Electronic Journal of Plant Breeding, 9 (2) : 589-597 (June 2018) DOI: 10.5958/0975-928X.2018.00072.8
ISSN 0975-928X

Research Article

Determination of stability of seedling characters of rice cultivars under different cold environments

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(Received: 23 Nov 2017; Revised: 26 Jun 2018; Accepted: 26 Jun 2018)

Abstract
Low temperature tolerance during seedling stage is an important yield contributing attribute for rabi/boro rice. Thirty five cold tolerant genotypes along with three checks were evaluated for the stability of seedling traits under four cold environments *viz*., controlled conditions at 8^0C, 13^0C & at 28^0C under field condition during *Rabi* season. The Genotype x Environment interaction was significant for all the characters which indicates differential behavior of genotypes in different cold environments. More pronounced linearity over non linearity for all the characters revealed the possibility of precise prediction of performance of genotypes over the cold environments. None of the genotypes showed average adaptability over all the cold regimes for shoot length. For root length, performance of all the genotypes was entirely unpredictable as they recorded significant non linearity. Among the genotypes, Vivek Dhan -85 and V L Dhan-86 were found to be stable for both vigour index and speed of germination. K-429 was highly suitable for poor environments for the traits *viz*; shoot length, root length and speed of germination.

Key words
Rice, seedling cold tolerance, Stability analysis

Introduction

Rice grown in *Rabi* / boro season is often subjected to low temperatures before and after emergence that can lead to disruption of seedling development and poor stand establishment. These damaging effects are often translated into a lack of seed germination and uneven stand establishment due to death of young seedlings. Cold tolerance in rice is defined as the ability to germinate, emerge and grow under low temperatures ranging from 6-15^0C. Increased capacity for seed germination and emergence under cold conditions has been recognized as a valuable attribute. Seed vigor was defined as the sum total of all seed attributes which favor stand establishment under a wide variety of field conditions (Isely, 1954) and has also been described as those physiological properties determined by the genotype and modified by the environment, which governs the ability of a seed to produce a seedling rapidly in the soil, and the extent to which the seed tolerates a range of environmental stresses (Perry, 1973b). *Rabi* rice requires specially bred cultivars having good seedling traits and strength in the coleoptile to facilitate normal emergence of the seedlings, early seedling vigour and an efficient root system for proper stand establishment over a range of low temperature conditions.

The present investigation was undertaken to study the stability of seedling traits of rice genotypes under laboratory and field (*Rabi*) conditions to identify highly cold tolerant cultures at seedling stage and estimate stability parameters of the genotypes for cold tolerance at seedling stage.

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 *viz*., Tellahamsa,Rajendra and MTU 1010). The lab experiment was carried at MFPI, Quality Control Lab under the controlled conditions at 8^0C, 13^0C & at 28^0C respectively and under field conditions during

Electronic Journal of Plant Breeding, 9 (2) : 589-597 (June 2018) DOI: 10.5958/0975-928X.2018.00072.8
ISSN 0975-928X

Rabi season 2009 at Rice section, PJTSAU, Rajendranagar, Hyderabad.

Twenty seeds of each genotype were placed in petri dishes containing two 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 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 for seven days. The experiment was conducted in a randomized complete block design with three replicates considering each rack in the incubator as one block.

Observations on seedling parameters viz; shoot length, root length, speed of germination and vigour Index were recorded on twenty seedlings per treatment in each replication as per ISTA (International Seed Testing Association), 1985. The mean data obtained at each environment was taken for stability analysis given by 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

$$yij= \mu i + BiIj+\delta ij+eijk$$

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:

$$bi = \Sigma j\ Yij\ Ij /\Sigma j\ Ij2 \text{ and; } \quad \delta^2 di = (\Sigma j\ \delta ij2/(e - 2) - (\delta e2/r).$$

The estimates were statistically tested for their significance using appropriate F and t test procedures. Stability analysis was done by using Indostat software. Box plots were created by PB tools software

Results and Discussion

The mean data collected for seed and seedling characters from crop raised during *rabi* 2009 and from controlled conditions at 28 ^{0}C, 13^{0}C and 8^{0}C temperature on shoot length, root length, vigour index and speed of germination were analysed and the pooled ANOVA for the four characters are presented in the Table.2. The pooled analysis of variance over four environments revealed significant differences among the environments and genotypes for all the characters studied.

The Genotype x Environment interaction was significant for all the characters indicated that the genotypes interacted considerably with environmental conditions that existed in different low temperature environments. Significant GxE interactions were also reported by Selvi *et al.* (2015) and Haradari *et al.* (2017) for yield parameters. The environment + (genotype x environment) was significant for all the characters indicating distinct nature of environments and genotype x environment interactions in phenotypic expression, which is in accordance earlier reports by Sellammal and Robin (2013), Banumathy *et al.* (2016) for yield parameters. Significant environment linear component indicating the linear response of genotypes to additive environmental variance for all the characters was observed. Importance of both linear and non linear components in determining the stability performance of the characters was indicated by the significant GXE (linear) and pooled deviations (non linear). These findings are in agreement with the earlier reports (Shinde and Patel, 2014; Selvi *et al.*, 2015; Patel *et al.*, 2015; Vanisree *et al.*, 2016; Haradari *et.al.*, 2017). However, more pronounced linearity over non linearity for all the characters in this study revealed the possibility of precise prediction of performance of genotypes over cold environments. Similar results were reported by Waghmode *et al.* (2011), Lal and Singh (2012), Yadav (2015) and Vanisree *et al.,* (2016) in different studies on different parameters.

According to Eberhart and Russell (1966), a stable genotype is the one, which has high mean with regression coefficient (bi) near "unity" and deviation from regression (δ^2di) approaching "zero". Genotypes with high mean, bi > 1 with non significant δ^2di are considered as below average in stability. Such genotypes are recommended for favourable environments. Genotypes with low mean, bi < 1 with non significant δ^2di do not respond favourably to improved environmental conditions and hence, it could be regarded as specifically adapted to poor environments. Genotypes with any bi value with significant δ^2di are unstable. The estimates of three stability parameters (i) mean performance (X), (ii) regression coefficient (bi) and (iii) deviation from regression (δ^2di) for different traits are presented in Table 3.

Germination and seedling development are the initial steps for crop growth, development and yield. Study of germination indices and seedling growth is highly indicative of subsequent performance of seed throughout the growing period. The root and shoot lengths are the most important initial plant growth parameters which will provide an important clue on plant response to cold stress during seedling stage. The genotypes *viz*; Vivek Dhan -65, Chenab, V L Dhan -206, V L Dhan -208, Vivek Dhan -85, K-429 recorded non significant deviation from regression for shoot length but none of genotypes are stable over all the cold regimes for this trait. Vivek Dhan -65 and Chenab recorded high mean, regression coefficient greater than unity and non–significant deviation from regression and can be recommended for favourable/better environments. Whereas, V L Dhan -206, V L Dhan-208, Vivek Dhan -85 and K-429 were found suitable for poor environments. In case of root length, the performance of all the genotypes was entirely unpredictable as they recorded significant non linearity, hence found unstable over different cold temperatures.

Vigour index is an important seed quality parameter which needs to be assessed to supplement germination performance of a seed. The genotypes namely, V L Dhan -86, Vivek Dhan -62, Chenab, V L Dhan -209 and Himalaya-registered high mean for vigour index with regression coefficient near to unity, minimum deviation from regression and were identified as superior and stable genotypes. The genotypes HPR-2336, RP-2421, SKAU-5, Himalaya-2216 exhibited high mean with regression coefficient greater than unity and non–significant deviation from regression are found to be suitable for better environment. The genotypes *viz* K-429 and Rajendra were found to be suitable for poor environments.

The genotypes *viz;* RP-2421, HPR-2336, Vivek Dhan -85, Sukaradhan-1, Vivek Dhan -65, Himalaya-741, Jhelum, HPR-2143, SKAU-382, HPR-1068, V L Dhan -209, V L Dhan -86, SKAU-389, Shalimar-1, Vivek Dhan -62, Chenab, SKAU-341, HPR-2373 and HPR-2513 were considered to be stable with high mean for speed of germination. MTU-1010 was found to perform well under favourable temperatures. The genotype Rajendra was suitable for poor environment.

Among the genotypes, V L Dhan-86 was found to be stable for both vigour index and speed of germination. K-429 was found highly suitable for poor environments for the traits namely shoot length, root length and speed of germination.

Distribution of data of different seedling parameters in different environments and range of phenotypic variation was shown in Fig.1. For all the parameters, environment 2 (28^0C temperature) was found favourable except for speed of germination. Environment 4 (8^0C temperature) was found most unfavourable and showed very less variability for all the traits studied.

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Table1. List of rice genotypes and their source

S.No.	Germplasm line	Centre/ Source
1	China-1039	SKAU, Kudwani, Kashmir
2	SKAU-382	SKAU, Kudwani, Kashmir
3	K-116	SKAU, Kudwani, Kashmir
4	K-475	SKAU, Kudwani, Kashmir
5	China -988	SKAU, Kudwani, Kashmir
6	Jhelum	SKAU, Kudwani, Kashmir
7	SKAU-5	SKAU, Kudwani, Kashmir
8	China -1007	SKAU, Kudwani, Kashmir
9	Shalimar-1	SKAU, Kudwani, Kashmir
10	SKAU-389	SKAU, Kudwani, Kashmir
11	Chenab	SKAU, Kudwani, Kashmir
12	K-332	SKAU, Kudwani, Kashmir
13	SKAU-339	SKAU, Kudwani, Kashmir
14	SKAU-341	SKAU, Kudwani, Kashmir
15	K-429	SKAU, 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

Table 2. Pooled ANOVA

SOURCE	DF	Shoot length	Root length	Vigour index	Speed of germination
Rep within Env.	8.00	0.00	0.00	10.87	0.22
Varieties	37.00	1.75 **	1.28 **	1110.58 **	8.98 **
Env.+ (Var.* Env.)	114.00	2.76 **	4.69 **	1401.13 **	3.75 **
Environments	3.00	91.76 **	163.69 **	47389.50 **	118.64 **
Var.* Env.	111.00	0.35 **	0.40 *	158.20 **	0.65**
Environments (Lin.)	1.00	275.29 **	491.07 **	142168.52 **	355.92 **
Var.* Env.(Lin.)	37.00	0.81 **	0.62 **	367.72 **	0.93 **
Pooled Deviation	76.00	0.12 **	0.28 **	52.04 **	0.49 **
Pooled Error	296.00	0.00	0.00	10.64	0.17
Total	151.00	2.51	3.86	1329.94	5.03

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ISSN 0975-928X

Table 3. Stability parameters of 38 genotypes over four environments for seedling characters

S. No.	Genotype	Shoot length			Root length			Vigour index			Speed of germination		
		Mean	bi	δ^2di	Mean	bi	δ^2di	Mean	bi	δ^2di	Mean	bi	δ^2di
1	CHINA-1039	2.35	1.27	0.21**	3.15	1.01	0.16**	44.40	1.10	47.96**	5.07	0.89	0.86**
2	SKAU-382	2.95	1.30*	0.03**	3.95	1.11	0.32**	65.47	1.25	45.05**	6.20	1.22	-0.11
3	K-116	1.99	0.93	0.19**	2.45	0.95	0.04**	17.32	0.42*	28.14*	1.48	0.41	0.30
4	K-475	2.61	1.30	0.24**	3.35	1.07	0.26**	37.09	1.04	255.89**	3.54	0.30	3.41**
5	CHINA-988	2.49	1.03	0.02**	3.35	0.71	0.47**	35.06	0.54	42.87**	3.60	0.51	0.28
6	JHELUM	2.75	0.93	0.09**	3.48	0.88	0.54**	55.38	0.97	55.01**	6.24	1.06	-0.14
7	SKAU-5	3.05	1.22	0.13**	4.01	1.11	0.06**	66.89	1.30**	-9.44	6.76	1.38	0.52 *
8	CHINA-1007	3.18	1.52	0.35**	4.17	1.32	0.17**	43.87	1.06	194.89**	3.98	0.57	0.91**
9	SHALIMAR-1	2.30	0.97	0.13**	3.68	1.17	0.15**	50.31	1.08	38.03*	5.82	0.93	-0.09
10	SKAU-389	2.56	1.08	0.07**	3.40	1.06	0.19**	57.15	1.18	66.53**	5.91	1.35	0.15
11	CHENAB	3.01	1.23**	0.00	3.51	1.01	0.04**	56.72	1.17	-3.14	5.74	0.86	-0.08
12	K-332	1.64	0.42	0.14**	2.82	0.61	0.14**	22.93	0.49**	-6.91	2.51	0.87	0.15
13	SKAU-339	2.39	0.82	0.02**	3.29	0.85	0.03**	50.39	0.80	43.77**	6.28	1.00	0.94**
14	SKAU-341	1.48	0.48	0.16**	2.85	0.66	0.24**	37.68	0.57	64.06**	5.67	1.18	0.11
15	K-429	2.15	0.43**	0.00	3.26	0.93	0.30**	41.40	0.73*	-3.72	4.53	0.92	0.73**
16	HIMALAYA-1	2.78	0.98	0.06**	3.24	0.90	0.10**	52.02	0.92	-8.98	6.19	0.98	0.49 *
17	HIMALAYA-741	2.54	1.06	0.16**	3.13	0.84	0.22**	54.06	1.00	91.70**	6.29	1.09	-0.11
18	HIMALAYA-2216	3.54	1.51	0.16**	3.54	1.04	0.40**	65.85	1.39*	15.30	6.63	1.50	0.48 *
19	RP-2421	4.01	1.72**	0.02**	4.37	1.11	0.14**	81.38	1.51*	15.92	7.01	1.23	-0.08
20	HPR-2143	2.40	0.64	0.08**	3.12	0.60*	0.04**	46.64	0.65	29.71*	6.20	1.02	-0.14
21	HPR-1068	4.22	1.57	0.30**	4.38	1.56	1.31**	78.61	1.58	83.63**	6.09	1.01	0.02
22	SUKARADHAN-1	3.84	1.43	0.14**	4.30	1.06	0.42**	75.62	1.36	49.40**	6.57	1.07	-0.13
23	HPR-2373	2.07	0.63	0.14**	2.90	0.70	0.13**	44.18	0.80	41.65**	5.66	1.14	0.13
24	HPR-2336	3.68	1.39	0.14**	4.75	1.24	0.17**	81.60	1.40*	-1.97	6.98	0.92	-0.17
25	HPR-2513	2.64	1.00	0.15**	3.24	0.90	0.08**	48.19	0.96	30.85*	5.05	0.95	0.10
26	VIVEK DHAN-85	2.33	0.80*	0.00	3.02	0.93	0.06**	51.49	0.98	-9.88	6.59	1.37	0.20
27	VIVEK DHAN-82	3.57	0.97	0.02**	4.34	1.07	0.09**	74.60	1.26	65.49**	6.80	1.59	0.50 *
28	VIVEK DHAN-62	2.75	1.09	0.06**	3.73	1.13	0.03**	58.63	1.17	5.01	5.79	1.05	0.15
29	VIVEK DHAN-65	3.32	1.10*	0.00	3.79	0.98	0.08**	67.28	1.15	26.37*	6.34	1.11	0.07
30	V L DHAN-86	3.28	1.11	0.24**	3.91	1.32	0.32**	64.56	1.34	19.71	5.92	1.10	0.07
31	V L DHAN-206	2.79	0.77*	0.00	3.54	1.30	1.17**	59.30	1.18	27.47*	6.48	1.27	1.48**
32	V L DHAN-207	2.66	0.70	0.04**	3.20	0.83	0.07**	54.93	0.89	36.37*	6.37	1.13	0.87**
33	V L DHAN-208	2.49	0.75**	0.00	2.92	0.69	0.13**	49.90	0.78	37.43*	6.70	1.14	0.41 *
34	V L DHAN-209	2.39	0.73	0.07**	3.64	0.96	0.02**	54.01	0.98	5.67	6.02	1.23	-0.03
35	V L DHAN-221	1.78	0.72	0.40**	2.02	0.78	0.31**	5.90	0.17**	-6.82	0.43	0.17	0.05
36	MTU 1010	1.94	0.75	0.04**	3.04	1.25	1.21**	45.26	1.10	111.01**	6.11	1.22*	-0.07
37	TELLAHAMSA	2.46	1.18	0.38**	3.37	1.18	0.21**	40.40	0.94	52.30**	4.70	0.67	0.00
38	RAJENDRA	1.69	0.47	0.19**	3.56	1.19	0.58**	38.65	0.79*	-3.61	4.91	0.61*	-0.15
	Population Mean	**2.686**			**3.468**			**51.978**			**5.503**		

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

S.No	Character	Genotypes with non significant deviation from regression	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	Shoot length	Vivek Dhan-65, Chenab, V L Dhan-206, V L Dhan -208, Vivek Dhan -85, K-429	--	Vivek Dhan -65, Chenab	V L Dhan-206, V L Dhan -208, Vivek Dhan -85 and K-429
2	Root length	--	--	--	--
3	Vigour Index	HPR-2336, RP-2421, SKAU-5, Himalaya -2216, V L Dhan -86, Vivek Dhan-62, Chenab, V L Dhan -209, Himalaya-1, Vivek Dhan -85, K-429, Rajendra, K-332, V L Dhan -221	V L Dhan -86, Vivek Dhan -62, CHENAB, V L DHAN-209, Himalaya-1and Vivek Dhan-85	HPR-2336, RP-2421, SKAU-5, Himalaya-2216	K-429, Rajendra
4	Speed of Germination	RP-2421, HPR-2336, Vivek Dhan -85, Sukaradhan-1, Vivek Dhan -65, Himalaya -741, Jhelum, HPR-2143, SKAU-382, MTU 1010, HPR-1068, V L Dhan -209, V L Dhan -86, SKAU-389, Shalimar-1, Vivek Dhan -62, Chenab, SKAU-341, HPR-2373, HPR-2513, Rajendra, Tellahamsa, China-988, K-332, K-116, V L Dhan -221	RP-2421, HPR-2336, Vivek Dhan-85, Sukaradhan-1, Vivek Dhan -65, Himalaya -741, Jhelum, HPR-2143, SKAU-382, HPR-1068, V L Dhan-209, V L Dhan -86, SKAU-389, SHALIMAR-1, Vivek Dhan -62, Chenab, SKAU-341, HPR-2373, HPR-2513, Tellahamsa	MTU-1010	Rajendra

Electronic Journal of Plant Breeding, 9 (2) : 589-597 (June 2018)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2018.00072.8

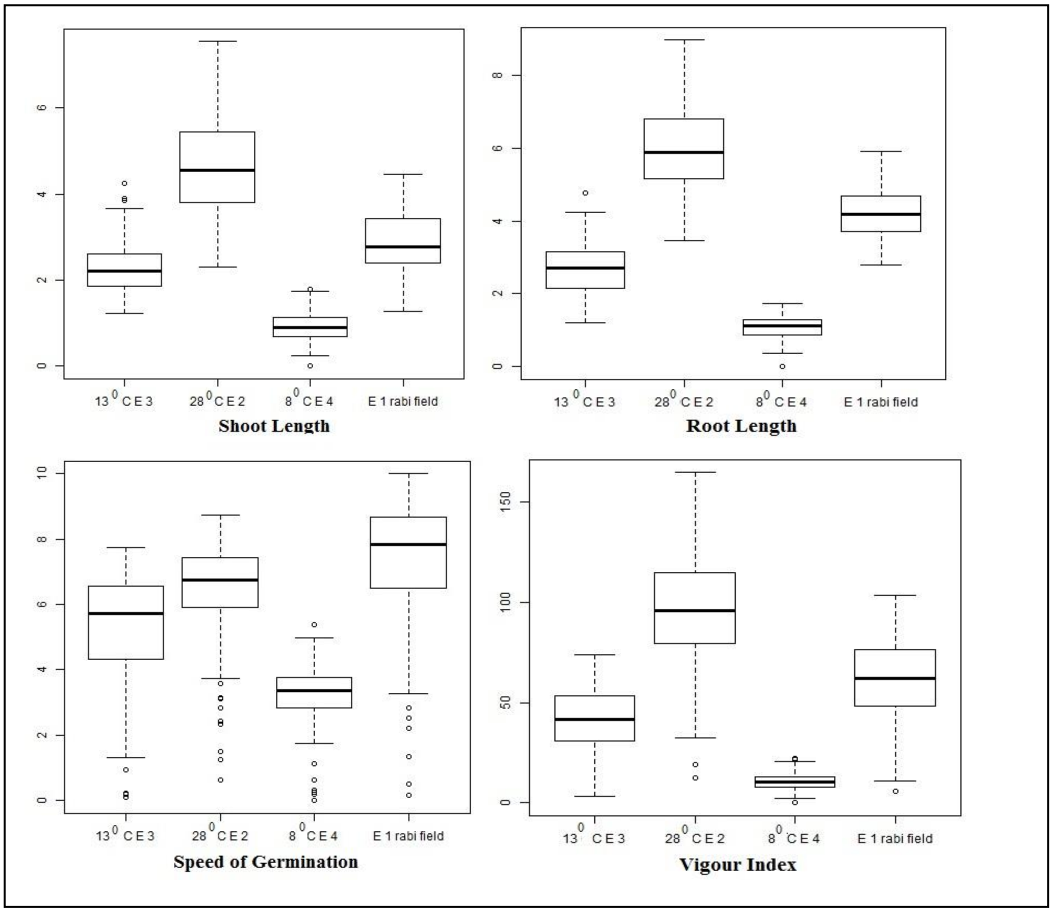

Fig. 1. Box plots illustrating the median (horizontal line inside each box), 25-75 percentiles (the box) for the seedling characters in four cold environments. The whiskers (the two lines outward from a box at each end) represent the smallest (the bottom whisker) and the largest (the top whisker) values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