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Cold tolerance in rice at seedling and reproductive stage

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Abstract
Rice (*Oryza sativa* L.) are normally grown in tropical and temperate climatic zones thought out the country but it has been susceptible by cold stress and it can be affect specially in seedling and reproductive stages during growing periods. Cold stress shows different effects on germination, seedling, vegetative, reproductive and grain maturity and weakens photosynthetic ability by inducing leaf discoloration, reduces plant height, produces degenerated spikes, delays days to heading, reduces spikelet fertility and finally led to reduces poor grain yield. One important strategy for increasing crop productivity is to minimize losses due to abiotic and biotic stresses by developing more stress tolerance varieties. Identification of new genetic sources for cold tolerance is very important for which effective, low cost screening techniques are essential. In this zone quite often the temperature drops below 10^0C during December and January resulting in poor growth of seedlings of rice crop. The sown *Kharif* crop will be exposed to low temperature at reproductive stage. This study aims to identify a suitable technique to estimate rice cold tolerance at the germination stage and identify the variability among 39 genotypes and these genotypes were evaluated to assess cold tolerance based on seedling and reproductive character in the field, under cold during late *Kharif*, 2015-2016 and this experiment was conducted in Randomized Block Design at Rice Research Scheme, Agricultural Research Institute, Rajendranagar.

Keywords: *Cold tolerance, Kharif, germination* and *Oryza sativa*

1. Introduction
Rice is cultivated round the year in many parts of the country with a wide range of ecological diversity. India is second in population at global level but have land share around 2% only. This massive increase in population and substantial income growth require an extra food grain annually. Cold temperatures can be negative impacts on major rice growing in 25 countries, including Korea and Japan. Singh *et al.* (2005) [7] reported in Australia, rice farmers have suffered losses ranging from 0.5 to 2.5 t/ha in 75% of the years due to low temperature during the reproductive stage. Cold temperature is major problem to restriction on rice cultivation at high latitudes or high altitudes as well as in tropical countries such as the Philippines and Thailand (Kaneda and Beachell (1974) [3].
Shinada (2013) [6] stated that cold temperature during the reproductive phase leads to seed sterility, which reduces yield and decreases the grain quality of rice. The fertilization stage, ranging from pollen maturation to the completion of fertilization, is sensitive to unsuitable temperature. Improving cold tolerance at the fertilization stage is an important objective of rice breeding program in cold temperature areas. Even though cold temperature affects rice growth from seed germination to seed maturity, episodes of cold temperature at the reproductive phase decrease the seed set. However, Cruz and Milach (2000) reported that transferring cold tolerance from different sources to locally adapted cultivars requires the presence of the selective agent, such as low temperature particulrly. Its abiotic nature makes it unpredictable under field conditions in terms of its intensity, duration and timing, which limits field selection for cold tolerance in rice. According to Ye *et al*., (2009) [9], cold temperature has the potential to reduce the growth and development of rice plants from any developmental stage to germination to grain filling.
While the minimum temperature is low, its results in poor seedling establishment, stunting, yellowing and mortality and exhibit various symptoms of chilling injury such as chlorosis, necrosis or growth retardation. To overcome the problem of damage caused by low temperature, rice breeders are giving efforts to develop more cold-tolerant cultivars at seedling stage (Smita *et al*., 2014) [8]. Evaluation of cold tolerance at the reproductive stage is important (Zhang *et al*., 2014) [11]. Roy *et al*., 1982 [5] observed that in regions where low temperature stress imposes a very poor growth and a shorter season for the rice crop, breeding for cold tolerance is sometimes addressed through indirect traits such as selection for taller plants and shorter

growth duration. According to Peterson *et al*. (1974) [4] cold temperature is an important stress that results in delayed heading or maturation and yield reduction due to spikelet sterility. Rice cultivars vary greatly in their tolerance to low temperature. Yoshida *et al*., 1981 [10] reported that optimum temperature for normal germination and early seedling growth in rice varieties is between 20 °C to 35 °C and critical temperature for germination is 10 °C. Hence this study was initiated to evaluate rice genotypes for cold tolerance based on seedling and reproductive quality parameters.

Materials and Methods

Thirty nine rice genotypes comprising of cold tolerant varieties, advanced generation breeding lines and a few pre-release varieties and released varieties were evaluated for cold tolerance in laboratory as well as in field against three checks viz; Sheetal, Tellahamsa and JGL 3844, obtained from Agricultural Research Institute, Rajendranagar and Regional Agricultural Research Station, PJTSAU, Jagitial, Karimnagar district, Telangana. This experiment was conducted at Rice Research Scheme, Agricultural Research Institute, Rajendranagar under Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during Kharif, 2015-16.

The experiment was conducted in Randomized Block Design with three replications with spacing of 15 cm between rows and 15 cm between plants. Nursery bed was raised in the third week of July 2015.The maximum and minimum temperatures at the sowing time were 12.3 ^{0}C and 30 ^{0}C respectively. Transplanting was done in August. The basal dose of 30 kg N, 45 kg P_2O_5 and 30 kg K_2O per hectare was applied at the time of sowing. The usual cultural practices like weeding, irrigation were followed during the crop growth, as per recommendations. Observations were recorded on five randomly selected plants from each treatment in each replication and mean was worked out. The mean of five plants for all the characters except days to 50% flowering, complete flowering and maturity which were utilized for statistical analysis, were recorded replication wise on whole plot basis.

Field emergence of seeds was assessed by sowing 400 seeds in four rows of 100 seeds each per treatment with three replications in raised beds. The seedlings were considered emerged when the plumule were just visible on the soil surface. The emergence of the plumule was recorded at the end of every 24 hrs from 3rd day to 10th day after sowing. Field emergence was calculated by adding the quotients of daily count divided by the number of days taken for germination. Accordingly seedling length was measured at one week after transplanting considering the following characters field emergence, seedling length, days to 50% flowering, days to complete flowering, pollen viability, days to maturity, plant height, total number of tillers per plant, productive tillers per plant, panicle length, spikelet fertility, panicle exertion, test weight, seed yield per plant and seed yield per ha (Table1).

Table 1: Analysis of variance for seedling and reproductive components of rice genotypes

S. No.	Character	Mean sum of square		
		Replication (d. f=2)	Treatments (d. f=38)	Error (d. f=76)
1	Field emergence (%)	1.36	263.03**	2.59
2	Seedling length(cm)	0.46	16.70**	0.55
3	Days to 50% flowering	1.64	210.23**	2.57
4	Days to complete flowering	12.21	288.12**	3.96
5	Pollen viability (%)	8.98	87.49**	19.38
6	Days to maturity	51.46	384.20**	2.61
7	Panicle exertion (%)	1.44	240.68**	0.69
8	Plant height(cm)	24.79	206.35**	14.25
9	No. of tillers plant^{-1}	0.92	13.72**	1.88
10	No. of productive tillers plant^{-1}	1.70	12.84**	2.63
11	Panicle length (cm)	4.67	12.02**	2.95
12	Spikelet fertility (%)	9.94	49.74**	13.194
13	Test weight(g)	0.26	35.02**	1.30
14	Seed yield plant^{-1}(g)	0.10	27.75**	1.78
15	Seed yield ha^{-1} (kg)	823.21	5475423.00**	335105.90

Table 2: Genetic parameters for seedling and reproductive components of rice genotypes

S. No.	Traits	Mean	Range		Std. Error (±)	PVC	GCV	h^2(b) (%)	GA (%)	GAM (%)
			Min.	Max.						
1	Field emergence (%)	71.53	55	98	0.92	8.01	8.0	98	14.31	16.26
2	Seedling length(cm)	24.43	20.4	30.0	0.42	14.6	13.9	99	14.26	42.85
3	Days to 50% flowering	91.38	73.7	99.7	0.92	2.5	2.4	97	6.84	5.02
4	Days to complete flowering	95.64	64.6	113.6	1.15	2.8	2.6	98	7.22	5.50
5	Pollen viability (%)	94.83	71.9	99.2	2.54	10.5	10.2	97	17.23	21.42
6	Days to maturity	118.30	87.3	136.6	0.93	4.6	1.48	99	1.28	1.34
7	Panicle exertion (%)	58.28	46.0	99.0	0.79	10.3	10.1	98	12.26	21.44
8	Plant height(cm)	88.17	72.3	108.3	2.17	9.2	9.1	94	16.47	17.31
9	No. of tillers plant^{-1}	10.56	7.3	16.0	0.79	16.9	16.2	96	2.93	32.62
10	No. of productive tillers plant^{-1}	8.98	5.6	13.6	0.93	23.5	22.4	84	2.52	39.88
11	Panicle length (cm)	23.95	19.3	30.3	0.99	9.1	8.8	94	4.01	15.84
12	Spikelet fertility (%)	93.54	81.3	98.6	2.09	1.9	3.4	97	3.2	18.9
13	Test weight(g)	17.54	11.86	24.7	0.65	18.1	17.8	87	4.72	29.98
14	Seed yield plant^{-1}(g)	12.06	5.7	19.6	0.77	19.5	18.2	96	5.36	27.80
15	Seed yield ha^{-1} (kg)	5796.00	2522.6	8729.3	334.21	21.5	21.1	98	2438.8	43.43

PCV: Phenotypic coefficient of variation GCV: Genotypic coefficients of variation GAM: Genetic advance as percent meanh 2 (b): Heritability in broad sense GA: Genetic Advance

Table 3: Phenotypic correlation coefficient among seed, seedling and reproductive components under cold in rice genotypes

	Germination (%)	**Germination index (%)**	**PERCOL (%)**	**REDCOL (%)**	**Field emergence (%)**	**Seedling Length (cm)**	**Days to 50% flowering**	**Days to complete flowering**	**Pollen viability (%)**	**Days to maturity**	**Panicle exsertion (%)**	**Plant height (cm)**	**No.of tillers plant^{-1}**	**No. of productive tillers plant $^{-1}$**	**Panicle length (cm)**	**Spikelet fertility (%)**	**Test weight (g)**	**Seed yield plant^{-1} (g)**
Germination (%)	1.000	0.777**	0.250	-0.043	0.223	-0.015	0.049	0.032	0.058	-0.177	0.100	-0.288	-0.085	0.003	-0.158	0.271	-0.271	0.101
Germination index (%)		1.000	0.305	-0.145	0.082	0.032	0.176	0.134	0.086	-0.057	0.296	-0.393*	-0.072	-0.028	-0.281	0.178	-0.181	0.003
PERCOL(%)			1.000	0.215	-0.155	0.284	0.139	0.008	0.062	-0.034	-0.067	-0.219	-0.182	-0.227	-0.106	0.074	-0.103	-0.060
REDCOL(%)				1.000	-0.007	-0.014	0.118	-0.057	-0.052	-0.231	-0.425**	0.0913	0.053	0.064	0.017	0.272	0.187	0.043
Field emergence(%)					1.000	-0.140	0.089	0.003	-0.014	-0.032	0.038	0.1385	-0.066	-0.018	0.028	-0.047	0.175	0.225
Seedling Length (cm						1.000	-0.109	-0.220	0.059	-0.055	0.175	-0.008	0.076	0.061	0.266	-0.034	-0.006	0.016
Days to 50% flowering							1.000	0.919**	0.416**	0.699**	0.032	-0.212	-0.113	-0.091	-0.107	-0.120	-0.232	-0.117
Days to complete flowering								1.000	0.489**	0.808**	0.052	-0.146	-0.080	-0.073	-0.088	-0.202	-0.194	-0.025
Pollen viability(%)									1.000	0.334*	0.111	-0.146	0.120	0.070	-0.038	-0.075	-0.264	-0.076
Days to maturity										1.000	0.074	-0.073	-0.156	-0.155	-0.111	-0.282	-0.231	-0.006
Panicle exsertion(%)											1.000	0.1968	0.297	0.254	0.180	-0.105	0.135	-0.292
Plant height (cm)												1.0000	-0.029	-0.096	0.638**	0.057	0.203	-0.010
No. of tillers plant^{-1}													1.000	0.944**	0.114	-0.008	0.336*	0.015
No. of productive tillers plant														1.000	0.053	-0.043	0.325*	0.015
Panicle length(cm)															1.000	-0.092	0.011	-0.060
Spikelet fertility(%)																1.000	-0.133	-0.079
Test weight (g)																	1.000	0.229
Seed yield plant^{-1}(g)																		1.000

The genetic parameters viz., genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance and genetic advance as per cent of mean were estimated for various traits (Table 2). The traits exhibiting high PCV, GCV, heritability and genetic advance respond to the selection. But the most efficient selection scheme needs to account for correlation among the traits. The association between laboratory and field parameters under cold temperature aids in selection of genotypes for cold tolerance. Hence, correlation analysis was carried out among seed, seedling and yield components and the results are presented in (Table 3).

Results and Discussion

In this experiment field recorded field emergence differed significantly among the genotypes and was high in cold tolerant varieties JGL 3844 (99%), Tellahamsa (98%) followed by sheetal (88%) whereas, significantly low field emergence was recorded in WGL 14 (55%) with a mean of 71.53%. whereas, seedling length was high in JGL 11118(30 cm), MTU 1075(29.5 cm) followed by RNR 15048 (27.8 cm) than checks. Except field emergence all parameters are more superior than checks in fluctuate environment.

Table 4: Parameters in field evaluation

Sl. No.	Parameters	Genotypes significantly superior to checks
1	Field emergence (%)	Nil
2	Seedling length (cm)	JGL 11118, MTU 1075, Sumathi anad IR 68
3	Days to 50% flowering	BPT 5204, Swarna and JGL11470
4	Days to complete flowering	BPT 5204, Swarna, Sathya and WGL 32100
5	Pollen viability (%)	Sumathi, MTU 1001,Swarna and WGL 32100
6	Days to maturity	BPT 5204, WGL 32100, Bhadrakali,Sathya, Sumathi and RNR 21567
7	Panicle exertion (%)	Pusa 1121 and Sumathi
8	Plant height (cm)	RNR 15038, Pusa1121 and RNR 21579
9	No. of tillers plant^{-1}	RNR 21582, Pusa 1121, Sathya,Sumathi, WGL 44, BPT 5204 and RNR 21588
10	No. of productive tillers plant^{-1}	RNR 21582 and Pusa 1121
11	Panicle length (cm)	RNR 15038, JGL 18047 Sathya and RNR 21579
12	Spikelet fertility (%)	KNM 110, WGL 14, Varalu and Erramallelu
13	Test weight (g)	MTU 1010, IR 64 and Sathya
14	Seed yield plant^{-1} (g)	RNR 21582, MTU 1075, JGL 18047 and RNR 21588
15	Seed yield ha^{-1} (kg)	Taramthi, RNR 21582 and WGL 44

The highest PCV (23.5) and GCV (22.4) were recorded for number of tillers per plant followed by yield per hectare (PCV – 21.5 and GCV 21.1). Days to 50% flowering had lowest PCV (2.5) and GCV (2.4). Environmental factors influence the yield attributing traits, for this reason phenotypic coefficient of variation (PCV) was higher than that of genotypic coefficient of variation (GCV) (Barbora and Hazarika, 1998 and Kumar *et al*., 2005). Heritability (%) was high for seedling length (99) and days to maturity (99) followed by field emergence (98), days to complete flowering (98), panicle exertion (98) and seed yield ha $^{-1}$ (98). High heritability estimates for panicle exertion and seed yield under cold can be relied upon for selection potential genotypes similar to the reports of Prianka *et al.*2000. The highest PCV and GCV were recorded for number of tillers per plant followed by yield per hectare. Days to 50% flowering had lowest PCV and GCV. Heritability (%) was high for seedling length and days to maturity followed by field emergence, days to complete flowering, panicle exsertion and seed yield ha $^{-1}$.The genetic advance was high for yield ha $^{-1}$followed by number of tillers plant $^{-1}$and lowest was days to maturity. The genetic advance as per cent of mean has high for yield ha $^{-1}$ followed by number of productive tillers plant^{-1}.

Conclusion

The results of experiment explained that among of the genotypes have recorded highest seedling length, days to 50% flowering, days to complete flowering, pollen viability, days to maturity, plant height, total number of tillers per plant, productive tillers per plant, panicle length, spikelet fertility, panicle exertion, test weight, seed yield per plant and seed yield per ha but field emergence has highest in JGL 3844 (99%), Tellahamsa (98%) followed by sheetal (88%). field emergence has to be evaluated during winter under cold for reliable data.

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