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Stress Agronomy
ORIGINAL ARTICLE

Effect of drought stress at different growth stages on yield and yield components of six rice (*Oryza sativa* L.) genotypes

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ABSTRACT

Drought stress affects plant growth and development and ultimately, reduced grain yield of rice. But stress at different growth stages may respond differently which is still unclear. Therefore, a pot experiment was carried out with six rice genotypes to determine the critical growth stage where drought stress effect on yield reduction and to find stress tolerance mechanism in rice genotypes. Drought stress (control i.e. no stress and 40% field capacity, FC) was imposed on Binadhan-13, Kalizira, BRRI dhan34, Ukunimodhu, RM-100-16 and NERICA mutant rice genotypes at maximum tillering, panicle initiation and grain filling stages and discontinued when the specific stage was over. The experiment was laid out in a complete randomized design with three replications. Drought stress affected number of effective tiller hill^{-1}, number of spikelets panicle^{-1}, filled grains hill^{-1}, 1000-grain weight and grain yield. Binadhan-13 produced the highest grain yield and the lowest sterility under drought stress at grain filling stage. Percentage of spikelet sterility increased under drought stress (40% FC) especially at the panicle initiation stage resulting low grain yield. Among the tested genotypes Binadhan-13 performed well by reducing spikelet sterility under drought stress condition. For 1000-grain weight and grain yield, grain filling stage was found more crucial. From the current research, drought tolerance mechanism was found in genotypes Binadhan-13 and NERICA mutant.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the important primary cereal crop in the world. It is the staple food for more than two-third of the world's population (Dowling et al. 1998). About 7.5 % of total rice production comes from irrigated lowlands (Bouman and Tung, 2001). Biotic and abiotic factors limit adversely the productivity of the rice growing areas of the world. It has been estimated that more than 200 million tons of rice are lost every year due to environmental stresses, diseases, and insect pests (Herdt, 1991; Chen et al. 2013). Drought, a period of no rainfall or irrigation that affects plant growth, is a major constraint for about 50% of the world production area of rice (Khush 2005). Drought effects in lowland rice can occur when soil water contents drop below saturation (Bouman and Tung, 2001). Some researchers reported that rice crops are susceptible to drought, which causes large yield losses in many Asian countries (Jearaknogman et al. 1995; Bouman and Tung 2001; Pantuwan et al. 2002), however, some genotypes are more drought resistance than others, out-yielding those exposed to the same degree of drought stress. The development of drought resistant cultivars may be assisted if mechanisms of drought resistance are known (Jearaknogman et al. 1995). In Bangladesh, north-western region usually experiences drought that may occur at any growth stages in different duration and at several intensities, thereby affecting growth and yield. Since information is not available on drought resistance of rice genotypes in Bangladesh especially in drought prone areas, this work was carried out determining the drought tolerant rice genotypes under drought conditions imposed at different growth stages, with particular emphasis on yield and yield components.

METHODOLOGY

Pot experiments were carried out with six rice genotypes viz., Binadhan-13, Kalizira, BRRI dhan 34, Ukunimadhu, RM-100-16 and NERICA mutant at Bangladesh Institute of Nuclear

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Agriculture (BINA), Mymensingh, Bangladesh. Control (100% FC) and drought stress (40% FC) (Fang et al. 2017) was imposed on rice genotypes at maximum tillering, panicle initiation and grain filling stages and discontinued when the specific stage was over. The genotypes were selected for their specialty in grain size and aroma which are considered as high valued rice. The experiment was carried out during aman seasons of 2013-14. The soil was sandy loam in texture having pH 6.67. Each pot contained 13 kg of soils. The fertilizer doses ha^{-1} was 160, 65, 120 and 90 kg Urea, TSP, MoP and Gypsum, respectively. The experiment was laid out in a complete randomized design with three replications. Data on effective tillers $hill^{-1}$, total spikelets $panicle^{-1}$ (no.), filled grains $panicle^{-1}$ (no.), % sterility, 1000-grain weight (g) and grain yield hill-1 were recorded at maturity. The collected data were analyzed by MSTAT-C computer package programme developed by Russel (1986). The treatment means were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

The response of rice yield to drought varies with growth stage being most sensitive at flowering, followed by booting and grain filling stage (O'Toole 1982). More reduction in grain yield, due to drought stress in flowering stage, is largely resulted from the reduction in fertile panicle and filled grain percentage.

In the present research all the yield parameters were adversely affected at all the stress stages and in all the rice genotypes over control under study. Grain yield was reduced under drought in both of the year (Tables 1-4). Under drought, plant development is reduced as a consequence of (a) poor root development; (b) reduced leaf-surface traits (form, shape, composition of cuticular and epicuticular wax, leaf pubescence, and leaf color), which affect the radiation load on the leaf canopy; (c) delay in or reduced rate of normal plant senescence as it approaches maturity; and (d) inhibition of stem reserves (Blum 2002). The results showed that the number effective tillers $hill^{-1}$ was decreased with drought (40% FC) (Tables 3-4). The reduction of effective tillers production under low soil moisture might be due to limited supply of assimilate under water stress condition. It might be also happened for less amount of water uptake to prepare sufficient food and inhibition of cell division of meristematic tissue (Zubayer et. al. 2007).

Drought stress at grain filling (anthesis to maturity) was more destructive followed by panicle initiation stage regarding effective tillers $hill^{-1}$, total spikelets $panicle^{-1}$, filled grains $panicle^{-1}$, 1000-grain weight and grain yield $hill^{-1}$, irrespective of the genotypes (Tables 1-4). This may be due to the significant reduction in photosynthetic rate resulting in reduced production of assimilates for growth of panicles and filling of rice grains; ultimately rice yield was drastically decreased. According to the result, under drought stress condition, NERICA mutant and BINA dhan-13 genotypes showed lesser reduction in above said parameters over control in different growth stages (Tables 1-4). Drought stress during different growth stages might decrease translocation of assimilates to the grains, which lowered grain weight and increased the empty grains. Pantuwan et al. (2002) and Cattivelli et al. (2008) have reported reduced rice yield because of drought stress at critical growth stages. Thus, yield traits such as effective tillers $hill^{-1}$, total spikelets $panicle^{-1}$, filled grains $panicle^{-1}$, 1000-grain weight, % sterility and grain yield $hill^{-1}$ are the most popular parameters used to identify droughttolerance in rice breeding programs. The findings are in harmony with those of Yang et al. (2001) ; Venuprasad et al. (2008) and Wang et al. (2010) who have stressed upon taking into account of different agronomic parameters during screening of rice varieties or while developing new rice varieties for drought prone areas.

Table 1. Yield and yield attributes of six rice genotypes influenced by drought (40% FC) at three growth stages; maximum tillering, panicle initiation and grain filling in 2013

Treatments	Effective tiller $hill^{-1}$	Total spikelets $panicle^{-1}$ (No.)	Filled grain $panicle^{-1}$ (No.)	1000-grain weight (g)	Sterility %	Grain yield $hill^{-1}$ (g)
Drought imposing stage						
Control	26.56 a	153.5 a	110.4 a	13.71 a	28.33 bc	39.41 a
Maximum tillering	24.44 ab	132.4 b	100.1 ab	13.00 b	23.35 c	38.85 a
Panicle initiation	23.33 b	149.9 a	93.51 bc	13.04 b	34.79 a	36.29 a
Grain filling	21.67 b	130.5 b	86.77 c	12.94 b	32.27 ab	35.33 a
Lsd $_{0.05}$	2.65	12.25	11.96	0.65	5.20	5.18
Genotype						
BINA dhan-13	21.92 cd	100.9 c	84.25 c	13.85 b	16.63 c	43.69 a
Kalizira	18.67 d	135.7 b	85.71 c	11.11 c	36.39 ab	34.31 bc
RM-100-16	28.00 a	165.2 a	111.7 a	10.68 cd	32.43 b	29.85 c
Ukunimodhu	24.25bc	150.8 a	103.3 ab	10.54 cd	33.67 b	34.47 bc
BRRI dhan-34	26.67 ab	162.8 a	92.92 bc	9.91 d	40.76 a	38.04 ab
NERICA mutant	24.50 bc	134.1 b	108.3 ab	22.92 a	18.23 c	44.46 a
Lsd $_{0.05}$	3.25	15.01	14.65	0.79	6.36	6.35

Data were separately analyzed for the year 2013 and 2014. In a year in each column, figures having common letter(s) do not differ significantly at $P \leq 0.05$ as per DMRT.

Table 2. Yield and yield attributes of six rice genotypes influenced by drought (40% FC) at three growth stages; maximum tillering, panicle initiation and grain filling in 2014

Treatments	Effective tiller hill^{-1}	Total spikelets panicle^{-1} (No.)	Filled grains panicle^{-1} (No.)	1000-grain weight (g)	Sterility %	Grain yield hill^{-1} (g)
Drought imposing stage						
Control	23.78 a	149.6 a	109.7 a	13.43 a	26.32 b	40.31 a
Maximum tillering	24.00 a	137.3 ab	100.5 ab	13.24 a	26.94 b	38.12 a
Panicle initiation	23.50 a	142.1 ab	90.59 bc	13.08 a	34.34 a	34.01 b
Grain filling	22.56 a	134.3 b	85.92 c	12.96 a	33.77 b	33.28 b
Lsd $_{0.05}$	2.20	12.96	10.07	0.51	5.43	2.64
Genotype						
BINA dhan-13	21.50 c	97.33 c	81.50 d	12.89 b	17.60 c	43.21 a
Kalizira	22.42 c	135.8 b	85.64 cd	11.04 c	37.06 a	35.48 bc
RM-100-16	27.33 a	165.2 a	111.4 a	10.56 c	32.41 a	30.22 d
Ukunimodhu	20.67 c	150.4 ab	109.7 ab	10.81 c	25.50 b	33.90 c
BRRI dhan-34	23.08 bc	146.9 b	93.92 cd	9.91 d	34.04 a	38.16 b
NERICA mutant	25.75 ab	149.3 ab	97.88 bc	23.84 a	35.44 a	37.60 b
Lsd$_{0.05}$	2.67	15.87	12.33	0.62	6.65	3.24

Table 3. Combined effect of yield and yield attributes of six rice genotypes under drought (40% FC) at maximum tillering, panicle initiation and grain filling stages in 2013

Interaction		Effective tillers hill^{-1}(no.)	Total spikelets panicle^{-1} (No.)	Filled grains panicle^{-1} (No.)	Sterility (%)	1000-grain wt (g)	Grain yield hill^{-1} (g)
Genotype	Drought imposing stage						
Binadhan-13	Control	21.67 b-e	111.0 g-i	94.00 a-f	13.99 c	15.14 h	44.47 a
	Maximum tillering	21.33 b-e	97.33 i	78.00 ef	13.72 c	20.67 f-h	43.93 a
	Panicle initiation	23.00 bcd	100.3 hi	86.33 b-f	13.83 c	13.23 h	43.63 a
	Grain filling	21.67 b-e	95.00 i	78.67 ef	13.88 c	17.48 gh	42.72 ab
Kalizira	Control	18.00 de	141.2 c-g	108.3 a-e	11.40 d	23.27 e-h	36.77 a-c
	Maximum tillering	20.33 c-e	138.9 c-g	83.87 c-f	10.46 d-f	37.31 a-e	45.27 a-c
	Panicle initiation	22.00 b-e	134.3 d-h	82.13 d-f	11.59 d	38.95 a-d	32.00 a-c
	Grain filling	14.33 e	128.3 e-i	68.50 f	10.99 d-f	46.04 ab	33.21 a-c
RM-100-16	Control	33.67 a	165.3 a-d	119.3 a-c	10.93 d-f	28.20 c-h	32.52 a-c
	Maximum tillering	29.33 ab	170.0 a-c	127.7 a	10.90 d-f	24.98 d-h	32.50 a-c
	Panicle initiation	25.67 b-d	173.7 a-c	100.1 a-f	10.13 d-f	42.43 a-c	26.67 c
	Grain filling	23.33 b-d	151.7 b-f	99.67 a-f	10.76 d-f	34.12 a-f	27.70 bc
Ukunimodhu	Control	28.33 abc	150.8 b-f	115.0 a-d	11.26 de	33.94 a-f	37.84 a-c
	Maximum tillering	21.00 c-e	140.0 c-g	111.7 a-e	11.40 d	20.98 f-h	38.15 a-c
	Panicle initiation	24.00 b-d	180.0 ab	94.00 a-f	9.24 f	47.77 a	32.07 a-c
	Grain filling	23.67 b-d	132.5 d-h	92.47 a-f	10.25 d-f	32.0 b-g	29.84 a-c
BRRI dhan34	Control	28.33 abc	196.0 a	104.0 a-e	10.67 d-f	46.94 a	39.86 a-c
	Maximum tillering	29.33 ab	124.3 e-i	98.00 a-f	10.08 d-f	21.17 f-h	40.29 a-c
	Panicle initiation	25.33 b-d	172.7 a-c	85.67 c-f	9.40 ef	48.08 a	38.44 a-c
	Grain filling	23.67 b-d	158.0 b-e	84.00 c-f	9.49 ef	46.84 a	33.57 a-c
NERICA mutant	Control	29.33 ab	156.5 b-e	121.5 ab	24.00 a	22.52 f-h	44.99 a
	Maximum tillering	25.33 b-d	124.0 e-i	101.3 a-f	21.43 b	15.00 h	42.96 ab
	Panicle initiation	20.00 de	138.1 c-g	112.9 a-e	24.03 a	18.29 gh	44.92 a
	Grain filling	23.33 b-d	117.7 f-i	97.33 a-f	22.23 b	17.12 gh	44.97 a
Lsd $_{0.05}$		6.70	30.01	29.30	12.73	1.59	2.69

Data were separately analyzed for the year 2013 and 2014. In a year in each column, figures having common letter(s) do not differ significantly at $P \leq 0.05$ as per DMRT.

Table 4. Combined effect of yield and yield attributes of six rice genotypes under drought (40% FC) at maximum tillering, panicle initiation and grain filling stages in 2014

Interaction		Effective tillers hill^{-1}(no.)	Total spikelets panicle^{-1} (No.)	Filled grains panicle^{-1} (No.)	Sterility (%)	1000-grain wt (g)	Grain yield hill^{-1} (g)
Genotype	Drought imposing stage						
Binadhan-13	Control	22.00 c-f	106.0 fh	94.0 d-i	13.75 c	14.97 gh	44.32 ab
	Maximum tillering	21.67 c-f	88.00 h	66.00 i	12.37 d-f	25.23 d-h	43.21 a-c
	Panicle initiation	20.33 d-g	100.3 f-h	87.33 e-i	12.90 cd	12.83 h	42.77 a-c
	Grain filling	22.00 c-f	95.00 gh	78.67 f-i	12.54c-e	17.38 f-h	42.53 a-c
Kalizira	Control	25.67 a-d	152.0 a-e	110.0 a-e	11.33e-g	27.52c-h	37.47 b-f
	Maximum tillering	18.33 fg	128.3 c-g	77.00 f-i	10.84 gh	39.62a-d	36.53 c-g
	Panicle initiation	20.67 d-g	134.3 b-f	83.13 e-i	10.97 gh	38.20a-d	33.15 d-i
	Grain filling	25.0 b-e	128.3 c-g	72.50 g-i	11.03 f-h	42.89 a-c	34.78d-h
RM-100-16	Control	31.33 a	165.3 a-c	118.7 a-d	10.71 gh	28.40 b-h	32.74 d-i
	Maximum tillering	27.33 a-c	170.0 ab	126.7 a-c	10.69 gh	25.49 d-h	33.68 d-i
	Panicle initiation	25.67a-d	173.7 a	98.73 c-h	10.31 gh	42.97 a-c	27.00 i
	Grain filling	25.00 b-e	151.7a-e	101.7 b-g	10.52 gh	32.77 a-f	27.44 hi
Ukunimodhu	Control	19.00 e-g	159.3 a	132.0 a	11.03 gh	26.39 d-h	37.41 b-f
	Maximum tillering	20.67d-g	159.2 a-d	126.7 a-c	10.78 gh	18.33 f-h	38.12 b-f
	Panicle initiation	24.33 b-f	151.7a-e	106.3 a-f	10.67 gh	27.90 c-h	30.59 f-i
	Grain filling	18.67 e-g	111.2 f-h	70.20 hi	10.77 gh	32.77 a-f	29.47 g-i
BRRI dhan34	Control	15.00 g	132.7 b-f	98.00 c-h	9.973 gh	25.63 d-h	40.41 b-d
	Maximum tillering	28.00 a-c	24.3 d-h	130.2 ab	10.08 gh	21.73 e-h	39.99 b-e
	Panicle initiation	25.00 b-e	172.7 a	93.33 d-i	9.87 gh	43.86 ab	38.01 b-f
	Grain filling	24.33 b-f	158.0 a-d	87.00 e-i	9.73 h	44.93 a	34.23 d-i
NERICA mutant	Control	29.67 ab	162.0 a-d	105.3 a-f	23.77 ab	35.00 a-e	49.49 a
	Maximum tillering	28.0 a-c	154.0 a-e	97.33 d-h	24.70 a	31.24 a-f	37.17 b-f
	Panicle initiation	25.0 b-e	119.8 e-h	74.67 g-i	23.73 ab	40.30 a-d	32.51 e-i
	Grain filling	20.33d-g	161.5 ad	105.5 a-f	23.17 b	35.24 a-e	31.24 f-i
Lsd $_{0.05}$		5.34	31.74	24.66	13.30	1.25	6.47

CONCLUSION

Drought affects more or less at every growth stage causing a reduction of yield components and yield. From the findings of the study, it may be concluded that NERICA mutant and Binadhan-13 were comparatively more drought tolerant rice genotypes irrespective of growth stages as these genotypes gave significantly higher yield than the other genotypes under study. So, these genotypes can successful be cultivated in drought prone areas. Moreover, it was made out that drought stress at grain filling was crucial regarding rice yield hence; at this growth stage drought stress may be avoided.

CONFLICTS OF INTEREST

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

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