Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 8(2): 129-140
http://dx.doi.org/10.7770/safer-V0N0-art1831

IRRIGATION MANAGEMENT FOR BINADHAN-8 AND BINADHAN-10 BORO RICE FOR OPTIMUM YIELD AND WATER PRODUCTIVITY UNDER NORMAL SOIL.

MANEJO DE RIEGO PARA EL ARROZ BINADHAN-8 Y BINADHAN-10 BORO PARA UN RENDIMIENTO ÓPTIMO Y PRODUCTIVIDAD DEL AGUA BAJO SUELO NORMAL.

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ABSTRACT

Alternate wetting and drying irrigation (AWD) has been reported to save water compared with continuous flooding (CF) in rice cultivation. However, the reported effects on yield varied greatly with soil type, cultivars, and detailed agrohydrological characterization is often lacking so that generalizations are difficult to make. This study quantified the impact of AWD on rice (Binadhan-8 and Binadhan-10) yield, water productivity and irrigation water savings. The irrigation treatments comprised of: Normal farmer's practice (continuous ponding, 3-5 cm) [T_1]; alternate wetting (irrigation by 5 cm) and drying (AWD) for 3 days after disappearance of ponded water (DOPW) [T_2]; AWD for 5 days after DOPW [T_3]; and a combination [T4]. The grain yields varied from 3.9 to 4.4 t ha^{-1} with no significant difference in yield attributes (except 1000 grain wt.), grain yields and straw yields between AWD and CF. The productivity of water in AWDs was about 6 - 40% higher than that of CF, and the water savings in AWDs compared to CF were 22 – 35%. Alternate wetting and drying for 5 days can save substantial amount of irrigation water without sacrificing yield. This practice can be adopted for cultivating those cultivars for sustainable irrigation management.

Keywords: Boro rice, Water management, Water productivity, Alternate wetting and drying irrigation.

RESUMEN

Se ha informado que el riego alternativo de humectación y secado (AWD) ahorra agua en comparación con las inundaciones continuas (CF) en el cultivo de arroz. Sin embargo, los efectos reportados sobre el rendimiento variaron mucho con el tipo de suelo, los cultivares y la caracterización agro hidrológica detallada a menudo falta, por lo que las generalizaciones son difíciles de hacer. Este estudio cuantificó el impacto de AWD en el rendimiento del arroz (Binadhan-8 y Binadhan-10), la productividad del agua y el ahorro de agua de riego. Los tratamientos de riego consistieron en: práctica normal del agricultor (estanque continuo, 3-5 cm) [T1]; humectación alternativa (riego por 5 cm) y secado (AWD) durante 3 días después de la desaparición del agua estancada (DOPW) [T2]; AWD durante 5 días después de DOPW [T3]; y una combinación [T4].

Los rendimientos de grano variaron de 3.9 a 4.4 t ha – 1 sin diferencias significativas en los atributos de rendimiento (excepto 1000 granos de peso), rendimientos de grano y rendimientos de paja entre AWD y CF. La productividad del agua en los AWD fue aproximadamente un 6 - 40% más alta que la de la FQ, y el ahorro de agua en los AWD en comparación con la CF fue del 22 - 35%. La humectación y el secado alternativos durante 5 días pueden ahorrar una cantidad sustancial de agua de riego sin sacrificar el rendimiento. Esta práctica se puede adoptar para cultivar esos cultivares para la gestión sostenible del riego.

Palabras clave: arroz Boro, gestión del agua, productividad del agua, riego alternativo de humectación y secado.

INTRODUCTION

Water resources are becoming scarce worldwide. Bangladesh is no exception (Sadia and Ali 2016). It contains world's one of the largest delta and is, therefore, heavily depends on rivers originating in other countries and rainfall for its water supply. Climate change (rise in temperature and changing rainfall patterns), deforestation and construction of dams in common rivers have led to a reduced amount of water entering into Bangladesh (Ali 2010). As surface water supply is decreasing day by day, irrigation pressure is going towards groundwater resource. But this resource is not unlimited. In intensive tube well areas, water level is declining gradually in dry season (Asraf and Ali 2015). Climate change has worsened the situation (Lee et al. 2016; Sarkar and Ali 2009; Islam et al. 2004). So, the judicious use of water resources in intensive irrigated area is a crucial need for maintaining sustainable crop production (Les et al. 2014).

Rice is the main staple food grain in Bangladesh. During 2016-17, total rice production (Boro, Aus and Aman) of the country is about 3,3804,000 Metric ton (BBS, 2017). Due to continuous increase in population, increased amount of rice should be produced and hence, there is a great need for sustainable rice production. In this context, a solution lies between development of drought tolerant rice variety and sustainable supply irrigation supply system.

In Bangladesh, rice grows in main three seasons: Boro (Jan.- May), Aus (April – July), and Aman (Aug.-Nov.). In Boro season, production of rice depends on irrigation (from surface or groundwater). In Aus and Aman season, the water demand is mostly meet by natural rainfall. Supplemental irrigation is needed for uneven or little rainfall, or during a long dry-spell.

It has been estimated that about 3000 -5000 litres of water is required to produce 1 kg of rice (SAIC 2007). Vertical (increased cropping intensities) and horizontal expansion (cultivation of crops on new lands) of irrigated agriculture to feed the increasing population of the country have contributed to excessive groundwater withdrawal and affected the availability of good quality irrigation water. This situation of groundwater may cause a great threat for future groundwater availability for irrigation and ultimately for sustainable Boro production (Sarkar et al. 2013). Farmers keep their rice field flooded throughout rice season as they think that standing water is inevitable for rice field. This causes huge wastage of water (Ali 2001) and increases the cost of production due to increased fuel/power cost for lifting underground water. In a situation of higher demand of rice (due to increasing population), there is no alternate choice but to produce more rice. In terms of solar radiation, November- April, is more suited for crop production (Amin et al. 2004; Adham et al. 2005). For Boro rice, irrigation is essential, as the entire growing season falls within the dry period. There is a great need to increase the productivity of water in rice irrigation systems in a sustainable way (Kang et al. 2017; Bouman and Tuong 2001).

Water stress is the main limiting factor for cereal crop production worldwide. The effects of water-stress (or drought) on plant growth processes, and adaptation strategies by plants have been studied and documented by numerous researchers (Arnon 1975; Clark and Hiller 1973; Turner 1986; Andersen and Aremu 1991; Neumann et al. 1994; Yang et al. 2001; Ali 2010 b; Sikuku et al. 2010; Zhang et al. 2004). But the ultimate signature of water stress reflects on grain yield. Sikuku et al. (2010) 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. Field and control condition studies were carried out by Ali (2018) to investigate the response of some rice cultivars to water-stress and to develop appropriate on-farm management strategy for sustainable yield under drought condition. The observed that most of the cultivars produced good yield under drought condition compare to normal irrigated condition. He concluded that those cultivars seemed to be appropriate for cultivation in drought-prone areas.

Alam and Mondal (2003) investigated the effect of continuous standing water, irrigation water application after disappearing of standing water, and irrigation water application 3 days after disappearing of standing water (AWD). They found the highest water productivity in 3 days AWD. They concluded that, maintaining continuous standing water in the hybrid rice fields is not necessary for optimum yield. Rather, application of irrigation water 3 days after standing water disappeared from the field could be practiced for obtaining optimum yield of hybrid rice, with minimum water application. Investigation on sprinkler irrigation in rice was also done by several researchers (Kahlown et al. 2006; Blackwell et al. 1985) to minimize water loss and thereby enhance water productivity. Yang (2007) used soil-water potential value to schedule irrigation for rice. Effect of site-specific nitrogen management and alternate wetting and drying irrigation (AWD) in super rice was investigated by Liu et al. (2013). They noted that synergistic interaction between nitrogen and AWD occurred in the yield formulation, and such an interaction could increase not only grain yield, but also resource-use efficieny.

The amount of water required and frequency of irrigation for the growing season depends on the water depth maintained, water management practices, soil type, cultivar, maturity period and evaporative demand of the growing environment (De Datta 1981, Ali and Talukder 2001).

Thus, it is not appropriate to make definite recommendation regarding the number and amount of irrigation to be applied for all cultivars.

Binadhan-8 and Binadhan-10 were developed by BINA for salt affected areas. Its performance under normal condition (i.e. non-saline soil) and its response to different irrigation regimes were not tested. The objective of this study was to investigate the total effect of different irrigation regimes on the yield, water productivity, and to suggest best irrigation practice for Binadhan-8 and Binadhan-10 under normal, non-saline soil.

MATERIALS AND METHODS

Study site: Field experiment was carried out at the experimental farm of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during 2014. The geographical location of the study site is $24^{o}43''$ North and $90^{o}26''$ East, under 'Old Brahamaputra Flood Plain (AEZ-9)'. The topography of the region is 'Highland', and the soil texture is silt-loam. The soil pH ranges from 5.1 to 5.6. The area is characterized by less infiltration due to semi to impermeable clay with excessive surface runoff. The lithology types include alluvial silt and clay. Hydrogeologically, the area covered by semi-impervious clay-silt aquitard is characterized by single to multiple layered aquifer system. The field capacity and permanent wilting point of the soils were 44% and 21% (by volume).

Climate: The climate of the regions falls within humid sub-tropic with summer dominant rainfall. The annual rainfall at the study site varies from 1500 mm to 3300 mm; approximately 70% of this rainfall occurs during the months of May – August which is noted as monsoon season. The yearly rainfall fluctuates considerably, having mean, standard deviation and coefficient of variation of 2300 mm, 500mm, and 20 %, respectively. The reference crop evapotranspiration (ET_0) pattern of the study area during the rice growth period (Jan. 15 to April) is depicted in Fig.1. The ET_0 was calculated using ET_0 calculator software (FAO 2012). The rainfall pattern during the crop period is depicted in Fig.2.

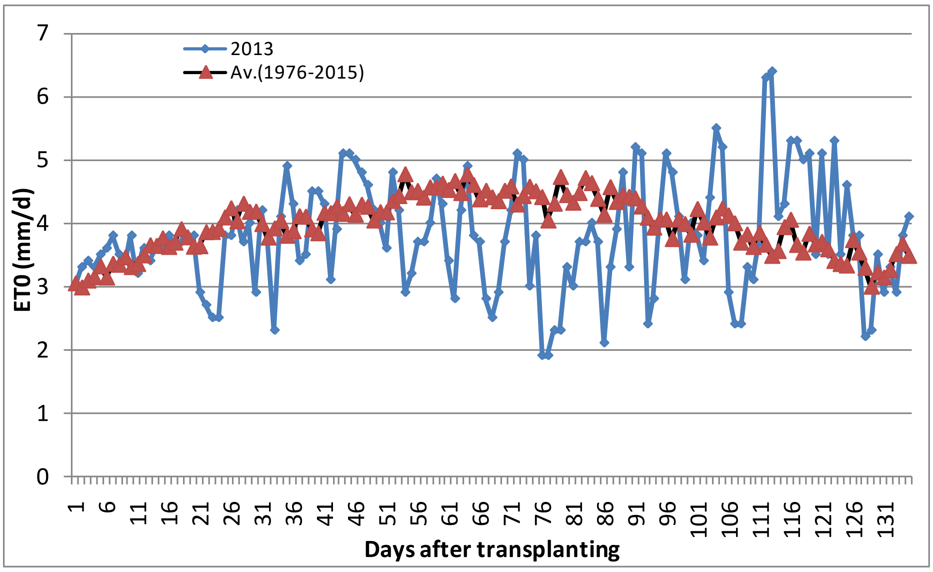

Fig.1. Crop-season and long-term ET0 pattern of the study area

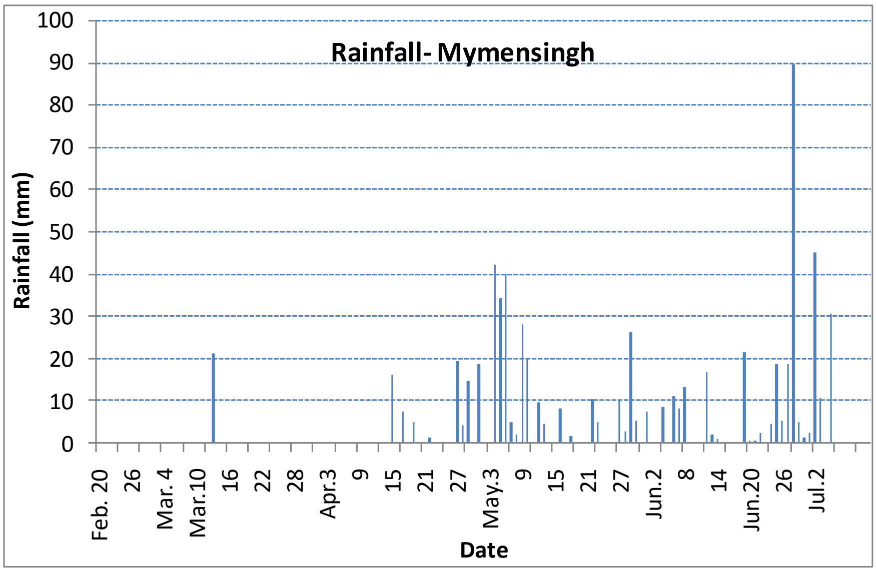

Fig.2. Rainfall pattern during crop-season in the study area

Experimental design: The design was RCBD (with split-plot). The individual main and sub-plot sizes were 7 m × 5 m and 5 m × 3.5 m, respectively and the treatments were replicated thrice. Main-plot treatments [Irrigation (AWD methods)] were: T_1 = Normal farmer's practice (continuous ponding, 3-5 cm); T_2 = alternate wetting (irrigation by 5 cm) and drying (AWD) for 3 days after disappearance of ponded water; T_3 = alternate wetting and drying (AWD) for 5 days after disappearance of ponded water (DAD); T_4 : 1st week (after transplanting): 2 - 4 cm ponding, 2-3 week: Irrigation (by 5 cm) at 2 DAD, 3-4 week (up to tillering): Irrigation (by 5 cm) at 3 DAD, 4-6 week(tillering to pre-heading)): Irrigation (by 5 cm) at 5 DAD, 6-9 week (heading – milking): Irrigation (by 5 cm) at 2 DAD, 9-11 week (soft dough- ripening): drying (no additional irrigation).

The Sub-plot treatments [Variety] were: V_1= Binadhan-8, V_2 = Binadhan-10.

Inter-cultural operations: The seedlings of rice were transplanted on 20 February 2014. Each plot was fertilized uniformly with basal dose of Triple super phosphate, Muriate of Potash, Gypsum, and Zinc by 80, 110, 70, 45, 4.5 kg ha^{-1}, respectively. Urea was applied in three equal splits by 70 N ha^{-1} at 10, 30 and 45 days after transplanting.

Up to three weeks from transplanting, continuous ponding was maintained for crop establishment. Irrigation treatments were then imposed. Measured amount of water applied in each plot through water-meter, attached at the outlet point of rubber hose pipe. All cultural practices were followed as and when necessary. The crop was harvested on 20 May. The grain and straw yields were adjusted to 12% moisture content.

Water balance components: Crop evapotranspiration was calculated from the simplified field water balance equation:

$$ET = I + P \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where, P = Effective rainfall

I = Irrigation water applied

ET = evapotranspiration from cropped soil

All quantities are expressed in the same unit (in terms of volume of water per unit area, or equivalent depth units) during the period considered. The effective rainfall was calculated following FAO guideline, as follows:

Rainfall less than 6.25 mm on any day is considered as ineffective. Similarly, any amount over 75 mm/day, and rainfall in excess of 125 mm in 10 days is treated as ineffective. That is,

<u>For daily case</u>: $Re = 0$ when $P<6.25$ mm

$Re = P$ when $6.25<P<= 75$ ……………(2)

$Re = P- (P-75)$ when $P>75$

For 10 days: Re = P when P<= 125 mm

Re = P – (P-125) when P>125 mm ……………..(3)

Water productivity:

Water productivity (WP) was calculated as:

$$WP = \frac{Y_{grain}}{ET} \qquad \text{………………. (4)}$$

Where ET is the crop evapotranspiration.

Data Analysis: The analysis of variance technique (ANOVA) was carried out on the data for each parameter as applicable to the design. The significance of the treatment effect was determined using F-test, and to determine the significant difference among the means of the treatments, least significant difference (LSD) were estimated at 5% probability level.

RESULTS AND DISCUSSION

Effect of irrigation regimes on yield and yield attributes: The mean effects of irrigation treatments on yield attributing characters, and grain and straw yield are summarized in Table 1. The results revealed that irrigation regimes had insignificant effect on yield attributing characters, except 1000 seed weight. The effects of irrigation regimes on grain and straw yield are also insignificant. The irrigation regimes had no significant effects, which indicate that we can adopt that irrigation regime which requires less irrigation amount.

The mean effects of variety and interaction effects (data are not shown) on yield attributing characters, and grain and straw yield are also insignificant.

Irrigation frequency, components of water balance and total water use (ET): Table 2 shows the water applied for crop establishment, number of irrigation according to the imposed treatments, effective rainfall and total water used by the rice crop.

The required irrigation amount increased with the lower days of drying period (AWD). The continuous ponding treatment (T_1) required the highest amount of irrigation water (52 cm), whereas the 5 days AWD throughout the growing period (T_3) required the least (25 cm). Consequently, the highest water use (ET) was in treatment T_1 (91.90 cm) and the lowest in T_3 (64.90 cm) (Table 2).

Table 1 Effect of AWD methods on the yield and yield attributing characters of Boro rice (Binadhan-8 and Binadhan-10) at BINA farm, Mymensingh

Treatments	Plant height (cm)	No of tiller (nos)	Panicle length (cm)	Seed/ panicle	1000 seed wt. (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_0	91.25	9.27	24.61	101.70	28.92	4.90	4.44
T_1	92.30	9.92	24.35	105.62	26.59	4.60	4.07
T_2	90.60	8.30	25.46	128.27	25.31	4.83	4.27
T_3	90.98	9.10	23.48	113.42	26.87	4.24	3.96
LSD(5%)	NS	NS	NS	NS	1.70	NS	NS
V_1	87.81	8.51	24.19	114.92	27.16	4.79	4.30
V_2	94.75	9.78	24.76	109.58	26.68	4.49	4.07
LSD(5%)	NS	NS	NS	NS	NS	NS	NS

Table 2. Irrigation frequency and components of ET under different irrigation treatments

Treatments	Water applied for crop establishments (cm)	Irrigation applied according to treatment		Total applied water (cm)	Effective rainfall (cm)	Total water used, ET (cm)
		Number Of irrigation (nos)	Water Applied (cm)			
T_1		14	52	77		91.9
T_2		7	35	60	14.9	74.9
T_3	25	5	25	50		64.9
T_4		7	35	60		74.9

Irrigation water saving and water productivity: Table 3 shows the irrigation water savings relative to continuous ponding and water productivity value under different treatments. Although yield reduction in deficit irrigation regimes (T_2 -T_4) was relatively small and insignificant (Table 1), the water savings was appreciable (22-35%) (Table 3). The 5 days AWD regime (T_3) saved 35% irrigation water, and the other two regimes (T_2 and T_4) saved about 22%. The water productivity was also highest in 5 days AWD regime, due to the large reduction in water input combined with only a slight reduction in grain yield. The 3 days AWD regime produced the second highest water productivity.

Table 3. Effect of different irrigation regimes on water saving and water productivity of rice.

Treatments	Irrigation water saving compared to T_1 (%)	Yield (t ha^{-1})	Water productivity (WP) (kg ha^{-1} cm^{-1})	Increase in WP compared to T_1 (%)
T_1	-	4.90	53.3	-
T_2	22	4.60	61.4	15.2
T_3	35	4.83	74.4	39.6
T_4	22	4.24	56.6	6.2

One of the most commonly practiced water saving irrigation (WSI) is alternate wetting and drying (AWD) method of irrigation. In AWD, soil is dried out to some degree (or, equivalent drying days) in between irrigation events. Xu (1982), Wei and Song (1989), Mao (1993) and Vories et al. (2017) reported that AWD maintained or even increased rice yield compared with the traditional irrigation practices with continuous flooding (CF). In our study, we found that AWD maintained statistically similar yield coupled with large irrigation water savings.

The AWD had slightly lower final biomass, grain yield than CF. The differences were, however, not significant at the 5% level. The results suggest that in typical irrigated medium and lowlands in Bangladesh, AWD can reduce water input without affecting rice yields. The results can be applied to many other irrigated rice areas in Asia having similar agro-climatic and soil conditions.

Alternate wetting and drying irrigation reduced irrigation by 22-35% (maximum 27 cm) compared to CF. However, savings from AWD may have a significant impact on the total amount of water saved when extrapolated to the whole rice ecosystem. In Asia, 70% of the groundwater withdrawal is used in irrigation purpose. Freeing only a small portion of water from rice areas can have large societal and environmental effects if this water is used for urban, industrial, or environmental purposes. Additionally, this will help in reducing groundwater withdrawal, and thus will help in sustainable use o groundwater, and hence, sustainable agricultural production.

The experimental conditions in this study were typical of, and therefore the findings are applicable to, many large rice-growing areas in Asia with relatively heavy soils (silt-loam to clay). Alternate wetting and drying irrigation can thus be an important technology for farmers to cope with water scarcity without sacrificing grain yield and may help increase water productivity at the regional scale if on-farm water saved can be used more productively downstream.

As conclusion, the need for "producing more rice with less water" is crucial for food security in Bangladesh and is typical for many other Asian countries where water for agricultural use is increasingly scarce. Irrigation has played a critical role in rice production in Bangladesh. Alternate wetting and drying for 5 days can save substantial amount of irrigation water without sacrificing yield of Binadhan-8 and Binadhan-10 and this practice can be adopted for cultivating those cultivars for sustainable irrigation management.

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Received:17th November 2018; Accepted: 14th June 2019; First distribution: 26th December 2020; Final publication: 01th Jule 2020.