



## Polyethylene Glycol (PEG) Induced Drought Stress on Five Rice Genotypes at Early Seedling Stage

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### ABSTRACT

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Drought is a major abiotic stress that restricts the production of crops throughout the world; Bangladesh is not an exception to this. Rice (*Oryza sativa* L.) as a drought-sensitive crop shows considerable varietal differences towards this environmental stress. With an aim to identify drought tolerant rice variety an experiment was conducted at the Growth Chamber of Plant Physiology Laboratory in the Department of Crop Botany, Bangladesh Agricultural University. Purple rice, Binadhan-8, Binadhan-19, BRRI dhan66 and BRRI dhan71 were evaluated for their drought tolerance during germination and early seedling growth stage. The varieties were tested against four levels of drought stress imposed by Polyethylene glycol 6000 (PEG-6000) @ 0, 5, 10 and 15%. The experiment was laid out in a complete randomized design with three replications. The results showed a gradual decrease in values of all the five varieties towards increasing drought stress of all the considered parameters. The difference in values between control and 5% PEG concentration was not so noticeable but at the highest stress levels the change was dramatic. From the experiment, it can be seen that Purple rice, Binadhan-8 and BRRI dhan66 were considerably tolerant in germination stage towards increasing concentration of PEG and showed better performance in all the considered parameters compared to the other varieties. Overall, these tolerant and sensitive genotypes might be used in the further genetic improvement of the same and different crops.

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### Introduction

Rice (*Oryza sativa* L.), a crop of Gramineae family is the most important human food crop in the world, directly feeding more people than any other crop. Rice is considered to be drought susceptible as it exhibits serious deleterious effects when exposed to water stress at critical growth stages, especially at the reproductive stage (Suriyan *et al.*, 2010). As a result drought stress is affecting about 50% of rice production in the world (Mostajean and Rahimi-Eichi, 2009). The percentage of drought affected land has approximately doubled over time, affecting grain yield and the quality of various crops resulting in food shortages in the world (Isendahl and Schmidt, 2006). Global climate change and increasing world populace augmented with drought stress are making the situation more serious day by day to cope with the ever-growing food, feed and shelter needs of human beings (HongBo *et al.*, 2005; Akram, 2007). Among the cereal crops, rice is particularly more

sensitive to water stress especially at critical growth stages such as panicle initiation, anthesis and grain filling (Tao *et al.*, 2006; Yang *et al.*, 2008). Drought stress causes various physiological changes in plants that may include, reduction in PAR, photosynthetic rate, transpiration rate, stomatal conductance, pigment degradation and relative water content (RWC) that decreases water use efficiency (WUE) and growth reduction (Chaves and Oliveira, 2004; Cattivelli *et al.*, 2008; Tuna *et al.*, 2010). Plants response to water stress is much complex that includes the adaptation of various mechanisms when they encounter drought stress at various growth stages (Levitt, 1962; Jones, 2004). Even the behavior of genotypes within a species is also different when exposed to water stress. There has been reports of water stress affecting seed germination and early seedling growth that are potentially the most critical stages of rice (Ahmad *et al.*, 2009). It has also been found that drought stress impairs seed germination (Swain *et al.*, 2014) and seedling height

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(Sokoto and Muhammad, 2014) of rice. However, the sensitivity of rice to drought stress varies with timing, duration, and severity of water unavailability, variety and the growth stage of rice (Sokoto and Muhammad, 2014). So, one of the strategies to abate drought stress is the selection of a genotype expressing comparatively better drought tolerance (Suriyan *et al.*, 2010). In order to proceed with the idea, understanding the mechanism of plant responses to water deficit conditions and studying the performance of new genotypes under water stress with the objective of improving crop performance in the drought prone areas of the world. Seed germination and seedling development are very important for the early establishment of plants under stress conditions. It is a recognized truth that tolerance at the mature stage is expressed by the tolerance at the early stage of the plant (Roy *et al.*, 2018). Thus, the election of varieties under water stress conditions through rapid and uniform germination is crucial during early seedling establishment. Therefore, selecting was rice varieties under drought stress conditions through proper screening, which will clearly distinguish drought-susceptible varieties from drought-tolerant varieties (Swamy *et al.*, 2012). Therefore, germination and seedling growth traits and their response to drought can be useful for the selection of drought-tolerant rice varieties. Hence, the present study was conducted with the aim of studying the impacts of drought stress at the early vegetative growth stage of rice cultivars.

### Materials and Methods

The experiment was conducted at the Growth Chamber of Plant Physiology Laboratory in the Department of Crop Botany, Bangladesh Agricultural University. Five rice varieties were used in the experiment for screening based on germination as affected by different levels of drought. From the five varieties, BRRI dhan66 and BRRI dhan71 were collected from Bangladesh Rice Research Institute (BRRI), Binadhan-8 and Binadhan-19 were collected from Bangladesh Institute of Nuclear Agriculture (BINA) and Purple rice was collected from Sundorganj, Gaibandha. The two factorial germination tests were set up in Completely Randomized Design (CRD) with three replications. Factor A was five varieties (Purple rice, Binadhan-8, Binadhan-19, BRRI dhan66 and BRRI dhan71) while factor B was four drought treatments (0, 5%, 10% and 15% PEG). Therefore, 60 Petri dishes were taken for the experiment. The different drought levels were obtained by dissolving poly-ethylene glycol 6000 (PEG 6000) in distilled water. The control i.e. 0 was maintained using distilled water only. At first, seeds were sterilized with 5% sodium hypochlorite for 30 minutes and washed thoroughly with distilled water. These seeds were then soaked in water and were imbibed for 24 h and then the seeds were placed in Petri

dishes containing filter paper to allow them to germinate. Then twenty-five seeds of each variety were set up in a Petri dish and were treated with respective treatment solutions and distilled water. Firstly, 5 ml of PEG solution was added in each Petri dish splitting twice in a day (First two days) and then 5 ml solution was used once in a day for the later days. Each treatment was performed three times and was allowed to germinate at around 25°C. Germination percentage, germination stress tolerance index (GSTI), vigor index, root length and root length stress tolerance index (RLSI), shoot length and shoot length stress tolerance index (SLSI), fresh weight stress tolerance index (FSTI), dry weight stress tolerance index (DSTI), root number and leaf number were determined in all the treatments.

### Percent germination

After 10 days, the final count of sprouted and germinated seeds was done and the germination percentage of the final day was calculated by the following formula (Sagar *et al.*, 2019):

$$\text{Germination}(\%) = \frac{SG}{ST} \times 100 \dots\dots\dots (1)$$

where, SG = total number of seeds germinated, and ST= total number of seeds taken for germination.

### Physiological indices

The number of sprouted and germinated seeds was counted daily commencing from 1<sup>st</sup> day till 10<sup>th</sup> day. To calculate the germination stress tolerance index (GSTI), promptness index (PI) was estimated using following formulae (Ashraf *et al.*, 2008; Sagar *et al.*, 2019):

$$PI = (nd1 \times 1.0) + (nd2 \times 0.75) + (nd3 \times 0.50) + (nd4 \times 0.25) \dots\dots\dots (2)$$

where, nd1, nd2, nd3 and nd4 = number of seeds germinated on the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> day, respectively.

Germination stress tolerance index (GSTI) was calculated in terms of percentage as follows:

$$GSTI = \frac{PIS}{PIC} \times 100 \dots\dots\dots (3)$$

where, PIS and PIC designate PI of stressed and control seeds, respectively.

Similarly, root and shoot length stress tolerance index (RLSI and SLSI), and fresh and dry weight stress tolerance indices (FSTI and DSTI) were calculated according to the following formulae:

$$RLSI = \frac{RLSs}{RLCc} \times 100 \dots\dots\dots (4)$$

$$SLSI = \frac{SLSs}{SLCc} \times 100 \dots\dots\dots (5)$$

$$FSTI = \frac{SLCc}{FWCc} \times 100 \dots\dots\dots (6)$$

$$DSTI = \frac{DWSs}{DWCc} \times 100 \dots\dots\dots (7)$$

where, RL, SL, FW, DW designate root length (cm), shoot length (cm), fresh weight (mg), dry weight (mg) respectively and subscript S and C associated with each equation designate stressed and control seedlings, respectively.

*Rate of germination*

Rate of germination (RG) was calculated as described in the following formula (Khodarahmpour, 2011 and Sagar, 2017):

$$RG = \frac{\sum Gc1/dc1 + Gc2 - Gc1/dc2 + \dots + Gcn - Gc(n-1)/dcn}{n} \dots\dots\dots(7)$$

where, Gc1, Gc2 and Gcn designate the cumulative seed germination 1st, 2nd and nth counts, respectively, and dc1, dc2 and dcn designate days to 1st, 2<sup>nd</sup> and nth counts, respectively from the date to seed set for germination.

*Vigor index*

Vigor index was calculated as described in the following formula (Sagar *et al.*, 2019):

$$VI = \frac{SL}{GE} \dots\dots\dots (8)$$

where, SL and GE designate seedling length (cm) and percent germination, respectively.

*Shoot and root length*

Shoot and root length of all seedlings from each replication were measured on the final day of harvest (10<sup>th</sup> day). Shoot length was measured from the shoot base to the tip of the longest leaf and root length was measured from the root base to the root tip.

*Root and shoot, fresh and dry weight*

Roots and shoots were separated from the seedlings immediately after harvest and fresh weight of 10 plants per Petri dishes was recorded. After recording fresh weight, seedlings were oven dried for 72 hrs and dry weight was recorded.

*Root and leaf number*

Root and leaf numbers were counted on the final day of harvest. Five seedlings from each Petri dish were taken for counting average root and leaf number.

*Statistical analysis*

The collected data were analyzed statistically following Completely Randomized Design by Statistix-10 computer package program. Data analysis was done using analysis of variance (ANOVA) and p<0.05 was considered as the significance level. The multiple comparisons of treatment means were done by LSD<sub>0.05</sub> test.

**Results**

*Germination and vigor indices*

In the life cycle of plant germination is one of the most critical periods. The effect of increasing concentration of PEG during seed germination and the response of varieties to the increasing concentrations was measured to determine the tolerance of rice genotypes under water deficit conditions. It was observed that increasing concentration of PEG seed germination reduced and different PEG concentrations had a significant effect on percent seed germination of different rice genotypes (Table 1). The maximum percentage of germination was found in the control condition and the minimum was at 15% PEG (Table 1). In table 1, the results showed that the germination percentage was decreased with the increase of PEG concentrations. However, the lowest germination value was showed in variety BRRI dhan71 when the highest PEG concentration rate which followed by Binadhan-19. Differential tolerance regarding, the germination percentages 69.67, 84.33, 54.67, 69.00 and 25.33 was observed in the varieties of Purple rice, Binadhan-8, Binadhan-19, BRRI dhan66 and BRRI dhan71 when used at the highest PEG concentration, respectively. In stress conditions, the highest rate of germination was observed at the control and the lowest one 15% PEG concentration. The highest rate of germination was recorded in BRRI dhan66 (10.30) and the lowest one BRRI dhan71 (1.42) at the concentration of 0 and 15% PEG, respectively. In the case of the vigor index, similar results were found in BRRI dhan71 variety while the highest and lowest vigor index 1999.0 and 243.1 was observed when the same PEG concentration, respectively. The highest vigor index (1100.9) was observed in Binadhan-8 and the lowest one (243.1) in BRRI dhan71 at the stress of 15% PEG concentration (Table 1).

*Vegetative growth parameters*

*Root and shoot length*

Root and shoot length also decreased as the PEG concentration increased and their length for different rice varieties were significantly affected by drought stress (Table 2 & Fig. 1). The maximum root length (12.73 cm) was observed in control condition and the minimum (2.96 cm) was observed in highest PEG concentration (Table 2). The results showed that root length was

observed 10.10 cm (Purple rice), 7.61 cm (Binadhan-8), 8.10 cm (Binadhan-10), 9.13 cm (BRRi dhan66) and 10.85 cm (BRRi dhan71) at 5% PEG concentration, respectively and at 10% and 15% PEG concentration the highest root length was observed in BRRi dhan66 (8.89 cm and 7.69 cm) and the lowest at BRRi dhan71 (4.71 cm and 2.96 cm), respectively (Table 2). Similarly shoot length decreased with the increase of drought level. The highest

shoot length (10.39 cm) was recorded at control and the lowest (1.57 cm) was recorded at 15% PEG concentration (Table 2). However, from table 2 we can see that the shoot length of all varieties was considerably good at 5% PEG concentration. In a table also showed, the shoot length was highest in BRRi dhan66 (5.51 cm) and lowest in BRRi dhan71 (1.57 cm) at 15% PEG concentration conditions (Table 2).

Table 1: Effect of water stress and genotypes on germination properties of rice

Genotype×%PEG	Germination (%)	Rate of germination	Vigor index
Purple rice × 0	84.33 e	8.24 cd	1745.5 bc
Purple rice × 5	84.00 e	7.71 de	1150.7 h
Purple rice × 10	80.67 f	6.05 gh	1143.8 h
Purple rice × 15	69.67 g	5.22i	762.8 j
Binadhan-8×0	96.67 a	9.37 b	1472.8 ef
Binadhan-8×5	89.33 bc	7.59 de	1432.3 ef
Binadhan-8×10	85.67 de	5.20i	1245.5 gh
Binadhan-8×15	84.33 e	5.06i	1100.9 hi
Binadhan-19 × 0	87.33 cd	7.26 ef	1540.9 de
Binadhan-19 × 5	84.67 de	6.72fg	1337.6 fg
Binadhan-19 ×10	65.67 h	3.70 j	337.3 k
Binadhan-19 ×15	54.67 i	3.13jk	329.9 k
BRRi dhan66 ×0	99.00 a	10.30 a	1783.1 bc
BRRi dhan66 ×5	92.00 b	8.45 c	1638.2 cd
BRRi dhan66×10	79.00 f	6.16 gh	1111.2 h
BRRi dhan66 ×15	69.00 g	5.70 hi	960.8 i
BRRi dhan71 ×0	91.67 b	7.19ef	1999.0 a
BRRi dhan71 ×5	91.33 b	6.73 fg	1860.5 ab
BRRi dhan71 ×10	55.00 i	2.84 k	285.6 k
BRRi dhan71 ×15	25.33 j	1.42 l	243.1 k
Level of Sig.	*	*	*

PEG = Polyethylene glycol; In a column, values having similar letter(s) do not differ significantly at 5% level of probability by LSD<sub>0.05</sub> test. \* indicates significant at 5% level of significance

Table 2: Effect of water stress and genotypes on seedling growth of rice

Genotype×%PEG	Root Length (cm)	Shoot Length (cm)	Root Fresh Weight of 10 Plants (mg)	Root Dry Weight of 10 Plants (mg)	Shoot Fresh Weight of 10 Plants (mg)	Shoot Dry Weight of 10 Plants (mg)	Leaf Number Plant <sup>-1</sup>	Root Number Plant <sup>-1</sup>
Purple rice × 0	10.35 b	8.47 bc	625.0 cd	79.67 c	532.00 c	81.00 f	2.87 a	6.03 ij
Purple rice × 5	10.10 bc	8.29 c	565.3 cde	73.00 d	431.67 h	66.67 g	2.17 bc	6.83 fg
Purple rice × 10	8.34 def	5.19 def	318.7 fg	54.33 g	127.00 m	39.00 i	1.43 g	4.97 k
Purple rice × 15	6.79 hi	4.91 def	268.7 fgh	46.33 h	109.37 n	26.33 k	1.30 gh	4.17 l
Binadhan-8×0	7.80 efgh	10.39 a	1463.0 a	122.67 a	941.33 a	139.67 a	2.33 b	9.4 ab
Binadhan-8×5	7.61 fgh	8.42 c	1230.7 b	121.33 a	418.33 i	124.33 b	2.10 bc	9.07 ab
Binadhan-8×10	6.96 ghi	5.96 d	269.3 fgh	65.33 e	214.33 j	51.00 h	1.70 ef	6.1 hij
Binadhan-8×15	6.35 i	4.46 efg	255.7 fgh	52.33 g	126.67 m	39.00 i	1.43 g	7.7 de
Binadhan-19 × 0	9.09 cd	9.68 ab	667.3 cd	75.33 d	485.33 d	117.00 c	2.27 bc	7.0 efg
Binadhan-19 × 5	8.10 defg	9.28 abc	464.0 def	55.33 fg	446.33 g	113.67 d	2.07 cd	8.33 cd
Binadhan-19 ×10	7.86 efgh	4.00 fgh	290.3 fgh	23.33 i	38.67 o	14.67 l	1.13 hi	5.1 k
Binadhan-19 ×15	3.95 jk	2.77 hi	96.0 hi	22.33 i	25.67 p	4.00 mn	1.00 i	5.27 k
BRRi dhan66 ×0	9.90 bc	8.69 bc	755.3 c	99.33 b	645.00 b	124.00 b	2.13 bc	6.07 hij
BRRi dhan66 ×5	9.13 cd	8.57 bc	707.0 c	73.67 d	433.00 h	111.00 d	2.10 bc	9.67 a
BRRi dhan66×10	8.89 cde	5.44 de	623.3 cd	58.33 f	175.67 k	32.33 j	1.83 de	6.77 fgh
BRRi dhan66 ×15	7.69 efgh	5.51 de	351.0 efg	52.67 g	123.67 m	31.00 j	1.37 gh	7.17 ef
BRRi dhan71 ×0	12.73 a	10.03 a	672.7 cd	67.67 e	476.67 e	91.67 e	2.70 a	6.37 ghi
BRRi dhan71 ×5	10.85 b	8.68 bc	364.0 efg	66.67 e	465.00 f	64.00 g	2.17 bc	8.77 bc
BRRi dhan71 ×10	4.71 j	3.31 gh	149.3 ghi	21.33 i	152.67 l	5.00 m	1.53 fg	5.63 jk
BRRi dhan71 ×15	2.96 k	1.57 i	5.0 i	2.67 j	13.67 q	1.67 n	0.67 j	2.17 m
Level of Sig.	*	*	*	*	*	*	*	*

PEG = Polyethylene glycol; In a column, values having similar letter(s) do not differ significantly at 5% level of probability by LSD<sub>0.05</sub> test; \* indicates significant at 5% level of significance

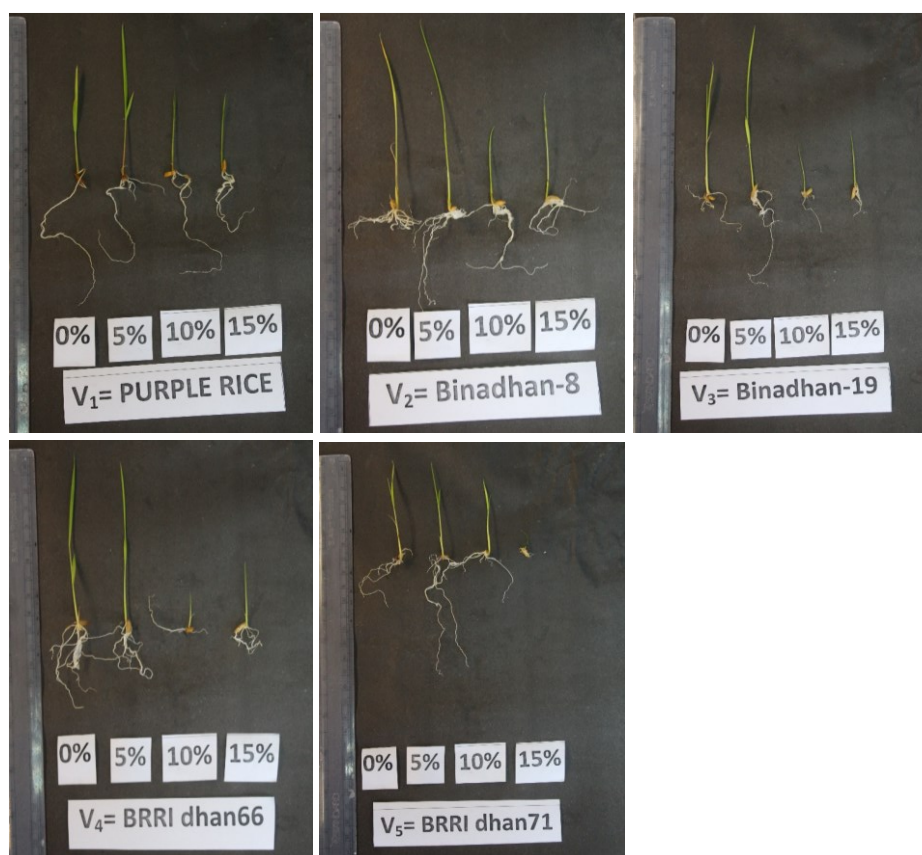


Figure 1. Morphological differences among five rice genotypes at different drought stress levels (0, 5, 10 and 15% PEG) during final harvest of plants.

#### Root and leaf number

From table 2, we can see that leaf and root number decreased with increasing PEG concentration but the differences in mean value were very low. The maximum value of leaf and root number at 15% PEG concentration was observed in Purple rice (1.30 and 4.17) and minimum at BRRI dhan71 (0.6667 and 2.17), respectively.

#### Root and shoot fresh weight

The root and shoot fresh weights (RFW) of different rice varieties were influenced by drought stress. In all the varieties, the fresh weight of roots decreased due to the increased PEG concentration (Table 2). The results revealed that, the highest root fresh weight (1463.0 mg) was observed in a variety Purple rice at control conditions whereas the lowest one (5.0 mg) was found in BRRI dhan71 at 15% PEG concentration conditions. At 15% PEG concentration conditions, the maximum RFW was recorded in BRRI dhan66 (351.0 mg) and the minimum (5.0 mg) was found in BRRI dhan71 (Table 2). On the other hands, Purple rice (268.7 mg), Binadhan-8 (255.7 mg) and BRRI dhan66 (351.0 mg) also performed better at highest drought stress level (Table 2). In table 2, the results revealed that maximum SFW was showed

in Binadhan-8 (941.33 mg) at control condition and minimum was in BRRI dhan71 (13.67 mg) at 15% PEG concentration conditions. Whereas, the shoot fresh weight performance of five varieties were recorded 109.37, 126.67, 25.67, 123.67 and 13.67 mg at the highest stress level of drought conditions, respectively.

#### Root and shoot dry weight (mg)

The root and shoot dry weight of different rice varieties were influenced by drought stress conditions. The root dry weight (RDW) was decreased when PEG concentration increased (Table 2). The RDW was maximum (122.67 mg) in controlled conditions and the minimum in highest drought stress level. At the highest drought level (15% PEG), the maximum root dry weight (RDW) was found in BRRI dhan66 (52.67 mg) and minimum one (2.67 mg) in BRRI dhan71, respectively (Table 2). Another way, in all varieties, the shoot dry weight (SDW) decreased due to increasing the PEG concentrations and the highest SDW (139.67 mg) was recorded in control conditions and the lowest one (1.67 mg) in 15% PEG concentration conditions. At 15% PEG concentration conditions, the highest SDW was found in Binadhan-8 (39.00 mg) and the lowest (1.67 mg) was found in BRRI dhan71 (Table 2).

## Stress Indices

### Germination stress tolerance index (GSTI)

The germination stress tolerance index (GSTI) showed a similar decrease pattern with increase PEG concentration (Fig. 2). At 5% PEG concentration the highest GSTI was observed in BRRI dhan71 (99.62) and the lowest in BRRI dhan66 (88.37) whereas at 10% and 15% PEG concentration the highest was in Purple rice (73.23 and 70.97) and lowest in BRRI dhan71 (23.14 and 39.09), respectively (Fig. 2).

### Root and shoot length stress index (RLSI and SLSI)

In case of stress index, RLSI decreased with the increase of drought stress level (Fig. 3). In all PEG concentrations

the highest RLSI were recorded in Binadhan-8 and the lowest were recorded in BRRI dhan71 (Fig. 3). The RLSI of all five varieties at highest drought stress level was recorded 65.42, 86.51, 44.37, 62.50 and 21.77, respectively (Fig. 3). In case of SLSI, the varieties showed gradual decrease with the increase of PEG concentration (Fig. 3). At 5% PEG concentration, the maximum SLSI value was recorded in BRRI dhan66 (106.18) which was statistically similar with BRRI dhan71 and Binadhan-19 and the minimum SLSI was Binadhan-8 (98.28). At highest drought stress level Purple rice, Binadhan-8 and BRRI dhan66 showed better performance while BRRI dhan71 was affected mostly.

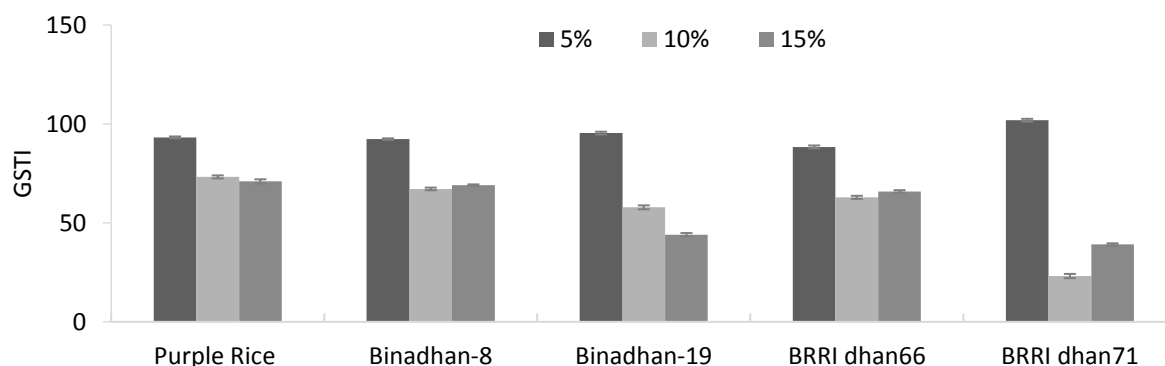


Figure 2. Effect of PEG on GSTI different varieties of rice. Vertical bars are SEM (n=3).

### Root and shoot fresh weight stress tolerance index (RFSTI and SFSTI)

The result indicated that as the drought level increased, root fresh weight stress tolerance index decreased. The RFSTI of rice seedlings exposed to increase of PEG concentrations, revealed a noticeable decrease (Fig. 3). The RFSTI value at 5% PEG concentration was maximum (229.85) and minimum at 15% PEG concentration conditions. The RFSTI values at 15% PEG concentration was maximum in BRRI dhan66 (50.49) and minimum in BRRI dhan71 (1.37), respectively. The values of RFSTI for Purple rice, Binadhan-8 and Binadhan-19 were recorded 47.52, 20.77 and 33.07, respectively. Similarly, shoot fresh weight stress tolerance index (SFSTI) also decreased with the increase in drought level (Fig. 3). Purple rice (123.25) showed the highest SFSTI at 5% PEG concentration and BRRI dhan71 (2.87) had the minimum value at 15% PEG concentration. At the highest stress level (15% PEG), Purple rice (25.34) had showed the highest SFSTI and BRRI dhan71 (2.87) was observed in lowest value (Fig. 3).

### Root and shoot dry weight stress tolerance index (RDSTI and SDSTI)

Root dry weight stress tolerance index (RDSTI) also decreased with the increase in drought level (Fig. 3). The

highest RDSTI (137.67) was recorded at 5% PEG concentration conditions and the lowest (3.81) were recorded at 15% PEG concentration conditions (Fig. 3). However, at 15% PEG concentration the maximum value of RDSTI was recorded in BRRI dhan66 (137.67), and the minimum in BRRI dhan71 (3.81), respectively. In case of SDSTI, the maximum value at highest stress level was recorded in Purple rice (31.14) and lowest in BRRI dhan71 (3.63), respectively at 15% PEG concentration conditions. The result indicated that as the drought level increased, SDSTI remarkably decreased.

## Discussion

Drought stress significantly affects in plants at seedling, pre-flowering and post-flowering stages of development ultimately affecting yield (Kebede *et al.*, 2001; Khaton *et al.*, 2016). Drought is an alarming issue because of its detrimental capacity of limiting crop production worldwide and with time becoming increasingly severe in Bangladesh. The scarcity of water is a major constraint for about 50% rice production area of the world (Mitcell *et al.*, 1998). Rice is the most important cereal crop in the world, as it used as a staple food in most countries of the world (Dowling *et al.*, 1998). Therefore, a study was conducted to screen drought-tolerant genotypes in rice based on germination and early seedling growth under different PEG concentrations.

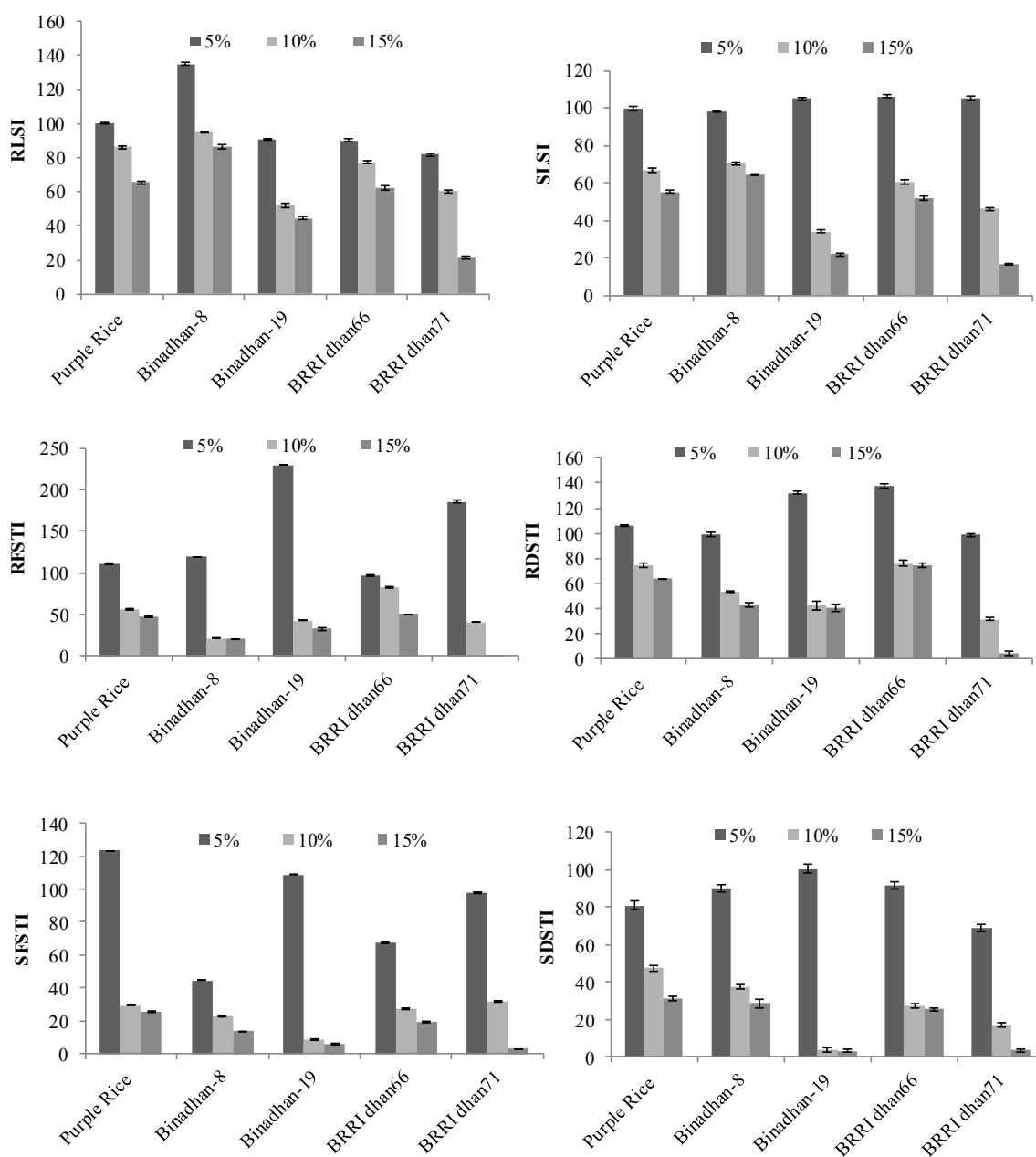


Figure 3. Effect of PEG on (a) root length stress index (RLSI), (b) shoot length stress index (SLSI), (c) root fresh weight stress index (RFSTI), (d) shoot fresh weight stress index (SFSTI), (e) root dry weight stress index (RDSTI) and (f) shoot dry weight stress index (SDSTI) of different varieties of rice. Vertical bars are SEM (n=3).

From the experiment it can be seen that germination percentage, GSTI, the rate of germination and vigor index of all the rice varieties declined with the increase in water stress level. On the basis of germination and GSTI; Purple rice, Binadhan-8 and BRR1 dhan66 performed better at different PEG concentration levels and BRR1 dhan71 showed better performance at 5% PEG concentration but little tolerance at higher stress level (Table 1 & Fig. 3). Sokoto and Muhammad (2014); Swain *et al.* (2014) reported that seed germination and seedling growth was adversely affected by drought stress, which is similar with the findings of this study. In the present

study seed germination was greatly affected by drought stress, but the response intensity and adverse effect of stress depend on the varieties (Table 1). The Polyethylene glycol used in this experiment is an osmotic agent. It plays an important role in the regulation of mineral elements, hormone, protein metabolism and effects of signal transduction (Verslues *et al.*, 1998). The use of PEG is to slow down the moisture rate of seeds and this low water potential is a determining factor for inhibiting seed germination (Wang *et al.*, 2002; Jiao *et al.*, 2009). It was reported that at low osmotic potential, germination and root elongation of genotypes were

inhibited by PEG (Murillo-Amador *et al.*, 2002). Manabendra *et al.* (1998, 2000) and Jha and Singh (1997) reported similar findings for rice genotypes. Water uptake by seed is a physical process that leads to the activation of metabolic process, as the dormancy of the seed is broken following by hydration. However, the use of PEG lowers the osmotic potential that decrease water availability for seeds and caused low germination.

Drought condition inhibits radicle emergence mainly because of a decrease in water potential gradient between the external environment and the seed (Murillo- Amador *et al.*, 2002; Sokoto and Muhammad, 2014). The root and shoot length decreased with an increase in PEG concentration (Table 2). At 15% PEG concentration the varieties i.e. Purple rice, Binadhan-8 and BRRI dhan66 showed better performance in terms of root length, RLSI, shoot length and SLSI (Table 2 & Fig. 3). In most cases root length was greater than shoot length that indicates the growth of plumule is more sensitive than radicle growth to water stress (Table 2). Matsuo *et al.* (1995) described the reasons as may be that the first organ emerged from the seed is radicle, therefore its growth is faster than plumule growth. Also, radicles have direct contact with water but plumules have not any direct contact with water resources because of its late emergence and its position on the seed (Matsuo *et al.*, 1995).

The dry weight of a plant reflects its vigor and stress index of dry weight is considered a good index of its exposure to stresses of all sorts (Xu *et al.*, 2006). Osmotic stress causes low water availability to plants leading to decrease in cell division and elongation by lowering turgor pressure as well as cell growth resulting in a reduction in biomass as well as a reduction in dry mass (Farooq *et al.*, 2015; Sagar, 2017 and Roy *et al.*, 2018). The fresh and dry weight of rice seedlings revealed a decrease exposed to increase PEG concentrations conditions (Table 2). The highest stress level (15% PEG) affected the fresh and dry weight of BRRI dhan71. Purple rice, Binadhan-8 and BRRI dhan66 varieties were less affected by the highest drought stress. Several studies have revealed a similar trend of reduction in the dry and fresh weights of roots (Ji *et al.*, 2012) and shoots (Mostajeran and Rahimi-Eichi, 2009) under drought conditions. Fresh root and shoot weights and lengths reduction ultimately reduce the biochemical processes and photosynthetic rate in rice (Usman *et al.*, 2013). The reason may be, water stress affects root cell development, which ultimately affects nutrient uptake leading to detrimental effects on photosynthesis, essential for biomass accumulation and therefore on the shoot and root elongation. The absorption and utilization of water is reduced to such an extent in a drought condition that is insufficient for plants to maintain normal growth. Leaf and root number also decreased with an increase in water stress (Table 2). Crops exposed

to drought stress in the growing medium causes water deficiency in leaf tissue, that ultimately affects many physiological processes with the final effect on the growth and yield of the crops (Kramer, 1983; Samuel and Paliwal, 1993).

From the above results, it is clear that all growth parameters were reduced by drought at all levels. Among the five varieties, Purple rice, Binadhan-8 and BRRI dhan66 performed better for all growth parameters at all stress levels whereas BRRI dhan71 was better at the initial level of drought but could not withstand higher stress levels of drought.

## Conclusion

The results of this paper showed that drought has a distinct effect on seed germination and seedling growth of five rice varieties at all concentration levels. At 15% PEG concentration, the highest water stress level, Purple rice, Binadhan-8 and BRRI dhan66 showed better performance in most of the parameters. On the other hand, BRRI dhan71 showed little tolerance at higher stress conditions. Thus, very useful information of rice genotypes is provided from these genetic variations that could be produced in the drought area and also could be used further in stress breeding programs.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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