62**	0.30	69.90	2.73**	0.06	56.85	2.09	0.41
HUBR-16	77.39	-0.12	0.59	66.93	0.16	0.51	53.96	-0.22	0.36
Improved Pusa Basmati 1	77.99	1.46**	-0.25	67.41	1.49**	-0.19	55.48	1.21**	-0.92
PAU-6297-1	77.78	1.42	0.27	66.33	1.11	-0.04	55.25	1.15	-0.76
Pusa 1475-03-42-45-119-1	77.33	2.40**	0.39	66.11	2.44**	0.16	52.06	1.79	0.86
Pusa 1637-2-8-20-5	77.10	-0.23	0.24	65.71	0.00	-0.12	53.09	0.31	-0.45
Pusa 1656-10-705	77.20	0.74	0.03	66.32	1.23	1.35	53.71	0.45	-0.22
Pusa 1734-8-3-85	77.81	2.07**	-0.17	66.17	2.77**	0.12	54.49	3.61**	1.07
Pusa 1826-12-271-4	77.90	2.75	0.90	66.65	0.61	2.98**	49.20	2.19	3.31**
Pusa 1884-3-9-175	77.33	-0.50	0.71	66.25	0.28	1.04	50.99	0.77	1.93
Pusa 1884-9-12-14	77.57	0.26	0.60	67.37	0.32	1.54**	52.78	0.47	1.07
Pusa 6295-2	77.41	-0.48	2.69**	65.71	-0.09	2.19**	52.29	-0.52	2.15
Pusa Basmati 1	79.71	1.62	1.78**	68.34	3.25**	1.08	58.14	2.68**	0.21
Pusa Basmati 1121	78.34	2.40**	0.21	68.74	1.62	0.46	56.56	1.92**	-0.37
Pusa Basmati 1509	78.00	2.30**	0.06	67.75	2.45**	0.09	54.85	2.37**	-0.56
Pusa Sugandh 2	76.54	1.34	0.40	65.40	0.53	0.06	53.64	0.20	-0.37
Pusa Sugandh 3	78.74	-0.90	0.51	67.73	-1.32	0.67	55.03	-1.19	-0.10
Pusa Sugandh 5	77.97	2.44**	0.94**	67.01	1.55	1.04	54.43	1.84	0.22
Pusa Sugandh 6	77.46	1.42	0.58	65.10	0.72	-0.28	51.34	-0.16	-0.39
SJR-70-3-2	78.04	2.75**	1.55**	66.48	0.91	1.78**	53.02	1.50	2.12
Super Basmati	78.81	2.67**	0.75	68.41	3.63**	1.04	57.30	4.06**	1.16
Taraori Basmati	77.56	3.99**	0.77	66.33	3.10**	0.09	49.90	3.35**	0.30
UPR-3886-9-1-1	78.78	0.50	0.20	68.41	1.33	2.44**	55.42	0.23	0.28
Mean	78.12			67.25			54.25		

Stability parameters

Milling quality traits

The mean values for hulling % ranged from 76.54% (Pusa Sugandh 2) to 80.05% (Haryana Basmati 1) and with an overall mean of 78.12% (Table 3). The genotypes Pusa Basmati 1121, HKR 98-476 and Super Basmati with high mean bi > 1 and non-significant deviation from regression performed well under better environment. None of the genotype was found suitable for poor environment. In comparison to other traits, a narrow range was observed for milling percentage *i.e.* from 65.1 (Pusa Basmati 6) to 69.9% (HKR 98-476) with an overall mean of 67.25%. The genotype Haryana Mahak 1 was found stable genotype as it recorded high mean, bi = 1 and non–significant deviation from regression. The genotypes *viz.*, Pusa Basmati 1509, Pusa Basmati 1, Improved Pusa Basmati 1, HKR 98-476 and Super Basmati were recorded high mean, bi > 1 and non-significant deviation from regression were found suitable for better environment. None of the genotype was found to be suitable for poor environment. Sufficient variation with low HRR% of 49.2 (Pusa 1826-12-271-4) to high HRR of 58.14 (Pusa Basmati 1) with an overall mean of 54.25 was observed for this trait. The genotype, HKR 08-425 with high mean, regression coefficient near to unity and minimum deviation from regression were stable for this important trait (Table 3). The genotypes Pusa Basmati 1121, Pusa Basmati 1509, Pusa Sugandh 5, Pusa Basmati 1, Improved Pusa

Table 4: Stability parameters for GLBC, LBBC and AC across different environments.

Genotypes	GLBC			LBBC			AC		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
Basmati 370	6.24	0.89**	-0.005	3.64	-1.110	0.001	22.11	1.43**	0.01
CSR-30	6.69	1.34**	-0.004	4.01	0.650	0.002	22.64	0.80	-0.01
CSR TPB-1	6.56	1.49**	0.006	3.88	0.970	0.004	22.24	1.09	0.33
Haryana Basmati 1	6.36	0.54**	-0.005	3.69	-2.980	0.001	23.17	0.15	-0.13
Haryana Mahak 1	7.50	0.59	0.003	4.59	2.070	0.002	23.16	0.42	-0.05
HKR -11-509	6.63	1.51**	0.002	4.04	1.38**	0.001	21.60	-0.27	2.49
HKR 03-408	7.38	1.15**	-0.002	4.34	0.550	0.000	22.69	1.40	0.66
HKR 08-417	6.99	0.75**	-0.004	3.94	-0.120	0.003	23.35	1.06	0.24
HKR 06-434	7.38	1.02**	-0.003	4.36	0.850	0.001	22.24	1.07	0.38
HKR 06-443	7.78	1.21**	-0.002	4.52	1.58**	-0.001	23.58	1.08**	-0.10
HKR 06-487	7.46	1.33**	0.006	4.33	1.190	0.002	23.23	1.30**	0.04
HKR 08-425	6.41	0.57	-0.001	4.32	-2.150	0.004	23.84	0.76	0.07
HKR 11-447	7.21	0.97	0.006	4.12	0.070	0.000	22.90	1.06	0.21
HKR 98-476	6.70	0.98**	-0.003	3.95	0.070	0.000	23.98	1.11**	0.05
HUBR-16	7.50	1.55**	0.005	4.38	2.77**	0.003	21.02	0.73	0.07
Improved Pusa Basmati 1	7.45	1.21**	-0.004	4.50	4.09**	-0.001	24.38	1.33**	-0.09
PAU-6297-1	7.10	1.19**	0.000	3.99	0.550	0.002	22.61	0.74	0.38
Pusa 1475-03-42-45-119-1	7.59	0.76	0.004	4.54	3.38**	0.006	21.98	1.36	1.19**
Pusa 1637-2-8-20-5	7.23	0.44	-0.001	4.47	2.64**	0.002	23.54	1.61**	0.34
Pusa 1656-10-705	7.71	1.14**	-0.003	4.51	1.24**	0.001	22.75	-0.25	-0.10
Pusa 1734-8-3-85	7.76	1.69**	-0.004	4.49	3.79***	0.001	22.80	0.60	0.26
Pusa 1826-12-271-4	7.86	1.01	0.007	4.67	1.590	0.003	22.96	2.14**	0.66
Pusa 1884-3-9-175	7.65	0.85**	-0.002	4.39	2.16**	0.000	23.12	0.50	0.06
Pusa 1884-9-12-14	7.76	0.75	0.004	4.58	2.70**	0.004	22.21	0.53	0.47
Pusa 6295-2	7.51	2.01**	0.006	4.48	4.68**	0.002	22.39	0.81	1.37**
Pusa Basmati 1	7.19	0.92**	-0.002	4.35	2.03**	0.000	24.01	0.50	1.14**
Pusa Basmati 1121	8.10	0.85**	-0.005	4.66	-0.610	-0.001	23.75	1.44**	0.20
Pusa Basmati 1509	7.95	0.90**	-0.005	4.58	-1.370	-0.001	23.61	1.19**	0.04
Pusa Sugandh 2	7.56	0.65**	-0.004	4.60	0.850	0.000	23.74	2.01**	0.22
Pusa Sugandh 3	7.53	0.68**	-0.003	4.22	-0.780	0.001	24.28	1.67**	0.12
Pusa Sugandh 5	7.59	0.67	-0.001	4.38	0.110	0.001	23.17	2.21**	0.69
Pusa Sugandh 6	7.41	0.43	0.004	4.48	-1.040	-0.001	23.33	0.85	0.13
SJR-70-3-2	7.39	0.72	0.001	4.30	0.83**	-0.001	24.65	1.29**	-0.08
Super Basmati	7.39	1.83**	0.003	4.41	3.17**	0.001	22.94	1.04	0.10
Taraori Basmati	6.71	0.95**	-0.004	4.21	-0.330	0.001	23.06	0.41	-0.11
UPR-3886-9-1-1	6.54	0.49	0.005	3.85	0.480	0.000	23.50	0.83	0.21
Mean	7.27			4.30			23.07		

Basmati 1, HKR 98-476, Super Basmati, Pusa 1734-8-3-85 and PAU-6297-1 having high mean, bi > 1 and non-significant deviation from regression were suitable for favorable environment with predictable performance. The promising genotype, Haryana Mahak 1 was recommended for poor environment as they recorded high mean, bi < 1 besides non-significant deviation from linearity. Madhukar and Raju (2013) identified genotypes RNR-2458, NK-5251, PAC-835 for favorable environments and KRH-2, DRH-775, RNR-2458 for unfavorable environments for hulling, milling and head rice recovery, respectively. Similarly, genotypes IR 64, WGL 32183, PA 6201; IR64, Rasi and JGL 13595; Rasi and RNR 2354 were identified as stable genotypes for hulling, milling and head rice recovery, respectively by Swapna *et al.* (2014).

Appearance quality traits

The mean values for grain length before cooking ranged from 6.24 mm (Basmati 370) to 8.10 mm (Pusa Basmati 1121) with an overall mean of 7.27 mm. One genotype, Pusa 1826-12-271-4was found stable with high mean, bi = 1 and non-significant deviation from the regression (Table 4). Genotypes, Improved Pusa Basmati 1, HKR 03-408, HKR 06-434, HKR 06-443, HKR 06-487,Super Basmati, Pusa 6295-2, Pusa 1734-8-3-85, HUBR-16 and Pusa 1656-10-705 were identified for favorable environment as these genotypes recorded high mean, bi > 1 and non-significant S^2di value. Genotypes, Pusa Basmati 1121, Pusa Basmati 1509, Pusa Sugandh 2, Pusa Sugandh 3 and Pusa 1884-3-9-175 with high mean than overall mean, bi < 1 and non-significant deviation from regression were found suitable for poor environment. The mean values for length breadth ratio before cooking varied from 3.64 (Basmati 370) to 4.67 (Pusa 1826-12-271-4) with an overall mean of 4.30. The genotype HKR 06-434which recorded high mean, regression coefficient near unity in addition to non–significant deviation from regression were considered as stable genotype (Table 4). The promising genotypes, Pusa Basmati 1, Improved Pusa Basmati 1, HKR 06-443, HKR 06-487, Super Basmati, Pusa 1826-12-271-4, Pusa 6295-2, Pusa 1734-8-3-85, Pusa 1475-03-42-45-119-1, HUBR-16, Pusa 1656-10-705, Pusa 1637-2-8-20-5, Pusa 1884-3-9-175 and Pusa 1884-9-12-14 with high mean and bi > 1 and non–significant deviation from regression were highly suitable for favorable environment. Whereas, genotypes, Pusa Sugandh 2 and SJR-70-3-2 were identified for poor environment in view of high mean, bi < 1 and non–significant S^2di estimate. Genotypes, RNR C28 and RNR 2354 for grain length before cooking and JGL 1118, DRRH-2, RNR 2354 for length breadth ratio before cooking were identified as stable genotypes by Swapna *et al.* (2014). Based on AMMI and GGE methodology, variety BPT-5204 was found as stable across different locations by Ashwini *et al.* (2019). Similar findings were also observed in barley (Khanzadeh *et al*., 2018) and cowpea (Ngalamu *et al*., 2019).

Table 5: Environmental indices for different quality traits across the environments.

Traits	Environmental Index																Mean
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	
H%	-0.29	-0.25	-0.29	-0.18	-0.41	-0.50	-0.24	-0.54	0.30	0.15	0.48	0.46	0.39	0.37	0.24	0.31	78.13
M%	-0.13	-0.04	-0.35	-0.26	-0.37	-0.44	-0.33	-0.71	0.40	0.35	0.64	0.57	0.36	0.38	-0.05	-0.01	67.25
HRR%	-0.22	-0.20	-0.23	-0.13	-0.53	-0.59	-0.30	-0.55	0.28	0.19	0.77	0.76	0.25	0.24	0.11	0.15	54.25
GLBC	-0.04	-0.02	-0.04	-0.01	-0.19	-0.18	-0.14	-0.15	0.14	0.13	0.12	0.12	0.05	0.06	0.08	0.06	7.27
LBBC	-0.01	-0.02	-0.02	-0.02	-0.03	-0.03	-0.04	-0.03	0.04	0.03	0.02	0.02	0.02	0.02	0.04	0.02	4.30
AC	-0.58	-0.17	-0.39	-0.09	-0.67	-0.86	-0.55	-0.63	0.83	0.89	0.75	0.83	-0.35	0.26	0.56	0.18	23.07

Cooking and eating quality traits

Amylose content is an important factor determining the eating quality of Basmati rice. It determines the hardness or stickiness of cooked rice. Higher amylase percentage *i.e.* >25.0% gives non-sticky or hard cooked rice. Medium value for amylase content *i.e.* 20-25% gives soft and flaky cooked rice. The genotypes, Pusa Basmati 1121, Pusa Basmati 1509, Pusa Sugandh 2, Pusa Sugandh 3, Pusa Sugandh 5, Improved Pusa Basmati 1, HKR 98-476, HKR 06-443, HKR 06-487, HKR 06-417, SJR-70-3-2 and Pusa 1637-2-8-20-5 with high mean, bi > 1 and non-significant deviation from regression were identified for better environment (Table 4). Whereas, the genotypes *viz*., Pusa Sugandh 6, HKR 08-425, UPR-386-9-1-1 and Pusa 1884-3-9-175 with high mean, bi < 1 and non-significant deviations from regression were found suitable for poor environment in the present investigation. Mutant genotypes 200-21-1 and 200-72-1 were found stable over the locations for amylose percentage (Radhamani *et al.*, 2017).

Environmental indices

Environment index reveals the suitability of an environment at a particular location. Based on the positive values of environment indices conclude the favorable environment for genotypes. Environmental indices of hulling%, milling%, head rice recovery %, grain length before cooking, length breadth ratio before cooking and amylose content are presented in the Table 5. The SRI and TPR during both the years at both locations Kaul as well as Uchani were found to be most favorable environments for all the studied traits.

CONCLUSION

Among the thirty six genotypes, Haryana Mahak 1, Pusa 1826-12-271-4 and HKR 06-434 showed stability in their performance over the environments with high mean value for milling%, grain length before cooking and length breadth ratio before cooking, respectively. Hence theses genotypes can be recommended for their cultivation in different production systems used in the present study.

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