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Effect of Low Temperature on Physiological and Biochemical Parameters in Selected Rice Genotypes

Yaseen, M[1], Shivakumar K.V.[2], Prakash Koler[3], Praveen, H.G.[4], Manjunatha H.[5], Kanavi MSP[6] and Nagappa Desai[7]

[1]M.Sc. Student of Crop Physiology, College of Agriculture, Mandya, UAS, GKVK, Bengaluru
[2]Professor of Crop Physiology, College of Agriculture, Mandya, UAS, GKVK, Bengaluru
[3]Assistant Professor of Crop Physiology, College of Agriculture, Karekere, Hassan, UAS, GKVK, Bengaluru
[4]Department of Crop Physiology, UAS, GKVK, Bengaluru
[5]Assistant Professor of Plant Pathology, College of Agriculture, Karekere, Hassan, UAS, GKVK, Bengaluru
[6]Associate Professor of Genetics & Plant Breeding, College of Agriculture, Karekere, Hassan, UAS, GKVK, Bengaluru
[7]Associate Professor of Horticulture, College of Agriculture, Mandya, UAS, GKVK, Bengaluru
Corresponding author E-mail: pkap2013uashsn@gmail.com

Abstract: A field and laboratory study was conducted by selecting 30 rice genotypes along with two cold tolerant check varieties (CTH-1 and CTH-3) to know the "Effect of Low Temperature on Physiological and Biochemical Parameters in Rice Genotypes". The laboratory experiment was carried out at Department of Crop physiology, UAS Bangalore and the field experiment was carried out at College of Agriculture V.C. Farm Mandya, during *late kharif*- 2019. Under laboratory condition seed germination test was done with four temperature regimes viz:, 28°C (control), 10°C, 12°C and 15°C. The results revealed that among the selected rice genotypes, Thanu, Daksha, KRH-4, NLR-3042, BPT x BR -6, GVT-501, GVT-4, Jyoti, Raksha, KMP-149 and IR-64 were found better in germination percentage, seedling length, changes in coleoptile length etc. However, the genotypes Thanu, Daksha, KRH-4, BPT x BR-6, GVT-501, Jyoti, Raksha, KMP-128 and KMP-200 were showed cold tolerance in field condition w.r.t three dates sowing. These genotypes can be used further for crop improvement in breeding programme.

***Keywords*:** cold tolerance, rice genotypes, low temperature, biochemical parameters in rice

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food crop in more than 60 per cent of the world's population and the cheapest form of food and energy (Fairhurst and Dobermann (2002); Shelton *et al*. (2002). Low temperature stress is an important factor affecting the growth and development of rice. Cold stress affects the crop right from germination to grain maturity causing slow growth, reduce seedling vigour and cause seedling injuries, delayed heading and yield reduction due to spikelet sterility. At seedling stage, cold stress results in less number of seedlings and reduced tillering. Cold stress, can be classified as chilling (0-15°C) and freezing (<0°C) stress, is a major environmental factor limiting the growth, productivity and geographical distribution of crops (Zhu *et al*. (2007)). Due to its origin in tropical and subtropical regions, rice is more sensitive to cold stress than other cereal crops such as wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.). Therefore, in temperate areas, the production of rice is severely limited by cold stress (Xie *et al*. (2012)). Low temperatures that occur at critical reproductive stages can adversely affect grain quality or

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cause yield reductions in high-latitude or high-altitude regions of China, Japan, Korea, and other parts of the world (Jena *et al*. (2012)). Low temperature not only inflicts obvious physical damage to rice plants including low germination rate, stunted seedling growth, high death rate, and low spikelet fertility, but also initiates physiological fluctuations, such as increased electrolyte leakage (EL), changes in chlorophyll fluorescence and increases in amounts of reactive oxygen species (ROS), Malondialdehyde (MDA), sucrose, lipid peroxidation, proline, and other metabolites. Analysis of metabolites in cold-stressed *Arabidopsis* by *gas chromatography-mass spectrometry* (GC-MS) has detected a total of 434 low-molecular-weight carbohydrates, amines, organic acids, and other polar molecules (Cook *et al*. (2004)).

MATERIAL AND METHODS

Experiment was conducted at the two different locations; the first objective experiment was conducted at both laboratory and in the field condition during 2019-2020. Screening of rice genotypes for cold tolerance was conducted in the laboratory growth chamber in the Department of crop physiology, University of Agricultural Sciences, GKVK campus, Bengaluru, during 2019-2020. The material for this study consisted of 30 selected rice genotypes developed at AICRP (Rice), Zonal Agricultural Research Station, *V. C. Farm*, Mandya. The released varieties namely CTH-1 and CTH-3 were used as cold tolerant checks.

The list of rice genotypes evaluated for cold tolerance was given below.

Serial number	*Genotypes*
1	CTH-1
2	CTH-3
3	Thanu
4	Gangavati Sona
5	IR-30864
6	IR-64
7	RNR-15038
8	RNR-1588
9	Raksha(KMP-105)
10	Daksha(KMP-175)
11	KRH-4
12	Rasi
13	Jyoti
14	MTU-1001
15	IR-15048
16	JGL-1798
17	KCP-1
18	BTP X BR-6
19	GVT-501
20	BPT X BR-17
21	Jyothi X BR
22	KMP-149
23	GVT-4(KMP-221)
24	GVT-7(KMP-222)
25	KMP-128
26	GVT-503
27	GVT-504
28	NLR-3042
29	KMP-200
30	KMP-201

Observations recorded

The following seed and seedling quality parameters were observed at different temperature levels and data were recorded as detailed below.

Germination (%)

The laboratory test for germination was conducted as per the ISTA rules (ISTA, 1985) by adopting between paper methods. Three replications of 20 seeds each in a treatment were used for the germination tests that were placed in seed germinator. The first and the final counts were taken on fourth and seventh day, respectively. Only the seeds that had coleoptile and radical were considered as normal for calculation.

On the day of final count, the number of seeds germinated was counted and the per cent germination was calculated as follows:

$$\text{Germination percent} \frac{= \text{Number of normal seedlings obtained}}{\text{Total number of seeds kept for germination}} \times 100$$

Germination index (GI)

The germination index was calculated by using the formula given by Cruz and Milach (2004).

$$GI = (N14+N21/2) / 20 \times 100$$

Where,

N14 = number of germinated seeds 14 days after the beginning of the cold treatment,

N21 = number of germinated seeds 21 days after the beginning of the cold treatment,

20 being the total number of seeds per genotype per replication.

For the calculation of GI only the seeds presenting coleoptile and radical were considered.

Percentage of seeds with coleoptile superior to 5 mm (PERCOL) (%)

The PERCOL was obtained by considering all the germinated seeds 28 days after the beginning of the cold treatment and by counting number of seeds showing coleoptile length superior to 5 mm, according to the formula given by Cruz and Milach (2004).

PERCOL = (Number of seeds with coleoptile > 5mm) x 100/20

Percentage of reduction in coleoptile length (REDCOL) (%)

This was obtained through comparison of average coleoptile length at 28 days after germination at 13°C (cold treatment) with that obtained 7 days after germination at 28°C (control) and calculating the percentage of reduction in coleoptile length by germination under cold temperature, according to the formula given by Cruz and Milach (2004).

REDCOL = [(coleoptile length under cold temperature x 100)/ coleoptile

Where coleoptile length is the average of the 10 seeds evaluated per replication length under control] – 100 per genotype.

Coleoptile regrowth (COLREG)/Coleoptile alleviation in cold stress (cm)

Cold tolerance evaluation was performed through coleoptile regrowth (COLREG in mm) where, seeds of the 86 rice genotypes were allowed for germination under the following conditions: 28°C for 72 hours, 13°C for 96 hours and again 28°C for 72 hours. COLREG was obtained by measuring coleoptile length in two occasions: after the period of 96 hours at 13°C (LENGTH 1) and after the second period of 72 hours at 28°C (LENGTH 2). According to the formula given by Cruz and Milach (2004),

COLREG = (LENGTH 2) – (LENGTH 1)

Where coleoptile length is the average of the 10 seeds evaluated per replication per genotype.

Shoot and Root length (cm)

Ten normal seedlings in each replication of treatments were randomly selected for measuring the shoot and root length on 7th day of germination test (control) and on 28th day of germination test (cold). The shoot length was measured from the cotyledonary node to the tip of the apical bud and the root length was measured from the collar region to the tip of the root respectively. The mean of shoot and root length of ten seedlings were computed and expressed in centimetres.

Seedling length (cm)

Ten normal seedlings in each replication of treatments were randomly selected for measuring the seedling length on 7th day of germination test (control) and on 28th day of germination test (cold). The seedling length was measured from the root tip to the shoot tip. The mean of seedling length of ten seedlings were computed and expressed in centimetres.

Seedling Vigour Index

The Seedling Vigour Indices were calculated as per the method suggested by Abdul- Baki and

Anderson (1973) as given below and expressed in whole number.

Seedling vigour index = Germination (%) x Seedling length (cm)

STATISTICAL ANALYSIS

Analysis of variance (ANOVA)

The mean values for all the above mentioned parameters were subjected for statistical analysis. The variance for various traits was estimated following ANOVA as per Completely Randomized Design as outlined by Panse and Sukatme (1985).

Experiment II: Evaluation of selected rice genotypes under field condition

Material

All the genotypes which were cold tolerant in experiment I based on seed and seedling quality parameters were evaluated to assess cold tolerance based on yield and yield attributes in the field, under cold during *Rabi,* 2019-2020 in 'A' block of Department of Crop Physiology, College of Agriculture, V. C. Farm, Mandya.

Experimental design

The experiment was laid out by using split plot design with a spacing of 20 x 10cm. The area of each plot occupied by a genotype is 1 m^2. Each date of sowing having two replication contain 60 m^2 areas. Therefore three date of sowing has 180 m^2 areas. The three date of sowing is considered as main plot and the genotype (treatment) which is sown in each main plot are considered as sub plot. The sub plot is having an area of 1m^2 with a spacing of 40cm.

Layout of the field

The field was laid out according to the Split-plot experiment design for three different dates of sowing (staggered sowing). Here the main plots are three dates of sowing, and the sub-plot is genotypes with two replication**s**. Total area of the field is 431.8 m^2, while the area of each sub-plot is 1 m^2. So therefore there are 30 sub-plots and 3 main plots with 2 replication**s**.

Sowing and cultural practices

The field was prepared according to the cultural practices before sowing of seeds. The raised bed was prepared for sowing and the seeds were directly sown in to the field with a spacing of 20 x 10 cm. 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 thinning, weeding, irrigation were followed during the crop growth. The three dates of sowing of main plot as follows

Trial I : 30 August 2019

Trial II : 10 September 2019

Trial III : 20 September 2019

Observations recorded

Following observations were recorded on five randomly selected plants from each treatment in each replication. The mean was laid out for the following parameter and statistical analysis was carried out.

Plant height (cm)

Plant height was measured from ground level to the tip of the plant on five randomly selected plants using a linear scale and is expressed in centimetres. The plant height was measured at 30 DAS, 60 DAS and harvest from the date of sowing.

Number of tillers plant $^{-1}$

The number of tillers was counted from the five randomly selected plants in each treatment (genotype). The number of tillers per plant was counted at 30 DAS, 60 DAS and harvest from the date of sowing.

Seed yield plot^{-1} (g)

Panicles from a single genotype were harvested at maturity, threshed, cleaned and seeds are dried to a safe moisture level i.e., 13 per cent. Weight of seed of each sub plot from two replication was recorded separately and expressed as seed yield in kg genotype^{-1}.

RESULTS AND DISCUSSION

Rice is a staple food for half of the human population. Unlike other cereals such as wheat and barley, rice plants are susceptible to cold stress, which often results in decreased productivity, especially in regions where the *indica* subspecies is cultivated. Such low temperature that affects crop growth and production. Low temperature shows negative impacts on rice plants during germination, vegetative growth and reproductive stages. Considering the frequency of extreme temperature events is expected to increase as part of the general global warming phenomena (IPCC, 2007) damage caused by cold temperatures may increase (Marengo and Camargo, 2008). Abiotic stresses directly or indirectly affect the physiological status of rice and negatively alter its overall metabolism, often with impacts on grain yield.

Experimental progress has been achieved in the understanding of cold tolerance in rice plants and cold-tolerant cultivars need to be designed according to the growth stage when plants will be exposed to cold in a particular region and a combined strategy that considers breeding and genetic engineering as tools to be used hand-in-hand could lead to successful projects. Practical progress in the field would probably be achieved faster if there was more integration between breeders and plant physiologist (Cruz *et al.,* 2013).

In vitro screening of rice genotypes for cold tolerance

Data on germination percentage, germination index, coleoptile length (cm), REDCOL (%), coleoptile regrowth (cm) and PERCOL (%) are presented in Table 1.

Germination (%)

In ambient temperature there was no significant difference among the genotypes for germination percentage. The germination percentage was maximum in Gangavati sona (100%), IR-30864, RNR-15038, Daksha (KMP-175), which were equal to the check varieties CTH-1 and CTH-3 (100%). It was followed by Thanu (98.3%) and GVT-503 (96%). The mean performance of the genotypes including check varieties is 99.2 %. The seeds have germinated within four days.

Germination percentage showed significant differences among the genotypes. Exposing of seeds to low temperature of 10˚C and 12˚C, i.e at temperature of 15˚C for 14 days gave a mean germination of 82.3%, further condition of cold stress for one more weak (21days) improve seed germination percentage by 87.8% against CTH-1 (91.7%) and CTH-3 (91.7%) at 21 DAS. Thanu (93.3%), Daksha (KMP-175) (96.7%), GVT-501 (98.3%), NLR-3042 (93.3%), RNR-1588 (93.3%) showed higher germination. These observations showed that genotypic variation selections for germination. Cruz *et al.* (2013) reported that low temperature stress may affect rice seed germination, avoiding development to the seedling stage. For rice, temperatures lower than 20°C decrease both the speed and percentage of germination (Xu, 2008).

Germination index

The germination index showed a significant difference among the genotypes (Table 2). The germination index was high in Thanu (1900), GVT-501 (1900), GVT-4 (1800), NLR-3042 (1817), RNR-1588 (1867) compared to the cold tolerant check varieties CTH-1 (1683) and CTH-3 (1800). Germination speed is important for crop establishment; however, it does not necessarily hold any relation with the ability of a genotype to elongate coleoptile and radical under cold temperature (Cruz and Milach, 2004).

Coleoptile length (cm)

Rice seedling coleoptile length measured after exposed to cold temperature has shown a significant difference among the genotypes (Table 3). The coleoptile length was significantly high in the Daksha (KMP-175) (7.84), Jyoti (7.64), Thanu (6.48), KRH-4 (6.42), Rasi (6.15) and so on. These genotypes were significantly superior to the cold tolerant variety CTH-1 (4.66). However, coleoptile length was less in BPT x BR-17 (5.54), IR-64 (5.29), Gangavati sona (5.16) and KMP-149 (4.64). The mean performance of the genotypes including the check varieties is 6.06 cm. Seeds with strong vigour may significantly improve the speed and uniformity of seed germination and the final percentage of germination and lead to perfect field emergence, good crop performance and even high yield under different conditions (Foolad *et al.*, 2007).

In cold stress condition coleoptile length showed the significant difference among the genotypes. During the germination process the growth of coleoptiles was monitored in ambient condition and cold stress for 21 days. Results revealed that the overall extent of reduction in coleoptiles growth was 55.2%. The CTH-1 variety had 74.6% reduction in coleoptile length due to cold stress; however, there are many genotypes which have lesser reduction than CTH-1 (1.17cm) and CTH-3 (4.05cm). The better genotypes with lesser reduction in coleoptile length were RNR-1588 (5.32cm), KCP-1 (5.28cm), GVT-501 (5.36cm) and Thanu (4.64cm). The genotypes which showed significantly high germination than CTH-3 have shown least reduction in coleoptile length (Thanu and GVT-501). These results are supported by Redona and Mackill (1996), they were reported that shoot weight, shoot length and coleoptile length were the best determinants to predict greenhouse and field seedling vigour of rice.

Percentage of seeds with coleoptile superior to 5 mm (PERCOL)

The selected genotypes showed significant difference for PERCOL. The PERCOL was high in KCP-1 (100.0%), GVT-501 (100.0%), Thanu (98.3%), Jyoti (98.3%), KMP-149 (96.7%) and so on, which were significantly superior to the cold tolerant varieties CTH-1 (88.3%). It can be used as a good criterion to distinguish cold-tolerant and cold-sensitive rice genotypes (Maya, 1988). As per Cruz and Milach (2004), this characteristic reflects the coleoptiles elongation capacity under cold temperature. Whereas, Sharifi (2010) reported that a decreased temperature causes delay in emergence of coleoptile and radical compared to the control, showing mperature. The PERCOL as measure of cold tolerance was reported by several authors (Cruz *et al.*, 2006, Sharifi, 2008, Farzin *et al.*, 2013 and Priyanka *et al.*, 2015.

Percentage of reduction in coleoptile length (REDCOL)

Cruz *et al.*, (2006) showed that reduction of coleoptile length was inversely proportional to cold tolerance, i.e., the higher the reduction in coleoptile length and the lower was the cold tolerance. There was a significant difference among the genotypes for REDCOL. The better genotypes with lesser reduction in coleoptiles length were observed in BPT X BR-6 (16.3%), KMP-149 (23.9%), GVT-501 (28.0%), Thanu (28.4%), RNR-1588 (29.4%) and so on, which were significantly reduced less than the cold tolerance varieties CTH-1 (74.6%) and CTH-3 (53.8%). Reduction in coleoptile length was one of the best characteristics for better distinction between the genotypes sensitive to cold stress.

It was further stated that comparison of coleoptile growth under normal temperature in relation to cold temperature show the genotypes response to cold stress effectively. In the breeding process for cold tolerance at germination period, evaluation of the percentage of reduction in coleoptile length indicates the identification of cold tolerant genotypes. It is in accordance with the results of Sharifi (2010) that there was a considerable reduction in the lengths of coleoptile and radical at the low temperature treatment. The decrease in radical length was more pronounced compared to that in coleoptile length in the low temperature treatment. The results in this study are also in accordance with Farzin *et al.* (2013) wherein there was a reduction in the length of the coleoptile due to exposure to cold temperature of 15° C which helped in distinguishing the tolerant genotypes and sensitive ones. Priyanka *et al.* (2015) also reported a reduction in coleoptile length due to cold in 25 rice genotypes. Lower values for this trait indicate the cold tolerance of a particular genotype (Cruz and Milach, 2004).

Coleoptile Re-growth (COLREG) (cm)

Coleoptile regrowth in selected rice shown the significant difference among genotypes. The coleoptiles regrowth was high in KCP-1 (7.14cm), GVT-501 (6.25cm), RNR-1588 (5.97cm), RNR-15038 (5.69cm) which were significantly superior to the cold tolerant variety CTH-1 (3.92cm). Therefore the differences in COLREG among genotypes may be an indicative of a distinct capacity of recovery of germination process after a cold period and depends on different degrees of cold tolerance.

Effect of low temperature on seedling parameters in rice genotypes

Observations on root length (%), shoot length (%), seedling length (cm), seedling vigour index and root to shoot ratio are presented in Table 2.

Root length (cm)

In control check varieties and selected genotypes the root length was significant different. The root length was high in RNR-1588 (10.10cm), Daksha (KMP-175) (8.92cm), MTU-1001 (8.83cm), KCP-1 (8.57cm), KMP-128 (8.35cm) which were compared to the cold tolerant varieties CTH-1 (7.33cm) and CTH-3 (8.15cm). In cold stress Root length has shown the significant difference among the genotypes. The genotypes with high in root length are KMP-200 (3.33cm), to the cold tolerant varieties CTH-1 (0.75cm) and CTH-3 (0.88cm).

RNR-1588 (3.26cm), KMP-128 (3.00cm), Jyoti (2.83cm), KCP-1 (2.73cm), was significantly superior followed by MTU-1001 (0.65cm), IR-15048 (0.80cm) and KMP-201 (0.55cm). Rapid shoot and root length were observed to be closely associated with seedling vigour. Rangel *et al.* (2006) studied the allele sources for seedling vigour in rice and presented root length at 25°C showed the lowest genetic variation coefficient and indicated that it is little informative as indicator of seedling vigour. It was supported by Sharifi (2010) that early and rapid elongation of roots is important for indicating resistance to abiotic stresses such as drought and cold.

Shoot length (cm)

In control shoot length showed significant difference among the genotypes (Table 4). The shoot length was significantly high in Daksha (KMP-175cm) (7.84cm), GVT-501 (7.46cm), RNR-1588 (7.53cm), Jyoti X BR (7.07cm), Thanu (6.56cm) which were significantly superior to the cold tolerant variety CTH-1 (4.66cm).

In cold stress the genotypes have shown the significant difference in shoot length. The genotypes with high shoot length are RNR-1588 (5.32cm), KCP-1 (5.28cm), GVT-501 (5.20cm), Thanu (4.65cm), were significantly superior to the cold tolerant varieties CTH-1 (1.17cm) and CTH-3 (4.05cm), followed by KRH-4 (3.99cm), BPT X BR-6 (3.81cm), KMP-200 (3.34cm). It was supported by Peterson *et al.* (1978) that shoot length was the best variable determinant of seedling vigour and hence greater is the shoot length of a variety indicates the direct effect on vigour, associated with seedling vigour in rice as the ability of genotypes to put forward the coleoptile is directly proportional to the seedling vigour. Similarly, Sujay (2007) reported that among 46 rice germplasm used for study, IR 64 recorded highest shoot length and lowest shoot length was recorded in BPT 5204, MTU 1001 and IR 20.

Root to shoot ratio

In control Root to shoot ratio showed the significant difference among the genotypes. The root to shoot ratio is significantly high in BRT X BR-6 (1.94), BRT X BR-17 (1.84), which were significantly superior to the cold tolerant varieties CTH-1 (1.70) and CTH-3 (0.93). It is followed by RNR-15038 (1.56), Gangavati sona (1.46), RNR-1588 (1.40), KMP-149 (1.38), IR-64 (1.36). In cold stress the thirty rice genotypes have shown the significant difference in the root to shoot ratio. The root to shoot ratio was high in KMP-128 (1.96), Rasi (1.73), KMP-200 (1.35), Jyoti (1.36), GVT-4 (1.48), were significantly superior to the cold tolerant varieties CTH-1 (0.78) and CTH-3 (0.25), followed by RNR-1588 (0.77), IR-64 (0.94).

Aghaee *et al*. (2011) reported that rice plant grown at normal temperatures (29/22° C) had significantly higher root to shoot ratio in contrast to plants grown at low temperature (15/10°C). Similar observations were also reported by Zhang *et al.* (2005) wherein there was a decrease in the root to shoot ratio due to decrease in temperature to 15° C. Zhang *et al.* (2005) also concluded that root to shoot ratio as the important character associated with seedling vigour in rice as the ability of genotypes to put forward the coleoptile is directly proportional to the seedling vigour.

Seedling length (cm)

In control with respect to the seedling length, the genotypes varied significantly. The seedling length was significantly higher in Daksha (KMP-175) (16.76), NLR-3042 (16.67cm), KCP-1 (15.87cm), Jyoti X BR (15.38cm), Rasi (14.89cm) which were significantly superior to the cold tolerant varieties CTH-1 (11.99cm), which is followed by GVT-504 (10.49cm), KMP-149 (10.79cm), JGL-1798 (9.92cm) and so on. The average length of the seedling including check varieties is 13.82cm.

In cold stress the seedling length has shown the significant difference among the rice genotypes. The genotypes with high seedling length are GVT-501 (7.03cm), KMP-200 (6.67cm), KRH-4 (6.25cm), BPT X BR-6 (6.30cm), KMP-149 (6.23cm), which were significantly superior to the cold tolerant varieties CTH-1 (1.92cm) and CTH-3 (4.94cm), followed by BPT X BR-17 (3.79cm), Jyoti X BR (3.46cm), Gangavati sona (2.79cm). The mean value of the seedling length including the check varieties is 4.55cm, which is 67.07 % reduction in average seedling length compared to the control seedling length mean value 13.82cm. The variation in seedling length was due to better quality of seeds of the genotypes. Another essential seedling trait useful for crop stand establishment is length of coleoptile. It is a highly heritable character and could be efficiently used in the selection programmes (Chowdhary and Allan, 1963). Hence the genotypes with higher seedling length are said to be tolerant to low temperatures.

Seedling vigour index

In control the genotypes showed significant difference for the seedling vigour index. The seedling vigour index was high in Jyoti (1799) and RNR-1588 (1763), which were significantly superior to the cold tolerant varieties CTH-1 (1199) and CTH-3 (1695), which is followed by Jyoti X BR (1538), KCP-1 (1587), KMP-128 (1433), and GVT-7 (1406). Seedling vigour is a parameter to evaluate plant's withstanding strength against any kind of stress conditions (Ranawake and Nakamura, 2011) and the temperatures below 25°C results in poor seedling vigour. Sun *et al.* (2007) reported that seed vigour is an important characteristic of seed quality, reflecting potential seed germination, seedling growth, seed longevity and tolerance to adversity. The variation in seed vigour may be due to varied germination and seedling length recorded among the genotypes.

In cold stress the thirty rice genotypes which are used for study has shown the significant difference in the seedling vigour index. The seedling vigour index was high in Thanu (628), RNR-1588 (801), GVT-501 (691), KMP-200 (567), KCP-1 (735), which were significantly superior to the cold tolerant verities CTH-1 (176) and CTH-3 (453), followed by Gangavati sona (242), IR-64 (364), MTU-1001 (136), IR-15048 (173) and so on. Seedling vigour index is the important character for optimum plant stand under unfavourable environments. Redona and Mackill (1996) found that shoot weight, shoot length and coleoptile length were the best determinants to predict greenhouse and field seedling vigour of rice. Seeds with strong vigour may significantly improve the speed and uniformity of seed germination and the final percentage of germination and lead to perfect field emergence, good crop performance and even high yield under different conditions (Foolad *et al.,* 2007).

Effect of low temperature on plant height and number of tillers in rice genotypes

Data on plant height and number of tillers is presented in Table 3.

Plant height (cm)

At harvest, plant height that is measured at the time of harvesting has shown the significant difference among the rice genotypes. In August-30 date of sowing the genotype Jyoti X BR (103.4cm), Daksha (99.7cm), KRH-4 (93.7cm) has shown the significantly in plant height compared to check variety CTH-1 (90.4cm). In September-10 date of sowing the genotype Jyoti X BR (101.4cm), Daksha (100.0cm) and KRH-4 (92.7cm) has shown significantly high in plant height compared to cold tolerant variety CTH-1 (89.2cm). In September-20 date of sowing the genotype Jyoti X BR (100.4cm), KMP-200 (95.1cm) and Daksha (98.0cm) have shown significantly high in plant height compared to check variety CTH-1(88.8cm).

Total number of tillers plant $^{-1}$

The genotypes have shown the significantly difference in total number of tillers per plant at the time of harvest. In August-30 date of sowing the genotypes Daksha (20), KRH-4 (24), Jyoti (23), JGL-1798 (21), GVT-503 (23) have shown the significantly high in tiller number compared to check varieties CTH-1 (18) and CTH-3 (19). In september-10 date of sowing the genotypes KRH-4 (22), Jyoti (21), JGL-1798 (20) and GVT-503 (21) have shown the significantly high in tiller number compared to cold tolerant varieties CTH-1 (17) and CTH-3 (17). In September -20 date of sowing the genotypes Daksha (17), KRH-4 (20), Jyoti (20), KCP-1 (22), NLR-3042(23) have shown the significantly high in tiller number compared to cold tolerant varieties CTH-1 (16) and CTH-3 (16).

Effect of low temperature on biochemical and yield parameters in rice genotypes

Data on biochemical and yield parameters is presented in Table 4.

Leaf chlorophyll content

The leaf chlorophyll content was measured by using SPAD meter. The genotypes have shown significant difference in leaf chlorophyll content. In August-30 date of sowing the genotype IR-64 (37.52), Raksha (39.90), Jyoti (38.12), KCP-1 (37.78), Jyoti X BR (38.97), NLR-3042 (38.62), KMP-200 (37.60), and KMP-149 (37.37) have recorded significantly high chlorophyll content compared to cold tolerant varieties CTH-1 (35.14) and CTH-3 (33.40). In september-10 date of sowing the genotype Raksha (39.83), IR-64 (37.75), Jyoti (38.29), Jyoti X BR (39.18), NLR-3042 (39.02) and

KMP-149 (37.27) have recorded significantly high chlorophyll content compared to check varieties CTH-1 (35.04) and CTH-3 (32.09).

In september-20 date of sowing the genotype Raksha (38.64), Jyoti (38.89), KCP-1 (37.72), Jyoti X BR (38.89), NLR-3042 (39.44), KMP-200 (37.90) have recorded high leaf chlorophyll content compared to cold tolerant varieties CTH-1 (35.23) and CTH-3 (33.40). Instantly the chlorophyll content in leaves can be measured through SPAD chlorophyll meter readings (Takebe *et al.*, 1990).

Electrolyte leakage (%)

The Electrolyte leakage has shown significant difference among rice genotypes. In August-30 date of sowing the genotype RNR-15038 (13.33%), Raksha (13.64%), Daksha (12.19%), Jyoti X BR (13.81%) and KMP-128 (12.43) have recorded significantly low electrolyte leakage compared to cold tolerant varieties CTH-1 (14.41%) and CTH-3 (14.58%). In September-10 date of sowing the genotype RNR-15038 (12.16%), Raksha (13.39%), Daksha (13.43%) and KMP-128 (13.02%) have recorded significantly low electrolyte leakage percentage compared to cold tolerant varieties CTH-1 (15.03%) and CTH-3 (14.68). In september-20 date of sowing the genotype RNR-15038 (13.46%), Raksha (14.72%), Daksha (14.55%), MTU-1001 (13.65), KMP-128 (13.49%) and Jyoti X BR (14.33%) have recorded significantly low electrolyte leakage percentage compared cold tolerant varieties CTH-1 (16.03%) and CTH-3 (15.68%). Chilling condition (below about 20˚C) caused large increase in leakage rates, indicating disruption of membrane integrity in the tissues (Paul Willing and Carl Leopold, 1983). Low temperature interferes with membrane expansion, possibly by lowering elasticity and hindering the incorporation of lipid material into the expanding membrane. The expansion of tissues at low temperatures may cause lesions in cellular membranes, contributing to chilling injury. Electrolyte leakage was more in last two sowings compare to first two. It was increased from first to last sowing with decreasing temperature.

Test weight (g)

In August-30, September-10 and 20 date of sowing Test weight was significantly higher in genotype Jyothi x BR (29.38, 29.26 and 29.22 respectively) compared to other treatments except genotype KMP-200(28.88). However, significantly lower test weight was recorded in IR-15048 (13.51, 13.91 and 13.14 respectively) Krishnaswamy and Seshu (1989)).

Seed yield subplot^{-1} (g)

The varied date of sowing results in higher yield in genotype Daksha (KMP-175) (Sown during August 30, September10 and September 20 was yielded 1026g, 894g and 871g respectively) as compared to other genotypes sown in different dates of sowing.

CONCLUSION

Based on the laboratory screening, the genotypes RNR-1588, Thanu, Daksha (KMP-175), GVT-501, KRH-4, KMP-128, NLR-3042, KCP-1and KMP-200 are found cold tolerant. The genotypes Daksha (KMP-175), Jyoti X BR, KMP-128, KMP-200, RNR-15038, Thanu and Raksha were found to be cold tolerant under field condition. The genotypes, Thanu, Daksha, KRH-4, BPT x BR -6, GVT-501, Jyoti, Raksha, KMP-128 and KMP-200 were found to be better for cold tolerance in the laboratory as well as in field condition for grain yield, chlorophyll content, electrolyte leakage etc. The new genotypes used in the study performed better than varieties CTH-1 and CTH-3 in terms yield, physiological and biochemical parameters they can be used for further studies like QTL and marker assisted selection for further crop improvement in breeding programme.

The response of genotypes under laboratory and field screening under cold is summarized in the Table 5.

Table 1: Effect of low temperature on seed germination and germination index in rice

Genotype	*Germination Percentage (%)*			*Germination index*	*Coleoptile length (cm)*		*REDCOL (%)*	*Coleoptile Re-growth (cm)*	*PERCOL (%)*
	Control (28˚C) 4 DAS	*Cold Stress (15˚C)*			*Control (28OC)*	*Cold Stress(15OC)*			
		14 DAS	*21 DAS*						
CTH-1	100.0 (90.0)	76.7 (61.1)	91.7 (73.3)	1683	4.66	1.17	74.6	3.92	88.3
CTH-3	100.0 (90.0)	88.3 (70.0)	91.7 (73.3)	1800	8.79	4.05	53.8	4.32	100.0
Thanu	98.3 (85.7)	93.3 (75.2)	96.7 (81.3)	1900	6.48	4.64	28.4	4.82	98.3
Gangavati Sona	100.0 (90.0)	76.7 (61.1)	86.7 (68.6)	1633	5.16	1.47	71.5	3.69	96.7
IR-30864	100.0 (90.0)	78.3 (62.2)	86.7 (68.6)	1650	5.14	1.55	70.1	4.15	63.3
IR-64	98.3 (85.7)	76.7 (61.1)	88.3 (70.0)	1650	5.29	2.35	55.6	4.85	98.3
RNR-15038	100.0 (90.0)	86.7 (68.6)	88.3 (70.0)	1750	4.64	2.91	37.1	5.69	93.3
RNR-1588	100.0 (90.0)	93.3 (75.2)	93.3 (75.2)	1867	7.53	5.32	29.4	5.97	98.3
Raksha (KMP-105)	100.0 (90.0)	78.3 (62.2)	86.7 (68.6)	1650	5.62	0.92	83.4	4.90	58.3
Daksha (KMP-175)	100.0 (90.0)	78.3 (62.2)	96.7 (81.3)	1750	7.84	2.52	67.8	5.04	86.7
KRH-4	98.3 (85.7)	83.3 (65.9)	91.7 (73.3)	1750	6.42	3.99	37.8	5.37	86.7
Rasi	100.0 (90.0)	81.7 (64.7)	88.3 (70.0)	1700	6.15	2.30	62.4	3.54	93.3
Jyoti	98.3 (85.7)	86.7 (68.6)	88.3 (70.0)	1750	7.64	2.90	62.1	4.18	98.3
MTU-1001	100.0 (90.0)	78.3 (62.2)	83.3 (65.9)	1617	5.43	0.98	81.8	3.43	60.0
IR-15048	100.0 (90.0)	81.7 (64.6)	83.3 (65.9)	1650	6.25	1.27	79.8	4.91	86.7
JGL-1798	98.3 (85.7)	71.7 (57.8)	81.7 (64.6)	1533	4.30	1.98	53.7	3.91	88.3
KCP-1	100.0 (90.0)	86.7 (68.6)	91.7 (73.3)	1783	7.22	5.28	26.5	7.14	100.0
BTP X BR-6	100.0 (90.0)	88.3 (70.0)	90.0 (71.5)	1783	4.47	3.74	16.3	4.05	98.3
GVT-501	98.3 (85.7)	91.7 (73.3)	98.3 (85.6)	1900	7.46	5.36	28.0	6.25	100.0
BPT X BR-17	100.0 (90.0)	83.3 (65.9)	86.7 (68.6)	1700	5.54	2.19	60.7	4.45	76.7
Jyothi X BR	100.0 (90.0)	76.7 (61.1)	83.3 (65.9)	1600	7.23	2.39	66.8	4.81	91.7
KMP-149	100.0 (90.0)	81.7 (64.6)	81.7 (64.6)	1633	4.64	3.52	23.9	3.07	96.7
GVT-4(KMP-221)	100.0 (90.0)	88.3 (70.0)	91.7 (73.3)	1800	4.81	2.61	45.5	3.57	88.3
GVT-7(KMP-222)	98.3 (85.7)	78.3 (62.2)	88.3 (70.0)	1667	6.58	2.73	58.4	3.59	91.7
KMP-128	98.3 (85.7)	83.3 (65.9)	86.7 (68.6)	1700	6.15	2.71	56.2	4.43	78.3
GVT-503	96.7 (81.4)	86.7 (68.6)	88.3 (70.0)	1750	5.91	1.53	74.0	4.73	88.3
GVT-504	93.3 (75.2)	86.7 (70.0)	88.3 (70.0)	1750	4.41	2.15	51.2	3.34	96.7
NLR-3042	100.0 (90.0)	88.3 (65.9)	93.3 (75.2)	1817	7.20	2.57	64.0	4.11	96.7
KMP-200	100.0 (90.0)	83.3 (65.8)	85.0 (67.1)	1683	6.60	3.38	48.9	4.01	96.7
KMP-201	98.3 (85.7)	55.0 (47.8)	56.7 (48.8)	1117	6.37	0.93	85.6	4.16	43.3
Mean	99.2 (87.9)	82.3 (65.5)	87.8 (70.5)	1701	6.06	2.71	55.2	4.58	87.9
SE(m)±	1.02 (1.36)	1.75 (1.36)	1.63 (1.95)	24	0.20	0.25	0.25	3.89	1.98
CD (5 %)	3.86 (3.86)	6.59 (3.87)	6.16 (5.52)	88	0.75	0.94	0.93	0.65	7.46
CV (%)	4.79 (3.605)	3.68 (3.67)	3.23 (4.78)	2.37	5.69	10.86	9.32	9.20	3.90

Table 2: Effect of low temperature on seedling parameters in rice genotypes

	Root length		*% RRL*	*Shoot length*		*% RRL*	*Seedling Length (cm)*		*Seedling Vigour index*		*Root to shoot ratio*	
	Control (28OC)	*Cold Stress (15OC)*		*Control (28OC)*	*Cold Stress (15OC)*		*Control (28OC)*	*Cold Stress (15OC)*	*Control (28OC)*	*Cold Stress (15OC)*	*Control (28OC)*	*Cold Stress (15OC)*
CTH-1	7.33	0.75	89.7	4.66	1.17	74.7	11.99	1.92	1199	176	1.70	0.78
CTH-3	8.15	0.88	89.2	8.79	4.05	53.9	16.95	4.94	1695	453	0.93	0.25
Thanu	6.23	1.85	70.3	6.56	4.65	29.2	12.79	6.50	1254	628	0.99	0.51
Gangavati Sona	7.18	1.18	83.6	5.06	1.61	68.2	12.24	2.79	1224	242	1.46	0.86
IR-30864	6.33	0.61	90.5	5.14	1.63	68.6	11.47	2.24	1147	194	1.37	0.74
IR-64	7.07	1.77	74.9	5.29	2.35	55.6	12.37	4.12	1216	364	1.36	0.94
RNR-15038	6.86	2.00	70.7	4.64	2.91	37.2	11.51	4.91	1151	434	1.56	1.05
RNR-1588	10.10	3.26	67.6	7.53	5.32	29.4	17.63	8.58	1763	801	1.40	0.77
Raksha(KMP-105)	7.23	1.00	86.0	5.62	1.03	81.6	12.85	2.02	1285	175	1.34	1.09
Daksha(KMP-175)	8.92	1.32	85.2	7.84	2.48	68.4	16.76	3.80	1676	367	1.22	0.63
KRH-4	7.14	2.26	68.4	6.42	3.99	37.9	13.56	6.25	1334	573	1.20	1.26
Rasi	8.75	2.64	69.8	6.15	2.28	62.8	14.89	4.92	1489	435	1.52	1.73
Jyoti	10.66	2.83	73.3	7.64	2.70	64.8	18.30	5.53	1799	488	1.44	1.36
MTU-1001	8.83	0.65	92.7	5.43	0.98	81.8	14.25	1.63	1425	136	1.66	0.85
IR-15048	6.64	0.80	88.0	6.25	1.28	79.6	12.89	2.07	1289	173	1.08	0.83
JGL-1798	5.84	1.45	74.8	4.08	1.98	51.5	9.92	3.43	975	280	1.64	1.38
KCP-1	8.57	2.73	68.3	7.30	5.28	27.4	15.87	8.01	1587	735	1.19	0.58
BTP X BR-6	7.89	2.49	68.3	4.27	3.81	10.4	12.15	6.30	1215	567	1.94	0.68
GVT-501	6.43	1.83	71.5	7.46	5.20	30.4	13.89	7.03	1366	691	0.89	0.46
BPT X BR-17	9.51	1.59	83.2	5.54	2.19	60.7	15.04	3.79	1504	328	1.84	0.83
Jyothi X BR	8.31	1.07	86.7	7.07	2.39	66.1	15.38	3.46	1538	289	1.21	0.72
KMP-149	6.15	2.73	55.6	4.64	3.50	24.4	10.79	6.23	1079	509	1.38	0.96
GVT-4(KMP-221)	6.73	2.51	62.7	6.43	2.61	53.3	13.16	5.12	1316	469	1.52	1.48
GVT-7(KMP-222)	7.85	1.97	74.9	6.44	2.73	57.6	14.29	4.70	1406	415	1.25	1.46
KMP-128	8.35	3.00	64.1	6.23	2.97	52.5	14.58	5.97	1433	517	1.42	1.96
GVT-503	6.41	1.42	77.9	5.93	1.53	74.2	12.34	2.95	1193	261	1.11	1.18
GVT-504	6.27	1.99	68.3	4.22	2.15	49.0	10.49	4.14	979	366	1.54	1.01
NLR-3042	9.48	2.31	75.5	7.19	2.57	64.0	16.67	4.88	1667	456	1.39	0.93
KMP-200	7.62	3.33	55.9	6.45	3.34	48.4	14.07	6.67	1407	567	1.35	1.35
KMP-201	9.02	0.55	93.8	6.42	1.06	83.8	15.45	1.61	1519	91	1.50	0.93
Mean	7.73	1.83	76.0	6.09	2.72	54.9	13.82	4.55	1371	406	1.38	0.99

Factors	SE(m)±	CD (5%)	CV (%)	SE(m)±	CD (5%)	CV (%)	SE(m)±	CD (5%)	CV (%)	SE(m)±	CD (5%)	CV (%)	SE (m)±	CD (5%)	CV (%)
Treatment (T)	0.05	0.11	6.03	0.06	0.16	9.45	0.07	0.20	5.67	6.82	19.12	5.69	0.03	0.08	9.23
Varieties (V)	0.20	0.41	10.57	0.22	0.61	10.18	0.28	0.78	12.73	26.41	74.0	10.49	0.12	0.34	7.58
T X V	0.30	0.59	-	0.31	0.87	-	0.40	1.11	-	37.35	104.7	-	0.17	0.48	-
Comparison	Root length of control (28OC) Vs cold stress (15OC)			Shoot length of control (28OC) Vs cold stress (15OC)			Seedling length control (28OC) Vs cold stress (15OC)			Seedling vigour index control (28OC) Vs cold stress (15OC)			Root to shoot ratio control (28OC) Vs cold stress (15OC)		

Table 3: Plant height (cm) in rice genotypes as influenced by dates of sowing during late kharif-2019

Genotype	*Plant height (cm)*			*Tiller number*		
	Aug-30	*Sep-10*	*Sep-20*	*Aug-30*	*Sep-10*	*Sep-20*
	At harvest	*At harvest*	*At harvest*	*At harvest*	*At harvest*	*At harvest*
CTH-1	90.4	89.2	88.8	18.40	17.40	16.40
CTH-3	107.1	106.1	105.8	19.70	17.90	16.70
Thanu	86.4	85.5	84.3	14.60	13.60	12.50
Gangavati Sona	75.2	74.9	75.5	16.90	17.00	16.80
IR-30864	71.8	70.7	71.6	17.50	16.30	15.30
IR-64	77.3	75.0	77.0	14.00	13.90	12.90
RNR-15038	84.9	85.5	82.9	15.80	14.80	16.30
RNR-1588	78.3	76.6	75.6	17.30	16.30	15.30
Raksha(KMP-105)	75.5	73.2	75.2	19.20	17.90	16.40
Daksha(KMP-175)	99.7	100.0	98.0	20.90	18.80	17.80
KRH-4	93.7	92.7	90.7	24.60	22.60	20.60
Rasi	80.0	82.0	80.0	19.50	18.50	17.50
Jyoti	67.6	66.2	67.2	23.80	21.90	20.90
MTU-1001	73.5	72.5	70.5	17.10	15.10	18.10
IR-15048	75.7	74.7	71.7	15.80	14.80	16.80
JGL-1798	72.0	70.0	71.0	21.90	20.90	19.90
KCP-1	93.5	91.5	90.5	21.10	19.10	22.10
BTP X BR-6	71.3	70.8	72.8	20.40	18.40	22.40
GVT-501	79.4	78.6	79.6	17.10	18.10	22.10
BPT X BR-17	79.6	77.6	75.6	14.80	13.80	15.80
Jyothi X BR	103.4	101.4	100.4	21.00	20.20	22.00
KMP-149	71.6	73.6	70.6	19.40	18.40	22.40
GVT-4(KMP-221)	74.9	71.9	72.9	11.70	10.70	21.70
GVT-7(KMP-222)	75.6	74.6	73.6	16.40	15.40	15.40
KMP-128	86.0	82.0	84.0	16.60	14.60	15.60
GVT-503	68.7	66.7	65.7	23.80	21.80	20.80
GVT-504	74.1	71.1	73.1	19.70	20.70	21.70
NLR-3042	61.9	58.9	60.9	22.90	20.90	23.90
KMP-200	92.1	96.1	95.1	17.30	16.30	15.30
KMP-201	78.8	70.8	77.8	17.70	15.70	15.00
Mean	80.7	80.8	79.6	18.56	17.56	18.58
Factors	SE(m) ±	CD (5%)	CV (%)	SE(m) ±	CD (5%)	CV (%)
Dates of sowing (D)	0.45	4.69	14.36	0.58	4.02	20.30
Varieties (V)	1.24	3.49	13.76	0.98	2.75	12.89
Factor (V) at same level of Factor D	2.49	N/A	-	3.19	3.92	-
Factor (D) at same level of Factor V	0.98	2.84	-	1.76	5.07	-
Interaction	Plant height At harvest Vs Dates of sowing			Tiller number at harvest Vs Dates of sowing		

Table 4: Effect of low temperature on biochemical and yield parameters in rice genotypes

	Leaf chlorophyll content			*Electrolyte leakage (%)*			*Test weight (g)*			*Seed Yield [g/sub plot(genotype)]*		
	Aug-30	*Sep-10*	*Sep-20*	*Aug-30*	*Sep-10*	*Sep-20*	*Aug-30*	*Sep-10*	*Sep-20*	*Aug-30*	*Sep-10*	*Sep-20*
CTH-1	35.14	35.04	35.23	14.41 (23.89)	15.03 (22.80)	16.03 (22.80)	17.84	17.86	18.39	790	690	686
CTH-3	33.40	32.99	33.40	14.58 (23.99)	14.68 (23.31)	15.68 (22.52)	19.73	19.33	19.36	681	581	513
Thanu	33.63	34.29	34.17	16.48 (23.94)	15.71 (23.33)	15.94 (23.52)	21.44	21.16	21.46	885	830	518
Gangavati Sona	35.94	36.12	37.90	15.43 (23.11)	15.67 (23.30)	14.94(22.07)	14.86	15.51	14.80	658	595	479
IR-30864	36.02	36.15	36.01	16.37 (22.74)	14.57 (22.42)	15.37 (23.07)	26.80	26.25	25.66	747	647	466
IR-64	37.52	37.75	37.71	14.96 (23.03)	14.85 (22.65)	15.03 (22.79)	18.34	18.98	18.24	495	495	501
RNR-15038	34.02	33.98	34.02	13.33 (23.22)	12.16 (22.05)	13.46 (21.45)	20.06	20.27	19.39	580	430	689
RNR-1588	30.76	31.27	30.47	15.55 (22.48)	14.91 (22.70)	14.37 (22.27)	21.84	22.34	22.58	633	533	655
Raksha (KMP-105)	39.90	39.83	38.64	13.64 (23.72)	13.39 (23.09)	14.72 (21.73)	16.94	17.47	17.20	665	565	674
Daksha (KMP-175)	33.10	33.14	33.36	12.19 (23.53)	13.43 (23.12)	14.55 (23.22)	21.91	22.50	21.72	1026	894	871
KRH-4	34.95	34.94	34.35	15.94 (22.85)	16.35 (23.84)	15.91 (23.50)	20.64	20.57	20.75	823	723	666
Rasi	36.78	36.67	36.68	15.10 (22.59)	15.12 (22.87)	14.49 (22.37)	23.67	24.17	24.30	730	630	534
Jyoti	38.12	38.29	38.89	14.77 (22.10)	14.86 (22.66)	14.32 (22.23)	28.37	28.56	29.18	832	732	680
MTU-1001	37.11	37.31	37.16	14.17 (22.51)	14.07 (21.98)	13.65 (21.67)	25.11	25.55	25.00	813	713	558
IR-15048	36.69	36.99	36.63	14.68 (22.76)	15.15 (22.90)	15.05 (22.82)	13.51	13.19	13.14	686	586	433
JGL-1798	35.71	35.55	35.87	15.00 (22.58)	14.57 (22.42)	15.72 (23.35)	15.46	15.63	15.43	533	761	661
KCP-1	37.78	37.79	37.72	14.76 (22.14)	15.50 (23.17)	14.85 (22.65)	26.08	26.05	26.20	799	704	604
BTP X BR-6	35.22	33.90	35.25	14.21 (24.38)	14.70 (22.54)	14.18 (22.10)	17.22	17.00	17.22	769	725	625
GVT-501	33.52	33.23	33.48	17.06 (23.41)	18.59 (25.53)	17.78 (24.92)	22.09	21.94	23.64	875	796	696
BPT X BR-17	34.59	34.58	35.09	15.80 (24.19)	14.55 (22.36)	15.80 (23.40)	26.32	28.09	28.44	806	934	884
Jyothi X BR	38.97	39.18	38.89	13.81 (23.57)	14.50 (24.72)	14.33 (23.81)	29.38	29.34	29.58	678	557	657
KMP-149	37.37	37.27	37.39	16.01 (22.45)	17.75 (24.91)	17.08 (24.40)	18.87	19.69	21.20	735	732	686
GVT-4(KMP-221)	35.43	35.18	35.50	14.60 (22.90)	15.79 (23.41)	14.60 (22.46)	20.12	20.37	20.27	695	685	584
GVT-7(KMP-222)	35.27	35.16	34.93	15.16 (22.32)	17.28 (24.56)	15.93 (23.51)	17.32	16.82	16.34	877	633	533
KMP-128	34.46	33.68	34.25	12.43 (23.05)	13.02 (22.79)	13.49 (22.37)	26.02	26.36	27.32	921	926	826
GVT-503	35.44	35.65	35.42	15.35 (20.71)	16.12 (23.66)	14.23 (22.12)	14.92	15.24	15.12	590	773	673
GVT-504	36.77	36.07	36.75	15.53 (22.76)	14.29 (22.20)	14.46 (22.34)	15.53	15.28	15.76	625	695	646
NLR-3042	38.62	39.02	39.44	15.01 (24.06)	17.10 (24.41)	15.99 (23.56)	16.99	17.38	17.41	678	705	605
KMP-200	37.60	37.28	37.90	16.63 (22.45)	16.25 (23.74)	17.07 (24.39)	28.88	29.26	29.22	870	646	546
KMP-201	36.77	37.17	36.81	17.012(3.31)	16.13 (23.60)	16.28 (23.45)	28.00	28.88	28.26	649	581	481
Mean	35.89	35.85	35.98	12.43 2(3.34)	14.60 (23.65)	15.21 (23.78)	21.14	21.37	21.42	738	683	601
Factors	SE(m) ±	CD (5%)	CV (%)	SE(m) ±	CD (5%)	CV (%)	SE(m) ±	CD (5%)	CV (%)	SE(m) ±	CD (5%)	CV (%)
Dates of sowing (D)	0.05	1.68	11.19	0.224	1.85	11.26	0.29	2.84	10.55	7.49	49.08	18.61
Varieties (V)	0.65	1.84	10.45	0.453	1.28	7.20	0.41	1.15	14.70	45.03	126.80	16.36
Factor (V) at same level of Factor D	0.30	2.68	-	1.228	1.89	-	1.59	1.76	-	41.03	181.76	-
Factor (D) at same level of Factor V	1.11	1.64	-	0.80	2.58	-	0.75	3.26	-	77.04	12.22	-
Interaction	Leaf chlorophyll content Vs Dates of sowing			Electrolyte leakage Vs Dates of sowing			Test weight Vs Dates of sowing			Seed yield Vs Dates of sowing		

Table 5: Response of genotypes under laboratory and field screening

SL No.	*Condition*	*Genotypes superior to cold tolerant checks*	*Parameters*
1	Laboratory	Thanu, RNR-1588, Daksha (KMP-175), KRH-4, KCP-1, BPT X BR-6, GVT-501, GVT-4, NLR-3042, KMP-200, KMP-128, Jyoti, Raksha (KMP-105), KMP-149 and IR-64	Germination (%), Coleoptile length, PERCOL, REDCOL, Seedling length and Seedling vigour index.
2	Field	Thanu, Daksha (KMP-175), Raksha (KMP-105), Rasi, RNR-1503864, BPT X BR-6, KRH-4, Jyoti, MTU-1001, GVT-501, GVT-7, KMP-128, KMP-200, GVT-7, and NLR-3042	Plant height, Days to flowering, Panicle exertion (%), Spikelet fertility (%), Leaf chlorophyll content, Electrolyte leakage (%) and Seed yield
3	Laboratory and Field	Thanu, Daksha (KMP-175), Raksha (KMP-105), KRH-4, Jyoti, BPT X BR-6, GVT-501, KMP-128 and KMP-200	Germination (%), Seedling length, Coleoptile length, Plant height, Panicle exertion (%), Spikelet fertility (%), Leaf chlorophyll content, Electrolyte leakage (%) and Seed yield.

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