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Seasonal low temperatures affect the growth of rice seedlings in Northern Bangladesh

Sabrina Shabnam[1], Bulbul Ahmed[2*], A.H.M. Motiur Rahman Talukder[2], Md. Arafat Hossain[3], Md. Toufiqur Rashid[4], Md. Jahangir Alam[5], Mominur Rahman[5], Mousumi Sultana[6], Rumana Akter[7] and Lutfun Nahar[8]

[1]*Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh*
[2]*Plant Physiology Division, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh*
[3]*Seed Technology Division, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh*
[4]*Floriculture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh*
[5]*Soil Science Division, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh*
[6]*Tuber Crop Research Sub Center, Bangladesh Agricultural Research Institute, Seujgari, Bogra-5800, Bangladesh*
[7]*Pathology Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh*
[8]*Agronomy Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh*

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****Corresponding Author***

Name: Bulbul Ahmed
E-mail: kbdahmed@gmail.com

ABSTRACT

A study was conducted to screen out the low temperature tolerant Boro rice seedlings during the period of November 2013 to January 2014 in research farm of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. The experimental area was facing rice production challenge due to climate change in the recent past. During cultivation period prevailing environmental temperature was below 15 ^oC. Seven rice cultivars (V_1: BR-11; V_2: BR-16; V_3: BRRI dhan28; V_4: BRRI dhan29; V_5: BRRI dhan50; V_6: BINA dhan7; and V_7: Hybrid SL-8H) varieties were selected for the study. The seedling shoot length, shoot weight and root length, root weight, total biomass, and seed mortality rate were investigated. The highest shoot length was measured in V_7 (9.56 cm at 33 DAS) and the highest percent shoot dry weight was found in V_7 (34.63 g at 33 DAS). Again, the highest root length (4.09 cm) and root dry weight (10.070 g) were measured in V_3 at 33 DAS. Most interestingly, V_7 plants showed the best performing cultivars among the tested varieties responding dry biomass production. Conversely, the V_3 cultivars showed very poor at low temperature at 12, 19, 26 DAS. Total biomass tends to decrease by low temperature environment. The highest mortality percentage was recorded in V_1 and V_5 (31.56 and 31.67%). The lowest seed germination percentage was found in V_7 (11.33%). The cultivar (Hybrid SL-8H) having highest seed germination percentage is lower temperature stress tolerate than other cultivars.

Introduction

As a cereal grain, rice is most widely consumed staple food for a large part of the world's population, especially in Asia. Approximately, half of the world's population derives a significant proportion of their caloric intake from rice consumption. Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh (BRRI, 2011). It is produced annually at worldwide levels of more than 600 million tons and will be more than 800 million tons as early as 2025 (Green et al., 2005). Unlike the other major cereals, more than 90% of rice is consumed by humans (Tuteja et al., 2012).

Bangladesh has a large agrarian base with 76% of total population living in the rural areas and 90% of the rural population directly related with agriculture. The population growth rate is two million per year. According to this rate, the total population will become 233.2 million within 2050. However, it faces a tremendous challenge for providing food security to the increasing population. Therefore, it is imperative to increase rice production in order to meet the growing demand for food emanating from population growth.

Stressors or stress factors are defined as extreme environmental conditions that induce functional changes in plants to such an extent that stress of the organism develops, resulting in inhibited growth, reduced bio-production, physiological acclimatization, and adaptation of species or some combination of these changes (Grime, 1993; Nilsen et al., 1996). In other words, stress in physical terms is defined as mechanical force per unit area applied to an object both biotic abiotic stresses are generally understood as the reaction of a biological system to extreme environmental factors that, depending on their intensity and duration, may cause significant changes in the system (Nilsen & Orcutt, 1996; Godbold, 1998). Abiotic stresses cause losses worth hundreds of million dollars each year due to reduction in crop productivity and crop failure. These stresses cause water reduction and osmotic changes in the cellular milieu, suppress the activities of cellular molecules, and can result in reduced growth and extensive losses in agricultural production (Xiogn et al., 2002). In response to these stress factors, various genes are unregulated, which can mitigate the effect of stress and lead to adjustment of the cellular milieu and plant tolerance. Abiotic stress in fact is the principle cause of crop failure worldwide, dipping average yield for most major crops by more than 50% (Eshghi et al., 2010). Plant growth and productivity is adversely affected by nature's wrath in the form of various abiotic and biotic stress factors. Plants are frequently exposed to a plethora of stress conditions such as low temperature, salt, drought, flooding, heat, oxidative stress and heavy metal toxicity. These stresses may induce the production of compounds that are structurally and biologically different from constitutive compounds (Tharayil et al., 2011). Among the stresses, temperature stress act as an abiotic stress factor that has a strong impact on the survival, growth, reproduction and distribution of plants in large area of the world (Boyer, 1982). Each plant has its unique set of temperature requirements, which are optimum for its proper growth and development. Every single plant is characterized by a certain genetically fixed level of resistance to low temperatures, which reduces its metabolic activity. This level of resistance can vary among individual plants and species.

A numerous research works has been carried out worldwide with low temperature stress on rice crop. Exposure to low temperatures is of primary concern during the seedling and reproductive stages. Seedlings subjected to prolonged exposure (i.e., several days to weeks) can exhibit necrosis and mortality while shorter or intermittent exposure often leads to yellowing (chlorosis) and stunting (Kim et al., 2012). Compared to other cereal crops such as wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*), rice is much more sensitive to low temperature as a result of its tropical origin (Cruz et al., 2004). As reported by Tuteja et al. (2012) low temperature at the seedling stage can result in poor germination, stunted seedlings, yellowing or withering, and reduced tillering. At lower temperatures, stress tolerance can be induced by exposure to reduced temperature and this is known as chilling tolerance and/or cold acclimation.

Chilling has been known to severely inhibit plant reproductive development in many crop plant species such as rice displaying sterility when exposed to chilling temperature during anthesis (Jiang et al., 2002). Chilling tolerance is the ability of a plant to tolerate low temperatures (0-15 ^{0}C) without injury or damage (Somerville, 1995), while cold acclimation is a enhanced tolerance to the physical and physicochemical vagaries of freezing stress (Thomashow, 1999). The chilling effect is manifested by physiological perturbations, generally called low-temperature injury (Yan et al., 2010; Zhang et al., 2010).The reduction in seedling growth of rice due to low temperature is one of the major problems in tropical and subtropical areas. However, the occurrence of low temperature stress during the early growth stages of rice inhibits seedling establishment, eventually leads to non-uniform crop maturation and dramatically reduce its production (Aghaee et al., 2011). As the cold environment has numerous adverse effects on raising rice seedling as well as on rice production, we should screen out cold stress tolerant rice variety or varieties suitable for the boro season cultivation under prevailing temperature (around 15 ^{o}C) in Bangladesh. Therefore, the research work had been carried out to find out suitable cold tolerant rice varieties for boro season to manage seasonal cold environment in Northern Bangladesh.

Materials and Methods

The research field of the Department of Agricultural Chemistry, HSTU, Dinajpur located in 25.13^{o}N latitude and 88.23^{o}E longitude and at an elevation of 34.5 m above the mean sea level. This site belongs to AEZ-1 (Agro-ecological Zone-1) categorized as Himalayan Piedmont Plain as classified by UNDP and FAO (1988). The experimental field was a medium high land having sandy loam soil with soil pH 6.0.

The experiment was followed a randomized complete block design with three replications. Seven HYV rice variety (V_1: BR-11; V_2: BR-16; V_3: BRRI dhan28; V_4: BRRI dhan29; V_5: BRRI dhan50; V_6: BINA dhan7; and V_7: Hybrid SL-8H) was taken in the experiment. The whole area was divided into three blocks and each block was divided into seven units maintaining plot dimension to 2 × 2 m. The plot to plot distance was 30 cm. The seeds of selected seven rice cultivars were sown in previously prepared seedbed. The sprouted seeds were placed in individual plots without any biasness at the rate of 330 g per plot. Proper irrigation was made as and when needed. To make the experimental plot weed free, weeding was done at 20 and 27 days after sowing (DAS).

The data regarding various relevant parameters were collected accordingly during the experimental period. The sample collected for fresh weight determination was used for measuring the dry weight of shoot and root of rice seedlings. The shoot and root portions of samples were oven (Model: LDO150N) dried at 60 ^{o}C for 72 hours separately followed by drying at room temperature for 72 hours. After complete drying, the dried root and shoot of rice seedlings were weighed and averaged carefully. The root and shoot length of rice seedlings was measured by using scale having millimeter (mm) divisions for accurate determination. The shoot length was determined by placing measuring scale at the transitional zone of root and shoot toward top of the leaves. For measuring root length, the whole seedling was uprooted with the help of khurpi keeping the root zone undisturbed. Then the collected root zone was washed carefully with running water so that all roots remained intake. Then the measurement of root length was made by placing the scale at transitional zone of root and shoot towards root apex.

The germination percentage was determined at field level at the initial stage of the experiment. This was done by counting the number of germinated seeds and total number of seed within a marked area. This counting was done after 10 days of first germination (DAG). The mortality rate was first calculated using following formula.

Mortality rate =100- $(\frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100)$

Results and Discussion

Effect on shoot length

The growth rate of shoot also depends on various environmental factors. Air temperature is one of them, which significantly controls the range of plant growth. Each plant has its optimum growth temperature but 18-21 ^oC temperature is considered as optimum for most of the temperate plants for subsequent growth and development (Junttila, 1986). This experimental result showed that the growth rate of selected rice cultivars varied due to change of prevailing air temperature during the experimental period (Table 1). At 12 DAS, the highest shoot length was measured in V_2 (3.5 cm) and the lowest shoot length was observed in V_5 (2.16 cm). The V_2 cultivar also had highest shoot length at 19 DAS. The V_2 cultivar showed the highest shoot length at 12 DAS, 19 DAS, 26 DAS, and 33 DAS. However, the V_2 and V_7 rice cultivars showed better performance against low temperature (below 15 ^oC) during the experimental period. It was found that the growth of shoot was increased with increasing temperature and vice-versa. The variation among the cultivars might be due to their genetical make up. Similar result was obtained by Sikder and Paul (2010) in wheat and Sarker et al. (2013) in rice.

Table 1. Shoot length of seven rice cultivars during experiment time.

Varieties	12 DAS	19 DAS	26 DAS	33 DAS
V_1	3.40 ab	4.69 ab	6.56 a	10.59 a
V_2	3.50 a	4.96 a	6.23 a	9.44 a
V_3	2.71 cde	3.53 cd	6.26 a	9.87 a
V_4	2.46 de	2.98 d	5.33 a	8.18 a
V_5	2.16 e	4.05 bc	5.31 a	7.84 b
V_6	2.87 bcd	4.43 ab	5.77 a	9.05 a
V_7	3.27 abc	4.42 ab	5.78 a	9.56 a
LSD	0.56	0.66	1.26	2.48
CV %	10.91	9.07	12.21	15.39

Mean followed by the same letter(s) did not differ significantly at 5 % level by DMRT.
V_1: BR-11; V_2: BR-16; V_3: BRRI dhan28; V_4: BRRI dhan29; V_5: BRRI dhan50; V_6: BINA dhan7; and V_7: Hybrid SL-8H.

Effect on root length

For subsequent growth and development of plants, there should have optimum environmental temperature as the activation of various functional enzymes needs proper temperature along with other requirements. Proper root growth of maximum plant species requires 27-30 ^oC soil as well as environmental temperature (Drennan & Nobel, 1998). Any deviation from this optimum level of temperature leads to the decrease root growth. In this study, the root length of selected rice cultivars showed no significantly varied which is shown in Table 2.

At 12 DAS, the highest root length was measured in V_7 (3.56 cm) and the lowest root length (1.94 and 2.10 cm) at V_4 and V_5. V_7 cultivar showed highest performance at 19 DAS (3.95 cm). The root length values of V_1, V_3, V_4, V_5 and V_6 rice cultivars are statistically similar. At 26 and 33 DAS, all the varieties are statistically similar. The result of this study also showed that the root growth of selected rice cultivars was increased with increasing environmental temperature and vice-versa. Similar research finding was obtained by Barber et al. (1988). Lopushinsky and Max (1990) also concluded that the reduction in temperature depresses root growth.

Effect on shoot dry weight

The production of percent shoots dry weight decreased in response to low environmental temperature. Low temperature severely reduces the dry weight content of plant (Hnilickova et al., 2002). The genetical makeup of the cultivars might responsible for the variation in percent shoot dry weight obtained in a day. Plants having highest percent shoot dry weight are definitely lower temperature stress tolerate than the other cultivars. In Table 3, it is observed that dry shoot weight of seven rice varieties at seedling stage.

In this study, at 12 DAS, the highest value was showed in V_7 (13.23 cm) and lowest value wasV_3 and V_5 4.833 and 5.633 cm, respectively). At 19 DAS the highest value was showed in V_1 (22.20 cm) and V_2, V_6, V_7 (19.27, 16.00 and 19.67 cm, respectively). The lowest value was 12.77, 14.57 and 13.03 cm in V_3, V_4 and V_5, respectively. At 26 DAS highest value was showed in V_1, V_2 and V_7 (34.00, 32.27 and 34.63 cm, respectively). The lowest value was in V_3 V_2, V_3, V_4, V_5 and V_6 (24.07, 22.10, 24.33 and 25.73 cm, respectively).

Table 2. Root length of seven rice cultivars at seedling stage during experiment time.

Varieties	12 DAS	19 DAS	26 DAS	33 DAS
V_1	2.32 ab	2.90 ab	3.60 a	2.99 a
V_2	2.57 ab	2.72 b	3.37 a	2.53 a
V_3	2.58 ab	2.87 ab	4.15 a	2.81 a
V_4	1.94 b	3.26 ab	3.66 a	2.45 a
V_5	2.10 b	2.97 ab	3.20 a	2.21 a
V_6	2.97 ab	2.83 ab	3.91 a	2.63 a
V_7	3.56 a	3.95 a	4.09 a	2.75 a
LSD	1.21	1.06	1.73	0.766
CV %	26.75	18.70	26.66	16.67

Mean followed by the same letter(s) did not differ significantly at 5 % level by DMRT
V_1: BR-11; V_2: BR-16; V_3: BRRI dhan28; V_4: BRRI dhan29; V_5: BRRI dhan50; V_6: BINA dhan7; and V_7: Hybrid SL-8H.

Table 3. Dry shoot weight (g) of seven rice cultivars at seedling stage during experimental time.

Varieties	12 DAS	19 DAS	26 DAS
V_1	9.200 bc	22.20 a	34.00 a
V_2	9.867 b	19.27 ab	32.27 a
V_3	4.833 d	12.77 b	24.07 b
V_4	9.137 bc	14.57 b	22.10 b
V_5	5.633 d	13.03 b	24.33 b
V_6	7.100 cd	16.00 ab	25.73 b
V_7	13.23 a	19.67 ab	34.63 a
LSD	16.39	5.651	12.08
CV %	2.45	6.69	6.051

Mean followed by the same letter(s) did not differ significantly at 5 % level by DMRT.
V_1: BR-11; V_2: BR-16; V_3: BRRI dhan28; V_4: BRRI dhan29; V_5: BRRI dhan50; V_6: BINA dhan7; and V_7: Hybrid SL-8H.

Effect on root dry weight

The effect of low temperatures on dry matter partitioning between shoot and roots is difficult to predict because temperature may affect directly water and nutrient uptake as well as other physiological and biochemical processes inside the plant body. The dry root weight of seven rice varieties at seedling stage in Table 4 showed that, at 12 DAS, the highest value was found in V_7 (24.80 cm), the lowest value was V_3 (10.07 cm), at 19 DAS, the highest value was showed in V_7 (42.50 cm) and V_2 respectively similar and lowest value was V_3, V_4, V_5, V_6 respectively (29.29, 33.20, 28.67, 28.60 cm) all the varieties are statistically similar. At 26 DAS, the highest value was showed in V_7 (49.43 cm), and lowest value wasV_3 and, V_5 respectively (20.73, 20.43 cm) all the varieties are statistically similar. However, the effect of low temperature on plant might be responsible for the lowering of percent root dry weight of selected rice cultivars. Similar result was obtained by Nagasuga et al. (2011), Engels (1994b) and Barta (1978). The genetical variations of the cultivars might be responsible for the variation in root dry weight percentage obtained in a day. Plants having highest percentage of root dry weight are definitely more low temperature stress tolerance than those of other cultivars.

Effect on dry biomass production

Table 5 shows that total dry biomass of seedling in different rice cultivars at different DAG. Most interestingly, V_7 plants showed the best performing cultivars among the tested varieties responding dry biomass production. Conversely, the V_3 cultivars showed very poor at low temperature at 12, 19, and 26 DAS total biomass tends to decrease by low temperature environment revealed by Sarker et al. (2013) and Kulchhum (2011).

Table 4. Dry root weight (g) of seven rice cultivars at seedling stage during experiment time.

Varieties	12 DAS	19 DAS	26 DAS
V_1	18.37 bc	26.40 b	35.30 bc
V_2	17.77 bc	40.17 a	42.38 ab
V_3	10.07 d	29.40 b	20.73 d
V_4	20.17 b	33.20 b	39.57 b
V_5	14.27 cd	28.67 b	20.43 d
V_6	21.10 ab	28.60 b	29.27 c
V_7	24.80 a	42.50 a	49.43 a
LSD	12.40	10.75	13.40
CV %	4.306	6.252	7.45

Mean followed by the same letter(s) did not differ significantly at 5 % level by DMRT.
V_1: BR-11; V_2: BR-16; V_3: BRRI dhan28; V_4: BRRI dhan29; V_5: BRRI dhan50; V_6: BINA dhan7; and V_7: Hybrid SL-8H.

Table 5. Biomass (g) of seven rice cultivars at seedling stage during experiment time.

Varieties	12 DAS	19 DAS	26 DAS
V_1	0.029	0.055	0.063
V_2	0.028	0.059	0.068
V_3	0.015	0.042	0.044
V_4	0.023	0.046	0.051
V_5	0.020	0.042	0.045
V_6	0.028	0.045	0.055
V_7	0.030	0.054	0.081

V_1: BR-11; V_2: BR-16; V_3: BRRI dhan28; V_4: BRRI dhan29; V_5: BRRI dhan50; V_6: BINA dhan7; and V_7: Hybrid SL-8H.

Effect on seed mortality

Seeds require a certain temperature in order to germinate. Each plant has a specific optimum and a range within which germination will occur. The closer the temperature is to optimum the quicker germination will occur. The seeds of maximum rice cultivars germinate at around 25°C (Fujino et al., 2008). Any deviation from this optimum temperature (low and high temperature stress) decreases the germination rate. However, the impact of temperature stress on plants depends upon the genetical make up of respective plant species. This study period was characterized by the air temperature below 15 °C. A significant variation was observed in seed germination percentage of selected rice cultivars which is shown in Figure 1. The highest mortality percentage was recorded in V_1 and V_5 (31.56 and 31.67%). The lowest seed germination percentage was found in V_7 (11.33%). The cultivar having highest seed germination percentage is lower temperature stress tolerate than other cultivars. Similar low temperature effect on mortality rate was observed by Guan *et al.* (2009) and Schonbeck and Egley (1980).

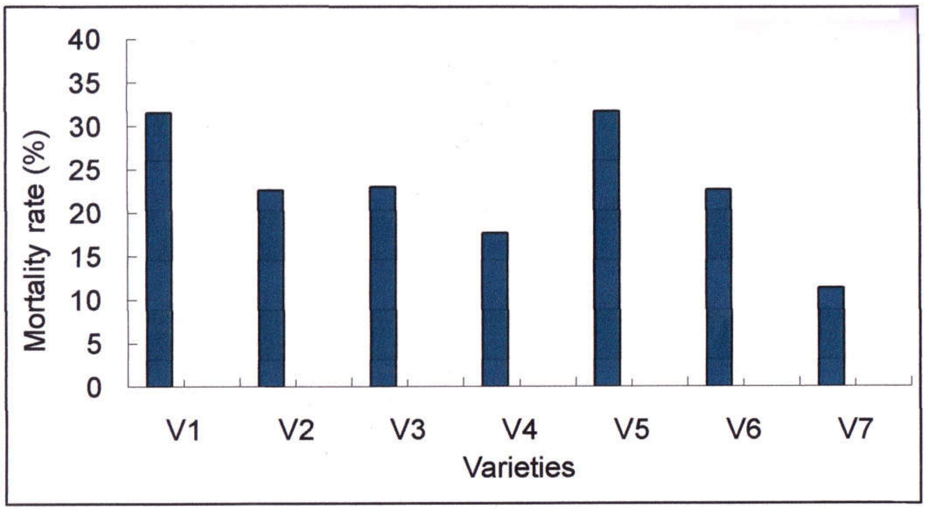

Fig. 1. Mortality rate of seven rice varieties at seedling stage. V_1: BR-11; V_2: BR-16; V_3: BRRI dhan28; V_4: BRRI dhan29; V_5: BRRI dhan50; V_6: BINA dhan7; and V_7: Hybrid SL-8H.

Conclusion

The present study indicated that growth and other phonological parameters activities of rice seedling of seven selected rice cultivars were influenced markedly due to low temperature stress. Based on the various parameters studied, it can be concluded that the performance of V_7 (Hybrid SL-8) and among the HYV cultivars, the performance of V_7 (Hybrid SL-8) was better during experimental period with a low environmental temperature of below 15 °C.

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