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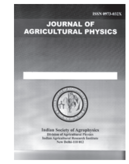

Research Article

Influence of Weather Parameters on Water Use Efficiency and Performance of Direct-seeded Autumn Rice (*Oryza sativa*) under the Agro-climatic Conditions of Assam

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ABSTRACT

An experiment was conducted at the Instructional-cum- Research Farm, Assam Agricultural University, Jorhat, during two consecutive summers (Feb-June) seasons of 2017 and 2018 to identify appropriate irrigation practice for combating the ill effect of heat and moisture stress and fulfill the evapotranspirational demand through different irrigation treatments in direct-seeded autumn rice. The rice variety Inglongkiri was sowed in split-plot design (3 replications) with 4 different irrigation regimes. The study revealed that there was 12.54% (1st year) and 29.82% (2nd year) increase in crop evapotranspiration and 32.90% (1st year) and 36.22% (2nd year) increase in rice grain yield under IW:CPE=1.60 in both the year as compared to rainfed treatment and highest crop water use efficiency also found under superior irrigation regime (IW:CPE=1.60). In regards to moisture availability, yield attributes, yield production and nutrient uptake were observed to be highest under IW:CPE=1.60, followed by lower irrigation regimes (IW:CPE=1.40 and IW:CPE=1.20) and rainfed.

Key words: Direct seeded rice, Evapotranspiration, Growth, Yield and Uptake

Introduction

The climatic condition of Jorhat as a whole is sub-tropical humid having hot summer and cold winter. The normal monsoon rain in this track starts from June and continues up to September with the pre-monsoon shower starting from mid-March. The intensity of rainfall decreases from October reaching the minimum during December/ January. In general, the maximum temperature rises to 34-37°C during summer and the minimum comes down to 8-10°C during winter. Transplanting is the most common method of rice cultivation in Assam but owing to increasing water scarcity, scarce labour coupled with higher wages during the peak periods, a shift towards less demanding alternative methods of rice cultivation aiming at higher water and crop productivity, is imperative. To overcome these problems, aerobic rice systems, wherein the crop is established via direct-seeding in non-puddled, non-flooded fields, are among the most promising approaches for saving water and labour (Kaur, 2004; Sharma *et al*., 2002; Tabbal *et al*., 2002 and Kigra and Kaur, 2017). Further, in irrigated direct-seeded rice culture, water use efficiency on the farm can be increased by applying only the amount of water needed without any substantial yield reductions (Gangwar *et al*., 2019).

Climate is the most important factor determining the crop water requirements needed for unrestricted optimum growth and yield. Changes in climate will increase the demand for atmospheric water by crops and increase the

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potential for limitations in the availability of soil water, because of the inappropriate monsoon and limitations in soil water holding capacity. Changes in climatic may create abiotic stress to the crops by water-deficient and heat stress (Hatfield *et al*., 2011). Cause for yield reductions in rice crop of Assam during the summer season found to be a combination of high temperatures and uneven rainfall distribution in the crop growing period. The demand for water by the crop must be met by the water in the soil through the root system. The total amount of water uptake by the crop from the soil concerning its crop consumptive use is determined by the weather. Evapotranspiration (ETc) is one of the important concepts of water balance and it is a key factor for determining proper irrigation scheduling and for improving water use efficiency in irrigated agriculture (Er-Raki *et al*., 2007). Important weather parameters affecting the evapotranspiration are radiation, air temperature, humidity and wind speed (Allen *et al*., 1998) and out of these temperature plays a key role in the evapotranspiration of the area (Hongjie *et al*., 2002; Kalluri *et al*., 2003).

Briggs and Shantz (1913) introduced a concept of Water use efficiency (WUE) 100 years ago only. Water use efficiency (WUE) is defined as the amount of carbon assimilated as biomass or grain produced per unit of water used by the crop. Water use efficiency mainly affected by weather characteristics like temperature (i.e., heat stress), precipitation (i.e., drought stress) and growing season length (Xiao *et al*., 2013). We have opportunities to enhance WUE through crop selection and cultural and management practices like crop residue management, mulching, row spacing adjustment and irrigation management. Several workers (Tomer *et al*., 1992, Trivedi *et al*., 2014 and Yadav *et al*., 1996) reported that the positive influence of irrigation on water use efficiency and fertilizer use efficiency by increasing the availability and uptake of nutrients to the crops. Roots can extract water from different sources viz., soil water, irrigation water, rainwater and groundwater (Shi *et al*., 2003 and Sun *et al*., 2005). The implementation of irrigation measures in crops influences the distribution of roots, maximum root depth, and water absorption by roots. The well-developed root system can able to extract moisture and nutrients efficiently (Bertrand *et al*., 2014; Chimner and Cooper, 2004).

Materials and Methods

The present study was conducted at Instructional Cum-Research Farm of Assam Agricultural University, Jorhat, Assam (26°74′N, 94.20°46′E and 87 m amsl) during two consecutive summer (Feb-June) seasons of 2017 and 2018. The experiment was laid out in a split-plot design with 3 replications. The entire experimental field was divided into as many numbers of main plots as per treatments of four irrigations in each replication and allocated randomly. Each main plot (19m × 4m) was subdivided into five sub-plots (4m × 3m) as per five treatments of integrated nutrient management practices which were also allocated randomly. The main plot treatments were I_0- Rain-fed, I_1-IW: CPE =1.20, I_2– IW: CPE =1.40 and I_3 - IW: CPE =1.60. The subplot treatments were N_1-Recommended dose of fertilizers (RDF), N_2 -RDF + FYM @ 5 t/ha, N_3 -75 % RDF + 25% N through FYM , N_4- 50 % RDF + 50% N through FYM and N_5- 50 % N of RDF + 50 % N as FYM + Bio-fertilizer (Consortium of *Azotobacter* and Phosphorous solubilizing bacteria. All the organic manures were applied once as a basal dose and incorporated in the soil 15 days before sowing. The rice variety used in the experiment was *Inglongkiri* with spacing 10 cm x 20 cm. It is a tall variety recommended for direct-seeded, rain-fed upland/*Jhum* situations of Hill zones of Assam. The observations of plant growth (Plant height, dry matter accumulation, crop growth rate and number of tillers in 25 days interval) and yield characteristics were taken. The daily meteorological data, recorded in the meteorological observatory of the Department of Agricultural Meteorology, Assam Agricultural University, Jorhat during the period of experimentation. The observations were made by using standard procedures and the data were analyzed as per the statistical methods are given by Panse and Sukhatme (1995).

Soil moisture

Volumetric soil moisture content (%) at different periodic intervals (25-day intervals) was determined from 0-20, 20-40 and 40-60cm depth of soil by gravimetric method.

Evapotranspiration

The evapotranspiration of direct seeded rice crop was computed from the soil moisture data by using the following formula (Monteith, 1965):

$$ET = \sum_{i=1}^{n}(E_0 \times K_cK_p) + \sum_{i=1}^{n}\frac{(M_{1i} - M_{2i})}{100} \times ASG_i \times D_i + ER + GWC$$

Where,

ET = Evapotranspiration (cm)

E_0 = Pan evaporation value (cm) from USWB class A pan evaporimeter from the day of irrigation to the day when sampling in wet soil is possible

N = Time interval (days)

M_{1i} = Percent of soil moisture of the i^{th} layer on the date of sampling after irrigation

M_{2i} = Percent of soil moisture of the i^{th} layer on the date of sampling before irrigation

ASG_i = Apparent Specific Gravity of i^{th} soil layer

D_i = Depth (cm) of the i^{th} layer of the soil

ER = Effective Rainfall during the period under consideration

N = Number of soil layers

K_c = Crop coefficient

K_p = Pan coefficient

GWC = Groundwater contribution (Determined with the help of the procedure described by Anat *et al.* (1965)

Water use efficiency

Water use efficiency (Briggs and Shantz, 1913) of the crop for different treatments was calculated as follows:

$$\text{Crop WUE (kg/ha-cm)} = \frac{\text{Weight of seed (kg/ha)}}{\text{ET of crop (cm)}}$$

$$\text{Field WUE (kg/ha-cm)} = \frac{\text{Weight of seed (kg/ha)}}{\text{Total water used (cm)}}$$

According to the evaporation data from the meteorological department, calculation of effective rainfall and main plot treatments the irrigation was given to different main plots at different time intervals. The number of irrigations and depth of irrigations are given in Table.1.

Results and Discussion

Rainfall and evaporation

During the investigation of direct-seeded autumn rice received 650.6 mm of rainfall in 41 rainy days with the maximum weekly total rainfall was115.9 mm received in 13th week (26th March

Table 1. Number and dates of irrigation in various treatments

Treatments	Date ofapplication	No. of irrigations	The depth of each irrigation (cm)	The total depth of irrigation water (cm)
Direct seeded rice, 2017				
I_0				
I_1	10th March and 18th April	2	4.02 and 3.91	7.93
I_2	8th and 20th March and15th April	3	4.02, 1.22 and4.36	9.60
I_3	6th and 17th March and14th April	3	5.00, 3.15 and4.36	12.51
Direct seeded rice, 2018				
I_0				
I_1	1st and 22nd March, and3rd April	3	2.33, 3.36 and3.69	9.38
I_2	25th, February, 20th and 30th March and 15th April	4	3.66, 3.36, 3.69 and 2.99	13.70
I_3	22nd February, 17th and 28th March,6th April	4	3.93, 3.52, 1.47 and 4.87	13.80

to 1st April 2017) in 1st year (Figure 1) and 456.6 mm, rainfall was received in 27 spells with the highest weekly total rainfall was 86.3 mm received in the 21st week (21st May to 27th May 2018) in 2nd year (Figure 2). The amount of rainfall during crop growing period of direct-seeded autumn rice in both the years was exceeded (355.3 mm in 1st year and 147.3 mm in 2nd year) than evaporation (295.3 mm in 1st year and 334.7 mm in 2nd year). Even the amount of rainfall is higher than the evapotranspiration demand of the crop, rainfall distribution was uneven to satisfy the crop needs and high temperatures of summer lead to heat and moisture stress. Overcome this situation and successful growth and development of the crop different

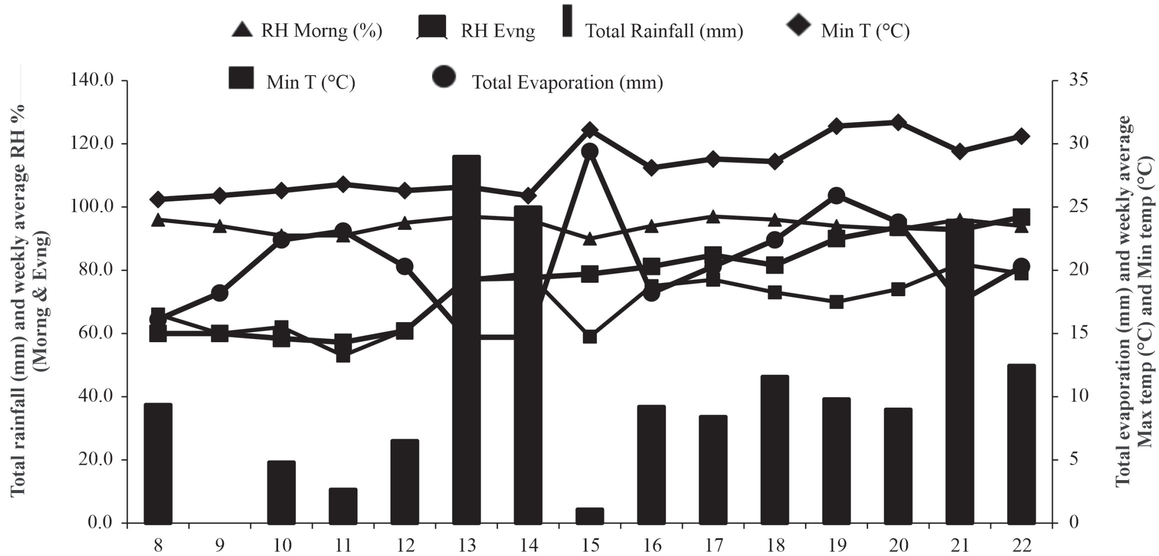

Fig. 1. Weekly meteorological data during crop growing period of direct seeded autumn rice (Feb, 2017- June, 2017)

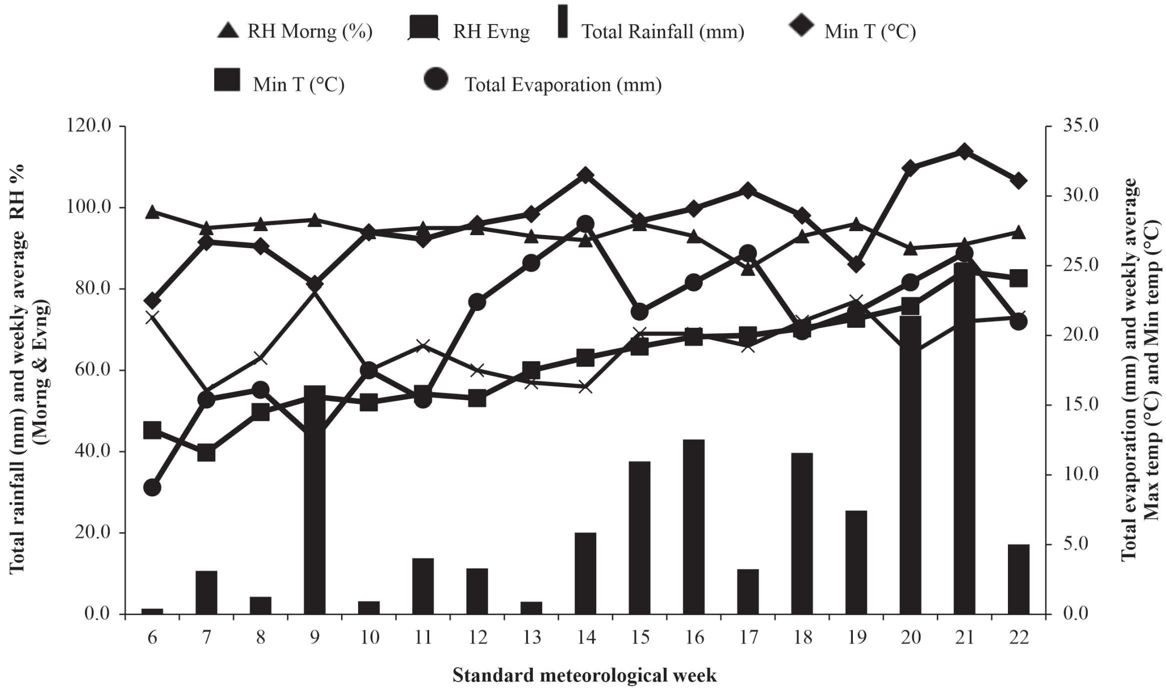

Fig. 2. Weekly meteorological data during crop growing period of direct seeded autumn rice (Feb, 2018 – June, 2018)

irrigation treatments were applied. Irrigation increased the evapotranspiration (consumptive use) and total water use by the crop in the growing period of both the year.

Evapotranspiration

The evapotranspiration and total water use by rice increased with the increasing levels of irrigation from IW:CPE ratio 1.20 to IW:CPE ratio 1.60 (Table 2) and the lowest values were recorded under rainfed in both the year. The higher irrigation requirements was obtained under IW(cm) /CPE (cm/crop growing period) ratio 1.60 (12.51 and 13.80 cm in 2017 and 2018, respectively) and IW:CPE ratio 1.40 (9.60 and 13.70 cm in 2017 and 2018, respectively) might have resulted in higher evapotranspiration (cm/ crop growing period) and total water use by the crop over their lower irrigation regime IW:CPE ratio 1.20 and rainfed. It is quite obvious that with the increasing levels of irrigation as well as from rainfed to irrigations at IW:CPE ratio 1.60 the evapotranspiration and total water use increased considerably because of more number of applied irrigations leading to higher availability of water in the soil profile which facilitated more loss of water through evapotranspiration as compared to lower irrigation regimes and rainfed (Bhalerao, 2001; Ramamoorthy *et al*., 1996; Singh and Dixit, 1989).

Yield attributing characters

The higher irrigation regimes IW:CPE ratio 1.60 followed by IW:CPE ratio 1.40 resulted from significantly higher values in respect to the yield attributes *viz*., number of panicles/m^2, weight of panicles/m^2, number of grains/panicle, filled grains/panicle as well as yield and harvest index of rice over rest of the treatments in both the year (Table 2). The better response of higher (frequent) irrigation regimes on growth parameters and yield attributes might be due to sufficient availability of moisture which ultimately reflected in producing the higher grain and straw yield and harvest index of the crop under these irrigation regimes. Similar results on higher yield attributes and yields of direct-seeded rice due to adequate availability of moisture and nutrients through

Table 2. Yield and water use of direct seeded autumn rice under different treatments

Treatments	Grain yield (q/ha)			Straw yield (q/ha)		Harvest index (%)		Evapo-transpiration (cm/crop growing period)		Total water use (cm/crop growing period)	
	2017	2018	Pooled	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation (I)											
I_0	18.66	18.20	18.43	30.98	29.57	37.58	38.09	29.14	27.50	29.14	27.50
I_1	20.32	21.29	20.81	31.59	33.32	39.14	39.02	32.58	35.60	33.25	36.89
I_2	25.34	25.65	25.49	35.11	36.77	41.95	41.10	32.65	36.40	32.98	39.86
I_3	26.01	26.25	26.13	35.59	37.33	42.28	41.34	33.04	37.14	35.25	39.93
S.Ed+	0.43	0.52	0.40	1.18	0.69	0.99	0.53	-	-	-	-
CD (P=0.05)	1.05	1.27	1.28	2.89	1.68	2.43	1.29	-	-	-	-
Nutrient Management (N)											
N_1	20.73	21.03	20.88	31.49	32.14	39.55	39.42	30.09	32.37	30.94	35.88
N_2	23.73	24.09	23.87	35.16	36.41	40.09	39.58	32.74	35.12	33.60	36.14
N_3	21.73	21.89	21.85	31.78	32.44	40.54	40.26	31.17	33.56	31.64	35.89
N_4	22.56	22.86	22.72	32.20	33.12	41.02	40.68	32.40	34.42	33.30	35.92
N_5	24.15	24.36	24.26	35.95	37.12	39.98	39.50	32.85	35.15	33.78	36.39
S.Ed+	0.68	0.71	0.04	0.99	0.99	0.97	1.00	-	-	-	-
CD (P=0.05)	1.38	1.44	0.11	2.03	2.02	N.S	N.S	-	-	-	-
Interaction (I × N)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	-	-	-	-

Table 3. Water use efficiency and uptake of primary nutrients under different treatments

Treatments	Crop water use efficiency (kg/ha-cm)		Field water use efficiency (kg/ha-cm)		Uptake of N (kg/ha)		Uptake of P (kg/ha)		Uptake of K (kg/ha)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation (I)										
I_0	64.01	66.49	64.01	66.49	48.09	45.35	11.38	10.57	54.27	51.59
I_1	62.36	59.77	61.08	57.72	52.21	55.82	12.33	13.01	57.20	60.70
I_2	77.53	70.41	76.75	64.49	64.64	66.52	14.90	15.57	67.13	70.25
I_3	78.66	70.63	73.77	65.86	66.10	68.45	15.83	16.45	68.68	71.83
S.Ed+	-	-	-	-	1.37	2.08	0.36	0.59	1.88	1.77
CD (P=0.05)	-	-	-	-	3.35	5.10	0.89	1.46	4.62	4.35
Nutrient Management (N)										
N_1	68.75	65.00	66.85	59.24	52.94	53.96	12.48	12.57	57.43	58.68
N_2	72.20	68.15	70.36	66.36	61.24	63.06	14.44	14.82	65.57	67.91
N_3	69.53	65.52	68.50	61.59	54.63	55.39	12.92	13.20	58.71	60.08
N_4	69.42	66.30	67.53	63.70	56.49	57.82	13.43	13.74	60.57	62.26
N_5	73.29	69.15	71.27	66.92	63.49	64.93	14.78	15.15	66.83	69.02
S.Ed+	-	-	-	-	2.12	1.72	0.28	0.28	1.38	1.49
CD (P=0.05)	-	-	-	-	4.32	3.50	0.57	0.57	2.82	3.05
Interaction (I × N)	-	-	-	-	N.S	N.S	N.S	N.S	N.S	N.S

higher irrigation regimes were also reported by Balamani *et al*. (2012) and Jadhav *et al*. (2003). Further, it can be explained from the fact that increased irrigation frequency might be attributed to better vegetative crop growth and development which ultimately increased the translocation of assimilates from source to sink thus, resulting in increased grain (Luikham *et al*., 2014; Sorour *et al*., 1998; Subramanian *et al*., 2008).

Grain yield

During both the year, among the four treatments, the highest grain yield (26.01 and 26.25 q/ha) was obtained under irrigation schedule IW:CPE ratio 1.60 followed by irrigation at IW:CPE ratio 1.40 the effect of which were at par, but significantly higher than grain yields observed under IW: CPE ratio 1.20 and rainfed control (Table 3 and Figure 3). However, irrigation at IW: CPE ratio 1.20 resulted in significantly higher grain yield over that of rainfed control. Thus the grain yield increased with increasing levels of irrigation regime from irrigation at IW:CPE ratio 1.20 to 1.60 and all were being proved superior to rainfed in producing higher grain yield of direct-seeded autumn rice.

Water use efficiency

The crop water use efficiency increased with increasing of irrigation regimes IW: CPE ratio 1.20 (62.36 and 59.77 kg/ha-cm) to IW:CPE ratio1.60 (78.66 and 70.63 kg/ha-cm) and the lowest values were observed under IW: CPE ratio 1.20 (Table 3 and Figure 3), which was even lower than rainfed crop (64.01and 66.49 kg/ha-cm). On the other hand, higher field water use efficiency was recorded with the irrigation regime IW:CPE ratio 1.40 (76.75 kg/ha-cm), in 2017, while such higher value was recorded under rainfed (66.17 kg/ha-cm) in 2018 under rainfed crop. However, in all such cases these were followed by the irrigation regime IW:CPE ratio 1.60 and resulted in the higher field as well as crop water use efficiency in both the year. Higher irrigation regimes facilitated more evapo-transpiration as compared to lower irrigation regimes and rainfed through frequent irrigation and increase the availability of moisture to the crop throughout the growing season (Behara *et*

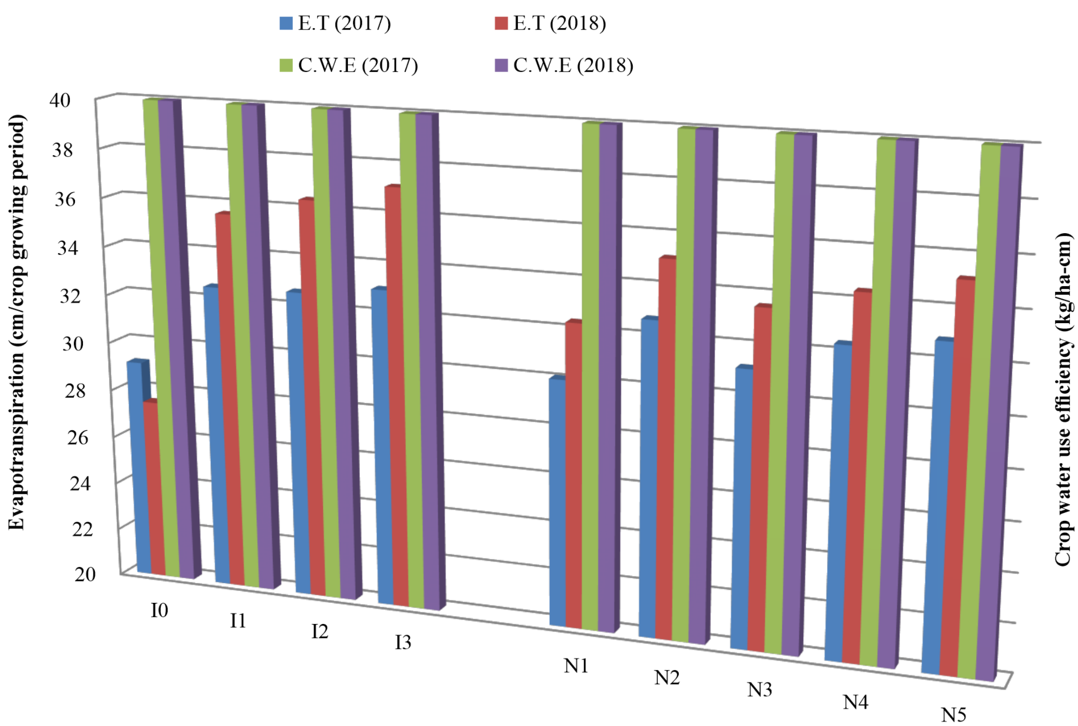

Fig. 3. Influence of irrigation and nutrient management on evapotranspiration and crop water use efficiency of the direct seed rice in 2017 and 2018

al., 2016; Ramamoorthy *et al*., 1996). However, the higher grain yield of rice realized under the higher irrigation regime IW:CPE ratio1.60 led to producing considerably higher crop water use efficiency. Similar results of higher crop water use efficiency due to increased grain yield of rice with intensive irrigation regime have also been reported by Bali and Uppal (1999). The crop water use efficiency directly influences the uptake of nutrients from soil. This can be explained in the light of the fact that adequate soil moisture supply achieved through frequent irrigations under those treatments made more availability of such nutrients to the crop (Balasubramanian and Krishnarajan, 2001). Higher nutrient contents coupled with higher dry matter production and grain and straw yield of direct-seeded rice associated with these irrigation regimes IW:CPE ratio 1.60 followed by IW:CPE ratio 1.40 might have attributed to result in higher uptake of such nutrients (N, P and K) by grain and straw as well as total uptake by the crop. Increased uptake of nitrogen (Jadhav and Dahiphale, 2005) and other nutrients N, P and K (Boruah, 2018; Parihar, 2004; Singh *et al*., 1997) with intensive irrigation regimes have also been reported. The higher crop growth and rate of photosynthesis owing to higher soil moisture availability may also be attributed to the increased nutrient uptake (Table 3) by more consumptive use (evapotranspiration) of crop (O'Toole, 1982).

Conclusion

From the two years field experiment, it was observed that soil moisture availability and uptake of the direct-seeded autumn rice under irrigation treatment IW:CPE ratio1.60 was favorable for crop growth environment, which was reflected in increasing evapotranspiration by crop, yield of crop and water use efficiency. Thus it can be concluded that adiquite irrigation practices may be a successful adaptive strategy for managing weather variability concerning heat and moisture stress in direct-seeded rice crop growth in Assam.

References

Allen, R.G., Smith, M., Perrier, A., Pereira, L.S. 1998. Crop Evapotranspiration, Guidelines for Computing Crop Water Requirements. FAO

Irrigation and Drainage. Food and Agriculture Organization of the United Nations, Rome, Italy, p.56.

Anat, A., Duke, H.D. and Corey, A.T. 1965. Steady upward flow from water tables. CO State Univ., Ft. Collins. CSU Hydrol, p.7.

Balamani, K., Ramulu, V., Reddy, M.D. and Devi, M.U. 2012. Effect of irrigation methods and irrigation schedules on aerobic rice. *Journal of Research ANGRAU* **40**(4): 84-86.

Balasubramanian, R. and Krishnarajan, J. 2001. Yield and correlation studies in direct seeded rice as influenced by irrigation levels. *Indian Journal of Agricultural Research* **35**(3): 194-197.

Bali, A.S. and Uppal, H.S. 1999. Irrigation schedule in producing quality basmati rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **69**(5): 325-328.

Behera, M.S., Singandhupe, R.B., Kundu, D.K., Kannan, K. and Brahmanand, P.S.. 2016. Effect of soil moisture and fertility on growth and yield of stevia in a sandy clay loam soil of Odisha. *Journal of Agricultural Physics* **16**: 22-28.

Bertrand, G., Masini, J., Goldscheider, N., Meeks, J., Lavastre, V., Celle-Jeanton, H., Gobat, J.M. and Hunkeler, D. 2014. Determination of spatio-temporal variability of tree water uptake using stable isotopes (δ18O, δ2H) in an alluvial system supplied by a high-altitude watershed, Pfyn forest, Switzerland. *Ecohydrology* **7**: 319- 333.

Bhalerao, P.D. 2001. Effect of Irrigation and nitrogen on Indian mustard (*Brassica juncea*) varieties. *Indian Journal of Agronomy* **46**(40): 727-731.

Boruah, K. 2018. Irrigation water saving through soil moisture conservation practices in direct seeded early *ahu* rice (*Oryza sativa*). M.Sc. (Agri) thesis submitted to the Department of Agronomy, AAU, Jorhat.

Briggs, L.J. and Shantz, H.L. 1913. "The water requirement of plants", in *Bureau of Plant Industry Bulletin* (Washington, DC: US Department of Agriculture), p. 282-285.

Chaodhary, A.K., Thakur, R.C. and Kumar, N. 2006. Effect of integrated nutrient management on water use and water use efficiency in wheat (*Triticum aestivum*)- rice (*Oryza sativa*) crop sequence in N-W Himalayas. *Indian Journal of Soil Conservation* **34**(3): 233-236.

Chimner, R.A. and Cooper, D.J. 2004. Using stable oxygen isotopes to quantify the water source used for transpiration by native shrubs in the San Luis Valley, Colorado USA. *Plant and Soil* **260**: 225-236.

Das, A., Patel, D.P., Munda, G.C., Ramkrushna G.I., Kumar, M. and Ngachan, S.V. 2014. Improving productivity, water and energy use efficiency in lowland rice (*Oryza sativa*) through appropriate establishment methods and nutrient management practices in the mid-altitude of north-east India. *Experimental Agriculture* **50**(3): 353-375.

Er-Raki, S., Chehbouni, A., Guemouria, N., Duchemin, B., Ezzahar, J., Hadria, R., 2007. Combining FAO-56 model and ground-based remote sensing to estimate water consumptions of wheat crops in a semi-arid region. *Agricultural Water Management* **87**: 41-54.

Gangwar, A., Vikas Kumar Rai, Nayak, T.R., Singh, R.M. and Ashish Rai. 2019. Irrigation scheduling of Rabi crops using CROPWAT model in Bina Command Area, Sagar District, Madhya Pradesh. *Journal of Agricultural Physics* **19**: 115-126.

Hatfield, J.L., Boote, K.J., Kimball, B.A., Ziska, L.H., Izaurralde, R.C. and Ort, D. 2011. Climate impacts on agriculture: implications for crop production. *Agronomy Journal* **103**: 351-370.

Hongjie X, Jan H., Shirley K. and Eric S. 2002. Comparison of evapotranspiration estimates from the surface energy balance algorithm (SEBAL) and flux tower data, middle Rio Grande Basin, Evapotranspiration, Available http://www.nmt.edu/~hjxie/sebal-agu.htm.

Jadhav, A.S. and Dahiphale, V.V. 2005. Effects of irrigation and nitrogen on yield and nitrogen uptake of basmati rice in vertisols. *Journal of Maharashtra Agricultural University* **30**: 368-369.

Jadhav, A.S., Dhoble, M.V. and Chavan, D.A. 2003. Effect of irrigation and nitrogen on yield and quality of Basmati rice. *Journal of Maharashtra Agricultural University* **28**: 187-188.

Jeyalal, A., Palaniappan, S.P. and Chelliah, S. 1999. Evaluation of integrated nutrient management techniques in rice. *Oryza* **36**(3): 263-265.

Kalluri S., Gilruth P., Bergman P. and Plante R. 2003. Impacts of NASA's remote sensing data on policy and decision making at state and local agencies in the United State. Evapotranspiration. Available http://earth-outlook.east.hitc.com: 1500/05_07_11.00_kallyri.pdf.

Kaur, J. 2004. Comparative performance of different planting techniques on growth, productivity and water saving in paddy (*Oryza sativa* L.). (M.Sc. thesis submitted to the Punjab Agricultural University, Ludhiana, India).

Kingra, P.K. and Kaur, H. 2017. Microclimatic modifications to manage extreme weather vulnerability and climatic risks in crop production. *Journal of Agricultural Physics* **17(1)**: 1-15.

Luikham, E., Krishanarajan, J. and Premsekhar, M. 2014. Irrigation and nitrogen application schedules for hybrid ADTRH 1 rice (*Oryza sativa*) in Tamil Nadu. *Indian Journal of Agronomy* **49**: 37-39.

Monteith, J.L. 1965. Evaporation and environment. In Symp. *Society of Experimental Biology* **19**: 205-234.

O'Toole, J.C. 1982. Adaptation of rice to the drought-prone environment In drought resistance in crops with emphasis on Rice. *International Rice Research Institute, Manila, Philippines* p.195-213.

Panse, V.G. and Sukhatme, P.V. 1995. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi.

Parihar, S.S. 2004. Effect of crop establishment method, tillage, irrigation and nitrogen on production potential of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **49**: 1-5.

Ramamoorthy, K., Arokiaraj, A. and Balasubramanian, A. 1996. Response of upland direct seeded rice to the soil-moisture regime and weed control. *Indian Journal of Agronomy* **43**: 82-86.

Sharma, P.K., Bhushan, L., Ladha, J.K., Naresh, R.K., Gupta, R.K., Balasubramanian, B.V. and Bouman, B.A.M. 2002. Crop-water relations in rice-heat cropping under different tillage systems and water management practices in a marginally sodic medium textured soil. In: Bouman B A M, Hengsijk H, Hardy B, Bihdraban B, Tuong T P and Ladha J K (eds) Proceedings of the International Workshop on Water-wise Rice Production. *International Rice Research Institute, Los Banos, Philippines* p. 223-235.

Shi, H., Liu, S. and Zhao, X. 2003. Application of stable hydrogen and oxygen isotope in water circulation. *Journal of chinese Soil and Water Conservation* **17**: 163-166.

Singh, A.K., Singh, G.R. and Dixit, R.S. 1997. Influence of plant population and moisture regimes on nutrient uptake and quality of rice. *Indian Journal of Agronomy* **42**(1): 107-111.

Singh, S.S. and Dixit, R.S. 1989. Response of mustard to various levels of irrigation and nitrogen. *Indian Journal of Agronomy* **34**(3): 307-311.

Sorour, F.A., Mosalem, M.E., Mahrous, F.N. and Ei-Refaee, I.S. 1998. Effect of irrigation interval and potassium fertilization level on growth, yield and quality of rice. *Annals of Agricultural Science,* pp. 663-678.

Subramanian, E., Martin, G.J., Suburayalu, E. and Mohan, R. 2008. Aerobic Rice: Water Saving Rice Production Technology. *Agricultural Water Management* **49**(6): 239-243.

Sun, S., Huang, J., Lin, G., Zhao, W. and Han, X. 2005. Application of stable isotope technique in the study of plant water use. *Chinese Journal of Acta Ecologica Sinica* **25**: 2362-2371.

Tabbal, D.F., Bouman, B.A.M., Bhuiyan, S.I., Sibayan, E.B. and Sattar, M.A. 2002 . Onfarm strategies for reducing water input in irrigated rice: Case studies in the Philippines. *Agricultural Water Management* **56**: 93-112.

Tomar, S., Tamar, S. and Singh, S. 1992. Effect of irrigation and fertilizer on nutrient uptake and moisture use of mustard *(Brassica juncea). Indian Journal of Agronomy* **37**(1): 97-99.

Trivedi, S.K., Pachauri, R.K. and Singh. N. 2014. Response of Mustard (*Brassica juncea* L.) to moisture regimes and levels of nitrogen, phosphorus, potash and zinc. *Applied Biological Research* **16**(2): 143-149.

Xiao, J., Sun, G., Chen, J., Chen, H., Chen, S. and Dong, G. 2013. Carbon fluxes, evapo-transpiration, and water use efficiency of terrestrial ecosystems in China. *Agricutural and Forest Meteorology* **18**: 76-90.

Yadav, K.S., Rajput, R.L., Verma, O.P. and Yadav, R.P. 1996. Effect of sowing date and irrigation levels on seed yield and quality of Indian mustard (*Brassica juncea*). *Indian Journal of Agronomy* **41**(2): 275-278.

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