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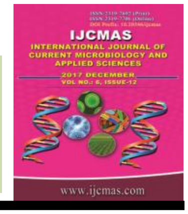

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Screening of Cold Tolerant Rice Genotypes for Seedling Traits under Low Temperature Regimes

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Thirty seven rice genotypes with reported cold tolerance at various phonological stages were used to evaluate for germination and seedling traits in laboratory conditions under three temperature regimes viz., normal (28°C), 8°C and 13°C respectively for identification of genotypes possessing seedling stage cold tolerance. The *per se* performance in cold environment was found to be related to parameters like germination percent, germination Index, root, shoot and seedling length and seedling vigour. In this context, it is very crucial to have a better understanding of the mechanism of cold tolerance at seedling stage, which is a potential production constraint in rabi. The response of genotypes differed with different low temperatures and was significant indicating the presence of considerable variability for cold tolerance at germination and seedling stage. Certain genotypes performed very well under 13°C and 8°C of temperatures for various seedling traits. However, few genotypes exhibited superior performance under 13°C but not performed well under 8°C of temperatures vice versa. On an overall basis HPR 1068, Himalaya-2216 and Vivek Dhan -82 showed lesser percentage of reduction for seedling vigour index at both temperatures and these genotypes can be used as cold tolerant donors in future breeding programs for development of seedling cold tolerant rice varieties.

Introduction

Climate change is likely to have a significant impact on agriculture, especially through the increased likelihood of extreme temperatures. Low temperature damage has long been a problem and has caused serious yield losses in more than 20 countries. The frequency of yield loss due to low temperature damage, vary from country to country and also region to region within the states. Rice is very sensitive to prolonged exposure to lower temperatures. Cold tolerance at seedling stage is a primary requirement of rice cultivars as seedlings are raised during the cold months of November and December even up to January (Tiwari *et al.*, 2009). Low temperature during seedling stage causes poor germination, stunted seedling growth and seedling mortality which directly affect the yield (Pathak *et al.*, 2003). The stunted seedling growth also affects manual uprooting and transplanting and further field establishment. The rice species (*Oryza sativa* L.) has wide adaptability to cold and cold-tolerant ecotypes are available for breeding. Japonica genotypes show higher cold tolerance at the germination stage than *indica* genotypes, although variability for this trait within both subspecies has been reported (Cruz and Milach, 2013). Evaluation of rice genotypes for represent traits under more than one temperature is necessary to distinguish cold tolerance. The availability of low temperature tolerant source is interesting for breeding cold tolerance, since it allows them to be used as progenitors in crosses as well as to transfer of desirable characters to make them adaptable to the target environment.

Keeping in view the above facts, an experiment was conducted in laboratory conditions simulating low field temperatures to evaluate rice genotypes against low temperature stress at germination stage for identification of the superior genotypes with good germination and seedling vigour traits. Identified genotypes can be utilized in future breeding programs for development of cold tolerant rice varieties at seedling stage.

Materials and Methods

Thirty seven rice genotypes collected from the VPKS, Almora, RRS, Palampur and SKAUT, Kashmir along with important cold tolerant varieties of ANGRAU (presently PJTSAU), Hyderabad are the basic material for the study. The experiment was carried out at Quality control Lab, PJTSAU, Rajendranagar, Hyderabad under the controlled conditions. All the genotypes were allowed to germinate at 28°C for seven days (control), 13°C and 8°C for 28 days (cold) as described by Cruz and Milach (2004). Twenty seeds of each genotype were placed in petri dishes containing 2 layers of germination paper, soaked with distilled water. Before placing the seeds for germination all the seeds were washed with aqueous ethanol (70% V/V) for 30 seconds followed by immersion in aqueous sodium hydro chlorite (5%v/v) for 20 minutes to prevent contamination and then washed six times with distilled water. For germination parameters seeds were sown in petri dishes and for seedling parameters seeds were sown in trays with soil after sterilization and kept in BOD germinator regulated to 28°C for the control, 13°C and 8°C for the cold treatment. The experiment was conducted in a randomized complete block design with three replicates considering each rack in the incubator as one block. Utilizing the mean data on root and shoot length (cm), seedling length (cm), the characters germination (%), germination index, and seedling vigour index were calculated. ***t***-test was performed to compare the significance of mean differences of germination and seedling traits for normal *vs* 13°C and normal *vs* 8°C by using WINDOWSTAT software. The calculated value was compared with 't' tabulated value at 0.05 significance.

Results and Discussion

The study of *per se* performance indicated that cold tolerance was related physiological parameters like germination percent, germination Index, root, shoot and seedling length, and seedling vigour. These parameters were chosen as they were the most adequate to differentiate cold tolerance exhibited by cold resistance genotypes at the germination stage (Cruz and Milach, 2004). It is very crucial to have a better understanding of the mechanism of cold tolerance at seedling stage, since the rice crop grown during rabi/boro season is affected by cold stress during nursery stage.

The mean values and percent reduction of genotypes at different temperatures for various traits are presented in tables 1-3. The response of genotypes differed with different cold temperatures. There was considerable variability for cold tolerance at the germination stage among the genotypes. Cruz and Milach (2004), Sharifi Peyman and Aminpanah Hashem (2010) and Carolina *et al.,* (2013) studied under different cold temperatures and reported similar results. Germination (%) ranged from 60 to 100 % at normal temperature. In case of 13°C germination (%) ranged from 50.0 to 100 and at 8°C it ranged from 53.3 (China-988) to 90.0(HPR-2336). The percent of reduction in mean germination was 1.8 and 17.6 at 13°C and 8°C, respectively (Table 1) as compared to normal temperature. As many as 16 genotypes recorded significantly superior germination percent with very less reduction at 13°C. However, at 8°C only 8 genotypes showed significantly superior germination percentage. The genotypes SKAU- 382, SKAU-5, SKAU-389, HPR-1068, HPR- 2336 and BPT 5204 registered significantly superior germination (%) along with very low percentage of reduction at both temperatures. Germination (%) seems to be the most appropriate trait to evaluate cold tolerance during seed germination period (Cruz and Milach, 2004 and Priyanka *et al.,* 2015). Similarly, germination index (GI) expresses the germination speed under cold temperature. GI calculated based on seeds that presented coleoptiles and radical and is an important index for better performance of genotypes under the cold stress. The genotypes China-1007 (56.7, 48.3) and RP-2421and Vivek Dhan 82 (100, 100) recorded lowest and highest germination index at normal and 13°C respectively. However, the range was from 41.7 (China -988) to 83.3 (HPR-2336) at 8°C. At 13°C reduction in germination Index (%) was very low for most of the genotypes and four genotypes, China 1007, HPR 2336, K-475 and HPR 1068 showed less than 20% reduction at and 8°C (Table 1). These results indicated that more number of seeds of these genotypes had germinated at 14 and 21 days after the sowing. In fact, variation in environmental effects is one of the limiting factors against evaluation of germination, in order to identify genetically best lines for cold stress conditions (Cruz *et al.,* 2006). In order to enhance and ensure uniform establishment of rice seedlings in the early season, cold tolerance during this time is vital (Sato *et al.*, 2001).

Root and shoot length and Seedling growth are the important traits and genotypes showing less reduction percentage for these traits show cold tolerance. The genotypes China- 1007 (10.7 cm), Chenab (7.6 cm) and Vivek Dhan-82 (3.3cm) recorded highest root length at normal, 8°C and 13°C respectively. The genotype Himalaya-741 registered lowest root length at normal (7.2 cm) and 13°C (3.5 cm). Shoot length ranged from 5.4 cm (Himalaya-1) to 12.1cm (SKAU-382) at normal temperature. Shoot length ranged from 3.5 cm (Himalaya-2216) to 8.4 cm (Chenab) at 13°C and 1.1 cm (MTU 1010) to 2.9 cm (Vivek Dhan -82 at 8°C. Genotypes SKU-382, SKAU-5, Chenab, Sukardhan-1, HPR-2336, Vivek Dhan -65, Vivek Dhan -86 and Vivek Dhan -206 recorded significantly superior performance over the population mean for root and shoot length and seedling growth. The genotypes Chenab, Sukardhan-1, HPR-2336, and Vivek Dhan -86 recorded lesser than 25 percent of reduction for the root, shoot length and seedling growth at 13°C. At 8°C genotypes Himalaya-1, Himalaya -2216, HPR 1068, HPR-2336, Vivek Dhan-82 and Vivek Dhan-65 were significantly superior over the mean and recorded lesser than 75 percent of reduction for the root, shoot length and seedling growth table.

Table.1 Mean values and percent reduction of rice genotypes for germination and Germination Index at low temperature regimes

Entry	Germination (%)					Germination Index				
	N	13°C	% reduction 13°C	8°C	% reduction 8°C	N	13°C	% reduction 13°C	8	% reduction 8°C
China-1039	80.0	86.7	-8.4	76.7	4.1	73.3	81.7	-11.5	56.7	30.6
SKAU-382	100.0*	100.0*	0.0	83.3*	16.7	98.3*	98.3*	0.0	63.3	35.6
K-475	80.0	66.7	16.6	63.3	20.9	60.0	51.7	13.8	50.0	3.3
China-988	70.0	63.3	9.6	53.3	23.9	63.3	58.3	7.9	41.7	28.5
Jhelum	86.7	86.7	0.0	80.0	7.7	85.0	86.7	-2.0	66.7*	23.1
SKAU-5	100.0*	96.7*	3.3	76.7	23.3	98.3*	96.7*	1.6	60.0	38.0
China-1007	60.0	50.0	16.7	66.7	-11.2	56.7	48.3	14.8	51.7	-7.0
Shalimar-1	90.0	90.0	0.0	83.3*	7.4	85.0	86.7	-2.0	66.7*	23.1
SKAU-389	100.0*	93.3	6.7	86.7*	13.3	98.3*	91.7	6.7	65.0	29.1
Chenab	86.7	86.7	0.0	73.3	15.5	83.3	85.0	-2.0	58.3	31.4
K-332	66.7	70.0	-4.9	16.7	75.0	58.3	58.3	0.0	13.3	77.2
SKAU-339	100.0*	96.7*	3.3	80.0	20.0	91.7*	91.7	0.0	63.3	31.0
SKAU-341	96.7*	93.3	3.5	76.7	20.7	95.0*	91.7	3.5	60.0	34.6
K-429	90.0	90.0	0.0	66.7	25.9	76.7	76.7	0.0	50.0	34.8
Himalaya-1	93.3	93.3	0.0	76.7	17.8	88.3	90.0	-1.9	63.3	29.7
Himalaya-741	100.0*	96.7*	3.3	76.7	23.3	100.0*	96.7*	3.3	65.0	32.8
Himalaya-2216	93.3	96.7*	-3.6	76.7	17.8	93.3*	96.7*	-3.6	60.0	38.0
RP-2421	100.0*	100.0*	0.0	80.0	20.0	100.0*	100.0*	0.0	63.3	36.7
HPR-2143	86.7	90.0	-3.8	80.0	7.7	85.0	90.0	-5.9	65.0	27.8
HPR-1068	93.3	96.7*	-3.6	86.7*	7.1	90.0	93.3*	-3.7	71.7*	23.2
Sukaradhan-1	93.3	90.0	3.5	86.7*	7.1	91.7	90.0	1.9	70.0*	22.2
HPR-2373	93.3	83.3	10.7	66.7	28.5	93.3*	81.7	12.4	53.3	34.8
HPR-2336	96.7	96.7*	0.0	90.0*	6.9	96.7*	96.7*	0.0	83.3*	13.9
HPR-2513	83.3	76.7	7.9	70.0	16.0	81.7	75.0	8.2	55.0	26.7
Vivek Dhan-85	100.0*	100.0*	0.0	76.7	23.3	98.3*	98.3*	0.0	61.7	37.2
Vivek Dhan -82	100.0*	100.0*	0.0	66.7	33.3	100.0*	100.0*	0.0	50.0	50.0
Vivek Dhan -62	93.3	93.3	0.0	83.3*	10.7	90.0	88.3	1.9	68.3*	22.7
Vivek Dhan -65	100.0*	100.0*	0.0	80.0	20.0	96.7*	98.3*	-1.7	66.7*	32.1
V L Dhan-86	93.3	93.3	0.0	73.3	21.4	90.0	91.7	-1.9	53.3	41.9
V L Dhan-206	100.0*	100.0*	0.0	76.7	23.3	100.0*	98.3*	1.7	60.0	39.0
V L Dhan -207	100.0*	100.0*	0.0	80.0	20.0	100.0*	98.3*	1.7	65.0	33.9
V L Dhan -208	100.0*	96.7*	3.3	80.0	20.0	100.0*	96.7*	3.3	68.3*	29.4
V L Dhan -209	93.3	96.7*	-3.6	76.7	17.8	91.7	90.0	1.9	56.7	37.0
MTU 1010	93.3	90.0	3.5	80.0	14.3	90.0	88.3	1.9	61.7	30.1
Tellahamsa	73.3	66.7	9.0	70.0	4.5	70.0	65.0	7.1	53.3	18.0
Rajendra	76.7	73.3	4.4	66.7	13.0	71.7	68.3	4.7	55.0	19.5
BPT 5204	96.7*	100.0*	-3.4	83.3*	13.9	95.0*	98.3*	-3.5	70.0*	28.8
Mean	**90.8**	89.2		**74.8**		**87.5**	**86.3**		**59.6**	
CD%		5.32		5.33			6.27		5.55	

Table.2 The mean values and percent reduction of rice genotypes for different temperatures for root and shoot length

Entry	Root length					Shoot length				
	N	13°C	% reduction 13°C	8°C	% reduction 8°C	N	13°C	% reduction 13°C	8°C	% reduction 8°C
China-1039	8.1	4.8	40.7	1.4	82.7	7.1	4.7	33.8	1.4	80.3
SKAU-382	8.3	6.8*	18.1	1.9	77.1	12.1	6.5*	46.3	1.6	86.8
K-475	8.3	6.3	24.1	1.7	79.5	7.4	5.8	21.6	1.6	78.4
China-988	7.4	6.0	18.9	1.9	74.3	11.8	5.6	52.5	1.8	84.7
Jhelum	8.4	7.3*	13.1	2.1	75.0	7.9	5.6	29.1	1.8	77.2
SKAU-5	9.8*	6.8*	30.6	2.9	70.4	7.6	5.9	22.4	2.4	68.4
China-1007	10.7*	6.7*	37.4	2.0	81.3	9.6	7.3*	24.0	1.8	81.3
Shalimar-1	9.8*	6.9*	29.6	1.9	80.6	7.6	5.8	23.7	1.7	77.6
SKAU-389	8.9	7.1*	20.2	2.1	76.4	9.3	6.1	34.4	1.4	84.9
Chenab	8.7	7.6*	12.6	1.7	80.5	10.6	8.4*	20.8	1.7	84.0
K-332	7.9	4.3	45.6	1.7	78.5	5.7	4.3	24.6	1.4	75.4
SKAU-339	8.1	4.3	46.9	2.0	75.3	9.1	4.9	46.2	1.9	79.1
SKAU-341	8.4	4.5	46.4	1.3	84.5	5.6	4.6	17.9	1.3	76.8
K-429	8.7	5.1	41.4	2.3	73.6	7.8	5.6	28.2	1.9	75.6
Himalaya-1	8.1	5.8	28.4	2.5	69.1	5.4	4.5	16.7	2.5*	53.7
Himalaya-741	7.2	3.5	51.4	1.5	79.2	6.8	3.7	45.6	1.4	79.4
Himalaya-2216	7.9	3.8	51.9	2.7	65.8	7.8	3.5	55.1	2.5*	67.9
RP-2421	8.1	5.8	28.4	2.4	70.4	9.3	4.9	47.3	2.1	77.4
HPR-2143	7.6	5.8	23.7	2.4	68.4	8.6	5.2	39.5	2.2	74.4
HPR-1068	10.4*	6.4*	38.5	3.2	69.2	9.1	5.5	39.6	2.8*	69.2
Sukaradhan-1	9.1*	7.2*	20.9	2.5	72.5	9.6	8.3*	13.5	1.8	81.3
HPR-2373	7.3	5.9	19.2	2.0	72.6	5.7	6.9*	-21.1	1.5	73.7
HPR-2336	9.4*	7.3*	22.3	2.8	70.2	11.3	7.1*	37.2	2.6*	77.0
HPR-2513	8.2	5.3	35.4	1.8	78.0	6.7	4.9	26.9	1.8	73.1
Vivek Dhan-85	7.9	4.3	45.6	2.0	74.7	6.4	3.8	40.6	1.7	73.4
Vivek Dhan -82	8.9	5.9	33.7	3.3	62.9	8.1	6.9*	14.8	2.9*	64.2
Vivek Dhan -62	9.1*	5.4	40.7	1.8	80.2	8.3	5.1	38.6	1.7	79.5
Vivek Dhan -65	9.3*	5.7	38.7	2.6	72.0	8.9	6.9*	22.5	2.3	74.2
V L Dhan-86	9.8*	7.6*	22.4	2.2	77.6	10.2	8.3*	18.6	1.9	81.4
V L Dhan-206	9.0	6.3*	30.0	2.1	76.7	6.5	5.3	18.5	2.0	69.2
V L Dhan -207	7.7	3.8	50.6	2.2	71.4	5.5	3.8	30.9	2.2	60.0
V L Dhan -208	8.3	6.4*	22.9	2.1	74.7	7.8	5.4	30.8	1.9	75.6
V L Dhan -209	8.9	4.7	47.2	1.8	79.8	5.4	3.8	29.6	1.6	70.4
MTU 1010	9.9*	5.9	40.4	1.4	85.9	5.7	4.3	24.6	1.1	80.7
Tellahamsa	9.4*	5.3	43.6	1.7	81.9	7.9	4.8	39.2	1.7	78.5
Rajendra	9.8*	5.9	39.8	1.2	87.8	5.9	4.3	27.1	1.1	81.4
BPT 5204	8.9	3.7	58.4	1.3	85.4	6.5	3.6	44.6	1.3	80.0
Mean	8.7	5.7	34.5	2.1	75.9	7.9	5.5	30.4	1.9	75.9
CD%		0.48		0.33			0.75		0.63	

Table.3 The mean values and percent reduction of rice genotypes for different temperatures for seedling growth and Seedling Vigour Index I

Entry	Seedling growth					Seedling vigour				
	N	13°C	% reduction 13°C	8°C	% reduction 8°C	N	13°C	% reduction 13°C	8°C	% reduction 8°C
China-1039	15.3	9.5	37.9	2.8	81.7	1222.9	826.6	32.4	214.9	82.4
SKAU-382	20.5	13.3*	35.1	3.5	82.9	2045.3*	1328.0*	35.1	289.3	85.9
K-475	15.7	12.2	22.3	3.4	78.3	1255.1	810.6	35.4	213.9	83.0
China-988	19.3	11.7	39.4	3.8	80.3	1348.1	739.2	45.2	200.2	85.1
Jhelum	16.3	12.9*	20.9	3.9	76.1	1412.0	1118.5*	20.8	312.0	77.9
SKAU-5	17.4	12.7*	27.0	5.3*	69.5	1743.3*	1230.9*	29.4	404.0*	76.8
China-1007	20.3	14.1*	30.5	3.8	81.3	1220.4	703.8	42.3	251.0	79.4
Shalimar-1	17.5	12.8*	26.9	3.7	78.9	1572.6*	1149.9*	26.9	304.6	80.6
SKAU-389	18.3	13.2*	27.9	3.5	80.9	1827.3*	1234.1*	32.5	301.0	83.5
Chenab	19.4	16.1*	17.0	3.4	82.5	1679.8*	1392.4*	17.1	251.1	85.1
K-332	13.7	8.6	37.2	3.1	77.4	911.0	602.8	33.8	52.3	94.3
SKAU-339	17.3	9.2	46.8	4.0	76.9	1728.0*	886.5	48.7	317.6	81.6
SKAU-341	14.0	9.1	35.0	2.6	81.4	1357.7	853.2	37.2	198.4	85.4
K-429	16.6	10.7	35.5	4.2	74.7	1492.8	964.8	35.4	279.8	81.3
Himalaya-1	13.4	10.3	23.1	5.0*	62.7	1253.2	961.6	23.3	382.6	69.5
Himalaya-741	14.0	7.2	48.6	2.9	79.3	1399.3	691.9	50.6	218.3	84.4
Himalaya-2216	15.8	7.3	53.8	5.2*	67.1	1474.1	706.6	52.1	395.8*	73.1
RP-2421	17.3	10.8	37.6	4.6	73.4	1730.3*	1076.3	37.8	367.0	78.8
HPR-2143	16.2	11.0	32.1	4.7*	71.0	1404.1	989.7	29.5	372.3	73.5
HPR-1068	19.5	11.9	39.0	6.1*	68.7	1819.9*	1147.9*	36.9	527.0*	71.0
Sukaradhan-1	18.7	15.5*	17.1	4.3	77.0	1743.7*	1396.2*	19.9	371.8	78.7
HPR-2373	13.0	12.8*	1.5	3.5	73.1	1212.9	1062.9	12.4	235.3	80.6
HPR-2336	20.7	14.5*	30.0	5.5*	73.4	2002.0*	1399.2*	30.1	493.0*	75.4
HPR-2513	15.0	10.2	32.0	3.6	76.0	1246.1	778.0	37.6	251.6	79.8
Vivek Dhan-85	14.4	8.1	43.8	3.7	74.3	1436.7	805.0	44.0	282.1	80.4
Vivek Dhan -82	17.1	12.9*	24.6	6.2*	63.7	1708.7*	1285.0*	24.8	416.0*	75.7
Vivek Dhan -62	17.5	10.5	40.0	3.4	80.6	1630.6*	984.8	39.6	284.9	82.5
Vivek Dhan -65	18.2	12.6*	30.8	4.8*	73.6	1819.7*	1264.3*	30.5	385.5*	78.8
V L Dhan-86	20.0	15.9*	20.5	4.2	79.0	1868.7*	1486.6*	20.4	305.3	83.7
V L Dhan-206	15.5	11.6	25.2	4.0	74.2	1551.0	1159.3*	25.3	308.8	80.1
V L Dhan -207	13.3	7.6	42.9	4.4	66.9	1326.7	763.0	42.5	351.2	73.5
V L Dhan -208	16.1	11.8	26.7	4.0	75.2	1614.0*	1139.7*	29.4	317.5	80.3
V L Dhan -209	14.2	8.5	40.1	3.4	76.1	1329.1	820.4	38.3	257.0	80.7
MTU 1010	15.7	10.2	35.0	2.5	84.1	1463.1	920.4	37.1	200.0	86.3
Tellahamsa	17.2	10.2	40.7	3.4	80.2	1264.0	678.2	46.3	236.1	81.3
Rajendra	15.7	10.2	35.0	2.3	85.4	1205.3	748.7	37.9	154.1	87.2
BPT 5204	15.4	7.3	52.6	2.6	83.1	1488.5	727.3	51.1	215.5	85.5
Mean	16.6	11.2	32.5	3.9	76.5	1508.3	995.5	34.0	295.1	80.4
CD%		1.07		0.78			116.98		89.64	

Seedling vigour index is an important parameter to assess the establishment efficiency of a genotype. Out of the 37 genotypes, fourteen genotypes exhibited significant superior performance for this trait and the genotypes VL Dhan-86, Sukardhan-1, HPR-2336, Chenab and SKAU-382 recorded highest seedling vigour index at 13°C (table 3). Genotypes viz., SKAU-5, Himalaya -2216, HPR 1068, HPR-2336, Vivek Dhan -86 and Vivek Dhan -65 were identified as superior at 8°C. HPR- 2373, Chenab, Sukardhan-1, and VL Dhan-86 showed only 20 percent reduction at 13°C and more than 80 percent reduction at 8°C. At 8°C genotypes Himalaya 1, HPR 1068, Himalaya -2216, HPR-2143 and VL Dhan-207 recorded more than 75 percent reduction for seedling vigour Index. Over all, HPR 1068, Himalaya -2216 and Vivek Dhan -82 recorded lesser percentage of reduction at both the temperatures for seedling vigour index under controlled conditions and these genotypes can be used as cold tolerant donors. Massardo *et al.,* (2000) reported evaluation of rice seed germination rate and new plant traits under more than one temperature treatments are necessary to distinguish cold tolerant genotypes from cold susceptible genotypes. Changrong *et al.,* (2008) reported that the seeds from the few varieties could germinate quickly at low temperature but, the seedling growth was severely delayed by low temperature stress. He also reported that cold tolerance at germination and seedling stage were correlated.

This study revealed that traits at the early growth stage of the investigated rice genotypes were significantly influenced by low temperature stress. However, the response of these genotypes to low temperatures was significant. Certain genotypes performed very well under 13°C and 8°C for various seedling traits. However, genotypes which are performing well under 13°C did not perform well under 8°C of temperatures and vice versa. The genotypes Chenab, Sukardhan-1, HPR-2336, and Vivek Dhan -86 recorded less than 25 percent of reduction at 13°C for the seedling characters studied. However, at 8°C of temperature, genotypes Himalaya-1, Himalaya -2216, HPR 1068, HPR-2336, Vivek Dhan-82 and Vivek dhan-65 recorded less than 75 percent of reduction and were significantly superior to the mean. Based on the percent of reduction of seedling vigour traits, these genotypes can be identified as superior cold tolerant lines and may be exploited as tolerant source in future rice breeding programmes aimed at development of cold tolerant varieties.

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