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Effect of supplemental irrigation to alleviate the adverse impact of terminal drought stress on aman rice

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ABSTRACT

An experiment was conducted at Crop Physiology and Ecology Research Field of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during August to December 2019 to find out effect of supplemental irrigation on growth and yield of T. aman rice and to assess requirement supplemental irrigation for sustainable rice production in aman season. Rice variety Binashail was used as planting material. The experiment was conducted following Randomized Complete Block Design with four treatments and four replications. The treatments were: i) Rainfed condition (I_0), ii) One supplemental irrigation at 45 days after transplanting (I_1), iii) Two supplemental irrigation at 45 and 60 days after transplanting (I_2) and iv) Three supplemental irrigation at 45, 60 and 75 days after transplanting (I_3). The total number of unit plots was 16 and the size of the unit plot was 2 m×2 m. The distance between plots was 1 m and block to block distance was 1.5 m. Rice variety Binashail was used as planting material. The impact of supplemental irrigation on plant height, tillers hill^{-1}, leaves hill^{-1}, panicle length, spikelets panicle^{-1}, unfilled spikelets panicle^{-1} and above ground biomass of T. aman was found insignificant but the SPAD value which indicates the greenness of leaf was significantly increased due to supplemental irrigation. Supplemental irrigation in aman rice causes significant increase in grain yield compared to rainfed condition. The increment in grain yield was 22.82% for one supplemental irrigation, 23.30% for two supplemental irrigation and 31.55% for three supplemental irrigation. The increase in grain yield in supplemental irrigation plots was contributed by the increment in grains panicle^{-1}, grain size and grain weight hill^{-1}. The results of the present study indicate that one supplemental irrigation in T. aman is enough for sustaining yield.

Key words: Alleviation, drought stress, supplemental irrigation and T. aman

INTRODUCTION

Rice is grown in Bangladesh under diverse ecosystems like irrigated, rainfed and deep-water conditions in three distinct seasons namely Aus, Aman, and Boro. Aman rice is one of the major crops of Bangladesh and accounts for about 41 % of the total rice production (BBS 2006). According to Bangladesh Rice Research Institute (BRRI 1991), aman is almost a completely rainfed rice that grows in the months of monsoon. The rainfall distribution pattern in this period is not uniform. Bangladesh receives about 95% of the total annual rain water (203 cm) during the months from April to October. This quantity of water can support safe yield of rice

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crops. Abrupt ending of monsoon in September can create severe water stress in T. Aman season. After October, rainfall is not sufficient for potential yield of rice and most of the Aman rice remains at the flowering and grain filling stages (Sattar and Parvin 2009). A rice crop can't be sustained during this period on rainfall alone (Rashid et al. 2005). Sattar (1993) stated that water stress at the vegetative phase caused about 25% yield loss and that of at reproductive phase caused as high as 50% yield loss. Islam (2007) observed from model studies that supplementary irrigation is a must for sustainable T. Aman production.

Supplemental irrigation plays a vital role in alleviating drought impact especially in T. Aman rice. The supplementary irrigation requirement is higher in October-November for T. Aman rice (Saleh 1991). If water is not supplied timely, rice yield is reduced drastically. Although the total rainfall during the crop growing period of T. Aman exceeds the crop water requirement, there is a need for supplementary irrigation due to the erratic distribution of rainfall (Khan 1979, Haq et al. 1985, Saleh 1987). In T. Aman season, supplementary irrigation at the right time may increase rice yields from 8 to 71 % over rainfed condition (Saleh 1987, BRRI 1991). Various researchers find out the effect of supplemental irrigation on rice yield and water requirement during drought period for different growth phases of rice. But information about the effect of supplemental irrigation on T. Aman rice at the northern part of Bangladesh is still scanty. Considering the limitation, the present investigation was undertaken to find out effect of supplemental irrigation on growth and yield of T. aman rice and to assess requirement supplemental irrigation for sustainable rice production in aman season.

MATERIALS AND METHODS

The experiment was conducted at Crop Physiology and Ecology Research Field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during August to December 2019. The experimental field was a medium high land belonging to the non-calcareous dark gray floodplain soil under the agro-ecological zone (AEZ-1) of Old Himalayan Piedmont Plain. The experimental site is situated in the sub-tropical region characterized by heavy rainfall during the months from June to September and scantly rainfall in the rest of the year.

The experiment was conducted following Randomized Complete Block Design with four treatments and four replications. The treatments were: i. Rainfed condition (I_0), ii. One supplemental irrigation at 45 days after transplanting (I_1), iii. Two supplemental irrigation at 45 and 60 days after transplanting (I_2) and iv. Thre supplemental irrigations at 45, 60 and 75 days after transplanting (I_3). The total number of unit plots was 16 and the size of unit plot was 2 m×2 m. The distance between plots was 1 m and block to block distance was 1.5 m. Rice variety Binashail was used as planting material.

N-P-K-S-Zn at the rate of 70-15-40-8-1.25 kg ha^{-1}, respectively was used as recommended doses of fertilizers (BARC 2005). Cowdung (10 t ha^{-1}), Triple super phosphate (TSP), Muriate of potash (MoP), Gypsum and Zinc Sulphate ($ZnSo_4$) were applied as basal dose to all the experimental plots. Urea was applied as top-dressing method in three equal splits. The first dose of urea was applied at l5 days after transplanting (DAT). The rest doses of urea were top dressed at 30 DAT (active tillering stage) and 45 DAT (panicle initiation stage).

Thirty days old seedlings were uprooted carefully from the seedbed in the morning and then transplanted on the same day on well puddled unit plot on August 2, 2019. The spacing was 20 cm × 20 cm and three healthy seedlings were transplanted in each hill. Rice in control plot was cultivated under rainfed condition. Supplemental irrigated plots were irrigated up to 5 cm on soil surface as per treatments. Intensive cares were taken during the growing period to ensure adequate growth and development of the crop. Intercultural operations were done as per necessary.

Plant height, tillers $hill^{-1}$ and leaves $hill^{-1}$ were recorded at 55 and 70 days after transplanting. SPAD value was taken from middle portion of the flag leaf of five main shoot at 60 DAT using SPAD meter (Model: MINOLTA, CHLOROPHYLL METER, SPAD-502, JAPAN). Number of panicles $hill^{-1}$ at harvesting stage were counted from five hills and mean value was recorded. Five panicles were taken at random from different hills and the filled and unfilled spikelet $panicle^{-1}$ were counted and averaged. Panicle length (cm) was taken from basal node of the rachis to apex of five panicles and the average value was recorded. Thousand grains from each plot were weighed after sun drying by an electrical balance and the data was recorded. Grain and straw yields were recorded for each plot after sun drying. The grain yield was expressed as g m^{-2} on 14% moisture basis and the above ground biological yield was expressed as kg m^{-2}.

The data were analyzed by partitioning the total variance with the help of computer using Statistix 10 program. The treatment means were compared using Tukey's test at $p \leq 5\%$ level.

RESULTS AND DISCUSSION

Plant height: Plant height of transplanted aman rice at 55 and 70 DAT was not significantly influenced by supplemental irrigation treatments (Figure 1). At 55 DAT, the highest plant height (111.05 cm) was recorded from three supplemental irrigations plot (I_3) and the lowest plant height (107.98 cm) was recorded from two supplemental irrigations plot (I_2). At 70 DAT, the highest plant height (118.75 cm) was obtained from rainfed condition (I_0) and the lowest plant height (107.98 cm) was obtained from three supplemental irrigations plot (I_3). Plant height was not affected by supplemental irrigation in the present study. It might be due to regular rainfall during August and September 2019 in the study area (Appendix II). Ganesh (2003) also observed that plant height of rice did not significantly vary with irrigation treatment during the period of 1990-91 and 1992-93.

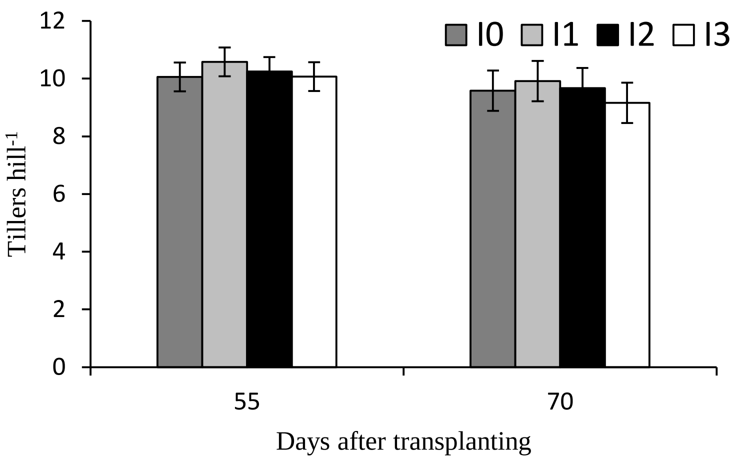

Figure 1. Plant height (mean ± lsd) of transplanted aman rice (Binashail) at 55 and 70 days after transplanting as influenced by supplemental irrigation. .Where, I_0 = Control (Rainfed), I_1 = One supplemental irrigation at 60 DAT, I_2 = Two supplemental irrigations at 60 and 75 DAT, I_3 = Three supplemental irrigations at 45, 60 and 75 DAT. Vertical bar indicates least significance difference for Tukey's test at $p \leq 5\%$.

Tillers hill^{-1}: Tillers hill^{-1} of transplanted aman rice at 55 and 70 DAT was not significantly influenced by supplemental irrigation treatments (Figure 2). In general, number of tillers hill^{-1} was reduced at 70 DAT compared to that at 55 DAT. At 55 DAT, the highest number of tillers hill^{-1} (10.58) was recorded from one supplemental irrigations plot (I_1) and the lowest number of tillers hill^{-1} (10.06) was recorded from control plot in which rice was cultivated under rainfed condition (I_0). At 70 DAT, the highest number of tillers hill^{-1} (9.91) was obtained from one supplemental irrigations plot (I_1) and the lowest number of tillers hill^{-1} (9.16) was obtained from three supplemental irrigations plot (I_3). In the present study, greater number of tillers hill^{-1} was found at 55 DAT after that it was reduced at 70 DAT. It is because of attaining of maximum tillering stage before 55 DAT and after that tiller abortion was occurred in rice (Badshah et al. 2014). Haque et al. (2012) also found increasing trend of total tillers hill^{-1} up to 45 and then declined up to 75 DAT. Tillers hill^{-1} was not affected by supplemental irrigation in the present study. It might be due to regular rainfall during August and September 2019 in the study area . (Appendix II). During this period aman rice attained at maximum tillering stage.

Leaves hill^{-1}: Leaves hill^{-1} of transplanted aman rice at 55 and 70 DAT was not significantly influenced by supplemental irrigation treatments (Figure 3). In general, number of tillers hill^{-1} was reduced at 70 DAT compared to that at 55 DAT. At 55 DAT, the highest number of leaves hill^{-1} (34.83) was recorded from rainfed condition (I_0) and the lowest number of leaves hill^{-1} (32.58) was recorded from three supplemental irrigations plot (I_3). At 70 DAT, the highest number of leaves hill^{-1} (27.75) was obtained from control plot (I_0) and the lowest number of leaves hill^{-1} (26.00) was obtained from one supplemental irrigations plot (I_3). As tillers hill^{-1} was not affected by supplemental irrigation the leaves hill^{-1} was not affected by supplemental irrigation treatments in the present study. A decreasing trend of leaf number hill^{-1} was observed after 55 days after transplanting. Yambao and Ingram (1988) also noticed general increased in leaf number hill^{-1} until the flowering stage and it declined there after till harvesting possibly due to leaf senescence

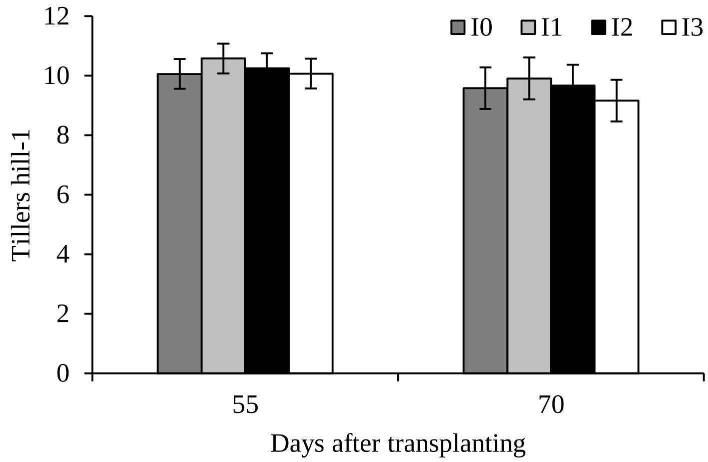

Figure 2. Tillers hill^{-1} of transplanted aman rice (Binashail) at 55 and 70 days after transplanting as influenced by supplemental irrigation. Where, I_0 = Control (Rainfed), I_1 = One supplemental irrigation at 60 DAT, I_2 = Two supplemental irrigations at 60 and 75 DAT, I_3 = Three supplemental irrigations at 45, 60 and 75 DAT. Vertical bar indicates least significance difference for Tukey's test at $p \leq 5\%$.

SPAD value of flag leaf: SPAD value of flag leaf which indicated the greenness of flag leaf was recorded at 60 DAT. Flag leaf SPAD value was significantly influenced by supplemental irrigation treatments (Figure 4). The highest SPAD value (35.97) was recorded from two supplemental irrigation plot (I_2) which was statistically equal to those recorded in one supplemental irrigation plot (35,20) and three supplemental irrigations plot (35.60). The lowest SPAD value was recorded from rainfed condition (33.60). The results in SPAD value indicated that supplemental irrigation in aman rice causes significant increase in greenness of flag leaf compared to rainfed condition. Mohanty et al. (2018) also found greater SPAD value of flag leaf in supplemental irrigated plot compared to rainfed plot.

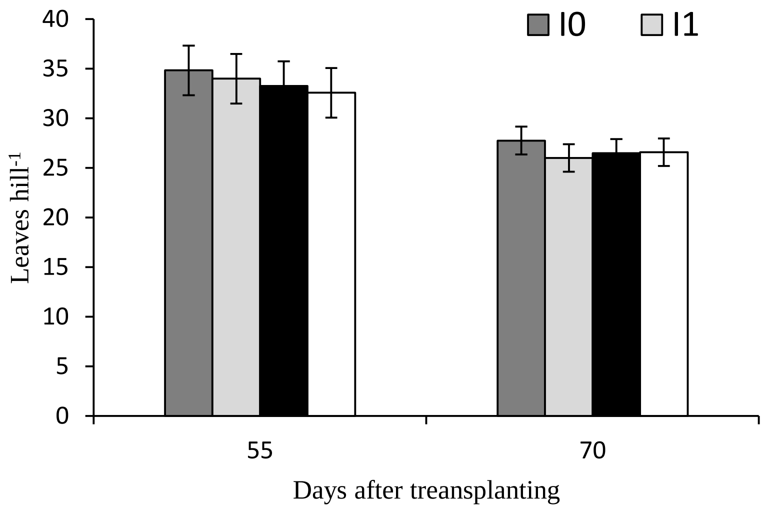

Figure 3. Leaves hill^{-1} of transplanted aman rice (Binashail) at 55 and 70 days after transplanting as influenced by supplemental irrigation. Where, I_0 = Control (Rainfed), I_1 = One supplemental irrigation at 60 DAT, I_2 = Two supplemental irrigations at 60 and 75 DAT, I_3 = Three supplemental irrigations at 45, 60 and 75 DAT. Vertical bar indicates least significance difference for Tukey's test at $p \leq 5\%$.

Plant height (cm) at harvest: Plant height of transplanted aman rice at harvest was not significantly influenced by supplemental irrigation treatments (Table 1). The highest plant height (115.80 cm) was recorded from two supplemental irrigations plot (I_2) and the lowest plant height (114.35 cm) was recorded from rainfed condition (I_0). Plant height at harvest was not affected by supplemental irrigation in the present study. It might be due to rice plants generally attain their maximum height at flowering stage and up to this stage (last of September 2019) regular rainfall occurred in the study area (Appendix II). Ganesh (2003) and Mohanty et al. (2018) also observed that plant height of rice did not significantly vary between supplemental irrigation treatment and rainfed condition.

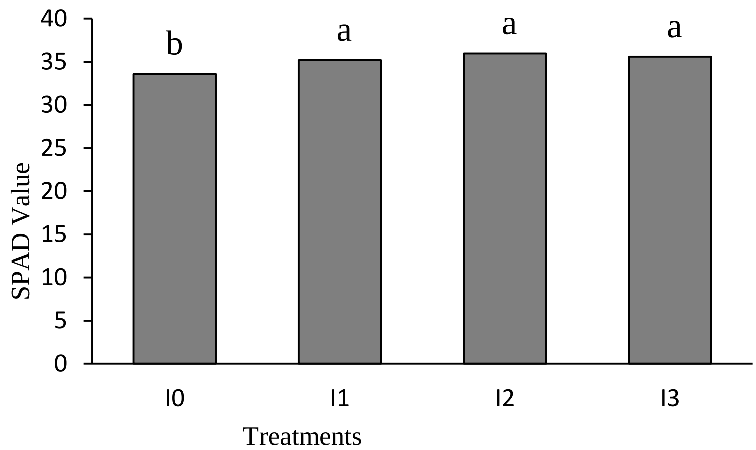

Figure 4. SPAD value of flag leaf of transplanted aman rice (Binashail) at 60 days after transplanting as influenced by supplemental irrigation. Where, I_0 = Control (Rainfed), I_1 = One supplemental irrigation at 60 DAT, I_2 = Two supplemental irrigations at 60 and 75 DAT, I_3 = Three supplemental irrigations at 45, 60 and 75 DAT, Values having different letter (s) differed significantly t at P ≤5 % level of probability by Tukey's test

Table 1. Plant height and panicle length of transplanted aman rice (Binashail) at harvest as influenced by supplemental irrigation

Treatments	Plant height (cm)	Panicle length (cm)	Tillers hill^{-1}	Panicles hill^{-1}	Spikelets panicle^{-1}	Unfilled spikelets panicle^{-1}
I_0	114.35 a	24.17 a	9.10 a	7.35 b	162.50 a	22.73 a
I_1	115.45 a	24.43 a	8.75 a	8.50 a	163.00 a	22.18 a
I_2	115.80 a	24.04 a	9.55 a	8.35 ab	155.85 a	25.83 a
I_3	114.65 a	25.01 a	9.30 a	8.65 a	172.00 a	20.83 a
CV	3.53	4.92	7.35	5.57	17.17	19.58
Level of significance	NS	NS	NS	*	NS	NS

In a column, values having different letter (s) diffred significantly at P ≤5 % level of probability by Tukey's test.
^{NS} indicates not significant, * indicates significant at 5% level of probability. Where, I_0 = Control (Rainfed), I_1 = One supplemental irrigation at 60 DAT, I_2 = Two supplemental irrigations at 60 and 75 DAT, I_3 = Three supplemental irrigations at 45, 60 and 75 DAT

Panicle length (cm): Panicle length of transplanted aman rice was not significantly influenced by supplemental irrigation treatments (Table 1). The highest panicle length (25.01 cm) was recorded from three supplemental irrigations plot (I_3) and the lowest panicle length (24.04 cm) was recorded from two supplemental irrigations plot (I_2). In the present study, panicle length was not significantly influenced by supplemental irrigation treatments but Shamsuzzaman (2007) found 5.86% increase in panicle length of transplanted aman rice in irrigated plots over rainfed conditioned plots.

Tillers hill^{-1} at harvest: Tillers hill^{-1} of transplanted aman rice (Binashail) at harvest was not significantly influenced by supplemental irrigation treatments (Table 1). The highest number of tiller hill^{-1} (9.55) was recorded from two supplemental irrigations plot (I_2) and the lowest number of tiller hill^{-1} (8.75) was recorded from one supplemental irrigation plot (I_1). Mohanty et al. (2018) also found higher number of tillers hill^{-1} in supplemental irrigated plot compared to rainfed plot.

Panicles hill^{-1}: Panicles hill^{-1} of transplanted aman rice (Binashail) at harvest was significantly influenced by supplemental irrigation treatments (Table 1). The highest number of panicles hill^{-1} (8.65) was recorded from three supplemental irrigation plot (I_3) which was statistically equal to those recorded in one supplemental irrigation plot (8.50) and two supplemental irrigations plot (8.35). The lowest number of panicles hill^{-1} (7.35) was recorded from rainfed condition (I_0) which was statistically similar to that recorded in two supplemental irrigations treatment (I_2). The results in number of panicles hill^{-1} indicated that supplemental irrigation in aman rice causes considerable increase in number of panicles hill^{-1} compared to rainfed condition. Mohanty et al. (2018) also found higher number of panicles hill^{-1} in supplemental irrigated plot compared to rainfed plot.

Spikelets panicle^{-1}: Supplemental irrigation treatments could not influence the number of spikelets panicle^{-1} of transplanted aman rice (Binashail) significantly (Table 1). The highest number of spikelets panicle^{-1} (172.00) was recorded from three supplemental irrigations plot (I_3) and the lowest number of spikelets panicle^{-1} (162.50) was recorded from control plot (I_0) in which supplemental irrigation was not applied.

Unfilled spikelets panicle^{-1}: Supplemental irrigation treatments could not influence the number of unfilled spikelets panicle^{-1} of transplanted aman rice (Binashail) significantly (Table 1). The highest number of unfilled spikelets panicle^{-1} (25.83) was recorded from two supplemental irrigations plot (I_2) and the lowest number of unfilled spikelets panicle^{-1} (20.83) was recorded from three supplemental irrigations plot (I_3).

Grains panicle^{-1}: Grains panicle^{-1} of transplanted aman rice (Binashail) at harvest was significantly influenced by supplemental irrigation treatments (Table 2). The highest number of grains panicle^{-1} (148.95) was recorded from three supplemental irrigations (I_3) which was statistically equal to that recorded in one supplemental irrigation (146.55). The lowest number of grains panicle^{-1} (132.60) was recorded from rainfed condition (I_0). The results in number of grains panicle^{-1} indicated that supplemental irrigation in aman rice causes considerable increase in number of grains panicle^{-1} compared to rainfed condition. Mohanty et al. (2018) also found higher number of grains panicle^{-1} in supplemental irrigated plot compared to rainfed plot. Fatima et al. (2018) reported that water stress tolerant variety Nagina 22 showed a minimum reduction in filled grain per panicle whereas PB1 showed a maximum reduction after water stress compared to supplemental irrigated plot.

Thousand grain weight (g): Thousand grain weight of transplanted aman rice (Binashail) was significantly influenced by supplemental irrigation treatments (Table 2). The highest thousand grain weight (18.15 g) was provided by three supplemental irrigations (I_3) which was statistically equal to those recorded in one supplemental irrigation (18.05 g) and two supplemental irrigations (17.95 g). The lowest thousand grain weight (17.17 g) was recorded from rainfed condition (I_0) which was statistically identical with those recorded from one and two supplemental irrigation plots. The results in thousand grain weight indicated that supplemental irrigation in aman rice causes considerable increase in grain size compared to rainfed condition. Greater grain size in supplemental irrigation plots might be due to greater photosynthetic ability of flag leaf which is indicated by greater SPAD value in the present study. But Mohanty et al. (2018) found insignificant change in 1000 grain weight between supplemental irrigated plot and rainfed plot.

Grain weight hill^{-1}: Supplemental irrigation treatments influenced the grain weight hill^{-1} of transplanted aman rice (Binashail) significantly (Table 2). The highest grain weight hill^{-1} (13.51 g) was recorded from three supplemental irrigation plot (I_3) which was statistically equal to those recorded in two supplemental irrigation plot (13.19 g) and one supplemental irrigation plot (12.27 g). Significantly the lowest grain weight hill^{-1} (9.22 g) was recorded from rainfed condition (I_0). The results in grain weight hill^{-1} indicated that supplemental irrigation in aman rice causes significant increase in grain weight hill^{-1} compared to rainfed condition. The increase in grain weight hill^{-1} in supplemental irrigation plots was contributed with the increment in grains panicle^{-1} and grain size in the respective treatments.

Grain yield: Supplemental irrigation treatments significantly influenced the grain yield (g m^{-2}) of transplanted aman rice (Table 2). The highest grain yield (271 g m^{-2}) was recorded from three supplemental irrigation plot (I_3) which was statistically equal to those recorded in two supplemental irrigation (I_2) (254 g m^{-2}) and one supplemental irrigation plot (253 g m^{-2}). Significantly the lowest grain yield (206 g m^{-2}) was recorded from rainfed condition (I_0). The results in grain yield indicated that supplemental irrigation in aman rice causes significant increase in grain yield compared to rainfed condition. The increment in grain yield was

22.82% for one supplemental irrigation, 23.30% for two supplemental irrigation and 31.55% for three supplemental irrigation. The increase in grain yield in supplemental irrigation plots was contributed with the increment in grains panicle^{-1}, grain size and grain weight hill^{-1} in the respective treatments which is found in the present study. Shamsuzzaman (2007) found 7.67% increase in grain yield of transplanted aman rice in irrigated plots over rainfed conditioned plots. Kabir (2011) showed that Binadhan-7 gave the minimum result 3.92 t ha^{-1} under rainfed condition while the highest was obtained when irrigated four times (5.86 t ha^{-1}). Pandey et al. (2003) stated that grain and straw yield were higher under irrigated condition over rainfed. Panigrahi and Panda (2003) found an increase of 39% in the yield of rice grain over rainfed conditions because of application of 84mm of supplemental irrigation, respectively. Roy et al. (2010) found that yield was linearly related with the amount of supplemental irrigation water. The increased yields due to supplemental irrigations over that of rainfed were as 2.2, 6.7, 11.1 and 13.3% for irrigation just after transplanting, till panicle initiation, till flowering and till harvesting, respectively. Islam et al. (1991) stated that one timely supplemental irrigation of 60 mm could produce about 58 to 70% more yield.

Above ground biological yield: Above ground biological yield of transplanted aman rice (Binashail) was not significantly influenced by supplemental irrigation treatments (Table 2). The highest above ground biological yield (1.61 kg m^{-2}) was recorded from three supplemental irrigations plot (I_3) and the lowest above ground biological yield (1.31 kg m^{-2}) was recorded from control treatment. Supplemental irrigation could not influence the above ground biological yield of rice in the present study. Mohanty et al. (2018) also found insignificant change in biomass yield between supplemental irrigated plot compared to rainfed plot. But Shamsuzzaman (2007) found 3.77% increase in above ground biological yield of transplanted aman rice in irrigated plots over rainfed conditioned plots.

Table 2. Spikelets panicls^{-1}, unfilled spikelets panicle^{-1} and grains panicle^{-1} of transplanted aman rice (Binashail) as influenced by supplemental irrigation

Treatments	Grains panicle^{-1}	Thousand grain weight (g)	Grain weight hill^{-1} (g)	Grain yield (g m^{-2})	Grain yield % increase over rainfed condition (I_0)	Above ground biological yield (kg m^{-2})
I_0	132.60 c	17.17 b	9.22 b	206 b	-	1.31
I_1	146.55 ab	18.05 ab	12.27 a	253 a	22.82	1.43
I_2	140.60 b	17.95 ab	13.19 a	254 a	23.30	1.45
I_3	148.95 a	18.15 a	13.51 a	271 a	31.55	1.61
CV	2.09	2.47	4.99	6.59	-	10.23
Level of significance	**	*	**	**	-	NS

In a column, values having different letter (s) diffred significantly at P ≤5 % level of probability by Tukey's test.
^{NS} indicates not significant, * indicates significant at 5% level of probability, ** indicates significant at 1% level of probability. I_0 = Control (Rainfed), I_1 = One supplemental irrigation at 60 DAT, I_2 = Two supplemental irrigations at 60 and 75 DAT, I_3 = Three supplemental irrigations at 45, 60 and 75 DAT

CONCLUSION

Supplemental irrigation in aman rice caused 22.82%, 23.30% and 31.55% yield increment due to one, two and three supplemental irrigation, respectively. The increase in grain yield in supplemental irrigation plots was contributed by the increment in leaf SPAD value, grains panicle^{-1}, grain size and grain weight hill^{-1}. One supplemental irrigation was enough for sustaining yield in T. aman.

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