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EFFECT OF COLD STRESS ON GROWTH AND YIELD OF BORO RICE GENOTYPES

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Abstract

During the Boro season of 2023-24, the experiment was carried out at the experiment field of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh to assess the effect of cold stress on growth and yield of rice plant and to identify cold stress tolerant rice genotypes. The experiment was set in a two factorial RCBD with three replications. The first factor was three date of transplanting: D/T1: 30/11/23, D/T2: 12/12/23 and D/T3: 28/12/23 and the second factor was seven rice genotypes (BNCR-20, BNCR-35, BNCR-45, BNDR 18, BNDR-48, BNDR-57 and BRRI dhan67). Rice plant faced the most critical low temperature in January, 24 that is below 15^{o} C. The best performance of physiological parameters like SPAD, TDM, CGR, RGR, NAR and LAI was observed in BNCR-45, BNDR-48, BNDR-48, BRRI dhan67, BRRI dhan67 and BNDR-57 genotype, respectively. On the other hand date of transplanting (D/T3: 28/12/23) performed better in terms of SPAD, TDM, CGR, RGR, NAR and LAI. The highest no. of filled grain panicle^{-1}, straw dry weight (t ha^{-1}), grain yield (t ha^{-1}) was recorded in BNDR-18. Among the date of transplanting, 28 December transplanting showed better performance in terms of yield and yield contributing characters. The highest grain yield (t ha^{-1}) was recorded in BNDR-18 when transplanted at 28 December and the lowest was recorded when transplanted at early i.e. November.

Keywords: Low temperature, chlorophyll, growth, genotypes, yield

Introduction

Rice is a key cereal crop in Bangladesh (Ghadirnezhad and Fallah, 2014). Rice is grown under different habitats with water sources and temperate weather is used to grow rice (IRRI, 2013). One of the most destructive environmental stresses has been temperature stress, with cold stress having the greatest impact on tropical and sub-tropical crops, resulting in lower rice yields. In Bangladesh aspects, low temperatures in reproductive phase during the Boro season have frequently been observed in rice yield (Khanam *et al*., 2022; Haque *et al*., 1992). Temperatures between 0 and 15 °C are considered cold or chilling stress in rice (Zhang *et al*., 2014). Low temperatures have a significant impact on rice (*Oryza sativa* L.), a tropical and sub-tropical crop, all over the world. Rice is a big issue in the socioeconomic conditions of people worldwide since it is the staple meal of over one-third of the world's population (Lahkar and Tanti 2018; Kalita and Tanti 2020).

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Low temperatures were observed to produce yield losses, which in turn led to inadequate pollen production and eventual floret sterility (Singh *et al*., 2005). Yield losses were also reported to occur at temperatures below 18 °C. Cold stress is a prevalent issue in rice agriculture and is a significant factor affecting worldwide output (Zhou *et al*., 2012). Cold temperature regime causes cold damage which depends on variety and growth stages of rice plant. Cold injury were associated with low seed germination, slow growth of seedlings and leaf discoloration, stunted vegetative growth and tillering, incomplete panicle exertion, prolonged flowering period with irregular heading, degeneration of spikelets, irregular maturity, sterility and formation of abnormal grains (Arif *et al*., 2020). Farrell *et al*., (2001 and 2006) reported that rice was susceptible to abundant low temperature (LT)-induced damage during the young microspore stage, and 12 h of exposure to LT can cause spikelet sterility. The young microspore stage was the most susceptible to cold injury in rice plants (Satake and Hayase, 1970) and this stage was found to remain approximately 10 to 12 days prior to heading (Heenan, 1984). Spikelet sterility might be resulted from pollen abortion due to cold during microsporogenesis, while pollen grains were formed in booting stage (Mackill *et al*., 1996). The months of October through early March were the lowest temperatures on record. Frequently, the temperature drops below 20 °C. Low temperatures can have an impact on rice in all phases, not only the reproductive stage, according to the Boro rice plant. High temperatures, in tandem with low temperatures, are crucial in mitigating the impact of low temperatures. In particular, early-established short-duration varieties seem to remain several degrees below room temperature throughout critical growth phases, while they are unable to escape it (Kabir *et al*., 2015). In 1990, crop failure occurred in numerous sections of the Boro field in Bangladesh due to high grain sterility (40-90%) caused by an exceptional drop in temperature in March (Haque and Islam, 1990; Haque *et al*., 1992). Low nighttime temperatures were often linked to low temperature-induced sterility, whereas high daytime temperatures seem to mitigate the effects of low nighttime temperatures (Yoshida, 1981b). Crops are cultivated without taking into account the length of time they need to grow and other physiological traits of the types; as a result, during the Boro season, the crops are damaged by low temperatures or the elements. The present study has been designed to find out the effect of cold stress on growth and yield of Boro rice genotypes.

Materials and Methods

The experiment was conducted at the experiment field of plant breeding division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh during Boro season (October-April) of 2023. The experiment was set in a two factorial RCBD with three replications. The first factor was rice genotypes (BNCR-20, BNCR-35, BNCR-45, BNDR 18, BNDR-48, BNDR-57 and BRRI dhan67) and the second factor was date of transplanting: D/T1: 30/11/23, D/T2: 12/12/23 and D/T3: 28/12/23. Date of sowing for D/T1 was D/S1: 26/10/23, for D/T2 was D/S2: 08/11/23 and for D/T3 was D/S3: 23/11/23. Unit plot size was 2.5 m × 4 m. Row to row and plant to plant distances were 20 cm and 15 cm, respectively. The land was fertilized with 220, 150, 130, 60 and 5 kg ha-1 of urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate, respectively. One third urea and other fertilizers were incorporated with the soil at the final land preparation and rest of the urea was top dressed in two equal splits at 25 and 50 days after transplanting (DAT). Others standard cultural practices were followed to ensure the normal plant growth and development. Five plants were harvested from each treatment at 15-day interval starting from seedling stage to maturity. Dry weights and different morphological characters of those plant samples were recorded. Leaf area was measured by LICOR leaf area meter (LI 3000A, USA) before drying. The growth analyses like crop growth rate (CGR) and relative growth rate (RGR) were carried out following the formulae of Hunt (1978) NAR were carried out following the formulae of Watson (1958). Yield data were harvested when 80% spikelets attained maturity. Data were recorded on yield and yield attributes at harvest from 10 randomly selected plants of each plot. The collected data were analyzed statistically by using computer package program, STATISTIX-10.

Results and Discussion

Temperature variation was observed through the experiment period (Fig. 1). From the Fig. 1, we can observe weekly variation of the temperature range from Nov, 23 to Apr, 24 (Fig. 1a). January, 24 was the coldest month (Fig. 1b) and the average weekly temperature was below 20^{o} C near to 15^{o} C (Fig. 1c). Rice plant faced the most critical low temperature in January, 24. According to the variety, length of the critical temperature, tidal variations, and physiological state of the plant, these critical temperatures vary (Yoshida, 1981a) (Table 1). Throughout the months it was observed that low temperature effect was the most at 6 am and 2 am and the most critical low temperature was recorded in January, 24 that is below 15^{o} C at this time. The lowest minimum and maximum temperature was recorded in January, 24 and the highest was recorded in April, 24.

From Fig. 2, different physiological growth analysis of rice genotypes are observed. SPAD value of different rice genotypes showed similar incremental trend at different days after transplanting (DAT). SPAD value of different rice genotypes at different DAT ranges from 31-48. The highest incremental pattern of SPAD value was observed in BNCR-45 followed by BNCR-20. Rice plants become susceptible below 15˚C (Warth and Ougham 1993) (Fujino *et al*., 2004). Due to exposure to low temperature, the physiology of crop changes like total chlorophyll content reduction (Ghaee *et al*., 2011), limitation of photosynthetic activity (Díaz *et al*., 2006) and oxidative stress. TDM (g plant^{-1}) of different rice genotypes at different DAT ranges from 0.90-38.52 g plant^{-1}.

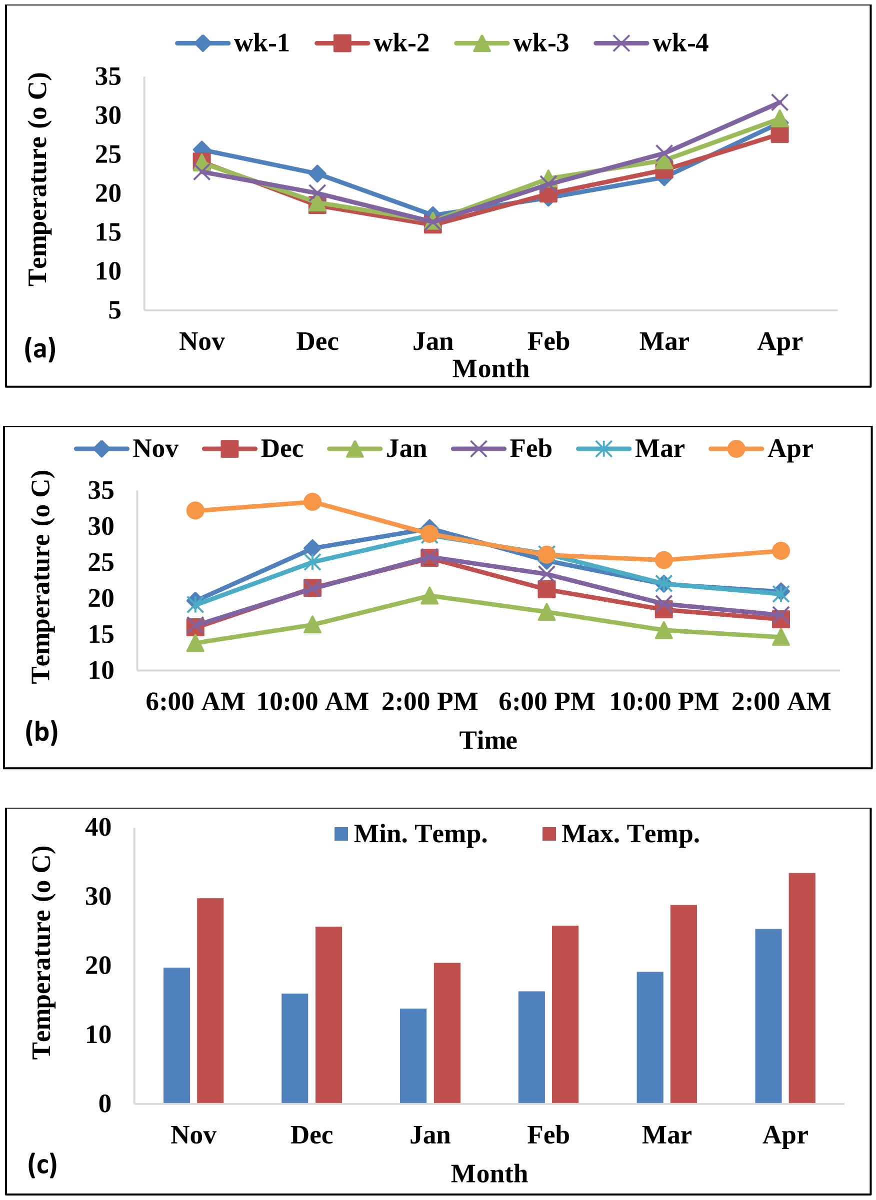

Fig. 1. **Temperature pattern from November, 2023 to April, 2024 (a) weekly temp. variation, (b) month wise temp. variation and (c) min. and max. temp. in every month.**

Table 1. Critical temperature for the development of rice plants in different growth stages

Growth Stages	Critical temperatures (ºC)	
	Low	Optimum
Germination	16-19	18-40
Seedling Emergence	12	25-30
Rooting	16	25-28
Leaf elongation	7-12	31
Tillering	9-16	25-31
Initiation of panicle primordial	15	-
Panicle differentiation	15-20	-
Anthesis	22	30-33
Ripening	12-18	19-20

Source: Yoshida (1981)

The highest incremental rate was observed in BNDR-48 and the lowest was observed in BNCR-35. Fageria and Baligar (2011) also reported that TDM production increased with the advance-ment of plant age up to flowering. In addition, it has been reported that in puddle transplanting rice plant received an ideal rhizosphere environment which may provide higher nutrient uptake which resulting in the greater source accumulation and efficient translocation of photosynthates into the sink (Bhardwaj *et al.*, 2018). CGR (g m^{-2} day^{-1}) of different rice genotypes at different DAT ranges from 1.99-30.51 g m^{-2} day^{-1}. The highest incremental rate was observed in BNDR-48 followed by BNDR-18 and the lowest was observed in BNCR-35. RGR (g g^{-1} day^{-1}) of different rice genotypes at different DAT ranges from 0.060-0.052 g g^{-1} day^{-1}. The highest decreasing rate was observed in BNCR-35 and the lowest was observed in BRRI dhan67. NAR (g g^{-1} day^{-1}) of different rice genotypes at different DAT ranges from 0.000497-0.000402 g g^{-1} day^{-1}. The highest decreasing rate was observed in BNCR-35 and the lowest was observed in BRRI dhan67. Ghasal *et al.,* (2014) also found the similar trend of CGR, RGR and NAR. LAI of different rice genotypes at different DAT ranges from 0.32-5.25. The highest incremental rate was observed in BNDR-57 followed by BNDR-48 and the lowest was observed in BNCR-45. Singh *et al.* (2009) found the similar results and stated that the crop establishment in stress condition which produces highest LAI might have had the capacity to higher photosynthesis rate resulting higher biological and economical yield.

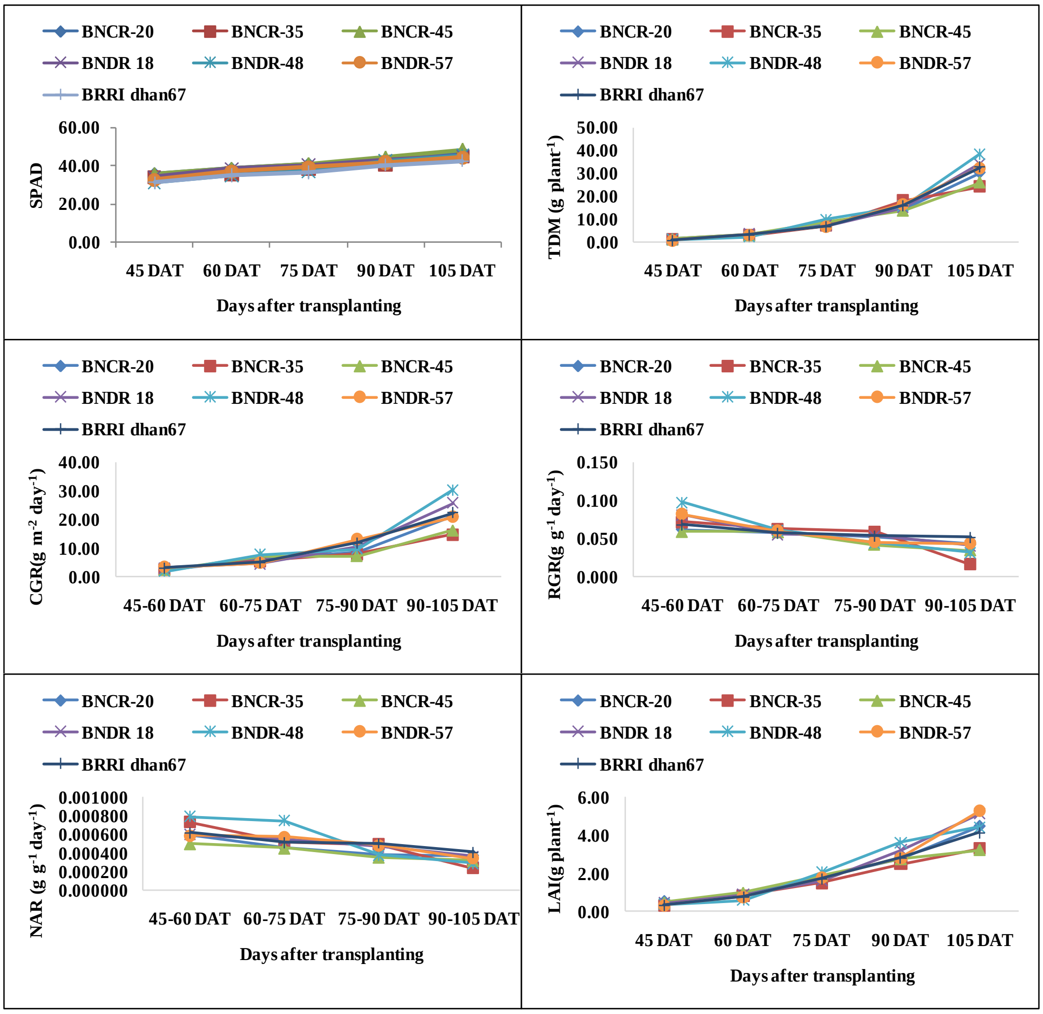

Fig. 2. Effect of cold stress on physiological growth of different rice genotypes.

From Fig. 3, it is observed that the effect of different date of transplanting on physiological growth of different rice genotypes. SPAD value showed similar trend for all the date of transplanting. SPAD value of different date of transplanting at different DAT ranges from 32.87-47.17. The highest incremental pattern of SPAD value was observed in D/T3: 28/12/23 and the lowest was observed in D/T2: 12/12/23. Sarker *et al*., (2013) also found the similar results and stated that some tolerant rice cultivar produced more chlorophyll during low temperature period. TDM (g plant^{-1}) of different date of transplanting at different DAT ranges from 0.88-47.64. The highest incremental pattern of TDM value was observed in D/T3: 28/12/23 and the lowest was observed in D/T2: 12/12/23. These results concur with those of Khakwani *et al*., (2006). CGR (g m^{-2} day^{-1}) of different date of transplanting at different DAT ranges from 1.61-29.83. The highest incremental pattern of CGR value was observed in D/T3: 28/12/23 and the lowest was observed in D/T2: 12/12/23. RGR (g g^{-1} day^{-1}) of different date of transplanting at different DAT ranges from 0.059-0.042. The highest reduction pattern of RGR value was observed in D/T3: 28/12/23 and the lowest was observed in D/T1: 30/11/23. At initial stage the highest RGR was observed in D/T3: 28/12/23. NAR (g g^{-1} day^{-1}) of different date of transplanting at different DAT ranges from 0.000679-0.000294. The highest reduction pattern of RGR value was observed in D/T1: 30/11/23 followed D/T2: 12/12/23 and the lowest was observed in D/T3: 28/12/23. Alam *et al.*, (2009) found the similar trend of CGR, RGR and NAR. LAI of different date of transplanting at different DAT ranges from 0.36-5.24. The highest incremental pattern of RGR value was observed in D/T3: 28/12/23 and the lowest was observed in D/T2: 12/12/23 through the growing period. Biswas and Salokhe (2001) also evident the similar results.

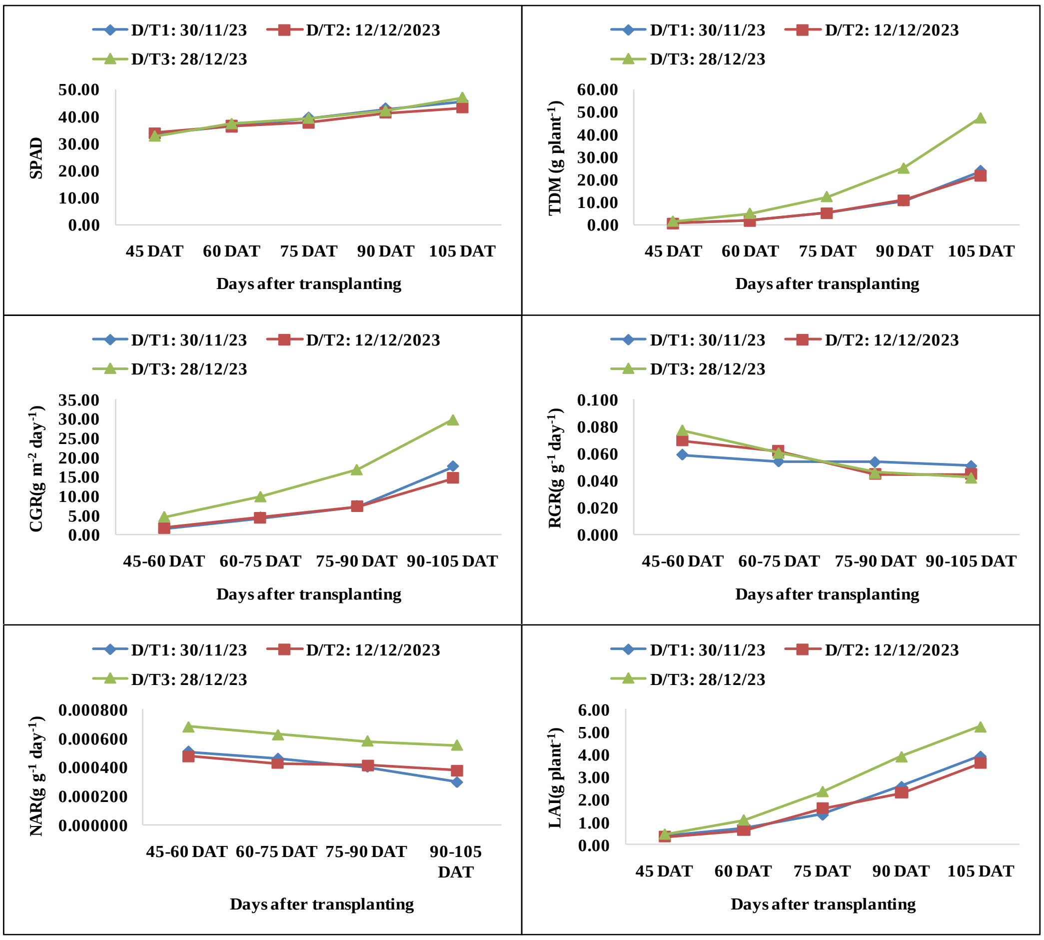

Fig. 3. Effect of different transplanting date on physiological growth of different rice genotypes.

Individual effect of genotype and date of transplanting showed significant variation on yield and yield attributes (Table 2). Plant height (cm) of different genotypes ranges from 75.31-108.18 cm. The highest plant height (cm) was observed in BNDR-57 followed by BNDR-48 and the lowest was observed in BNCR-20. The highest no. of effective tiller hill^{-1} was recorded in BRRI dhan67 followed by BNDR-18 and the lowest was recorded in BNDR-48. The highest no. of non-effective tiller hill^{-1} was recorded in BNCR-35 and the lowest was recorded in BNDR-18. The highest panicle length (cm), no. of un-filled grain panicle^{-1} and 1000 seed weight (g) was recorded in BNDR-48 and the lowest was recorded in BNCR-20, BNCR-35 and BNCR-20 respectively. The highest no. of filled grain panicle^{-1}, Straw dry weight (t ha^{-1}), Grain yield (t ha^{-1}) was recorded in BNDR-18 and the lowest was recorded in BNCR-35, BNCR-20 and BNCR-20 respectively. Among the date of transplanting D/T3: 28/12/23 showed better performance in terms of yield and yield contributing characters.

Table 2. Individual effect of genotype and date of transplanting (D/T) on yield and yield attributes of different rice genotypes

Genotype	Plant height (cm)	No. of effective tiller hill^{-1}	No. of non-effective tiller hill^{-1}	Panicle length (cm)	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	1000 seed wt. (g)	Straw dry wt. (t ha^{-1})	Grain yield (t ha^{-1})
BNCR-20	75.31 d	8.80 c	1.33 ab	21.48 d	94.84 f	89.70 e	19.48 f	5.24 f	3.51 g
BNCR-35	99.02 c	9.28 bc	1.51 a	23.31 c	92.02 g	62.71 g	23.20 b	5.18 f	3.70 f
BNCR-45	98.40 c	9.43 b	1.30 b	23.05 cd	115.94 e	102.47 c	22.54 c	5.71 e	3.87 e
BNDR 18	103.80 b	10.67 a	0.93 d	25.38 b	165.44 a	66.61 f	20.67 e	7.30 a	5.91 a
BNDR-48	107.24 a	6.62 e	1.18 bc	28.27 a	149.83 b	144.22 a	24.23 a	6.56 b	4.47 d
BNDR-57	108.18 a	7.98 d	1.31 b	23.26 c	127.14 c	111.10 b	20.54 e	6.42 c	5.02 b
BRRI dhan67	103.73 b	11.11 a	1.02 cd	22.23 cd	118.11 d	97.24 d	21.12 d	6.16 d	4.92 c
CV (%)	1.56	5.88	6.20	4.70	1.84	1.13	2.05	1.83	1.90
D/T									
30/11/23	96.95 b	8.74 b	1.32 a	23.07 b	119.92 c	104.83 a	21.30 c	5.88 b	4.31 c
12/12/23	97.88 b	8.76 b	1.29 a	23.68 b	122.82 b	96.96 b	21.67 b	6.44 a	4.53 b
28/12/23	103.32 a	9.88 a	1.07 b	24.82 a	127.25 a	87.09 c	22.08 a	5.92 b	4.62 a
CV (%)	1.56	5.88	6.20	4.70	1.84	1.13	2.05	1.83	1.90

All the yield and yield contributing characters showed significant results (Table 3). All the genotypes performed better in terms of almost all characters of yield and yield attributes at 28 December except BNCR-45. We can observe that all the rice genotypes needed minimum days to maturity when it was transplanted at 28 December and needed maximum days to maturity when it was transplanted at 30 November. It was observed that the highest plant height (cm) in case of all genotypes was recorded at 28 December transplanting. Nahar *et al.*, (2009) reported the similar results. Results indicated that tiller number increased with delay transplanting. The highest number of effective tiller hill^{-1} was recorded in BNDR-18 when transplanted at 28 December and the lowest was recorded in BNCR-20 at 30 November. Reverse trend was observed in case of non-effective tiller production.

Table 3. Interaction effect of genotype and date of transplanting on yield and yield attributes of different rice genotypes

Genotype	D/T	Days to maturity	Plant height (cm)	No. of effective tiller hill^{-1}	No. of non-effective tiller hill^{-1}	Panicle length (cm)	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	1000 seed weight (g)	Straw dry weight (t ha^{-1})	Grain yield (t ha^{-1})
BNCR-20	30/11/23	137	74.20 n	5.93 k	1.93 b	20.68 hij	87.02 k	66.21 m	18.10 m	4.60 j	3.00 l
	12/12/23	127	72.87 n	5.60 k	1.00 ef	20.48 ij	95.36 j	63.49 n	19.00 l	4.80 i	3.87 h
	28/12/23	120	78.87 m	8.33 gh	1.07 e	23.29 def	102.13 i	70.15 l	21.33 fgh	6.32 e	3.68 i
BNCR-35	30/11/23	140	88.73 l	8.60 gh	1.00 ef	22.48 efgh	98.45 ij	64.28 n	24.20 bc	5.42 h	3.43 jk
	12/12/23	129	98.40 jk	8.57 gh	2.40 a	23.70 cdef	95.74 j	73.70 k	21.77 ef	5.96 g	4.62 f
	28/12/23	122	109.93 bc	10.67 abcde	1.13 de	23.75 cdef	81.88 l	50.15 o	23.63 cd	4.15 k	3.05 l
BNCR-45	30/11/23	148	98.73 jk	9.07 fg	1.53 c	21.92 fghi	95.12 j	91.56 g	21.87 ef	6.30 ef	4.61 f
	12/12/23	133	97.40 k	10.30 cde	1.50 c	23.10 defg	131.91 e	131.64 c	22.18 e	6.62 d	3.70 i
	28/12/23	125	99.07 jk	8.93 fg	0.87 ef	24.14 bcde	120.79 g	84.22 i	23.57 cd	4.20 k	3.30 k
BNDR 18	30/11/23	144	103.27 fgh	11.00 abc	0.93 ef	22.64 efg	118.55 g	81.03 j	19.80 k	7.13 b	5.40 c
	12/12/23	131	102.80 ghi	10.80 abcd	1.00 ef	21.38 ghij	195.61 a	126.70 d	22.03 ef	7.37 a	6.11 a
	28/12/23	125	105.33 efg	11.53 a	0.87 ef	25.77 b	182.10 b	83.99 i	20.17 ijk	7.40 a	6.23 a
BNDR-48	30/11/23	151	107.93 cd	7.07 ij	1.40 cd	27.98 a	120.93 g	113.82 f	23.23 d	6.30 ef	4.71 f
	12/12/23	133	102.73 hi	6.47 jk	0.73 f	28.47 a	142.61 d	127.14 d	24.50 ab	7.01 bc	3.57 ij
	28/12/23	123	111.05 ab	10.40 bcde	1.40 cd	28.37 a	158.09 c	80.34 j	24.97 a	6.39 e	5.13 de
BNDR-57	30/11/23	147	105.15 efgh	11.27 ab	1.53 c	25.93 b	178.66 b	112.43 f	21.00 gh	5.97 g	5.07 e
	12/12/23	131	106.20 de	10.73 abcd	1.40 cd	24.77 bcd	143.64 d	86.32 h	20.60 hij	6.47 de	4.28 g
	28/12/23	123	113.20 a	10.00 de	1.00 ef	25.44 bc	127.18 f	134.56 b	20.03 jk	6.82 c	5.69 b
BRRI dhan67	30/11/23	139	100.67 ij	7.73 hi	0.93 ef	19.82 j	78.39 l	191.72 a	20.87 hi	5.48 h	3.93 h
	12/12/23	127	104.73 efgh	8.87 g	1.00 ef	23.87cde	106.22 h	69.73 l	21.63 efg	6.87 c	5.57 b
	28/12/23	119	105.80 def	9.80 ef	1.13 de	23.00defg	129.56 ef	119.02 e	20.87 hi	6.13 fg	5.25 d
CV (%)			1.56	5.88	6.20	4.70	1.84	1.13	2.05	1.83	1.90

The lowest number of non-effective tiller hill^{-1} was recorded in BNDR-48 at D/T2: 12/12/23 and the highest was recorded in BNCR-35 at D/T2: 12/12/23. Similar observations were also supported by (Kabir *et al.,* 2015). The highest panicle length (cm) was recorded in BNDR-48 at D/T2: 12/12/23 and the lowest was recorded in BRRI dhan67 at D/T1: 30/11/23. The highest no. of filled grain panicle^{-1} was recorded in BNDR-18 at D/T2: 12/12/23 and the lowest was recorded in BRRI dhan67 at D/T1: 30/11/23. The highest no. of unfilled grain panicle^{-1} was recorded in BNDR-18 at D/T2: 12/12/23 and the lowest was recorded in BNCR-35 at D/T1: 30/11/23. Ye *et al.,* (2009) reported that low temperature had the potentiality to affect growth and development of rice plants from germination to grain filling stage. The highest 1000 seed weight (g) was recorded in BNDR-48 at D/T3: 28/12/23 and the lowest was recorded in BNCR-20 at D/T1: 30/11/23. The highest Straw dry weight (t ha^{-1}) was recorded in BNDR-18 at D/T3: 28/12/23 and the lowest was recorded in BNCR-35 at D/T3: 28/12/23. The highest Grain yield (t ha^{-1}) was recorded in BNDR-18 at D/T3: 28/12/23 and the lowest was recorded in BNCR-20 at D/T1: 30/11/23. Cruz *et al.,* (2006) studied that low temperature (17 °C) resulted in non-uniform seedling growth and weak seedlings, and affected final grain yield.

Conclusion

From the experimental result, it can be concluded that, in terms of different physiological growth and development analysis BNCR-20, BNCR-45, BNDR-57, BNDR-18 and BNDR-48 perform better under cold stress. Considering the transplanting date all the rice genotypes showed better physiological growth and development when transplanted on last week of December than other date of transplanting may be due to lower cold stress at this time than other. So, early date of transplanting time has no effect on physiological growth and development rather than it exposes the rice genotypes into higher cold stress at early growth phase. The highest grain yield (t ha^{-1}) was recorded in BNDR-18 at when transplanted on last week of December. So, in cold tolerant rice breeding program we can use BNCR-20, BNDR-18 and BNDR-48 to develop high yielding cold tolerant rice variety with better physiological growth and development.

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