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Title: Effect of Water Stress and Potassium Fertilizer on Growth and Yield of Transplanted Aman Rice

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## ABSTRACT

Drought stress affects plant growth and development and ultimately reduces the grain yield of rice. The use of periodical water stress and potassium fertilization may enhance rice tolerance to drought stress. But drought at different growth stages may respond differently which is still unclear. This research work was carried out to determine the effects of different periodical water stress combined with potassium fertilization on growth, yield, leaf gas exchanges and biochemical changes in transplanted Aman rice (cv. BRRI dhan71) grown in the field condition and compare them with standard practice (control). Three levels of water stress (Control: Regular irrigation with 1 cm standing water, periodical water stress for 10 days from 15 days after transplanting (DAT) to harvest and water stress for 10 days after panicle initiation or reproductive phase) and two potassium (K) fertilization levels (41 kg K ha$^{-1}$ and 51 kg K ha$^{-1}$) were evaluated in this experiment. The application of water stress for 10 days at the reproductive phase and application of potassium at 51 kg K ha$^{-1}$ showed tolerance to drought stress by increasing chlorophyll content, proline levels and maximum efficiency of photosynthesis in comparison to other treatments. It was observed that rice yield and other physiological parameters reduced with increasing duration of water stress by periodical water stress for 10 days from 15 DAT to maturity while application of additional potassium fertilizer (51 kg K ha$^{-1}$) has a slight effect on those parameters. From our observation, 10 days of water stress at the reproductive phase of rice with potassium fertilization at 51 kg K ha$^{-1}$ produced higher grain yield and yield components that are equivalent to standard practice. It was also observed that the biomass and filled spikelet were not affected by without irrigation for 10 days at reproductive phase. Therefore, it could be stated that the rice variety BRRI dhan71 does not require flood irrigation and water stress for 10 days at the reproductive phase is more appropriate to increase water use and optimum yield of rice.

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## INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major cereal crops of the world that provides 20% of the total calories and 15% of the protein requirements of the world population (FAO, 2012). Rice is grown in a wide range of ecosystems and vulnerable to a wide range of abiotic stresses, like drought, salinity, cold and submergence (Lafitte et al., 2004). Lack of adequate water leading to drought stress is common in upland cultivation systems. Drought is the most important climate-related risk for rice production in rainfed areas (Pandey et al., 2007). More than half of the 40 million hectares of rain-fed lowland rice worldwide suffer from water scarcity at some of the growth stages (Cabangon et al., 2002). The lower productivity of rice in most of the cases is attributed to various abiotic stresses including drought, which has now become a severe threat to ensure food security in the developing world as well as in Bangladesh (Habiba and Abedine, 2015). Although water is required all over the growth periods of rice plant, there are some critical growth stages when drought stress impacts seriously and create a massive reduction in quantity and quality of yield (Roy et al., 2010). Crop responses to drought stress and its tolerance level can be measured by monitoring different physiological changes during drought period (Bajji et al., 2001). Drought stress reduces the rice growth and severely affects the seedling biomass, photosynthesis, stomatal conductance and plant water relations (Sarkarung et al., 1997). Depending on timing, duration and severity of the plant water deficit, the grain yield of some rice genotypes could be reduced by up to 81% under drought conditions (Pantuwan et al., 2000). Severe drought stress also inhibits the photosynthesis of plants by causing changes in chlorophyll content, by affecting chlorophyll components (Iturbe Ormaetxe et al., 1998). Ommen et al. (1999) reported that leaf chlorophyll content decreases as a result of drought stress. The decrease in chlorophyll content under drought stress is mainly the result of damage to chloroplasts caused by reactive oxygen species (Smirnoff, 1995).

The survival of plants under various abiotic stresses depends on the status of plant growth and metabolism that are critically governed by potassium (K). Particularly, K is essential for photosynthesis, osmoregulation, stomatal movement and stress resistance in plants (Marschner, 2012). The application of periodical water stress and potassium fertilization has been reported to induce tolerance of crops to osmotic stress (Razak et al., 2013). The maintenance of high plant water status and plant functions at low plant water potential and the recovery of plant function after water stress are the major physiological processes that contribute to the maintenance of high yield under cyclic drought periods (Farooq et al., 2009 and Quampah et al., 2011).

Proline is one of the most common compatible osmolytes and plays a highly protective role in plants that are exposed to abiotic stresses (Cha-um and Kirdmanee, 2008; Teixeira and Pereira, 2007). The proline content is found to be increased under drought stress in plants (Sanchez et al., 1998; Alexieva et al., 2001). In these regards, it was hypothesized that the use of periodical water stress and potassium fertilization could mitigate the impacts of water stress in rice by increasing the production of anti-oxidative enzymes as, proline. Determination of proper water stress cycle is important to increase water use efficiency and rice productivity. Therefore, the objective of this study was to investigate the impact of periodical water stress and potassium fertilization on growth and yield, chlorophyll content, proline content and leaf gas exchange of BRRI dhan71, a drought tolerant variety of Bangladesh.

## MATERIALS AND METHODS

The experiment was conducted at rain out shelter of Bangladesh Rice Research Institute (BRRI) farm, Gazipur during T. Aman 2017. Rice variety BRRI dhan71 was used as plant material. BRRI dhan71 was developed and released by BRRI as drought tolerant variety and are currently recommended for cultivation in the drought prone areas of Bangladesh. The experiment was laid out in split plot design with three replications of the treatments. The main plot treatments were irrigation water management, i.e., $I_1$ = Control (Regular irrigation with 1 cm standing water), $I_2$ = Periodical water stress for 10 days from 15 DAT to maturity and $I_3$ = Water stress for 10 days after panicle initiation (PI) or reproductive phase. The sub plot treatments were K management, i.e., $K_1$ = 41 kg K ha$^{-1}$ (30% at 15 DAT, 70% at 30 DAT) and $K_2$ = 51 kg K ha$^{-1}$ (30% at 15 DAT, 30% at 30 DAT, 40% at 50 DAT). The unit plot size was (4 m × 2.5 m). Fertilizers were applied @ 70-10-11 kg ha$^{-1}$ N-P-S as urea, TSP and gypsum. Thirty-day-old seedlings were transplanted using one seedling hill$^{-1}$. The full doses of P, S and 1/3 of N were applied during final land preparation and the remaining N was top dressed at 20 and 45 DAT.

Before initiation of water treatment the soils were brought to the same moisture condition (20-30 %). To avoid rainfall all the plots were shaded by polythene sheet before transplanting. The water table depth and soil moisture were measured at an interval of 10 days. The water table depth was measured by installing PVC pipe and the portion of the pipe (35 cm) below the ground surface was perforated. Soil moisture content was determined with the fresh soil sampled from the depths of 0 - 0.2 m and 0.21 - 0.4 m in the experimental field. Sampled fresh weight was weighed and dried in the oven for 24 hours at 105°C. The gravimetric soil water content was determined using the formula as follows:

Soil moisture content (%) = [(fresh soil weight-dry soil weight)/dry soil weight × 100].

Tiller number was counted from twelve hills in each of the plots then converted into per square meter from 15 DAT and continued till maturity at an interval of 15 days. Tiller mortality (TM) was calculated using the following formula (Zain et al., 2014):

TM (%) = [(Maximum number of tillers - panicles number)/Maximum number of tillers × 100]. At maturity, the plant height was measured from the soil surface to the tip of the tallest panicle. Rice leaf area index (LAI) was taken at the heading stage by LICOR 3100. SPAD meter was used to measure the greenness or relative chlorophyll content of leaves (Inada, 1985). The youngest fully expanded leaf of a plant was used for SPAD measurement. Readings were taken on one side of the midrib of the leaf blade.

Proline content was determined using ninhydrin acid reagent according to Bates et al. (1973). The level of photosynthesis was measured from the topmost fully expanded leaves during grain filling stage and by using a closed infrared gas analyzer LICOR 6400 portable photosynthesis system (IRGA, Licor Inc., Lincoln, NE, USA). The rate of photosynthesis was measured at an interval of three minutes. The temperature of the block and the leaf was 32 ± 1°C, relative humidity was maintained at 65 ± 5% with constant light intensity of 1400 µmol m$^{-2}$ s$^{-1}$ and the flow rate was maintained at 400 µmol s$^{-1}$.

For dry matter and proline determination, plant samples were harvested by cutting about 2 cm above the soil surface at active tillering, maximum tillering, heading and maturity stage. The vegetative plant parts were oven-dried at 72°C for 72 h to constant weight and then weighed to calculate the stem dry weight of the respective stage. The remaining root mass of each section was washed to remove soil and then oven dried at 72°C for 72 h and weighed again for root dry weight.

At maturity, the plants of 5 m² area were harvested for the determination of yield and yield components.

The collected data were analyzed using statistical program cropstat7.2 (Gomez and Gomez, 1984). The treatment means were separated using least significance difference test at the 5% level of probability.

## RESULTS AND DISCUSSION

### *Meteorological conditions*

The highest rainfall prevailed in the study area during August followed by October and the mean maximum temperature was highest in September - October during the crop growth (Figure. 1A and B).

### *Perch water table and soil moisture*

The water table depth was recorded from the day of the treatment started. The range of water table at control condition was 3 to 5 cm depth below surface till 75 DAT. Water table ranged from 15 to 25 cm depth under periodical drought stress condition ($I_2$) while at drought stress for 10 days after PI ($I_3$) it was 27 to 32 cm. The soil moisture (%) was also recorded at ten days interval. Soil moisture was around 34 to 40% at control condition whereas 13-25% soil moisture was found from periodical drought stress condition ($I_2$) and drought stress for 10 days after PI or reproductive phase ($I_3$), respectively (Figure. 2 and 3A, B ). There was no significant difference observed from K management, and interaction effect of irrigation water and K management on soil moisture. The findings are in harmony with Kader et al. (2019) who have showed that maintaining high soil moisture can enhance water productivity of rice in control condition and in reproductive phase perch water table depth and soil moisture was reduced during screening of rice varieties or while developing new rice varieties for drought prone areas.

### *Tillering pattern*

Interaction effect of irrigation water and K management on tillering pattern was not significant. Therefore, individual effect of irrigation water and K management on tiller production has been shown in the Figures 4A and B. Irrespective of irrigation and K management, number of effective tillers $m^{-2}$ increased significantly over time, peaked in 60 DAT and then declined slightly. Effective tiller number $m^{-2}$ ranged from 67 to 129 in irrigation water management and 68 to 128 in K management treatments. During 60 DAT the highest number of tillers (129) was produced from control treatment (regular irrigation) followed by periodical water stress for 10 days from 15 DAT to maturity (127) and drought stress for 10 days after PI (124) management plots. Zubaer et al. (2007) found that number of tiller per hill decreased with decreased soil moisture level, which is in agreement with our findings.

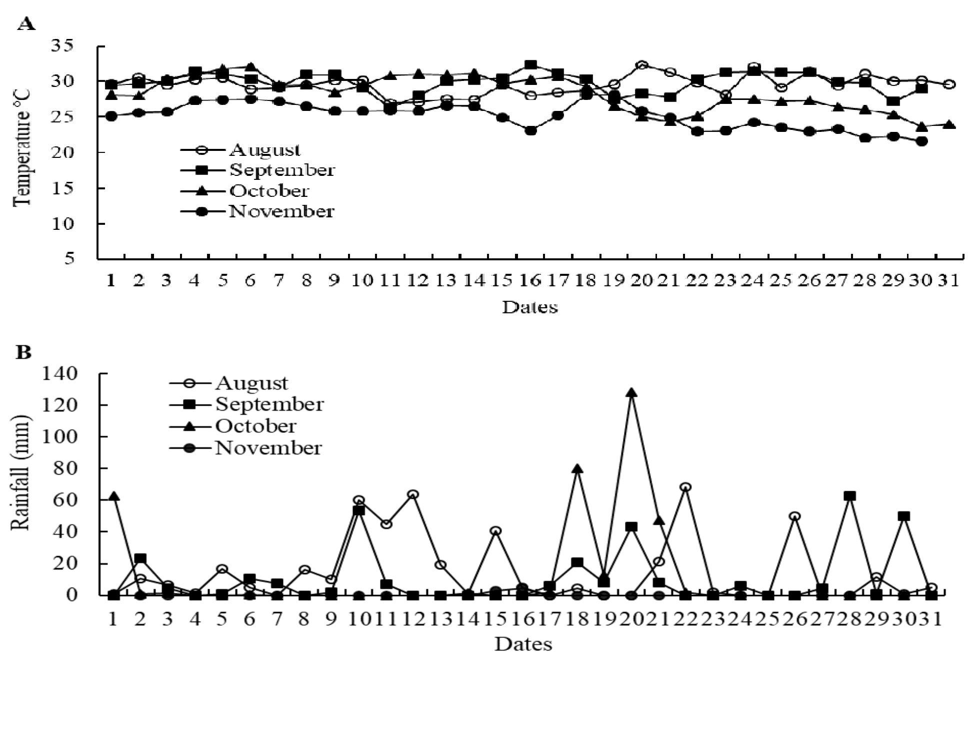


**Figure 1. Temperature (A) and Rainfall (B) status of BRRI, Gazipur during the experimental period from August 2017 to November 2017 (Daily average)**

***Tiller mortality***

Tiller mortality of BRRI dhan71 varied significantly among the treatments. However, the tillers mortality rate also increased with increasing duration of water stress cycle. Among the treatments highest tiller mortality (6.8%) was observed from periodical water stress for 10 days from 15 DAT to maturity ($I_2$) followed by drought stress for 10 days after PI ($I_3$) and regular irrigation ($I_1$). Number of tillers reduced with increased duration of water stress cycle as observed by Zain et al., (2014), which is in consistent with the results from this study. However, among the potassium management, higher tiller mortality was found for 41 kg K $ha^{-1}$ (4%) followed by 51 kg K $ha^{-1}$ (3.14%) (Figure 5A and B). Due to some environmental limitations such as water and nutrient supply etc. tiller production may be inhibited and all the tiller buds do not develop into tillers (Yoshida, 1981).

***Dry matter production***

Dry matter production varied significantly among the treatments both at heading (HD) and maturity (MA) stage. The tiller dry weight gradually increased till HD and decreased at the MA stage. Tiller dry weight for rice subjected to regular irrigation ($I_1$) was higher (365.5 g $m^{-2}$) at heading stage in comparison to other treatments of irrigation water management. At maturity, the highest dry matter (321.1 g $m^{-2}$) was produced from drought stress for 10 days after PI or reproductive phase ($I_3$) followed by regular irrigation (314 g $m^{-2}$) treatment, whereas the lowest dry matter (293.8 g $m^{-2}$) was recorded from periodical water stress for 10 days from 15 DAT to maturity ($I_2$). In case of K management, application of potassium @ 51 kg $ha^{-1}$ ($K_2$) produced highest dry matter (319.8 g $m^{-2}$) during maturity (Figure. 6A and B). This result is in conformity with Islam et al. (2004) who found that plants under severe water stress and treated with 37.5 kg K $ha^{-1}$ produce the lower dry matter.

***Yield and yield components***

Grain yield and yield components of BRRI dhan71 were affected by irrigation water and K management (Table 1). However, Interaction effect of irrigation water and K management was not significant in grain yield and yield components (*P*> 0.05). Grain yield of rice grown under periodical water stress for 10 days ($I_2$) was significantly lower (2.64 t $ha^{-1}$) as compared to regular irrigation (3.38 t $ha^{-1}$) and drought stress for 10 days after PI (3.22 t $ha^{-1}$). Higher grain yield from regularly irrigated plots ($I_1$) was associated with higher panicle $m^{-2}$, grains $panicle^{-1}$ and 1000 grain weight. Grain yield was comparable when rice was grown under regular irrigation and water stress for 10 days at reproductive phase (Table 1). Results suggest that it is not necessary to apply flood irrigation method in rice cultivation to obtain high grain yield. However, grain yield decreased significantly in rice plants treated with periodical water stress for 10 days and this result agrees with the findings of Beyrouty et al. (1994) and Grigg et al. (2000). The lower grain yield of rice in periodical water stress for 10 days from 15 DAT to maturity was attributed to highest tiller mortality (%) (Figure 5A and B), lowest dry matter (Figure. 6A and B) and less spikelets per panicle. The increased yield of rice under short water stress cycle might be due to increase in biomass production (Figure. 6A and B), filled spikelet per panicle and tillers number $m^{-2}$ (Table 1). Grain yield is a function of biomass accumulation from heading to maturity and translocation of reserves (pre-stored before heading) to kernels (Yang et al., 2008). It has often been suggested that rice yield increase depends more on translocation of biomass to kernels those accumulated before heading than on biomass accumulation from heading to maturity (Miah et al., 1996, Laza et al., 2003). The decrease of rice yield with increasing water stress was also observed by Zulkernain et al. (2009). In the current study, it was observed that the biomass and filled spikelet were not affected by without irrigation for 10 days at reproductive phase (Table 1), however, exceeding 10 days water stress at reproductive phase, there would be reduction of the biomass and filled spikelet per panicle and also reduce yield.

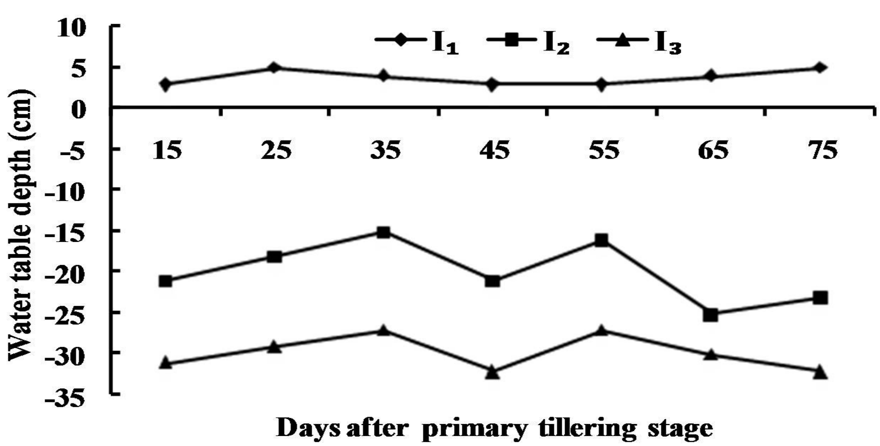


**Figure 2. Perch water table depth at field under different moisture levels. ($I_1$ = Regular irrigation with 1 cm standing water; $I_2$ = Periodical water stress for 10 days from 15 DAT to maturity; $I_3$ = Drought stress for 10 days after PI or reproductive phase; $K_1$ = 41 kg K $ha^{-1}$ and $K_2$ = 51 kg K $ha^{-1}$)**

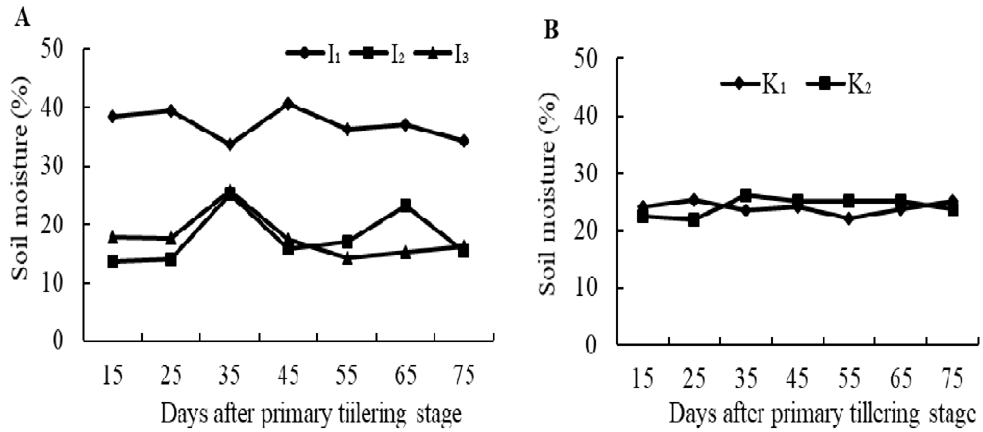


**Figure 3. Soil moisture at different moisture levels as influenced by irrigation water (A) and K management (B). ($I_1$ = Regular irrigation with 1 cm standing water; $I_2$ = Periodical water stress for 10 days from 15 DAT to maturity; $I_3$ = Drought stress for 10 days after PI or reproductive phase; $K_1$ = 41 kg K ha$^{-1}$ and $K_2$ = 51 kg K ha$^{-1}$)**

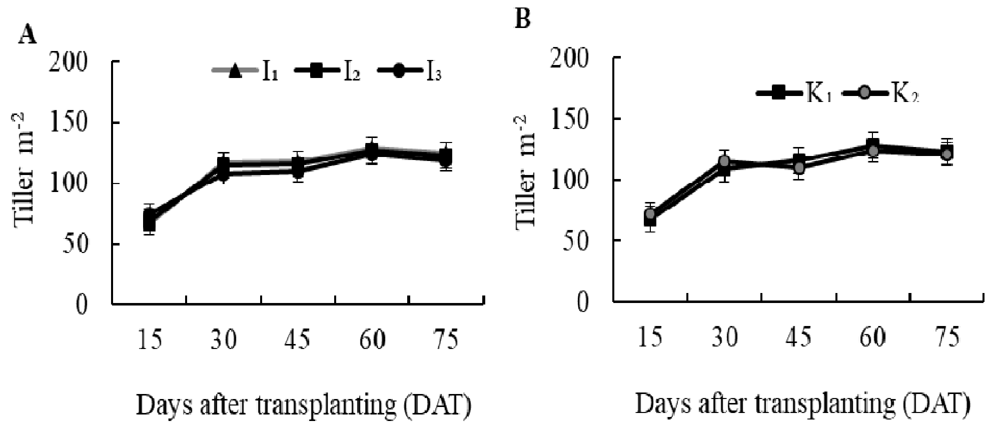


**Figure 4. Tillering pattern of BRRI dhan71 as affected by irrigation water (A) and K management (B). Vertical bars represent standard errors (SE). ($I_1$ = Regular irrigation with 1 cm standing water; $I_2$ = Periodical water stress for 10 days from 15 DAT to till maturity; $I_3$ = Drought stress for 10 days after PI or reproductive phase; $K_1$ = 41 kg K ha$^{-1}$ and $K_2$ = 51 kg K ha$^{-1}$)**

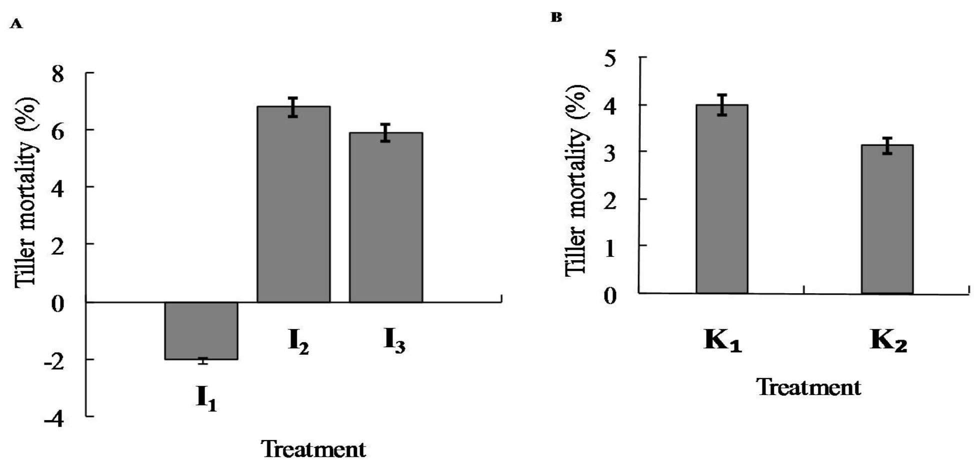


**Figure 5. Tiller mortality of BRRI dhan71 as affected by irrigation water (A) and K management (B). Vertical bars represent standard errors (SE). ($I_1$ = Regular irrigation with 1 cm standing water; $I_2$ = Periodical water stress for 10 days from 15 DAT to till maturity; $I_3$ = Drought stress for 10 days after PI or reproductive phase; $K_1$ = 41 kg K ha$^{-1}$ and $K_2$ = 51 kg K ha$^{-1}$)**

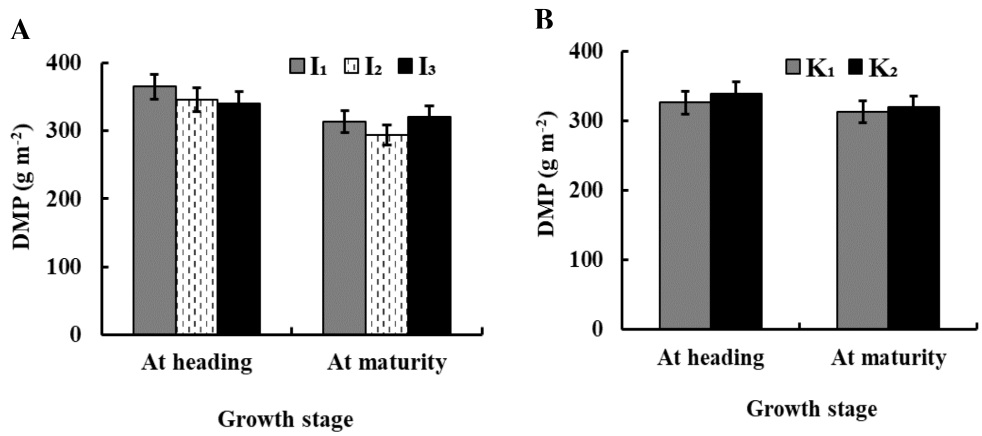


**Figure 6. Dry matter production (g m$^{-2}$) of BRRI dhan71 as affected by irrigation water (A) and K management (B). Vertical bars represent standard errors (SE). ($I_1$ = Regular irrigation with 1 cm standing water; $I_2$ = Periodical water stress for 10 days from 15 DAT to maturity; $I_3$ = Drought stress for 10 days after PI or reproductive phase; $K_1$ = 41 kg K ha$^{-1}$ and $K_2$ = 51 kg K ha$^{-1}$)**

***Morphological and physiological parameters***

Plant height ranged from 106 to 108 cm among the treatments (Table 2). There was no significant difference in plant height in respect of the combined effects of water management and potassium fertilization. Irrigation water managements showed significant effect on leaf area index (LAI). The highest LAI was observed in regular irrigation ($I_1$) treatment (2.65) followed by drought stress for 10 days at reproductive phase treatment (2.48), whereas the lowest LAI was observed in periodical water stress for 10 days from 15 DAT to maturity (1.93). Reduced soil moisture levels produced lower leaf area; it might be due to inhibition of cell division under water stress condition. The results from the current study are in agreement with Zubaer et al. (2007) who found that water stress reduced the leaf area in rice.

The SPAD value indicates the greenness or relative chlorophyll content of leaves, which differed significantly due to different water regimes. The highest chlorophyll content was measured in rice plants from the plots received regular irrigation (47.3) followed by drought stress for 10 days at reproductive phase (43.07) and periodical water stress for 10 days from 15 DAT to maturity (39.03). Cyclic water stress had significant influence on chlorophyll contents in rice (Table 2). It was observed that increased duration of water stress can significantly reduce total chlorophyll content in leaves and the similar result was also reported by Nilsen and Orcutt (1996) and Petrov (2012). Decreased chlorophyll level during drought stress has been reported in other species, depending on the duration and severity of drought (Kpyoarissis et al., 1995).

Root dry weight of rice was significantly affected due to differences in the management of water. The significant increase in root dry weight was observed while applied periodical water stress for 10 days from 15 DAT to maturity compared to the regular irrigation condition ($I_1$). The application of potassium fertilization showed no significant effect to enhance the root dry weight during this cylic water stress (Table 2). Our results indicated that the periodical water stress led to a increase in root dry weight in rice. Boutraa et al. (2010) and Ichsan et al. (2020) also reported that dry weight of wheat and rice root increased under the water stress conditions.

**Table 1. Impact of potassium fertilization on yield components of BRRI dhan71 under water stress at different growth stages at BRRI farm, Gazipur. ($I_1$ = Regular irrigation with 1 cm standing water; $I_2$ = Periodical water stress for 10 days from 15 DAT to maturity; $I_3$ = Drought stress for 10 days after PI or reproductive phase; $K_1$ = 41 kg K ha$^{-1}$ and $K_2$ = 51 kg K ha$^{-1}$)**

| Treatments | Panicles m$^{-2}$ | Grains panicle$^{-1}$ | 1000 grain wt. (g) | Grain Yield (t ha$^{-1}$) |
|---|---|---|---|---|
| Irrigation water management | | | | |
| $I_1$ | 119 | 116 | 26.06 | 3.38 |
| $I_2$ | 113 | 104 | 24.40 | 2.64 |
| $I_3$ | 112 | 113 | 26.36 | 3.22 |
| $LSD_{0.05}$ | NS | 8.69 | NS | 0.23 |
| K management | | | | |
| $K_1$ | 112 | 109 | 25.75 | 3.01 |
| $K_2$ | 117 | 111 | 25.46 | 3.20 |
| $LSD_{0.05}$ | NS | NS | NS | NS |
| CV (%) | 7.1 | 7.8 | 5.9 | 9.6 |

**Table 2. Impact of potassium fertilization on plant height, leaf area index, growth, total chlorophyll content (SPAD value), proline content, photosynthetic rate (µmol $CO_2$ $m^{-2}$ $s^{-1}$) of BRRI dhan71 under water stress at different growth stages at BRRI farm, Gazipur. ($I_1$ = Regular irrigation with 1 cm standing water; $I_2$ = Periodical water stress for 10 days from 15 DAT to maturity; $I_3$ = Drought stress for 10 days after PI or reproductive phase; $K_1$ = 41 kg K $ha^{-1}$ and $K_2$ = 51 kg K $ha^{-1}$)**

| Treatments | Plant height (cm) | Leaf area index (LAI) | Root dry weight (g) | Total chlorophyll content (SPAD value) | Proline content (µmol $g^{-1}$ leaf | Net Photosynthesis (µmol $CO_2$ $m^{-2}s^{-1}$) |
|---|---|---|---|---|---|---|
| Irrigation water management | | | | | | |
| $I_1$ | 108.00 | 2.65 | 1.40 | 47.30 | 1.71 | 22.24 |
| $I_2$ | 107.30 | 1.93 | 1.90 | 39.03 | 2.54 | 17.61 |
| $I_3$ | 106.70 | 2.48 | 1.40 | 43.07 | 3.06 | 22.34 |
| $LSD_{0.05}$ | NS | 0.50 | 0.29 | 1.63 | 0.37 | 1.15 |
| K management | | | | | | |
| $K_1$ | 106.80 | 2.38 | 1.55 | 43.26 | 2.45 | 19.16 |
| $K_2$ | 108.00 | 2.33 | 1.58 | 43.01 | 2.42 | 24.60 |
| $LSD_{0.05}$ | NS | NS | NS | NS | NS | 1.45 |
| CV (%) | 1.9 | 9.2 | 25.9 | 3.6 | 3.9 | 6.4 |

Proline content was influenced by the water stress (Table 2). Higher proline content (3.06 µmol $g^{-1}$ leaf) was found in drought stress for 10 days at reproductive phase followed by periodical water stress for 10 days from 15 DAT to maturity (2.54 µmol $g^{-1}$ leaf) and lowest in the regular irrigation condition (1.71 µmol $g^{-1}$ leaf). The data indicated that proline content significantly increases when the rice plants are exposed to periodical water stress, especially for 10 days at reproductive phase. Zain et al. (2014) also observed the increase in proline content under cyclic water stress in rice.

Results from this study indicated that there were significant differences of photosynthetic rate in different irrigation water management and applications of K. Photosynthetic rate was significantly higher in both regular irrigation (22.24 µmol $CO_2$ $m^{-2}$ $s^{-1}$) and drought stress for 10 days at reproductive phase (22.34 µmol $CO_2$ $m^{-2}$ $s^{-1}$) and it was comparable among the treatments (Table 2). These results also indicate that photosynthetic rate differed significantly with LAI (Table 2) and grain yield (Table 1) under different irrigation water management practices. Net photosynthesis was higher under regular irrigated condition followed by periodical water stress condition and was lowest at water stress in reproductive phase (Table 2). The decrease in photosynthesis in drought stressed plants could be attributed both to stomatal and non-stomatal responses. Stomatal responses has been associated with chemical signals, particularly to the synthesis of abscisic acid (ABA), which regulate the rate of transpiration and plant moisture status (Grigg et al., 2000). This result is also supported by Centritto et al. (2009). It was also found that potassium fertilization under water stress conditions at the reproductive phase could minimize drought stress effects such as reduction in net photosynthesis (Fukai and Cooper, 1995).

## CONCLUSIONS

The results of the present study indicate that the increase of water stress cycle reduces yield of rice. However, proline accumulation in leaves increased and chlorophyll content reduced with increased duration of water stress cycle. There was no interaction between irrigation and K levels in respect of the parameters studied for the BRRI dhan71. It was also observed that the biomass and filled spikelet were not affected by the withdrawal of irrigation for 10 days at reproductive phase. The imposition of water stress for 10 days at the reproductive phase has been found to enhance rice tolerance to water stress. Therefore, the cultivation of the rice variety BRRI dhan71 does not require flood irrigation as it is necessary for most of the traditional rice varieties. These findings might be suggested for the rice growers of Bangladesh where irrigation water is scarce.

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## Conflict of Interest

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

## REFERENCES

Alexieva, V., Sergiev, I., Mapelli, S. and Karanov, E. 2001. The effect of drought and ultraviolet radiation on growth and stress markers in pea and wheat. Plant, Cell & Environment, 24: 1337-1344.

Bajji M., Lutts, S. and Kinet J. M. 2001. Water deficit effects on solute contribution to osmotic adjustment as a function of leaf ageing in three durum wheat (*Triticum durum* Desf.) cultivars performing differently in arid conditions. Plant Science, 160: 669-681.

Bates, L.S., Waldren, R.P. and Teare, I.D. 1973. Rapid determination of free proline for water-stress studies. Plant Soil, 39: 205-207.

Beyrouty, C.A., Grigg, B.C., Norman, R.J. and Wells, B.R. 1994. Nutrient uptake by rice in response to water management. Journal of Plant Nutrition and Soil Science, 17: 39-55.

Boutraa, T., Abdellah, A., Al-Shoaibi, A.A. and Alhejeli, A.M. 2010. Effect of water stress on growth and water use efficiency (WUE) of some wheat cultivars (*Triticum durum*) grown in Saudi Arabia. Journal of Taibah University for Science, 3: 39-48.

Cabangon, R.J., Tuong, T.P. and Abdullah, N.B. 2002. Comparing water input and water productivity of transplanted and direct-seeded rice production systems. Agricultural Water Management, 57: 11-31.

Centritto, M., Lauteri, M., Monteverdi, M.C. and Serraj, R. 2009. Leaf gas exchange, carbon isotope discrimination, and grain yield in contrasting rice genotypes subjected to water deficits during the reproductive stage. Journal of Experimental Botany, 60: 2325-2339.

Cha-um, S. and Kirdmanee, C. 2008. Effect of osmotic stress on proline accumulation, photosynthetic abilities and growth of sugarcane plantlets (*Saccharum officinarum* L.). Pakistan Journal of Botany, 40:2541-2552.

FAO. 2012. FAO statistical yearbook. http://www.fao.org/statistics/yearbook.

Farooq, M., Basra, S.M.A., Wahid, A. and Rehman, H. 2009. Exogenously applied nitric oxide enhances the drought tolerance in fine grain aromatic rice (*Oryza sativa* L.). Journal of Agronomy and Crop Science, 195:254-261.

Fukai, S. and Cooper, M. 1995. Development of drought-resistant cultivars using physio-morphological traits in rice. Field Crops Research, 40: 67-86.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research (2nd edn.). John wiley and sons, NewYork, p 680.

Grigg, B.C., Beyrouty, C.A., Norman, R.J., Gbur, E.E., Hanson, M.G. and Wells, B.R. 2000. Rice responses to changes in flood water and N timing in southern USA. Field Crops Research, 66: 73-79.

Habiba, U. and Abedin, M.A. 2015. Eds., Food security and risk reduction in Bangladesh. Springer. p 273.

Ichsan, C.N., Basyah, B., Zakaria, S. and Efendi, E. 2020. Difference of water status and relationship with roots growth and yield of rice under water stress. Systematic Reviews in Pharmacy, 11(8): 611-618.

Inada, K. 1985. Spectral ratio of reflectance for estimating chlorophyll content of leaf. Japan Journal of Crop Science, 54: 261-265.

Islam, M.S., Haque, M.M., Khan, M.M., Hidaka, T. and Karim, M.A. 2004. Effect of fertilizer potassium on growth, yield and water relations of Bushbean (*Phaseolus vulgaris* L.) under water stress conditions. Japanese Journal of Tropical Agriculture, 48(1):1-9.

Iturbe Ormaetxe, I., Escuredo, P.R., Arrese-Igor, C. and Becana, M. 1998. Oxidative damage in pea plants exposed to water deficit or paraquat. Plant Physiology, 116: 173-181.

Kader M.A., Aditya, T.L., Majumder, R.R., Hore, T.K., Shalahuddin, A.K.M. and Amin, A. 2019. Development of drought tolerant rice variety BRRI dhan66 for rainfed lowland ecosystem of Bangladesh, Bangladesh Rice Journal, 23 (1): 45-55.

Kpyoarissis, A., Petropoulou. Y. and Manetas, Y. 1995. Summer survival of leaves in a soft-leaved shrub (*Phlomis fruticosa* L., Labiatae) under Mediterranean field conditions: avoidance of photoinhibitory damage through decreased chlorophyll contents. Journal of Experimental Botany, 46: 1825-1831.

Lafitte, H., Ismail, A. and Bennett, J. 2004. Abiotic stress tolerance in rice for Asia. Progress and the future; Proceedings of the 4th International Crop Science Congress; 26 September-1 October, Brisbane, Australia.

Laza, R.C., Peng, S., Akita, S. and Saka, H. 2003. Contribution of biomass partitioning and translocation to grain yield under sub-optimum growing conditions in irrigated rice, Plant Production Science, 6(1): 28-35.

Marschner, P. 2012. Marschner's mineral nutrition of higher plants, (3rd edn.). Academic Press, London, UK. pp. 178-189.

Miah, M.N.H., Yoshida, T., Yamamoto, Y. and Nitta, Y. 1996. Characteristics of dry matter production and partitioning of dry matter in high yielding semi-dwarf indica and japonica–indica hybrid rice varieties. Japanese Journal of Crop Science, 65: 672-685.

Nilsen, E.T. and Orcutt, D.M. 1996. The physiology of plants under stress. John Wiley & Sons, New York, pp. 322-361.

Ommen, O.E, Donnelly, A., Vanhoutvin, S., Van Oijen, M. and Manderscheid, R. 1999. Chlorophyll content of spring wheat flag leaves grown under elevated $CO_2$ concentrations and other environmental stresses within the ESPACE-wheat project. European Journal of Agronomy, 10: 197-203.

Pandey, S., Bhandari, H. and Hardy, B. 2007. Economic costs of drought and rice farmers' coping mechanisms: a cross-country comparative analysis. International Rice Research Institute. Los Baños (Philippines).

Pantuwan, G., Fukai, S., Co-oper, M., Rajatasereekul, S. and O'Toole J C. 2000. Field screening for drought resistance. *In*: Increased Lowland Rice Production in the Mekong Region; Proceedings of the International Workshop: 30 October-2 November 2000, Vientiane, Laos. pp. 69-77.

Petrov, P.I. 2012. Ion leakage and leaf anatomy of barley plants subjected to dehydration. Genetics and Plant Physiology, 2: 15-23.

Quampah, A., Wang, R.M., Shamsil, I.H, Jilanil, G., Zhang, Q., Hua, S. and Xu, H. 2011. Improving water productivity by potassium application in various rice genotypes. International Journal of Agriculture and Biology, 13:1560-1853.

Razak, A.A., Ismail, M.R., Karim, M.F., Wahab, P.E.M., Abdullah, S.N. and Kausar, H. 2013. Changes in leaf gas exchange, biochemical properties, growth and yield of chilli grown under soilless culture subjected to deficit fertigation. Australian Journal of Crop Science, 7:1582-1589.

Roy, D., Islam, M.T. and Nath, B.C. 2010. Impact of supplemental irrigation applied at different growth stages of transplanted aman rice (*Oryza sativa*). The Agriculturists, 8 (1):109-114.

Sanchez, F.J., Manzanares, M., De Andres, E.F., Tenorio, J.L. and Ayerbe, L. 1998. Turgor maintenance, osmotic adjustment and soluble sugar and proline accumulation in 49 pea cultivars in response to water stress. Field Crops Research, 59: 225-235.

Sarkarung, S., Pantuwan, G., Pushpavesa, S. and Tanupan, P. 1997. Germplasm development for rainfed lowland ecosystems: breeding strategies for rice in drought-prone environments. Proceedings of International Workshop: 5-8 November 1997, Ubon Ratchathani, Thailand. pp. 43-49.

Smirnoff, N. 1995. Antioxidant systems and plant response to the environment. *In*: Smirnoff, V. (Ed.), Environment and Plant Metabolism: Flexibility and Acclimation, BIOS Scientific Publishers, Oxford, UK.

Teixeira, J. and Pereira, S. 2007. High salinity and drought act on an organ-dependant manner on potato glutamine synthetase expression and accumulation. Environmental and Experimental Botany, 60: 121-126.

Yang, W., Peng, S., Laza, R.C., Visperas, R.M., M.L. and Dionisio-Sese, M.L. 2008. Yield gap analysis between dry and wet season rice crop grown under high-yielding management conditions. Agronomy Journal, 100: 1390-1395.

Yoshida, S. 1981. Fundamentals of rice crop science. International Rice Research Institute, Los Banos, Laguna, and Philippines. p 267.

Zain, N. A. M., Ismail, M.R., Puteh, A., Mahmood, M. and Ismail, M.R. 2014. Impact of cyclic water stress on growth, physiological responses and yield of rice (*Oryza sativa* L.) grown in tropical environment. Ciência Rural, Santa Maria, 44 (12): 2136-2141.

Zubaer, M.A., Chowdhury, A.K.M.M.B., Islam, M.Z, Ahmed, T. and Hasan, M.A. 2007. Effects of water stress on growth and yield attributes of Aman rice genotypes. International journal of Sustainable Crop Production, 2(6):25-30.

Zulkernain, W.M., Ismail, M.R., Ashrafuzzaman, M., Saud, H.M. and Haroun, I.C. 2009. Rice growth and yield under rain shelter house as influenced by different water regimes. International Journal of Agriculture and Biological Science, 11: 556-560.