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Genotypic variation in the effect of drought stress on phenology, morphology and yield of aus rice

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Abstract

In Bangladesh, rainfed lowland rice occupies about 5.8 million hectares of which 40 percent is severely affected by drought. Variety(s) tolerant to drought is imperative for increasing aus rice production in such a drought-prone areas. For this, a systematic evaluation was carried out to observe the drought stress effects on the variability of aus rice genotypes. Drought stress was imposed once at the vegetative and three times at the reproductive stage. In each time, drought was relieved after curling of leaves. The impact of the drought on phenology, morphology, growth and grain yield of the genotypes was assessed. There were significant differences in plant traits of the genotypes in response to drought. In general, drought stress delayed phenological events, i.e. days to flowering and maturity. Plant height was found to reduce significantly under drought stress condition. All the genotypes showed a marked reduction in root dry weight, albeit some recovered to a great extent. Flowering time was the most sensitive stage to adverse impact of drought showing 39% reduction in grain yield compared to that of 24% at the vegetative stage drought. Among the genotypes, Bhora Bhadui, BRRIdhan 42, Bhadai, and BRRIdhan 48 were the best entries possessing some desirable traits like less reduction in tillers, panicles per plant, grain sterility and grain production under drought condition. The result suggests that these genotypes have the capability to withstand drought and could be used as breeding materials for the development of drought-tolerant variety after affirming through further study.

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Introduction

Rice supplies 30-80 percent of the daily calories consumed in Asia (Narciso and Hossain 2002). In Bangladesh, it supplies 71 percent of the total calories and 51 percent of the protein in the diet. It also provides about 40 percent employment and 60 percent income generation particularly in rural people of Bangladesh. Drought is considered as one of the most important constraints of rice production affecting 20 percent of the total rice growing area in Asia (Pandey and Bhandari, 2009). Water deficit is a consistent feature across the 63.5 million ha of rainfed rice in tropical Asia, Africa, and Latin America (Narciso and Hossain, 2002). The most drought stress-prone area of Bangladesh is the north-western part including the entire Barind and Madhupur tracts (Rahman, 2011). Rainfed lowland rice occupies about 5.8 million ha of which 40 percent are severely affected by drought stress resulting in the reduction of 8 percent of the annual production (Mazid *et al.*, 1998; Eunus, 2001). Yield reduction in aus rice accounts for 3-32 percent depending on the area and degree of drought stress (Ahmed, 1988). Generally, drought stress starts when the evaporation exceeds the natural precipitation. This situation demands supplementary irrigation at the early stages of aus rice, but the drought stress-prone areas of Bangladesh have very few of such measures. Thus, the scientists are in a challenge to improve the variety of rice resistant to drought stress.

Rice carries a wide range of tolerance and susceptibility to abiotic stresses as compared to other crops. It has submergence tolerance, but highly sensitive to drought stress. However, farmers have been selecting rice plants used to survive under water stress condition for many years, and the genetic variability of drought tolerance are present among traditional cultivars (Mackill and Xu, 1996). Research activities on drought stress for rainfed rice in Bangladesh are limited and slower in progress due to the complexity of drought stress. A very few physiological and morphological traits have been identified as drought stress tolerant mechanisms of rice. Generally, drought stress severely decreases the spikelet fertility as well as grain filling. However, Henrey (2013) suggested that root characteristics are definitely involved in improving grain yield of rice under drought. In Bangladesh, the effects of drought stress on the growth and yield of transplanted aman cultivars have been addressed in a number of research works. However, the systematic evaluation of drought stress responses and mechanism in aus rice is inadequate. Therefore, the study aims evaluating the phenology, growth and yield attributes of aus rice genotypes of diverse growth habits with a view to identifying plant characters and the growth stages associated with drought tolerance.

Materials and methods

Experimental site and plant materials

The study was carried out at the Experimental Field of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during the Aus season (March to August 2009). A total of 14 aus cultivars collected from Germplasm Center of Bangladesh Rice Research Institute, and Chapainawabganj, Rajshahi, Rangpur, Gopalganj and Jessore areas of Bangladesh were used in the experiment.

Soil preparation and fertilization

The soil used in the experiment was olive brown, clay loam in texture, and slightly acidic in reaction with low contents of nitrogen and phosphorus. The soil had been air-dried and mixed with well-decomposed cow dung in 4:1 ratio.

The twelve-kg soil was added in waggoner pots of 25 cm diameter and 30 cm height. Triple super phosphate, muriate of potash, gypsum, and zinc sulphate were applied as the sources of P_2O_5, K_2O, S and Zn at a rate of 90, 50, 40, and 5.0 kg ha^{-1}, respectively. All fertilizers except urea were applied and thoroughly mixed with the soil at the time of final soil preparation. Urea was applied as a top dressing in three equal installments i.e. at active tillering stage (18 days after transplanting, DAT), maximum tillering stage (35 DAT) and before panicle initiation stage (50 DAT).

Plant establishment

The seedlings of the rice cultivars were grown in the pots those placed in rows 0.5 m apart with a distance of 20 cm between the pots inside a Vinyl-house. A total 420 pots, each having 12 kg soil, were used. Weeding, irrigation, and application pesticide were done as and when necessary.

Drought treatment imposition

Drought stress treatments were imposed through withdrawal of the water supply at the vegetative stage i.e. 45 days after sowing and flowering stages. At the flowering stage, three drought stress treatments were imposed *viz.* first at flower initiation time, second at 7-day after flowering and third at 14-day after flowering. In each time of drought imposition, the plants were irrigated 3 days after leaf curling. This pattern was followed in all the treatments and all the varieties. Standing water of 2 to 4 cm was maintained in the field until the crop attained hard dough stage for the control

Plant traits and grain yield measurements

When single flower visualized for a particular genotype, the days from seeding was counted as days to first flowering. When the panicles of about 50% tillers in each genotype were fully headed, the days from seeding was treated as days to 50% flowering. When the base of the panicles of about 50% tillers in each plots was changed up its color from greenish to brown, then the days from seeding was recorded as days to maturity. The total number of emerged panicle per hill was count at the maturity stage. Both fertile and sterile spikelets per panicle were separately counted manually from all of the panicles of sample hill. From the filled grains of a hill, 1000-grains were randomly counted by Multi-auto counter and the weight of these grains was recorded. The grain yield was adjusted to 14% moisture content. All the measurements were taken for both stressed and unstressed plants.

Experimental design and statistical analysis

The experiment was laid out in a two-factor randomized complete block design with six replications. The statistical analyses were performed using Microsoft EXCEL and MSTAT-C software programs (Russel and Eisensmith, 1983). The treatment means were compared using Least Significant Difference (LSD) test according to Gomez and Gomez (1984). Necessary correlations were determined with the program SPSS version 16.

Results and discussion

Variation in phenological traits

In general, the vegetative stage drought stress remarkably delayed the phenological events of the genotypes (Table 1).

Table 1. Phenology of rice genotypes as affected by drought stress at vegetative stage.

Genotypes	Days to 1st flowering		Days to 50% flowering		Days to maturity	
	Control	Drought stress	Control	Drought stress	Control	Drought stress
BR 3	89	98 (+9)	92	103 (+11)	120	131 (+11)
BR 14	89	98 (+9)	92	104 (+12)	120	132 (+12)
BR 16	103	112 (+9)	107	118 (+11)	136	147 (+11)
BR 26	76	91 (+15)	79	96 (+17)	107	124 (+17)
BRRIdhan 27	88	91 (+3)	91	98 (+7)	123	130 (+7)
BRRIdhan 42	77	87 (+10)	80	93 (+13)	111	124 (+13)
BRRIdhan 43	78	85 (+8)	81	93 (+13)	110	121 (+12)
BRRIdhan 48	78	86 (+8)	82	91 (+10)	113	122 (+10)
Bhora Bhadai	71	83 (+12)	76	89 (+13)	105	120 (+15)
Kalchi Aus	68	76 (+8)	71	82 (+11)	99	110 (+11)
Goria	68	81 (+13)	74	86 (+13)	102	114 (+13)
Bhadai	69	73 (+4)	77	80 (+3)	105	109 (+4)
Shielporani	69	76 (+7)	74	82 (+9)	103	110 (+8)
Lal Shilparani	73	82 (+9)	78	90 (+12)	109	121 (+12)
Mean	78	87 (+9)	82	93 (+11)	112	123 (+11)
$LSD_{0.05}$	6.32		10.2		9.6	

Values in parenthesis indicate percent increase (+) due to drought stress relative to control.

On an average, the stressed genotypes took 87, 93 and 123 days to first flowering, 50 percent flowering and maturity, respectively with the corresponding delaying of 9, 11 and 11 days relative to control. Earlier it was also reported that water stressed plants generally took longer days to mature compared to unstressed plants (Sikuku *et al.*, 2010). In this regard, Davatgara *et al.* (2009) observed that drought stress delayed 50 percent flowering at mid-tillering and booting stages. In this study, the trend of delaying 50 percent flowering and maturity of each genotype was almost similar to that observed for days to first flowering, but on an average took extra two days relative to control. The varietal differences in delaying phenological events were highly evident.

Table 2. Plant height, number of tillers and number of panicle of rice cultivars as affected by drought stress at vegetative stage.

Genotypes	Plant height (cm)		No. of tillers/plant		No. of panicle/plant	
	Control	Drought stress	Control	Drought stress	Control	Drought stress
BR 3	113.9	93.1 (-18)	21.0	20.5 (-3)	18.8	16.9 (-10)
BR 14	114.7	93.9 (-18)	21.8	21.3 (-3)	20.0	15.6 (-22)
BR 16	127.3	119.5 (-6)	24.6	19.7 (-20)	16.0	10.6 (-34)
BR 26	112.8	92.2 (-18)	21.0	20.3 (-14)	16.5	18.5 (-5)
BRRIdhan 27	143.9	127.0 (-12)	16.6	16.6 (0)	11.3	10.7 (-5)
BRRIdhan 42	105.8	105.7 (0)	19.0	19.0 (0)	16.5	14.5 (-13)
BRRIdhan 43	143.3	121.0 (-16)	30.0	23.5 (-22)	24.0	16.0 (-33)
BRRIdhan 48	112.4	96.8 (-14)	19.2	18.3 (-5)	17.4	16.8 (-3)
Bhora Bhadai	159.2	149.3 (-6)	23.5	19.0 (-19)	19.0	18.0 (-5)
Kalchi Aus	148.3	146.5 (-1)	22.3	20.3 (-9)	18.0	13.0 (-28)
Goria	125.4	111.2 (-11)	28.6	27.5 (-14)	16.5	14.5 (-12)
Bhadai	126.9	105.7 (-17)	23.3	22.6 (-3)	18.5	18.0 (-3)
Shielporani	147.0	136.0 (-7)	45.4	28.3 (-38)	26.1	23.0 (-12)
Lal Shilparani	143.3	121.0 (-16)	30.0	23.5 (-22)	24.0	17.0 (-29)
Mean	130.3	115.6 (-11)	24.7	21.5 (-12)	18.8	15.9 (-15)
$LSD_{0.05}$	10.26		3.26		6.36	

Values in parenthesis indicate percent decrease (-) and no change (0) due to drought stress relative to control.

The genotype BR26 delayed 15 days to flower followed by the genotype Goria and Bhora Bhadui those took 13 and 12 days respectively. The genotypic differences in delaying flowering are also observed by Kondhia *et al.* (2015). Perhaps, the delay in flowering was due to impairing vegetative growth of plant for drought stress. However, the differences in delaying flowering and maturity were narrowed down in BRRIdhan 27 and Bhadai. This might be the fact that these two varieties quickly complete their life cycles and hence can escape drought period and later on grow satisfactorily under favorable soil moisture. Drought stress before flowering usually delayed flowering time in rice The genotypes having a delay in flowering time generally extract additional water during their vegetative drought stress resulting to higher water deficit (Pantuwan *et al.*, 2002).

Variation in morphological traits

Plant height, the number of tillers and number of panicle as affected by drought stress at the vegetative stage is illustrated in Table 2. Plant height showed a wide range of variation among the genotypes under both stressed and unstressed conditions. When comparing plant height under drought stress condition with the respective control, plant height reduction was found in a range between zero to 17 percent with a mean of 11 percent. Most of the genotypes exhibited reduced height growth more than average. It was also reported that plant height of rice cultivars reduced significantly under water deficit condition at vegetative stage (Sarvestani *et al.*, 2008; Davatgar *et al.*, 2009). Plant height reduction is explained by the fact that drought stress generally restricts cell elongation resulting in the reduction of internode length and later giving shorter plant height (Patel *et al.*, 2010).

Table 3. Root dry weight of rice cultivars as affected by drought stress at different growth stages.

Genotypes	Root dry weight (g plant^{-1})				
	Control	Drought stress at vegetative stage	Drought stress at flowering stage		
			At the time of flowering	7-day after flowering	14-day after flowering
BR 14	5.3	5.3 (0)	4.9 (-8)	4.4 (-17)	5.8 (+9)
BR 16	5.6	5.4 (-4)	4.8 (-14)	4.4 (-21)	6.4 (+14)
BR 26	5.0	5.1 (+2)	4.7 (-6)	4.1 (-18)	5.5 (+10)
BRRI dhan 27	5.7	6.4 (+12)	4.8 (-16)	5.0 (-12)	4.6 (-19)
BRRI dhan 42	5.5	4.7 (-15)	6.1 (+11)	5.6 (+2)	4.2 (-24)
BRRI dhan 43	7.0	6.3 (-10)	6.7 (-4)	7.3 (+4)	6.1 (-13)
BRRI dhan 48	6.3	7.3 (+16)	5.5 (-13)	6.4 (+2)	6.0 (-5)
Bhora Bhadai	7.0	6.7 (-4)	6.2 (-11)	5.5 (-21)	7.2 (+3)
Kalchi Aus	7.2	6.6 (-8)	7.8 (+8)	8.4 (+17)	7.9 (+10)
Goria	6.1	5.2 (-15)	4.9 (-20)	6.9 (+13)	6.4 (+5)
Bhadai	5.6	4.8 (-14)	5.3 (-5)	5.7 (+2)	6.1 (+9)
Shielporani	7.9	7.3 (-8)	8.0 (+1)	7.0 (-11)	6.5 (-18)
Lal Shilparani	6.8	6.0 (-9)	6.5 (-2)	5.9 (-11)	6.1 (-8)
Mean	6.2	5.9 (-5)	5.9 (-6)	5.9 (-5)	6.1 (-2)
$LSD_{0.05}$			1.38		

Values in parenthesis indicate percent increase (+) and decrease (-) due to drought stress relative to control.

It is evident that plant height reduction in the study was not remarkable in BR 16, BRRI dhan 42, Bhora Bhadui, Kalchi Aus and Shielporani due to drought stress. On an average, drought stress reduced the number of tillers per plant by 12 percent at vegetative stage, although the reduction was recorded up to 38 percent. Many authors reported that the number of tillers tended to decrease with increasing water deficit (Sikuku *et al.*, 2010). However, there were significant differences in number of tiller among the genotypes .The genotypes BRRI dhan 27 and BRRI dhan 42 produced the same number of tillers both stressed and unstressed conditions.

The genotype BR16, BRRI dhan 43, Bhora Bhadui Shielporani and Lal Shilparani produced the comparatively lesser number of tillers, and the latter one produced comparatively a much lesser number (38 percent reduction). The reduction in the number of panicle per plant ranged from 3 to 34 percent with a mean of 15 percent. The genotype BRRIdhan 48, Bhadai, Bhora Bhadui, BR 26 and BRRI dhan 27 performed better in producing the number of panicles compared to other genotypes.

Variation in root dry weight

Root dry weight was recorded after harvesting the plants and results showed a remarkable variation of root dry weight due to drought stress in different genotypes (Table 3).

On an average, root dry matter decreased 5% for vegetative stage drought and almost similar responses occurred when drought was imposed at the time of flowering and 7-day after flowering. Root production was less affected when drought imposed at 14-day after flowering. Several studies also showed that drought stress used to reduce the root growth (Suralta and Yamauchi, 2008; Suralta *et al.*, 2008). Under water stress, limited oxygen supply with soil physical barrier is assumed to be restricted deeper penetration of root and hence reducing root dry matter (Samson and Wade, 1998). The genotypic differences were highly evident in producing root dry matter.

Table 4. The number of filled-grain per panicle of rice genotypes as influenced by drought stress at different growth stages.

Genotypes	Filled grain per panicle				
	Control	Drought stress at vegetative stage	Drought stress at flowering stage		
			At the time of flowering	7-day after flowering	14-day after flowering
BR 14	60.7	55.5 (-9)	23.4 (-61)	64.0 (+5)	63.8 (+5)
BR 16	70.7	64.5 (-9)	50.8 (-28)	70.3 (-1)	59.6 (-16)
BR 26	59.2	56.0 (-5)	38.0 (-36)	59.4 (0)	62.3 (+5)
BRRI dhan 27	41.6	42.7 (+)	35.4 (-15)	42.1 (+1)	29.3 (-30)
BRRI dhan 42	57.8	60.0 (+4)	48.0 (-17)	63.2 (+9)	53.8 (-7)
BRRI dhan 43	73.5	61.3 (-17)	58.6 (-20)	71.0 (-3)	49.9 (-32)
BRRI dhan 48	78.0	68.0 (-13)	57.6 (-26)	60.0 (-23)	60.3 (-23)
Bhora Bhadai	72.4	72.9 (+1)	52.1 (-28)	72.9 (+1)	61.1 (-16)
Kalchi Aus	55.9	61.5 (+10)	57.2 (-2)	61.1 (+9)	58.7 (+5)
Goria	59.5	57.3 (-4)	25.3 (-57)	58.7 (-1)	44.5 (-25)
Bhadai	40.1	37.9 (-5)	37.9 (-5)	43.5 (+9)	43.0 (+7)
Shielporani	43.5	36.0 (-17)	16.0 (-63)	32.2 (-26)	25.8 (-41)
Lal Shilparani	52.9	47.6 (-10)	45.8 (-13)	55.7 (+3)	54.8 (+4)
Mean	58.9	55.5 (-6)	42.0 (-29)	57.9 (-2)	51.3 (-13)
$LSD_{0.05}$			10.65		

Values in parenthesis indicate percent increase (+) and decrease (-) due to drought stress relative to control.

The root dry matter reduced in nine genotypes experiencing stress at vegetative and such reduction was found flooding stress during the flowering stage, but most of the genotype increased their root growth at 7- or 14-day after flowering stage drought. Among the genotypes. The damaging of root systems was much greater in BRRI dhan 42 and BRRI dhan 43, Goria and Bhadai at vegetative stage. However, some genotype showed a recovery of root growth at flowering stage. The genotypes Kalchi Aus and Bhadai performed better showing less affected root dry matter and had the tendency to increase root dry weight due to drought stress.

Table 5. Grain yield of rice genotypes as influenced by drought stress at different growth stages.

Genotypes	Grain yield (g plant^{-1})				
	Control	Drought stress at vegetative stage	Drought stress at flowering stage		
			At the time of flowering	7-day after flowering	14-day after flowering
BR 14	19.0	15.0 (-21)	9.7 (-49)	13.2 (-30)	18.5 (-2)
BR 16	20.9	11.6 (-44)	5.4 (-74)	12.0 (-43)	14.6 (-30)
BR 26	17.0	14.0 (-18)	8.8 (-48)	12.3 (-28)	17.6 (+3)
BRRI dhan 27	20.6	18.3 (-11)	12.3 (-40)	12.2 (-41)	15.8 (-23)
BRRI dhan 42	16.7	14.2 (-15)	16.0 (-4)	16.5 (-1)	12.5 (-25)
BRRI dhan 43	30.7	17.3 (-44)	15.0 (-51)	13.0 (-58)	16.8 (-45)
BRRI dhan 48	17.8	17.1 (-4)	13.4 (-25)	14.2 (-20)	17.2 (-4)
Bhora Bhadai	26.2	26.0 (-1)	23.4 (-11)	23.4 (-11)	25.7 (-2)
Kalchi Aus	24.8	17.9 (-28)	13.1 (-47)	24.1(-3)	24.9 (+1)
Goria	19.5	15.4 (-21)	10.3 (-47)	17.4 (-11)	19.8 (+1)
Bhadai	17.1	15.8 (-7)	12.7 (-26)	16.0 (-6)	17.2 (+1)
Shielporani	31.6	21.7 (-31)	18.7 (-41)	17.1 (-46)	15.4 (-51)
Lal Shilparani	30.7	17.3 (-44)	20.3 (-34)	16.4 (-46)	16.8 (-45)
Mean	22.5	17.0 (-24)	13.8 (-39)	16.0 (-29)	17.9 (-20)
$LSD_{0.05}$			4.50		

Values in parenthesis indicate percent increase (+) and decrease (-) due to drought stress relative to control.

Variation in number of filled grains

A total number of filled grain per panicle of rice cultivars as influenced by drought stress application is presented in Table 4. The total number of filled-grain per panicle was adversely affected when drought imposed at the time of flowering. At this stage, all the genotypes showed a lesser number of filled-grain compared to control, and the reduction of filled-grain ranged from 2-63 percent with an average of 29 percent. The number of filled grain per panicle was found to decrease up to 50 percent when drought was imposed at flowering stage (Sarvestani *et al.*, 2008; Rahman *et al.*, 2002).

Table 6. Functional relationship between grain yield and other plant characters under water stress at vegetative stage.

Plant Characters	Regression equation and correlation coefficient	
	Well water control	Drought stress
Plant height (cm)	y=0.26x-11.70, r=0.79*	y=0.14x+0.67, r=0.61**
No. of tillers plant^{-1}	y=0.56x+8.63, r=0.73*	y=0.50x+6.87, r=0.29^{ns}
No. of panicle plant^{-1}	y=1.35x-3.23, r=0.84*	y=1.23x-1.52, r=0.66**

*Significant at P < 0.05,

**Significant at P < 0.01 and ^{ns}Non-significant.

The reduction in filled-grain under drought situation might be due to decrease in translocation of assimilates to the grains. The drought-induced effect on the production of filled-grain was not so prominent at 7-day and 14-day after flowering. However, corresponding reductions in the number of filled-grain were 2 and 13% for drought stress at 7- and 14-day after flowering. The vegetative stage drought did not affect much on the number of filled-grain of the genotypes. Among genotypes, Kalchi Aus and Bhadai performed better showing less reduction in the number of filled-grains when drought imposed at the time of flowering, whereas the effect was nullified in the production of filled-grain for the drought stress at 7- and 14-day after flowering.

Table 7. Functional relationship between grain yield and different plant traits under water stress at vegetative stage.

Treatment*	Regression equation and correlation coefficient		
	Root dry weight	Unfilled grain	Filled-grain
WW	y=5.06x-8.72, r=0.78*	y= -0.18x+28.71, r=0.25	y=0.43x-4.61, r=0.64*
DSV	y=4.52x-8.73, r=0.82*	y= -0.23x+24.85, r=0.39	y=0.28x+1.72, r=0.64*
DSF	y=2.74x-2.27, r=0.63*	y= -0.14x+18.63, r=0.62*	y=0.14x+7.21, r=0.78*
DSF2	y=2.06x+4.86, r=0.64*	y= -0.18x+23.80, r= 0.59*	y=0.21x+6.84, r=0.66*

WW=Well water control, DSV=Drought stress at vegetative stage, DSF=Drought stress at the time of flowering, DSF2=Drought stress at 14-day after flowering. *Significant at P < 0.05, **Significant at P < 0.01.

Variation in grain yield

Grain yield of the rice genotypes varied remarkably under differential drought stress conditions (Table 5). Drought stress at the time of flowering reduced grain yield much compared to other stages encountering the stresses. At this stage, the reduction of grain yield ranges from 4 to 74 percent with a mean of 39 percent, whereas yield reductions were 29 and 20 percent when drought imposed at 7- and 14-day after flowering. Pantuwan *et al.* (2002) also observed that rice is most susceptible to drought stress at the reproductive stage. The vegetative stage drought also showed grain yield reduction of 24 percent. This reduction in grain yield was mostly attributed due to the reduction of the number of tillers and panicles per plant. Moreover, drought stress during different growth stages of rice might reduce assimilates translocation to the grains and increase unfilled grains and eventually lowered grain yield. Moisture stress might restrain photosynthetic activities and assimilate translocation to grain resulting in reduced grain yield (Van Heerden and Laurie, 2008; Liu *et al.* 2008). However, the genotypes Bhadai and BRRI dhan 48 performed well under the vegetative stress drought, whereas BRRI dhan 42 and Bhora Bhadai showed less reduction in grain yield when drought imposed at flowering stage.

The varietal differences in grain yield are well documented, and Rahman *et al.* (1985) explain it by the fact that variety having smaller grain size produced less amount of grain yield per panicles. However, Salam *et al.* (2001) identified some genotypes of direct seeded rice having better yield contributing traits under drought stress environment.

Correlation coefficient between plant characters under drought stress

The functional relationship between grain yield and plant characters as influenced by drought stress is illustrated in Table 6. The grain yield is closely related to plant height, the number of tillers and the number of panicles per plant under well water conditions, their relationships under drought condition at the vegetative stage were to some extent weak, even very weak between the number of tillers and grain yield. This suggests a little contribution of the number of tillers towards increasing grain yield under drought stress condition. On the other hand, root dry matter had a strong positive correlation with grain yield (r=0.82*) under drought imposed at vegetative stage indicating a greater contribution of root system recovery to the grain production (Table 7).

It is important that the relationship between unfilled grain and yield was highly significant under drought stress at the time flowering and 14-day after flowering (r=0.62* and r=0.59*), but it showed an insignificant relationship between them under well water or vegetative stage drought. The severe water stress at different growth stages caused substantial yield losses by a large percentage of unfilled grains (Davatgar *et al.*, 2009). From the study, the varietal differences in producing unfilled grain were highly evident that eventually showed higher correlation coefficient. However, the number of filled-grain is highly associated with grain yield at all stages encountering drought stress. Kondhia *et al.* (2015) also reported that the grain yield and the rate of filled grain were highly correlated with each other, indicating that the yield loss of rice under the drought stress was associated with the reduction in spikelet fertility and grain weight.

Conclusion

Among the 14 genotypes Bhora Bhadui, Bhadai and BRRI dhan 48 showed better performance under drought stress condition and might be treated as drought tolerance. Lal shielporani, BRRI dhan 43, BR 16 and BR 14 performed poorly under drought stress condition and might be treated as drought stress susceptible. Further study is needed with physiological emphasis on drought stress escaping mechanism and root growth dynamics against drought at different growth stages of rice.

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