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Effect of Drought and Irrigation Management on Two Rice Mutants of Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author MAI wrote the protocol of the study, first draft of the manuscript and managed the analyses of the study. Author MHA designed the study and performed the statistical analysis. Author PB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Drought stress is a major constraint to the sustainable production of of crops. Rice (*Oryza sativa* L.) is considered as a drought-sensitive crop species. The experiment was carried out to investigate the response of two rice mutants to drought condition and to develop appropriate irrigation management. Experiment was conducted at mini-lysimeter (1.5 m x 1.0 m x 0.28 m, having drainage outlet and rain-shed) at BINA, Mymensingh in Aman season (August to October, 2017) and Aus season (March to June, 2018) consecutively. The mutants used were N4/250/P-1(2) and N4/250/P-2(6)-26. The mutants were tested against four levels of drought stress. The imposed treatments were: Normal irrigation (3 days AWD), supplemental irrigation (ASM drops below 85%, throughout the growing season), irrigation at 0.85 ASM (up to booting stage) then irrigation at 0.60 PASM, irrigation at 0.85 ASM (throughout the growing season). Treatments were imposed after 3 weeks from transplanting. Experiment was laid out according to random complete block design (RCBD) with split-plot arrangements and three replications. The results showed that the mutants produced reasonable yield under stress condition compared to normal irrigation condition, which indicates their tolerance capacity under drought condition. Rice drought tolerance could help the country deal with the shortages in water that are facing Bangladesh farmers already.

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Keywords: NERICA; AWD; available soil moisture; water footprint.

ABBREVIATIONS

AWD : Alternate Wetting and Drying
ASM : Available Soil Moisture
BINA : Bangladesh Institute of Nuclear Agriculture
WF : Water Footprint

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for nearly half of the world's population, and thus its production is needed to feed the rapidly increasing population in coming decades, especially in Asia countries [1,2]. Asia is the largest producer and consumer of rice [3,4], and thus it requires to produce more staple rice to meet the food demand of growing population of the world [5]. Drought is considered one of the main constraints that limit rice yield in rainfed and poorly irrigated areas. At least 23 million hectares of rainfed rice area in Asia are estimated to be drought prone, and drought is becoming an increasing problem even in traditionally irrigated areas [6]. The effects of drought stress on final product, that is yield, and the frequency of supplemental irrigation requirement under rainfed rice depends on the soil type, cultivar (maturity period, drought resistance capacity), ET demand, and rainfall availability at the field site [7,8]. In Bangladesh, water supply heavily depends on rivers originating from neighbor countries and rainfall. Climate change, deforestation and construction of dams in common rivers have contributed to enter a reduced amount of water [9]. As surface water supply is decreasing day by day, irrigation pressure is going towards groundwater resource. But this resource is not unlimited. Intensive crop cultivation (irrigated) during dry season have contributed to excessive groundwater withdrawal of many parts of Bangladesh [10,11,12]. Therefore, it is important to save water and increase the crop water use efficiency (WUE) in arid, semi-arid areas and seasonal drought regions [13,14]. The present and anticipated global food demands necessitate a significant increase in crop productivity on these less favorable rainfed lands. With diminishing water supplies for agriculture worldwide, the needs to improve drought adaptation of rice and to screen resistant varieties are becoming increasingly important [15]. Genes from *O. glaberrima* were used to develop NERICA lines with improved yield, earliness, weed competitive ability and tolerance to abiotic stresses, by interspecific hybridization with *O. sativa* [16]. Sikuku et al. [16] investigated the effects of water deficit on physiology and morphology of three varieties of NERICA rainfed rice in the field and green house. They imposed treatments as: Irrigating once in a day (control), after every 2 days, 4 days and 6 days, respectively. They found that water deficit causes reduction in plant growth and biomass accumulation. Among the three varieties, NERICA was the most tolerant in terms of plant growth [17]. The objectives of this study were to analyze the yield components and water use of two rice cultivars under different level of soil moisture stress compared with flood irrigation.

2. MATERIALS AND METHODS

The experiment was conducted in mini-lysimeter (1.5 m × 1.0 m ×0.28 m, having drainage outlet, and rain-shed over it) at field lysimeter complex of 'Bangladesh Institute of Nuclear Agriculture' (BINA), Mymensingh, Bangladesh (24°43″N latitude and 90°26″E longitude). The experiment was carried out in Aman season (August to October, 2017) and Aus season (March to June, 2018) consecutively. The maximum and minimum temperature, average relative humidity and sunshine hour at the rice growing period in Aman and Aus season are shown in the Figs. 1, 2, 3 and 4.

The scheduled treatments were: T_1 = Control (normal irrigation, 3 days Alternate Wetting and Drying); T_2= Supplemental irrigation when Available Soil Moisture (ASM), drops below 85% (throughout the growing season); T_3= Up to booting stage, irrigation at 0.85 ASM; then for the remaining period, irrigation at 0.60 PASM; T_4 =Irrigation at 0.85 ASM (throughout the growing season), treatment beginning at 17 days after transplanting. Treatments were imposed after 3 weeks from transplanting except T_4. The mutants were V_1 = N_4/250/P-1(2) and V_2 = N_4/250/P-2(6)-26. The mutant lines V_1 and V_2 were derived from NERICA Rice through mutation breeding by Plant Breeding division of BINA. The experiment was laid out in three series of container with RCBD design, with split-plot arrangements in three replications. The experimental soil was fertilized with the 2.5 times recommended doses for field soil (of Urea 215 kg/ha, TSP 180 kg/ha and MP 100 kg/ha). The seedlings of 22 days old were transplanted. Treatments were imposed accordingly. Intercultural operations were done as when required. Time to time, soil moisture in different treatments was determined by (quick soil moisture meter) and gravimetric method. The yield parameters; plant height, panicle length, tillers per plant, number of grains per panicle, number of filled and unfilled grains and grain and straw yield data were recorded at maturity during rice harvest. The grain weight was adjusted to 12% moisture according to (Ali 2010). The statistical analysis was performed using statistical software of IRRI, "STAR" (Version: 2.0.1).

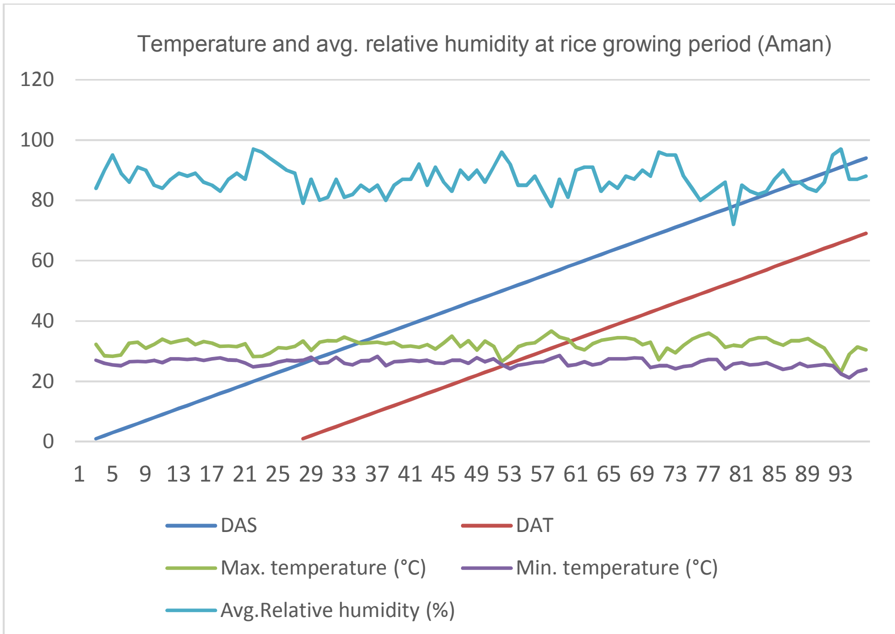

Fig. 1. Max and min. temperature and average relative humidity at rice growing period (Aman)

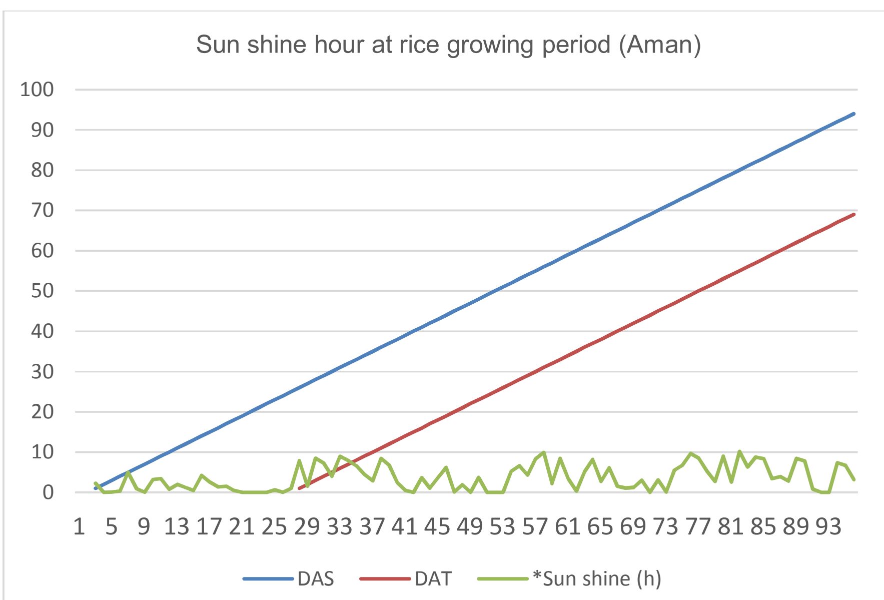

Fig. 2. Sun shine hour at rice growing period (Aman)

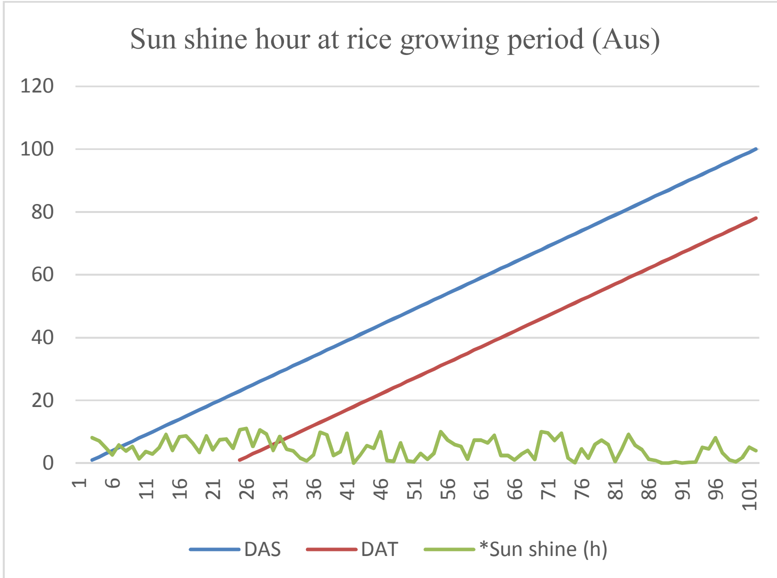

Fig. 3. Max and min. temperature and average relative humidity at rice growing period (Aus)

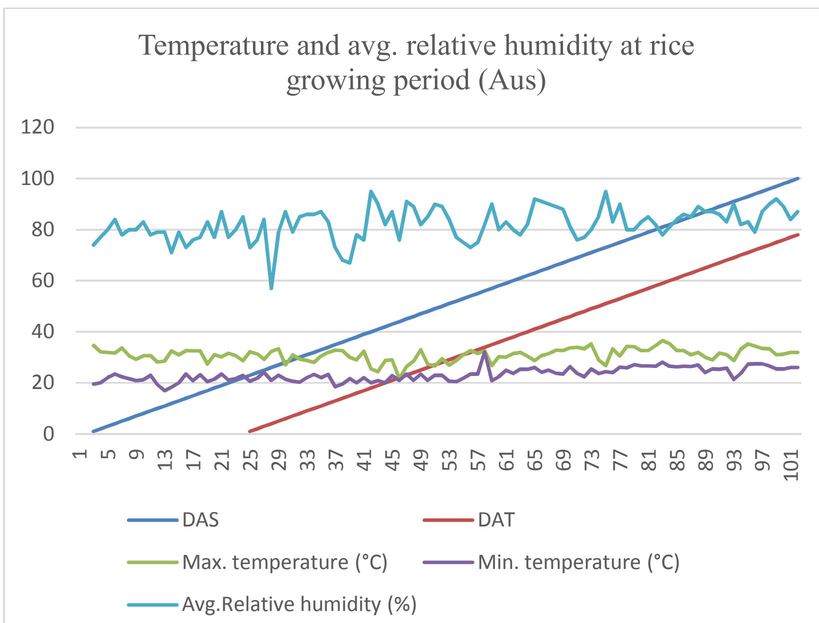

Fig. 4. Sun shine hour at rice growing period (Aus)

3. RESULTS AND DISCUSSION

The mean effects of irrigation treatments and mutants on yield and component of yield are summarized in Table 1. The mutants showed insignificant difference in all parameters. The irrigation treatments showed significant difference in grain yield, tiller/plant in both years and incase of Aus season, plant height and seed/panicle also shows insignificant. The mutants produced lower yield under soil moisture stress, but survived until the soil moisture drops around wilting point.

Interaction effects of irrigation treatments and cultivars on grain yield showed insignificant difference (Table 2).

Table 1. Mean effectsof irrigation treatments and cultivars on yield and yield attributing characters of rice mutants

Treatment	Plant height (cm)		Tiller/ plant		Panicle length (cm)		seed/ panicle (Fill grain)		Un fill grain (No.)		Grain yield (gm/m^2)		1000 grain wt. (gm)		Straw yield(gm/m^2)	
	Aman	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**
T_1	110.45	106.43 a	9.60 b	11 a	24.45	25	104.35	142 a	28.35	19	405.92 a	406 a	19.55	23.35	486.73	473
T_2	99.38	90.13 b	9.28 bc	8 b	24.08	23	105.33	97 b	22.94	20	302.95 b	273 b	19.25	19.65	427.23	354
T_3	97.20	88.96 b	7.70 c	7 b	24.00	24	93.7	95 b	28.00	22	328.19 b	250 b	18.90	18.91	409.37	308
T_4	91.80	88.43 b	11.40 a	7 b	24.53	24	114.13	99 b	19.45	23	380.85 a	309 b	18.55	17.62	454.77	414
F-test at (5%)	NS				NS	NS	NS		NS	NS			NS	NS	NS	NS
Cultivars	**Plant height (cm)**		**Tiller/ plant**		**Panicle length (cm)**		**seed/ panicle (Fill grain)**		**Un fill grain (No.)**		**Grain yield (gm/m^2)**		**1000 grain wt. (gm)**		**Straw yield (gm/m^2)**	
	Aman	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**
V_1	99.58	92.64	9.88 a	8	24.36	24	102.90	107	26.03	22	362.41	313	19.13	20.40	464.48	399
V_2	99.84	94.33	9.11 b	9	24.16	24	105.85	110	23.34	20	346.55	306	19.00	19.35	424.56	357
F-test at (5%)	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Means with the same letter are not statistically different at 5% probability level by Tukey's Honest Significant Difference (THSD) test [Appropriate test statistic is selected by the software automatically].

Table 2. Interaction effects of irrigation treatments and mutants on grain yield of rice

Treatment	Grain yield of different cultivars (gm/m^2)			
	V_1		V_2	
	Aman	**Aus**	**Aman**	**Aus**
T_1	412.47	416	399.38	395
T_2	294.14	273	311.78	304
T_3	347.03	254	309.34	249
T_4	396.00	309	365.71	278
F-test at (5%)	NS	***NS***	NS	***NS***

Table 3. Irrigation frequency, total irrigation, water savings and water footprint under different treatments

Irri. Treatment	Irri. up to establishment, (cm)		No. of irri. after treatment started		Total irrigation amount (cm)		Water savings (%, compared to T1)		WF, L/kg		WF, L/kg
	Aman	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Aman**	**Aus**	**Average**
T1	18	17.5	5	5	40.47	38.8	-	-	996.91	525.5	761.20
T2	18	17.0	2	3	25.47	31.2	37.06	19.6	840.62	521.0	680.81
T3	18	17.5	3	3	26.40	30.8	34.75	20.6	804.41	533.0	668.70
T4	17.5	17.0	2	3	24.97	31.2	38.29	19.6	655.55	460.3	557.92

Irrigation frequency, total irrigation, water savings and water footprint under different treatments are shown in Table 3. The treatment (T_1) yielded height with 40.47 cm and 38.80 cm irrigation water, respectively in Aman and Aus. The treatment (T_4) yielded 2nd highest with 38.29% and 19.60% irrigation water savings compare to treatment (T_1), respectively in Aman and Aus.

In the experiment of 2018, under severe water stress condition (T_4), to produce 1 kg of rice, 460.3 litter water was required, while normal irrigated plot (T_1) required 525.5 litter per kg. Similarly in the Aman in treatment T_4 required 655.55 litter per kg water was required, while T_1 required 996.91 litter per kg. From average (Aman and Aus), under severe water stress condition (Irrigation at 0.85 ASM, throughout the growing season), to produce 1 kg of rice, 557.92 litter water was required, while normal irrigated plot (3 days AWD) required 761.20 litter per kg.

4. CONCLUSION AND RECOMMENDATION

The rice mutants N_4/250/P-1(2) and V_2 = N_4/250/P-2(6)-26 produced reasonable yield under stress condition compared to normal irrigation condition, which indicates their tolerance capacity under drought. This means that there is great scope for expanding rice production in Bangladesh even if there is a shortage of water resources in the future. If rice crops are managed according to intervals irrigation, the present cultivated area could be expanded even with less total water being available.

In Bangladesh, the cultivated area of Aus rice is low. Due to rapid declination of groundwater level as a result of irrigated Boro rice, sustainability of groundwater is at risk. The present government policy is to reduce the Boro cultivation and migrate to other alternative crops such as wheat, pulse and oil-seed in Rabi season, and introduction of Aus rice cultivation. In Aus season, rainfall at initial and middle parts is uncertain and uneven, which disfavor Aus rice cultivation. In Aman season, erratic rainfall and frequent long dry-spell (especially in the north-western part of Bangladesh) reduce the potential rice yield. In such situation, the water-stress tolerant mutants can be a hope for the farmers in such environmental situation. The nation will also be benefited, and will contribute to sustainable rice yield under environmental vagaries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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