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Research Article

Genotype x Environment Interaction of yield traits under low temperature stress adopting different planting dates in rice (*O. sativa* L.)

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Abstract
Low temperatures pose a major climatic problem for all rice growing countries as the rice crop growth and development requires optimum temperatures specific for each and every developmental stage. Thirty Five cold tolerant genotypes were evaluated under different dates of sowing for yield and yield related parameters, to identify high yielding genotypes suitable for late kharif and rabi seasons. Pooled analysis over environments shown highly significant mean squares due to G × E interaction for all the traits when tested against the pooled error, indicated that the genotypes interacted considerably with the environmental conditions that are associated with different dates of sowing. Significant environment linear component for all the characters indicating that the variation among the environments is linear and the linear response of genotypes to additive environmental variance. K-475, Himalaya-1, SKAU-82, Vivek Dhan -62 and Vivek Dhan -65 recorded favourable mean values for early flowering. MTU 1010 and RP-2421 are the stable genotypes for higher number of tillers. Twenty thee genotypes were found for panicle exertion, which is an important trait that influences yield under cold stress. Vivek Dhan-62, V L Dhan -207, V L Dhan -208, SKAU-339, RP-2421 and Rajendra are the stable genotypes with panicle length more than 20 cm. Spikelet fertility ranged between 70-87% in twenty five genotypes which recorded non significant deviation from regression. V L Dhan -206, SKAU-382, HPR-2373, Vivek Dhan -85, Sukaradhan-1, V L Dhan -207, Vivek Dhan -65, SKAU-389 and V L Dhan -208 registered their adaptability to wider environments for filled grains per panicle. For seed yield per plant, V L Dhan-209, V L Dhan-208, Sukaradhan-1, Vivek Dhan -65 and Himalaya-1 were considered as ideal genotypes for all seasons. Among the stable genotypes for seed yield per plant, Sukaradhan-1, Vivek Dhan -65 and Himalaya-1 showed stability for important yield contributing characters *viz*; days to 50% flowering, tillers per plant, panicle length, panicle exertion, spikelet fertility and filled grains per panicle.

Keywords
Rice, Genotype x environment interaction, yield, cold

Introduction

The food security of more than half the world's population depends on the ability of the world to supply and distribution of rice. Climate change has become a major concern disrupting the normal climate patterns over large areas and there were noticeable shifts in the rice planting dates in the context of climate change related late onsets of monsoonal rains. Abiotic stress related with temperature, due to changing climatic conditions of twenty first century is the burning concern for plant scientists worldwide. Low temperatures pose a major climatic problem for all rice growing countries. It has alarming consequences on rice crop growth and development, since these processes have optimum temperature requirements specific for each and every developmental stage. Low temperature has the potential to affect growth and development of rice plants during any developmental stage, from germination to grain filling (Ye *et al*. 2009). Delays in *kharif* planting results in the coincidence of reproductive stage with cold temperatures which translates into incomplete panicle exertion, pollen abortion and spikelet sterility. Rice grown in *rabi* / boro season that is often subjected to low temperatures during germination and seedling stage, leads to disruption of seedling development and poor stand establishment. Crop yield under low temperature fluctuates in different growing seasons or growth stages based on genotype x environment interactions. In order to identify the stable genotypes under different seasons and to identify genotypes suitable for late *kharif* and *rabi* seasons without much toll on yield due to cold stress, the present investigation was carried out to study the stability performance of 35 cold tolerant genotypes with three check varieties over four different planting dates.

Material and Methods

The experimental material comprised of 35 cold tolerant genotypes (Table.1) collected from the VPKS, Almora, RRS, Palampur and SKAUT, Kashmir along with three checks (Tellahamsa, Rajendra and MTU 1010). Field experiments were conducted at Rice section, ARI, Rajendranagar, Hyderabad with four different sowing dates *viz.*, early *kharif*, mid *kharif*, late *kharif* and *rabi* in randomized block design with 2 replications. For each different date of sowing the nursery was sown in raised beds and healthy nursery was raised following uniform package of practices. Thirty days old seedlings were transplanted with a spacing of 15 x 15 cm with a row length of 4.5 m for each entry. The recommended packages of practices were adopted. Observations were recorded on important yield, yield contributing and quality characters *viz.*, Plant height (cm), Days to 50% flowering, Number of tillers, Panicle exertion (cm), Panicle length (cm), Spikelet fertility (%), Number of filled grains/panicle, Test weight (g) and Seed yield/plant (g).

The mean data obtained at each environment was considered for final stability analysis according to Eberhart and Russell (1966) to estimate three parameters viz; (i) overall mean of each genotype over a range of environments, (ii) the regression of each genotype on the environmental index and (iii) a function of the squared deviation from the regression, by using the linear model

$$Yij = \mu i + \beta iIj + \delta ij$$

where, Y_{ij} is the mean performance of the i^{th} variety (I = 1, 2, ….., g) in j^{th} (j = 1, 2, …..,n) environments; μ_i is the mean of the i^{th} variety over all the environments; β_i the regression coefficient that measures the response of the i^{th} variety to varying environments; δij is the deviation from regression of the i^{th} variety at the j^{th} environment; and Ij is the environmental index. The environmental index, I_{ij}, for the j^{th} environment defined as the deviation of the mean of all the genotypes at a given location from the overall mean, was calculated as:

$$[\Sigma\ i\ Yij / g - \Sigma i\ \Sigma j\ Yij / gn], \Sigma j\ Ij = 0.$$

Stability parameters i.e., mean performance (X_i), regression coefficient (b_i), and mean square deviations from the linear regression (δ^2di) were estimated as:

$$bi = \Sigma j\ Yij\ Ij / \Sigma j\ Ij2 \text{ and;}$$

$$\delta^2 di = (\Sigma j\ \delta ij2/(e - 2) - (\delta e2/r).$$

The estimates were statistically tested for their significance using appropriate F and t test procedures.

Results and Discussion

Pooled analysis of variance for stability revealed the presence of significant differences among the genotypes and environments for all the characters studied indicating the significant variability among the genotypes and environments used in the study, which is in agreement with the earlier studies done by Patel *et al.* 2015; Haradari *et.al.* 2017. Highly significant mean squares due to G × E interaction for all the traits when tested against the pooled error indicated that the genotypes interacted considerably with the environmental conditions that are associated with different dates of sowing (Mall *et al.,* 2014; Mosavi *et al*., 2013; Shinde and Patel, 2014; Selvi *et al.,* 2015; Haradari *et al.* 2017). Environment + (Genotype x Environment) interaction was observed to be significant for all the characters indicating distinct influence of environments and genotype x environment interactions on phenotypic expression, which is in accordance with Patel *et al.,* 2015, Bhanumathy *et al.* 2016. Significant environment linear component for all the characters indicating that the variation among the environments are linear and the linear response of genotypes to additive environmental variance. Significance of both linear (GXE linear) and non linear (pooled deviations) components for plant height, days to 50% flowering, panicle exertion, spikelet fertility and filled grains/ panicle indicated the importance of both the components in determining the stability of these traits and only part of variation could be predicted (Swapna *et al.,* 2013; Haradari *et al.,* 2017). When both linear and non linear components are significant, prediction will depend upon relative magnitude of these two measures, whereas, the prediction will be more reliable when only former is significant against latter (Breese 1969 and Samuel, 1970). Higher proportion of linear component of GxE interaction than non linear component for plant height, days to 50% flowering, panicle exertion, spikelet fertility, filled grains/ panicle and seed yield/plant emphasizing the importance of linear regression in the feasible prediction of these traits with some reliance under different dates of sowing (Vanisree *et al.,* 2016; Bhanumathy *et al.,* 2016). However, significant higher non linear component for number of tillers/plant, panicle length and test weight suggested the unpredictable in nature of these traits over different seasons. These results were agreement with the findings of Swapna *et al.,* 2013 and Vanisree *et al.,* 2016.

Mean performance of genotype, regression co-efficient (bi) and mean deviation from regression (δ2di) are important in deciding the stability performance of a variety. According to Eberhart and Russell (1966), a stable genotype is one which has high mean with regression coefficient (bi) near "unity" and deviation from regression (δ2di) approaching "zero". The estimates on the three stability parameters for seven yield and yield component traits are presented in Table(1). Early flowering, dwarfness, low sterility percentage are desirable in rice, negative values were treated on favourable side and for rest of the traits positive values were considered as desirable. General mean for plant height over the four environments is 105.7 cm. Out of thirty eight entries; fourteen entries had non significant deviation from regression hence their performance can be precisely predicted for this trait. Ten genotypes registered non significant deviation from regression for days to 50 per cent flowering of which, K-475, Himalaya-1, SKAU-382, Vivek Dhan -62 and Vivek Dhan -65 recorded favourable mean values for early flowering. Shalimar -1 found suitable for better environments and SKAU-389, MTU 1010, Vivek Dhan-82 and Tellahamsa were found suitable for poor environments for earliness. Productive tillers per plant are an important yield contributing character in rice. Mean number of tillers recorded over environments are 10.93. MTU 1010 and RP-2421 are the two stable genotypes with higher number of tillers and for favourable environments Sukaradhan-1was found suitable. Panicle exertion is highly influenced by the environments especially on time of sowing. Late kharif crop in Telangana frequently experiences poor panicle exertion due to onset of cold from October 2nd fortnight onwards. Twenty three genotypes showed stable performance for this trait. Himalaya-741 showed better performance in favourable environments and V L Dhan-206, V L Dhan -207 and Vivek Dhan -65 performed well in unfavourable environments with good panicle exertion. Panicle length and Filled grains per panicle are important yield contributing factors as they represent larger sink size. Vivek Dhan-62, V L Dhan -207, V L Dhan -208, SKAU-339, RP-2421 and Rajendra are the stable genotypes with panicle length more than 20 cm. Sterility is one of the major constraints in late kharif rice due to reproductive cold stress which will affect the number of filled grains per panicle. Spikelet fertility ranged between 70-87% in twenty five genotypes which recorded non significant deviation from regression. Among these, nineteen genotypes were suited for all environments with unit regression coefficient. The higher values of regression for genotypes SKAU-339 and China-988 indicated that these genotypes might be recommended only for favourable environments. V L Dhan-206, RP-2421, K-475 and K-429 recorded less than unit regression with non significant deviation from regression suggesting their adaptability to unfavourable environments. For filled grains per panicle, V L Dhan -206, SKAU-382, HPR-2373, Vivek Dhan -85, Sukaradhan-1, V L Dhan -207, Vivek Dhan -65, SKAU-389 and V L Dhan -208 registered "bi" values near unity, whereas, V L Dhan -209 had bi > 1 with non significant deviation from regression and mean values greater than general mean, suggesting their adaptability to wider environments and unfavourable environments respectively. All most all the genotypes except Vivek Dhan-82, V L Dhan-208, HPR-2373 and Himalaya-1 had unit regression coefficient and non-significant δ^2di, indicating that this character is less influenced by environmental changes. For seed yield per plant, V L Dhan-209, V L Dhan-208, Sukaradhan-1, Vivek Dhan -65 and Himalaya-1 had high mean, unit regression coefficient, non-significant deviation hence they would be considered as ideal genotypes for all seasons. Vivek Dhan -85 recorded higher values of regression for seed yield per plant indicating that it can be recommended only for favourable environments. Among the stable genotypes for seed yield per plant, Sukaradhan-1, Vivek Dhan -65 and Himalaya-1 showed stability for important yield contributing characters *viz*; days to 50% flowering, tillers per plant, panicle length, panicle exertion, spikelet fertility and filled grains per panicle.

Variability and performance of genotypes for the characters studied in different environments were illustrated in the form of box plots in fig.1. For many of the characters *kharif* and mid *kharif* seasons were found suitable. Late kharif was the unfavourable environment for all the characters studied.

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Table 1. List of rice genotypes and their source

S.No.	Germplasm line	Centre/ Source
1	China-1039	SKAUST, Kudwani, Kashmir
2	SKAU-382	SKAUST, Kudwani, Kashmir
3	K-116	SKAUST, Kudwani, Kashmir
4	K-475	SKAUST, Kudwani, Kashmir
5	China -988	SKAUST, Kudwani, Kashmir
6	Jhelum	SKAUST, Kudwani, Kashmir
7	SKAU-5	SKAUST, Kudwani, Kashmir
8	China -1007	SKAUST, Kudwani, Kashmir
9	Shalimar-1	SKAUST, Kudwani, Kashmir
10	SKAU-389	SKAUST, Kudwani, Kashmir
11	Chenab	SKAUST, Kudwani, Kashmir
12	K-332	SKAUST, Kudwani, Kashmir
13	SKAU-339	SKAUST, Kudwani, Kashmir
14	SKAU-341	SKAUST, Kudwani, Kashmir
15	K-429	SKAUST, Kudwani, Kashmir
16	Himalaya-1	KVV, Malan, Himachal Pradesh
17	Himalaya -741	KVV, Malan, Himachal Pradesh
18	Himalaya -2216	KVV, Malan, Himachal Pradesh
19	RP-2421	KVV, Malan, Himachal Pradesh
20	HPR-2143	KVV, Malan, Himachal Pradesh
21	HPR-1068	KVV, Malan, Himachal Pradesh
22	Sukaradhan-1	KVV, Malan, Himachal Pradesh
23	HPR-2373	KVV, Malan, Himachal Pradesh
24	HPR-2336	KVV, Malan, Himachal Pradesh
25	HPR-2513	KVV, Malan, Himachal Pradesh
26	Vivek Dhan -85	VPKS, Almora, Uttrakhand
27	Vivek Dhan -82	VPKS, Almora, Uttrakhand
28	Vivek Dhan -62	VPKS, Almora, Uttrakhand
29	Vivek Dhan -65	VPKS, Almora, Uttrakhand
30	V L Dhan -86	VPKS, Almora, Uttrakhand
31	V L Dhan -206	VPKS, Almora, Uttrakhand
32	V L Dhan -207	VPKS, Almora, Uttrakhand
33	V L Dhan -208	VPKS, Almora, Uttrakhand
34	V L Dhan -209	VPKS, Almora, Uttrakhand
35	V L Dhan -221	VPKS, Almora, Uttrakhand
36	MTU 1010	APRRI, Maruteru
37	Tellahamsa	Rice Section, Rajendranagar
38	Rajendra	Rice Section, Rajendranagar

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Table 2. Stability ANOVA

Source	DF	Plant Height cm	Days to 50% Flowering	Tillers/ Plant	Panicle Exertion	Panicle Length	Spikelet Fertility	Filled Grains/ Panicle	Test Weight	Seed Yield/ Plant
Rep within Env.	4	0.76	0.48	0.09	0.04	0.15	1.91	19.11	0.79	0.21
Varieties	37	1258.15**	178.25**	15.38**	2.35**	24.10**	103.24**	868.30**	13.24**	56.06**
Env.+ (Var.* Env.)	114	195.57**	384.58**	7.06	1.48**	6.85**	332.77**	564.03**	3.29**	30.02**
Environments	3	5036.57**	14085.10**	80.67**	35.44**	122.96**	10093.96**	10512.55**	60.35**	568.99**
Var.* Env.	111	64.73*	14.30**	5.07**	0.56**	3.71**	68.95**	295.15**	1.74	15.45**
Environments (Lin.)	1	15109.72**	42255.29**	242.00**	106.31**	368.89**	30281.87**	31537.64**	181.04**	1706.97**
Var.* Env.(Lin.)	37	102.87**	32.49**	3.30	1.03**	3.42	153.38**	354.29	1.67	17.20
Pooled Deviation	76	44.46**	5.06**	5.80**	0.32**	3.75**	26.04**	258.59**	1.73*	14.20**
Pooled Error	148	5.17	0.84	0.21	0.16	0.20	9.19	92.87	1.20	0.73
Total	**15**	**455.93**	**334.02**	**9.10**	**1.69**	**11.07**	**276.53**	**638.58**	**5.72**	**36.40**

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Table 3. Stability of 38 genotypes over the four environments for yield characters

S. No.	Genotype	Plant Height cm			Days to 50% Flowering			Tillers/ Plant			Panicle Exertion			Panicle Length		
		Mean	**bi**	**δ^2di**	**Mean**	**bi**	**δ^2di**	**Mean**	**bi**	**δ^2di**	**Mean**	**bi**	**δ^2di**	**Mean**	**bi**	**δ^2di**
1	**CHINA-1039**	110.76	1.64*	2.37	93.75	1.02	9.41**	11.40	1.87	19.35**	3.88	1.24	0.29	22.63	1.73	0.48*
2	**SKAU-382**	114.15	0.82	24.16**	99.13	1.00	-0.55	13.39	1.12	14.97**	3.00	1.15	-0.01	24.15	0.77	2.02**
3	**K-116**	87.32	0.15	195.50**	85.75	0.96	2.52*	7.14	0.32	0.61*	1.38	0.55	0.76**	18.00	0.70	27.69**
4	**K-475**	87.82	0.26*	-1.32	87.13	1.06	1.40	7.57	1.48	3.45**	1.88	1.01	0.01	16.73	0.03	0.71*
5	**CHINA-988**	114.28	1.08	14.64*	95.25	1.24	6.24**	14.20	2.19	1.77**	3.38	1.00	0.53*	23.71	1.28	4.40**
6	**JHELUM**	108.70	0.97	3.50	92.63	1.29	4.39**	10.60	1.59	1.85**	3.00	1.39	0.41*	22.73	0.84	1.05**
7	**SKAU-5**	111.03	1.12	16.69*	92.63	1.33	12.06**	8.25	1.32	11.51**	2.88	1.24	0.29	23.55	0.70	0.59*
8	**CHINA-1007**	112.95	1.20	88.90**	95.38	1.10	5.47**	15.13	1.02	3.03**	3.25	0.52	0.09	22.73	1.70	3.22**
9	**SHALIMAR-1**	113.22	1.09	10.14	88.63	1.19*	1.01	10.02	1.11	1.89**	3.63	0.83	-0.03	23.10	1.05	1.38**
10	**SKAU-389**	110.93	1.04	1.14	90.50	0.94*	-0.72	9.43	1.58	14.55**	2.75	0.86	-0.08	23.48	1.24	1.60**
11	**CHENAB**	114.28	1.28	-2.48	94.63	1.34	8.23**	13.00	1.40	1.98**	3.13	1.06	-0.15	23.92	1.15	0.44*
12	**K-332**	76.82	0.46	13.43*	89.13	1.03	11.19**	7.88	1.00	5.25**	1.75	1.32	0.02	15.02	0.14	1.57**
13	**SKAU-339**	106.70	0.70	-0.05	95.75	1.33*	3.22**	11.80	2.19	20.84**	3.50	1.50	-0.04	23.20	0.95	-0.02
14	**SKAU-341**	121.84	0.79	82.32**	99.25	1.05	2.33*	10.52	1.14	16.79**	3.25	0.52	0.09	24.98	1.55	1.91**
15	**K-429**	74.99	1.06	166.30**	86.88	1.09	1.80*	7.53	1.50	7.29**	1.13	0.83	-0.04	17.19	1.54	0.58*
16	**HIMALAYA-1**	75.68	1.05	150.85**	98.88	0.92	1.48	13.85	-0.23	4.11**	1.75	2.02	0.52*	19.40	1.84	0.24
17	**HIMALAYA-741**	73.82	0.80	-0.44	95.13	0.82	5.91**	9.88	0.28	14.91**	2.63	2.56*	0.00	18.73	0.88	1.27**
18	**HIMALAYA-2216**	124.40	1.43	30.65**	99.00	0.85	7.93**	13.95	0.64	0.74*	3.75	1.78	0.02	24.42	0.97	2.26**
19	**RP-2421**	114.77	1.38	18.09*	98.75	1.07	2.91*	12.45	0.50	0.13	2.13	1.29	0.61**	21.67	0.54	0.33
20	**HPR-2143**	93.35	1.37	6.48	101.38	1.12	11.66**	9.32	0.31	0.43*	2.88	0.66	0.07	21.63	1.71	2.62**
21	**HPR-1068**	86.97	1.07	7.95	102.50	1.12	1.10	11.98	-0.21	3.26**	1.88	1.24	0.30	21.05	1.26	1.01**
22	**SUKARADHAN-1**	122.65	1.43	58.86**	101.75	0.72	15.43**	12.70	2.01*	-0.01	2.63	1.41	-0.10	23.35	0.81	1.00**
23	**HPR-2373**	81.03	0.61	84.98**	109.75	0.79	7.44**	10.52	-0.33	11.92**	1.38	0.89	0.08	18.29	1.84	22.20**
24	**HPR-2336**	109.82	1.24	-3.23	102.75	1.00	-0.83	11.27	0.77	1.20**	2.00	1.38	0.19	21.65	1.19	1.63**
25	**HPR-2513**	86.57	1.62	28.53**	102.13	0.90	7.02**	11.10	0.74	1.34**	1.63	0.95	0.43*	19.63	1.72	13.09**
26	**VIVEK DHAN-85**	102.18	-1.23	168.40**	95.38	0.81	3.23**	9.73	1.35	0.73*	2.13	1.52	0.19	21.50	-0.04	22.87**
27	**VIVEK DHAN-82**	124.30	0.86	34.03**	96.75	0.89*	-0.52	9.13	1.46	0.32	2.50	0.69	-0.07	25.25	0.82	0.82**
28	**VIVEK DHAN-62**	121.93	0.96	32.01**	100.13	0.97	0.24	9.57	1.16	0.27	2.63	1.06	-0.15	23.67	0.26	0.18
29	**VIVEK DHAN-65**	116.81	1.58	34.71**	101.13	1.14	1.12	11.55	0.40	4.06**	2.38	0.15*	-0.09	22.20	0.30	2.73**
30	**V L DHAN-86**	119.13	1.00	22.83**	94.13	1.05	6.42**	10.89	1.51	4.03**	2.38	1.81	0.10	22.64	0.50	0.79**
31	**V L DHAN-206**	128.30	1.56	108.34**	110.63	0.73	3.98**	10.40	0.00	0.40	3.38	0.09*	-0.07	23.02	1.53	2.08**
32	**V L DHAN-207**	129.93	1.06	25.31**	112.38	0.98	-0.38	9.82	0.38	0.51*	3.13	0.14*	-0.09	23.33	0.98	0.39
33	**V L DHAN-208**	126.63	1.09	3.52	108.50	0.97	-0.65	10.10	1.33	3.68**	3.88	1.01	0.01	23.30	0.66	0.11
34	**V L DHAN-209**	131.82	1.36	7.70	109.75	0.99	5.51**	11.65	1.95	3.75**	2.88	0.43	-0.08	23.30	0.76	0.54*
35	**V L DHAN-221**	119.38	1.36	60.89**	103.38	0.86	0.91	10.33	-0.15	7.83**	1.50	-0.81	0.67**	25.37	1.71	9.84**
36	**MTU 1010**	87.70	0.92	7.23	96.50	0.75*	0.85	13.10	0.27	0.42	1.50	0.80	0.44*	21.38	1.13	0.83**
37	**TELLAHAMSA**	90.50	1.11	-1.36	100.00	0.79*	1.05	11.63	2.07	11.37**	2.25	0.98	-0.12	21.50	1.55	0.40*
38	**RAJENDRA**	83.18	0.71*	-4.39	96.25	0.79	10.91**	12.40	0.98	11.94**	2.25	1.20	1.19**	21.19	1.12	0.26
	Population Mean	**105.70**			**97.98**			**10.93**			**2.56**			**21.91**		

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S. No.	Genotype	Spikelet Fertility			Filled Grains/ Panicle			Test Weight			Seed Yield/ Plant		
		Mean	**bi**	**δ^2di**	**Mean**	**bi**	**δ^2di**	**Mean**	**bi**	**δ^2di**	**Mean**	**bi**	**δ^2di**
1	**CHINA-1039**	81.03	1.05	1.83	78.50	1.05	-41.48	23.52	1.48	0.90	17.53	1.78	41.05**
2	**SKAU-382**	79.89	0.91	-3.78	100.15	1.19	58.57	23.35	0.96	1.97	16.58	0.74	18.02**
3	**K-116**	65.53	1.59	19.54*	46.75	1.12	-54.66	23.02	1.10	-0.76	6.84	0.53	1.69*
4	**K-475**	83.37	0.34**	-8.41	77.26	0.25	19.51	23.46	1.42	-0.54	10.68	0.11	13.54**
5	**CHINA-988**	73.88	1.76*	10.61	78.55	1.62	312.50*	24.17	0.96	-0.72	17.30	1.98	13.74**
6	**JHELUM**	80.01	1.13	-5.74	79.43	1.51	-44.64	23.01	0.22	-0.47	15.65	1.62	11.15**
7	**SKAU-5**	79.28	1.04	-0.29	67.91	0.97	160.28	23.79	1.52	0.35	13.88	1.03	20.37**
8	**CHINA-1007**	77.96	0.84	105.58**	66.70	1.08	304.31*	23.24	2.39	-0.68	14.98	0.93	-0.19
9	**SHALIMAR-1**	77.91	1.13	-0.97	75.21	0.99	131.27	23.92	0.70	-0.81	15.01	0.97	1.96*
10	**SKAU-389**	81.38	1.19	12.53	85.57	0.80	77.09	24.70	1.30	-0.21	15.34	1.03	27.23**
11	**CHENAB**	75.28	1.86*	7.35	76.41	1.58	563.39**	23.76	1.48	1.07	16.85	1.96*	0.26
12	**K-332**	81.03	0.72	1.94	72.00	0.20	632.07**	24.80	1.36	-0.65	9.58	0.18	14.62**
13	**SKAU-339**	75.06	1.71*	9.12	99.60	2.50	510.90**	24.63	1.73	-0.92	13.60	1.05	1.01
14	**SKAU-341**	81.53	0.99	12.59	88.61	1.15	503.16**	24.44	1.11	-1.13	20.85	1.58	13.17**
15	**K-429**	75.39	0.23*	2.64	48.11	-0.65	77.04	22.92	0.86	-0.65	8.60	-0.28	14.54**
16	**HIMALAYA-1**	69.21	0.96	76.08**	62.22	1.00	-41.24	18.98	0.61	4.66**	10.64	0.87	17.60**
17	**HIMALAYA-741**	72.50	0.76	26.31*	79.05	0.87	581.07**	20.54	0.94	-0.88	11.27	0.60	9.78**
18	**HIMALAYA-2216**	77.65	1.31	42.55**	94.86	1.41	613.77**	21.13	0.82	-1.07	23.54	2.51	42.08**
19	**RP-2421**	84.32	0.56*	-4.80	77.40	0.17	13.60	19.48	0.92	0.84	19.02	0.27	30.47**
20	**HPR-2143**	72.00	0.51	31.70*	61.55	-0.16**	-89.38	19.89	1.48	1.12	11.50	0.61	1.78*
21	**HPR-1068**	68.64	0.20	22.50*	57.64	0.05	166.20	23.04	1.19	-0.52	13.92	0.18	17.52**
22	**SUKARADHAN-1**	75.03	1.08	9.94	91.93	0.86	-48.68	21.50	0.37	-1.05	18.54	1.35	7.48**
23	**HPR-2373**	80.15	0.41	22.27*	99.74	0.63	115.37	19.20	0.86	9.20**	14.71	0.46	6.68**
24	**HPR-2336**	70.93	0.91	4.68	74.05	0.37*	-82.51	25.15	-0.40	0.38	18.78	1.25	14.44**
25	**HPR-2513**	69.69	0.91	118.37**	67.95	0.63	105.26	21.48	-0.66	0.80	12.24	0.94	11.91**
26	**VIVEK DHAN-85**	81.04	0.83	1.67	95.03	1.51	-69.22	22.42	0.97	0.14	17.66	1.46	0.16
27	**VIVEK DHAN-82**	72.45	1.58	12.44	72.76	1.37	307.17*	24.77	0.44	9.21**	16.62	2.10*	0.65
28	**VIVEK DHAN-62**	80.31	0.89	41.59**	108.53	1.98	896.95**	21.48	1.11	-1.07	17.58	1.07	7.46**
29	**VIVEK DHAN-65**	71.93	0.24	21.05*	86.36	0.51	-59.93	20.45	0.61	-1.09	15.93	1.02	11.29**
30	**V L DHAN-86**	68.61	1.32	29.64*	68.26	1.11	52.76	22.89	0.79	1.34	9.99	0.52	0.29
31	**V L DHAN-206**	87.24	0.39*	-4.44	106.28	1.30	25.13	21.61	0.60	0.26	20.54	0.34	0.50
32	**V L DHAN-207**	78.89	1.33	3.55	90.86	1.64	153.40	21.80	1.09	-0.18	14.68	0.54	62.08**
33	**V L DHAN-208**	73.59	1.47	23.98*	80.61	1.41	40.36	20.75	0.83	2.93*	13.06	1.04	0.43
34	**V L DHAN-209**	75.02	1.06	-6.30	92.35	1.38*	-88.51	21.17	0.50	-0.71	13.95	0.79	18.99**
35	**V L DHAN-221**	71.76	1.49	4.17	92.45	2.12	617.22**	24.99	2.15	1.41	19.96	1.87	13.95**
36	**MTU 1010**	72.81	1.33	10.09	78.36	1.41	-57.59	19.92	1.11	-0.65	12.75	0.69	32.19**
37	**TELLAHAMSA**	70.27	1.04	-0.35	72.39	1.01	-23.07	20.50	1.79	-0.19	15.02	1.11	2.61*
38	**RAJENDRA**	72.65	0.92	-3.81	73.64	0.08	33.63	20.33	1.26	-0.94	20.54	1.19	9.71**
	Population Mean	**75.93**			**79.61**			**22.37**			**15.15**		

Table 4. Classification of genotypes for different characters based on stability parameters

S. No.	Character	Genotypes with non significant deviation from regression (δ^2di = NS)	Genotypes stable over all environments (bi = 1, High Mean, δ^2di = NS)	Genotypes suitable for favourable environments (bi >1, High Mean, δ^2di = NS)	Genotypes suitable for poor environments (bi < 1, High Mean, δ^2di = NS)
1	Plant Height (cm)	Himalaya-741,Rajendra, HPR-1068, MTU 1010, K-475, Tellahamsa, HPR-2143 SKAU-339, Jhelum, HPR-2336, China-1039, SKAU-389, Shalimar-1, Chenab V L Dhan-208, V L Dhan -209	Himalaya-741,Rajendra, HPR-1068, MTU 1010, Tellahamsa, HPR-2143, SKAU-339, Jhelum, HPR-2336, SKAU-389, Shalimar-1, Chenab, V L Dhan-208, V L Dhan -209	China-1039	Rajendra, K-475
2	Days to 50% Flowering	K-475, Shalimar -1, SKAU-389, MTU 1010, Vivek Dhan-82, Himalaya-1, SKAU-382, Tellahamsa, Vivek Dhan -62, Vivek Dhan -65, HPR-1068, HPR-2336, V L Dhan-221, V L Dhan-208, V L Dhan -207	K-475, Himalaya-1, SKAU-382, Vivek Dhan -62, Vivek Dhan -65, HPR-1068, HPR-2336, V L Dhan-221, V L Dhan-208, V L Dhan -207	Shalimar -1	SKAU-389, MTU 1010, Vivek Dhan-82, Tellahamsa
3	Tillers/ Plant	MTU 1010, Sukaradhan-1, RP-2421, V L Dhan -206, Vivek Dhan-62, Vivek Dhan -82	MTU 1010, RP-2421, V L Dhan -206, Vivek Dhan-62, Vivek Dhan -82	Sukaradhan-1	
4	Panicle Exertion	V L Dhan -208, China-1039, Himalaya-2216, Shalimar-1, SKAU-339, V L Dhan-206, China-1007, SKAU-341, V L Dhan -207, Chenab, SKAU-382, HPR-2143, V L Dhan -209, SKAU-5, SKAU-389, Himalaya-741, Sukaradhan-1, Vivek Dhan-62, Vivek Dhan -82, Vivek Dhan -65, V L Dhan-86, Tellahamsa, Vivek Dhan-85, HPR-2336, K-475, HPR-1068, K-332	V L Dhan -208, China-1039, Himalaya-2216, Shalimar-1, SKAU-339, China-1007, SKAU-341, Chenab, SKAU-382, HPR-2143, V L Dhan -209 SKAU-5, SKAU-389, Sukaradhan-1, Vivek Dhan-62, Vivek Dhan -82, , V L Dhan-86, Tellahamsa, Vivek Dhan-85, HPR-2336, K-475, HPR-1068, K-332	Himalaya-741	V L Dhan-206, V L Dhan -207, Vivek Dhan -65
5	Panicle Length	Vivek Dhan-62, V L Dhan -207 V L Dhan -208, SKAU-339 RP-2421, Rajendra, Himalaya-1	Vivek Dhan-62, V L Dhan -207 V L Dhan -208, SKAU-339 RP-2421, Rajendra, Himalaya-1	--	--
6	Spikelet Fertility	V L Dhan-206, RP-2421, K-475, SKAU-341, SKAU-389, Vivek Dhan -85, China-1039, K-332, Jhelum, SKAU-382, SKAU-5, V L Dhan -207, Shalimar-1, K-429, Chenab, SKAU-339, Sukaradhan-1, V L Dhan -209, China-988, MTU 1010, Rajendra, Vivek Dhan -82, V L Dhan -221, HPR-2336, Tellahamsa	SKAU-341, SKAU-389, Vivek Dhan -85, China-1039, K-332, Jhelum, SKAU-382, SKAU-5, V L Dhan -207, Shalimar-1, Chenab, Sukaradhan-1, V L Dhan -209, MTU 1010, Rajendra, Vivek Dhan -82, V L Dhan -221, HPR-2336, Tellahamsa	SKAU-339. China-988	V L Dhan-206, RP-2421, K-475, K-429,
7	Filled grains/Panicle	V L Dhan -206, SKAU-382, HPR-2373, Vivek Dhan -85, V L Dhan -209, Sukaradhan-1, V L Dhan -207, Vivek Dhan -65, SKAU-389, V L Dhan -208, Jhelum, China-1039, MTU 1010, RP-2421, K-475, Shalimar-1, HPR-2336, Rajendra, Tellahamsa, V L Dhan -86, HPR-2513, SKAU-5, Himalaya-1, HPR-2143, HPR-1068, K-429, K-116	V L Dhan -206, SKAU-382, HPR-2373, Vivek Dhan -85, Sukaradhan-1, V L Dhan -207, Vivek Dhan -65, SKAU-389, V L Dhan -208, Jhelum, China-1039, MTU 1010, RP-2421, K-475, Shalimar-1, Rajendra, Tellahamsa, V L Dhan -86, HPR-2513, SKAU-5, Himalaya-1, HPR-1068, K-429, K-116	V L Dhan -209	HPR-2336, HPR-2143
8	Test weight	RP-2421, HPR-2143, MTU 1010, Rajendra, Vivek Dhan-65, Tellahamsa, Himalaya-741, Himalaya-2216, V L Dhan-209, HPR-2513, Vivek Dhan-62, Sukaradhan-1, V L Dhan -206,V L Dhan -207, Vivek Dhan -85, V L Dhan -86, K-429, Jhelum, K-116, HPR-1068, China-1007, SKAU-382, K-475, China-1039, Chenab, SKAU-5, Shalimar-1, China-988, SKAU-341, SKAU-339, SKAU-389, K-332, V L Dhan-221,HPR-2336	RP-2421, HPR-2143, MTU 1010 Rajendra, Vivek Dhan-65, Tellahamsa, Himalaya-741, Himalaya-2216, V L Dhan-209, HPR-2513, Vivek Dhan-62, Sukaradhan-1, V L Dhan -206, V L Dhan -207, Vivek Dhan -85, V L Dhan -86, K-429, Jhelum, K-116, HPR-1068, China-1007, SKAU-382, K-475, China-1039, Chenab, SKAU-5, Shalimar-1 China-988, SKAU-341, SKAU-339, SKAU-389, K-332, V L Dhan-221, HPR-2336	--	--
9	Seed yield /plant	V L Dhan-209, V L Dhan-208, Vivek Dhan -85, K-116, Sukaradhan-1, Vivek Dhan -65 Himalaya-1, Himalaya-741	V L Dhan-209, V L Dhan-208 Sukaradhan-1, Vivek Dhan -65 Himalaya-1, Himalaya-741	Vivek Dhan -85, K-116	--

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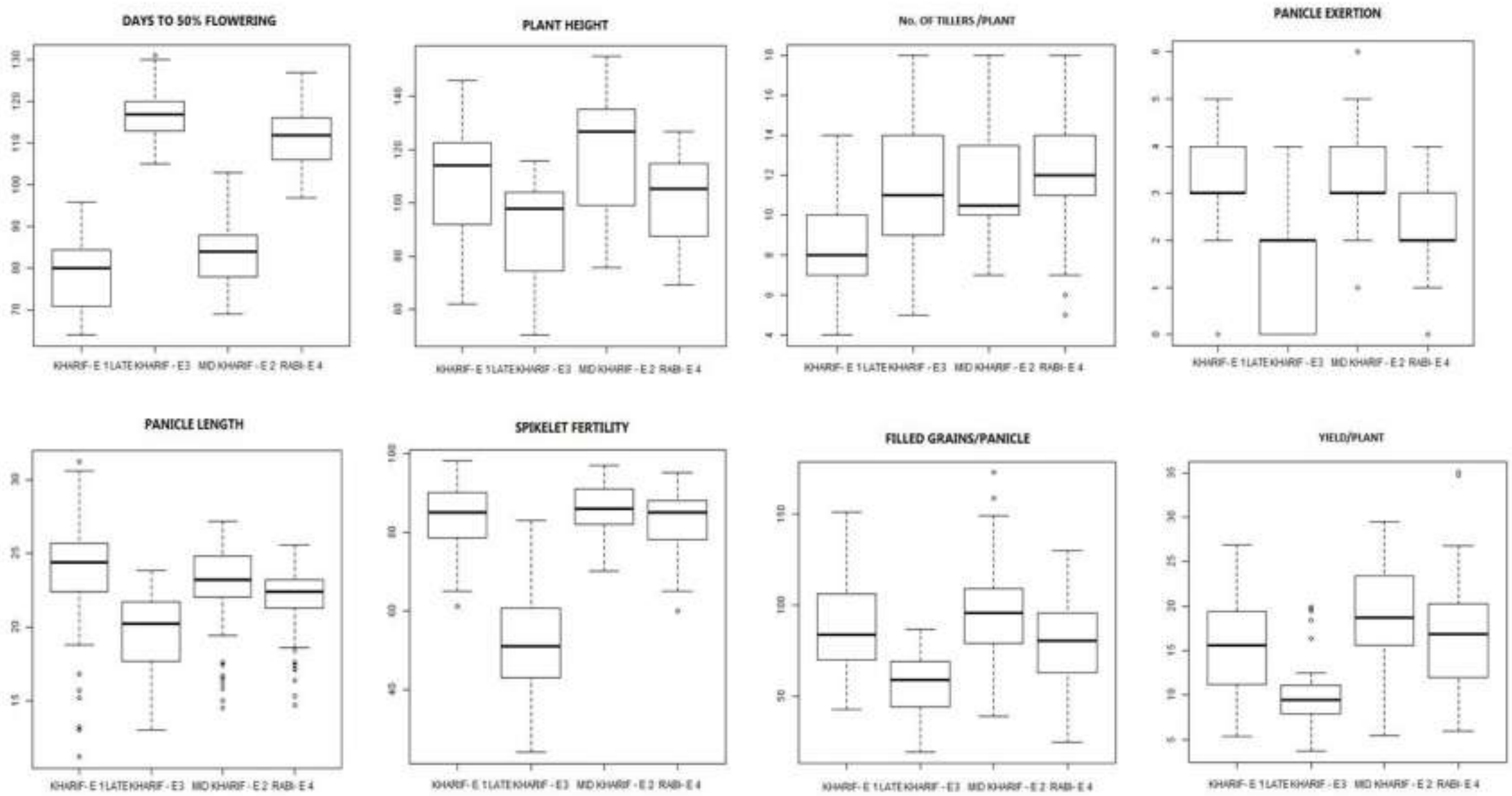

Fig. 1. Box plots illustrating the variability and performance of genotypes for the characters studied in different environments. The median (horizontal line inside each box), 25-75 percentiles (the box) for the seedling characters in four cold environments. The whiskers (the two lines outward from a box at each end) represent the smallest (the bottom whisker) and the 25largest (the top whisker) values of the data of each trait. Circles represent the outliers.