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Irrigation Scheduling of Wheat using Pan Evaporation Method

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Abstract— An experiment was conducted at Bangladesh Agricultural University (BAU) farm during the Rabi season 2013-14 to investigate the possible effects of different level of irrigation on wheat production. The experiment was set up using split plot design with two modern varieties of wheat, BARI Gom-21 (V_1) and BARI Gom-24 (V_2) and four irrigation treatments viz., rainfed (T_1), one irrigation at CRI stage (T_2), two irrigation at CRI and Booting (T_3) and three irrigation at CRI, Booting and Grain filling stages (T_4) that were randomly replicated thrice. Irrigation was applied on the basis on Cumulative Pan Evaporation. The variety and the irrigation treatments were affected the wheat yield and some other yield contributing characters at 1% level of probability. Maximum grain yield was found for the variety BARI Gom-24 which was 4.51 t ha^{-1} followed by 4.07 t ha^{-1} for BARI Gom-21. It also showed that though the highest grain yield (4.59 t ha^{-1}) was found in treatment T_4, its water productivity was the lowest (479 kg $ha^{-1}cm^{-1}$) of all. On the contrary, treatment T_3, gave a yield of 4.55 t ha^{-1} having the highest water productivity of (630 kg $ha^{-1}cm^{-1}$). The highest irrigation requirement (5.48 cm) was found in the treatment T_4, while treatment T_3 needed only 3.23 cm of water. The highest interaction effect on grain yield was found 5.26 ton ha^{-1} for the combination of V_2T_3. The study also revealed that increasing water stress reduced the plant height, effective tillers per hill, grain yield, straw yield and biological yield as did for the harvest index. Considering all the outputs from the experiment, it can be inferred that practicing interaction V_2 T_3 would be the best choice for the wheat cultivation.

Keywords—Water productivity, Irrigation, pan evaporation, wheat and yield.

I. INTRODUCTION

Water is a vital input for agriculture as it controls all the physiological process during plant growth. So it is essential for every crop to access adequate amount of water during its different growth stages [1]. On the other hand, excess amount of water may result reduced crop yield which is undesirable for agriculture [2]. When adequate rainfall is not available to meet the total water requirement for potential crop production, irrigation is generally applied. But, in many cases irrigators tend to over irrigate when water and other irrigation equipment are adequate, believing that it will increase crop yields. Unfortunately, instead of increasing crop production it often results plant disease, nutrient leaching, and reduced pesticide effectiveness [3] [4]. Moreover, wastage of water and energy increase production costs that ultimately minimize benefits [4]. Hence, proper irrigation scheduling is required for every crop to prevent over-application of water in the field by determining exact amount and timing for application [5]. After rice, wheat (*Triticumaestivum L.)* is the second largest cereal crop grown in Bangladesh [6]. Due to declining groundwater level and reduced rainfall resulted by changing climate, scientists have been trying to introduce wheat in many rice growing areas as it consumes significantly less water than that of rice [7]. Moreover, to feed the ever increasing population of the country, more attention should be given to produce more supplementary crops like wheat, maize and other cereals along with cultivating rice[8][7]. According to Hossain & Silva (2013) [9], current requirement of wheat in the country is 4 million tons and consumption is increasing at a rate of 3% per year. But the total annual production of wheat is now 1.15 million tons, mitigating only around 30% of the national requirement [9]. To minimize this demand gap, per ha yield should be increased along with the expansion of the wheat growing area. One of the major constrains for wheat cultivation in Bangladesh is the adjustment of growing season according to the favorable temperature and rainfall. Usually wheat is grown in Rabi season (November to March) when the rainfall is characteristically scanty and uncertain [10]. Due to unavailability of rainfall during this period, irrigation is inevitable for cultivation to get reasonable yield.

But irrigation water in Bangladesh, especially in dry periods, is a scare and mostly associated with expensive groundwater pumping [11]. Hence irrigation practices must be rationalized with the availability of water and different growth stages of wheat. When water supply is limited, it is necessary to take the critical stages of crop growth into account with respect to soil moisture level [12] [8].

Thus proper irrigation strategies are essential for wheat to optimize water use without sacrificing the yield [13]. This study investigated the effects of number of irrigation on growth and yield attributes, yield, and water productivity of two different wheat varieties with the view to define an appropriate irrigation scheduling.

II. MATERIALS AND METHODS

Site characteristics

The experiment was carried out at Bangladesh Agricultural University (BAU) farm, Mymensingh, Bangladesh during the Rabi season of 2013-2014. The study area lies approximately between 24˚36´ to 24˚54´ west latitude and between 90˚15´ to 90˚30´ east longitude. The topography of the land was medium high land which includes mainly the "old Brahmaputra flood plain" (AEZ-9). The texture of the soil was clay loam to silty clay loom and color was generally gray. The soil of the study area is considered to be the best agricultural productive soil in the country. The climate of this area is mainly tropical and tends to remain mild throughout the year. Average rainfall of 2420 mm concentrated over the month of May to September. The summer (March-September) is hot and humid, and the winter (November-February) is moderate with occasional rainfall. The maximum temperature during the warm months of April to May varies from 28.8 to 35.9°C while usually January is the coldest month. The minimum temperature varied from 9.6 to 12.9°C.

Experimental design and treatments

The experimental plots were laid out with split plot design (SPD) having four irrigation treatments and two varieties. There were three replications in combinations of both the treatments (Variety and irrigation). According to the split plot design, irrigation treatment was assigned in the main plot and the varieties were assigned in the sub plots. All of these events were randomly chosen to avoid any biasness towards the selection. Hydrological information's were collected from the weather station at BAU farm near the experimental site. Two high yielding varieties of wheat, V_1= BARI Gom-21 (Shatabdi) and V_2= BARI Gom-24 (Prodip) developed by Bangladesh Agricultural Research Institute (BARI) were used for the study. Both of the variety is heat tolerant. Shatabdi released in 2000 which attains at a height of 90-100 cm and takes 105-112 days to complete the life cycle and it is resistant to leaf rust and leaf spot diseases as well. Prodip released in 2005 and matures at 105-110 days which is almost similar to Shatabdi. The average yield of Shatabdi and Prodip are (3.5-4.0) t ha^{-1} (BARI 2011). Wheat seeds were weighed for different plots at the rate of 120 kg ha^{-1}. For sowing the seeds in rows 2-3 cm deep furrows were made manually using single tine and rakes. The distance between two adjacent furrows was kept at 20 cm. The plots were fertilized in the furrows with Urea TSP, MP, Gypsum, Zink and Boron at a ratio of 230:180:60:130:21:17 kg ha^{-1}. Two third amount of total Urea was applied during land preparation and the rest one third was applied 30 days after sowing [14].
Irrigation was applied using pan evaporation data and soil moisture content of the field. The treatments were: $T_{1:}$ No irrigation (control), $T_{2:}$ Irrigation application at CRI stage (17-21 days after sowing), T_3 : two irrigation at CRI and Booting (17-21 DAS + 45-50 DAS), T_4 : three irrigation at CRI, Booting and Grain filling stages (17-21 DAS + 45-50 DAS + 75-80 DAS).

Irrigation requirement

The daily pan evaporation data were obtained from standard "USWB class-A pan" and rainfall from standard rain-gauge was collected from BAU Weather Yard.

The following equations were used to calculate water related parameters

i) $$IR = (CPE \times k_p \times k_c) - ER \qquad \text{...............(i)}$$

Where, IR = irrigation requirement, CPE = cumulative pan evaporation, k_p = pan coefficient, usually has a value of 0.7 for USWB pan [15], ER = Effective rainfall and k_c = crop factor

ii) $$\text{Water productivity (WP)} = \frac{Ya}{WU} \qquad \text{..................(ii)}$$

Y_a = actual yield and WU = water used

Effective rainfall is the portion of rainfall available in the plant root zone, allowing the plant to germinate or maintain its growth. From the point of view of water requirement of crops, the Food and Agriculture Organization (FAO) of the United Nations [16] has defined the annual or seasonal effective rainfall as that part of the total annual or seasonal rainfall, which is used directly and/or indirectly for crop production at the site where it falls. However, effective rainfall was estimated using the USDA Soil Conservation Method as given:

$P_{effective} = P_{total} (125 – 0.2 P_{total})/125$…………………(iii) for $P_{total} < 250$ mm
$P_{effective} = (125 + 0.1 P_{total})$ …………………(iv) for $P_{total} > 250$ mm

Where, $P_{effective}$ = effective rainfall (mm), P_{total} = total rainfall (mm)

Irrigation was calculated and applied based on predesigned irrigation schedule. Water was supplied from nearby source. A 25 liter capacity pot was used to irrigate the field. First irrigation was scheduled (T_1) at 17 DAS, but 23.0 and 18.6 mm rainfall was occurred on 7 December 2011 and 8 December 2011 (6 and 7 days after sowing) respectively.

As a result no irrigation was applied due to sufficient moisture present in the field. Treatment T_3 and T_4 were applied according to the predesigned schedule. The crop was harvested on 03 April 2011after 122 days of sowing when the spikes were completely ripped. After recording data on plant height, length of panicle and number of spike of each plant, the plant materials were dried in the sun. Threshing, cleaning and drying of grains and straws of each plot were done carefully. Finally, the grain and straw yields and yield contributing parameters were recorded separately. Yield and yield contributing data were statistically analyzed using analysis of variance technique with the help of computer package programmed MSTAT and significance of mean difference was adjudged by Duncan's Multiple Range Test (DMRT).

III. RESULTS AND DISCUSSION

Yield and yield parameters

Different yield contributing character likes plant height, number of spikelet per panicle, 1000 grain weight and grain yield was significantly affected by variety at 1% level of probability. Highest grain yield was found in BARI Gom-24 (4.51 t/ha) where as for BARI Gom-21 it was 4.07 t/ha (table 1). Spikelets per panicle were significantly influenced by different levels of irrigation treatments. Maximum spikelets per panicle were found 22.21 when three irrigations were applied and minimum spikelets per panicle were found 15.79 when treatment was rainfed (Table 2). But there was no significant difference between treatment T_3 and T_4. Varietal effect on spikelets per panicle was not significant.

Variety, Irrigation and interaction have significant effect on 1000 grain weight found in analysis. Shatabdi gave 39.84 g where Prodip yielded 44.57 g of thousand grain weight. From Table 2 it was found that maximum weight of 1000 grain was 45.14 g for the treatment T_4 and minimum 37.68 g for T_1. It is also observed that maximum yield was 47.32 g for the interaction V_2T_4, and minimum was 34.23 g for the interaction V_1T_1 (Table 3). The effect of irrigation treatments was significant at 1% level of probability. Water supply has a strong effect on production of wheat. Maximum yield was found to be 4.59 t/ha when treatment T_4 was applied and minimum was obtained as 3.65 t ha^{-1} for treatment T_1 (control). But Treatment T_3 produced 4.55 t/ha which was very close to T_4. It was found that additional application of irrigation did not increase the considerable quantity of yield (Table 2). The interaction between the variety and irrigation treatments was also significant. The highest yield (4.75 t ha^{-1}) was obtained in interaction V_2T_4 and the lowest yield (3.21 t ha^{-1}) was in V_1T_1 (Table 3)

TABLE 1: VARIETAL EFFECTS ON THE YIELD AND YIELD CONTRIBUTING CHARACTER

Variety	Plant height (cm)	Panicle length (cm)	No. of spikelets per panicle	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Shatabdi	88.50	11.92	18.55	39.84	4.07	4.78	8.85	45.87
Prodip	98.00	12.03	19.23	44.57	4.51	4.62	9.14	49.68
LSD	2.431	0.296	0.657	0.998	0.013	0.470	0.474	2.71
Level of sig.	**	NS	NS	**	**	NS	NS	**

** = significant at 1% level of probability, NS = not significant, LSD = Least significant difference

TABLE 2: YIELD AND YIELD ATTRIBUTES OF WHEAT UNDER DIFFERENT IRRIGATION TREATMENTS

Treatment	Plant height (cm)	Panicle length (cm)	No. of spikelet's/ panicle	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1	91.00b	10.84c	15.79c	37.68c	3.65c	3.96c	7.61c	47.84
T_2	91.17b	11.05c	16.63c	41.59b	4.37b	4.56b	8.93b	49.18
T_3	97.67a	12.44b	20.93b	44.41a	4.55a	5.18a	9.73a	46.77
T_4	95.17b	13.57a	22.21a	45.14a	4.59a	5.11a	9.71a	47.30

LSD	2.35	0.29	0.64	0.97	0.01	0.46	0.46	2.62
Level of sig	**	**	**	**	**	**	**	NS

** = Significant at 1% level of probability, NS = not significant, LSD = Least significant difference

TABLE 3: INTERACTION EFFECT ON YIELD PERFORMANCE OF WHEAT

Interaction	Plant height (cm)	Panicle length (cm)	No. of spikelets per panicle	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1T_1	86.00c	10.91	15.89	34.23e	3.21d	4.10	7.31	43.94c
V_1T_2	86.33c	10.74	15.77	40.00d	4.21c	4.80	9.02	46.73b
V_1T_3	95.67b	12.46	20.60	42.17bc	4.41b	5.10	9.51	46.37b
V_1T_4	86.00c	13.55	21.94	42.95b	4.43b	5.12	9.55	46.42b
V_2T_1	96.00b	10.77	15.69	41.13cd	4.09c	3.82	7.91	51.73a
V_2T_2	96.00b	11.35	17.49	43.18b	4.53b	4.31	8.84	51.62a
V_2T_3	99.67a	12.41	21.27	46.65a	4.69a	5.26	9.95	47.18b
V_2T_4	100.33a	13.58	22.48	47.32a	4.75a	5.11	9.86	48.18b
LSD	3.33	0.41	0.90	1.37	0.02	0.64	0.65	3.71
Level of sig	**	NS	NS	**	**	NS	NS	**

** = Significant at 1% level of probability, NS = not significant, LSD = Least significant difference

Water productivity

Water productivity of wheat in response to different treatment is shown in the Table 4. It is clear from the table that maximum water productivity of wheat was 630 kg ha^{-1} cm^{-1} for treatment T_3 followed by 479 kg ha^{-1} cm^{-1} for the treatment T_4. As treatment T_1 was control and no artificial water was applied during the growing season, the water productivity is not applicable. Normally rainfall did not occur in winter especially in December. But in the season when we carried out this study 23 mm and 18.6 mm rainfall occurred in 7th and 8th December respectively (6 and 7 days after sowing). And at the time of first irrigation (T_2), available moisture content was present in the soil and no irrigation was applied. As a result water productivity for the treatment T_2 became invalid.

TABLE 4: WATER PRODUCTIVITY FOR TREATMENTS AND INTERACTIONS

Interactions	Effective rainfall (cm)	Irrigation applied (cm)	Total water used (cm)	Average total water used (cm)	Average yield (ton ha^{-1})	Productivity kg $ha^{-1}cm^{-1}$ (kg m^{-3})
V_1T_1	4.09	0	4.09	4.09	3.96	-
V_2T_1		0	4.09			
V_1T_2		0	4.09	4.09	4.37	-
V_2T_2		0	4.09			
V_1T_3		3.23	7.23	7.23	4.55	630
V_2T_3		3.23	7.23			
V_1T_4		5.48	9.59	9.59	4.59	479
V_2T_4		5.48	9.59			

The total water used by the crop includes soil moisture contribution, effective rainfall and irrigation applied. But in this case soil moisture contribution was not significant and it was considered to be negligible.

IV. CONCLUSION

The current investigation revealed the yield performance of two varieties BARI Gom-21 and BARI Gom-24 against different treatments. BARI Gom-24 showed better yield performance than BARI Gom-21. Irrigation treatments have a significant effect on yield and yield attributes. Highest yield was obtained for the treatment T_4, but performance of T_3 is very close to T_4 with high water productivity. Both the treatment T_3 and T_4 has a yield advantages over T_1 and T_2. On the other hand the interaction (variety and irrigation) effect V_2T_4 shows the best performance and V_2T_3 is very close to V_2T_4 with highest water productivity.

So it can be concluded that irrigation application at critical stages CRI (Crown Root Initiation, 17-20 DAS) and booting (45-50 DAS) increased the yield performance of both variety and irrigation at grain filling stage (80-85 DAS) insignificantly increased total yield but decreased water productivity. According to the experiment, T_3 (two irrigation at CRI and Booting) would be the best irrigation scheduling for wheat cultivation and V_2T_3 would be the best practice.

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