ISSN-1923-7766 (Online)
Int. J. Expt. Agric. 1(2):20-24(September 2010)

PHOTOSYNTHESIS, CONDUCTANCE, TRANSPIRATION, WATER USE EFFICIENCY AND GRAIN GROWTH OF HIGH YIELDING RICE VARIETIES UNDER WATER STRESS

M.T. ISLAM

Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh

Corresponding author & address: Dr. Md. Tariqul Islam, Email: islamtariqul05@yahoo.com
Accepted for publication on 15 August 2010

ABSTRACT

Islam MT (2010) Photosynthesis, conductance, transpiration, water use efficiency and grain growth of high yielding rice varieties under water stress. *Int. J. Expt. Agric.* 1(2), 20-24.

A pot experiment was carried out at the Bangladesh Institute of Nuclear Agriculture, Mymensingh, during January to May of 2009 to assess the effect of water stress on photosynthetic rate (P_N), leaf conductance (Cond), transpiration rate (Trmmol), water use efficiency (WUE) and grain growth of high yielding rice varieties and to find out relationships among those with microclimatic parameters. Water stress of 40% Field Capacity (FC) and control (100% FC) were maintained from heading to grain maturity of cv. Binadhan-5, Binadhan-6, Binadhan-7 and Iratom-24. Grain dry weight, P_N, cond and Trmmol decreased and WUE increased with stress. Iratom-24 accumulated the highest grain dry matter and Trmmol followed by Binadhan-7. The highest P_N was observed in Binadhan-5 followed by Binadhan-6 and Iratom-24. The highest WUE was noticed in Binadhan-5 and the lowest in Iratom-24. Grain dry matter accumulation significantly increased from fertilization to 24 days but P_N decreased. Higher cond and Trmmol were observed at the beginning of grain development. Cond (r= -0.928**), Trmmol (r= -0.941**) and P_N (r= -0.956**) were negatively correlated with average grain dry weight during fertilization to maturity. P_N (r= -0.766*) was negatively correlated with leaf temperature (Tleaf°C) and photosynthetically active radiation (r= -0.716*) in sample chamber (PARi) and positively correlated with relative humidity (r= 0.753*) in sample chamber (RH_S%). Tleaf°C (r= 0.759 *) was positively correlated with PARi whereas RH_S% and CO_2 in sample chamber (CO_2S_µmol) was negatively correlated (r= -0.786*). P_N (r= 0.811*) was positively correlated with relative grain growth rate (RGGR); however, RGGR (r= -0.964**) was negatively correlated with dry weight grain^{-1}.

Key words: *photosynthesis, conductance, transpiration, water use efficiency and rice grain growth*

INTRODUCTION

Bangladesh receives monsoon rain during June to September and this is the cropping season for T. aman rice. The residual moisture or irrigation is used for growing crops during the remainder period of the year. Boro rice is cultivated under irrigation during January to May. Low water demanding varieties are preferable from the point of our environmental safety. Some areas do not have any facility for irrigation. Therefore, after monsoon rains, the conditions prevailing in the country can be classified as drought and severe drought (0.57 million and 1.75 million hectares, respectively, of the cultivable land). Drought affects every aspects of plant life and inhibits growth, development and productivity. The effect of water stress on photosynthesis, conductance, transpiration, water use efficiency and grain growth may vary with four high yielding rice varieties developed at the Bangladesh Institute of Nuclear Agriculture (BINA) and thus help in identifying water stress tolerant variety for further development.

MATERIALS AND METHODS

A pot experiment was carried out at the Bangladesh Institute of Nuclear Agriculture, Mymensingh, during Boro season (January to May) of 2009 to assess the effect of water stress on photosynthesis, conductance, transpiration, water use efficiency and grain growth of four high yielding rice varieties *viz*., Binadhan-5, Binadhan-6, Binadhan-7 and Iratom-24 developed at BINA, Mymensingh, Bangladesh. Each pot contained 8 Kg of soils (Silty loam, organic matter 1.05%, total N 0.07%, available P 14.3 ppm, exchangeable K 0.25 meq. per 100g soil, available S 13.2 and soil pH 6.67). The experiment was laid out in a Randomized Complete Block design with three replications. Recommended doses of fertilizers were applied and other cultural practices were followed as and when necessary. Water stress (40% FC) was maintained from heading to maturity for grain growth studies. Ten grains were harvested from selected panicles at 3 days' interval during fertilization to grain maturity. Photosynthetic and microclimatic parameters were recorded using *Portable Photosynthesis System LI-6400XT, LI-COR Inc.*, Lincoln, NE, USA. Statistical analysis was done as per design used with the help of MSTAT computer packages. Duncan's Multiple Range Test (DMRT) compared the means at 5% level of significance.

RESULTS

Grain dry weight, photosynthetic rate, conductance, and transpiration rate decreased and water use efficiency increased with stress (Table 1). Iratom-24 accumulated the highest grain dry matter followed by Binadhan-7. Binadhan-5 accumulated the lowest grain dry matter. The highest photosynthetic rate was observed in Binadhan-5 followed by Binadhan-6 and Iratom-24. The lowest photosynthetic rate was observed in Binadhan-7. The varieties did not show significant variation in conductance. The highest transpiration rate was observed in Iratom-24 followed by Binadhan-7. Binadhan-5 had the lowest transpiration rate which was identical to that of Binadhan-6. The highest water use efficiency was noticed in Binadhan-5 and the lowest in Iratom-24. Water use efficiency was identical in Binadhan-6 and Binadhan-7. Grain dry matter accumulation significantly increased from fertilization to 24 days. Thereafter it did not increase significantly (Table 2). Photosynthetic rate decreased gradually from fertilization to grain maturity. Higher conductance and transpiration rate were observed at the beginning of grain development and those did not show significant variation from 8 days to grain maturity. Water use efficiency varied during grain development period. Conductance, transpiration rate and photosynthetic rate were negatively correlated with grain dry weight during fertilization to maturity (Table 3 & 4). Photosynthetic and transpiration rate were positively correlated and also with conductance. Photosynthesis rate was negatively correlated with leaf temperature and photosynthetically active radiation in sample chamber and positively correlated with relative humidity in sample chamber during fertilization to maturity (Table 5 & 6). Leaf temperature is positively correlated with photosynthetically active radiation whereas relative humidity and CO_2 in sample chamber was negatively correlated. Photosynthetic rate was positively correlated with relative grain growth rate, however, relative grain growth rate was negatively correlated with grain dry weight per grain (Table 7 & 8).

DISCUSSION

Photosynthetic rate, conductance, transpiration rate decreased and water use efficiency increased with stress imposed on rice varieties are agreed with those of Pieters and Nunez (2008) who observed decreased photosynthesis, transpiration rate and stomatal conductance with water deficit in rice. Higher water use efficiency in water stress might be due to the water savings reducing transpiration rate. The result is in agreement with that of Baker and Allen (2002) who observed reduced evapo-transpiration by about 10% with elevated CO_2 and water deficit. Grain dry matter accumulation (Average grain weight) significantly increased from fertilization to maturity. But grain growth rate followed a sigmoid pattern, initially low (up to 4 days), sharp increase with a peak at the 8^{th} day thereafter decreases slowly. The results are almost similar to those of Murchie *et al.* (2002) who observed a rapid grain filling phase approximately 10 d after flowering in most of the rice varieties. As average grain weight significantly increased up to 24 days and photosynthetic rate gradually decreased from fertilization to maturity, so, a negative relationship was observed. A positive relationship between photosynthetic and grain growth rate in this study also fully supported by Huqu *et al.* (2002) who observed a completely synchronous relationship of photosynthate in leaves and the demand of grain filling in super high yielding hybrid rice. These results suggest that higher photosynthetic rate in leaves at fertilization and its complete synchronization with grain filling on the key approaches to high yield of rice.

Table 1. Grain dry weight, photosynthetic rate, conductance, transpiration rate and leaf photosynthetic water use efficiency of rice varieties under water stress

Treatments	Dry wt grain^{-1} (mg)	P_N	Cond	Trmmol	WUE
Control	16.48 a	21.27 a	0.947 a	7.43 a	2.42 a
Water stress	15.03 b	14.05 b	0.414 b	5.80 b	2.72 b
Varieties					
Binadhan-5	14.71 d	18.69 a	0.590	5.63 c	3.96 a
Binadhan-6	15.32 c	17.77 b	0.798	6.36 bc	2.12 b
Binadhan-7	15.86 b	16.88 d	0.683	6.65 b	2.94 b
Iratom-24	17.13 a	17.29 c	0650	7.82 a	2.26 c

Values having common or without letter(s) in a column do not differ significantly at $p \leq 0.05$ by DMRT

Where,
P_N = Photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$)
Cond = Conductance ($mmolH_2Om^{-2}s^{-1}$)
Trmmol = Transpiration rate ($mmolH_2Om^{-2}s^{-1}$)
WUE = Water use efficiency

Table 2. Grain dry weight, photosynthetic rate, conductance, transpiration rate and leaf photosynthetic water use efficiency of rice varieties from fertilization to grain maturity

Days after fertilization	Dry wt per grain (mg)	P_N	Cond	Trmmol	WUE
0	2.95 g	22.33 a	1.282 a	8.43 a	2.87 b
4	4.49 f	19.99 b	1.047 ab	8.17 a	2.67 b
8	12.03 e	18.84 c	0.563 c	6.47 b	3.25 ab
12	17.66 d	18.06 d	0.679 bc	6.07 bc	3.74 a
16	19.92 c	17.09 e	0.616 bc	6.60 b	2.74 b
20	21.80 b	15.84 f	0.439 c	6.13 bc	2.94 b
24	23.56 a	14.92 g	0.454 c	5.77 b	3.33 ab
28	23.61 a	14.19 h	0.361 c	5.27 b	3.01 b

Values having common letter(s) in a column do not differ significantly at $p \leq 0.05$ by DMRT

Where,
P_N = Photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$)
Cond = Conductance ($mmolH_2Om^{-2}s^{-1}$)
Trmmol = Transpiration rate ($mmolH_2Om^{-2}s^{-1}$)
WUE = Water use efficiency

Table 3. Correlation matrix of photosynthetic parameters with grain weight of rice varieties

	Cond	Trmmol	WUE	P_N
Trmmol	0.958 **			
WUE	-0.346	-0.520		
Pn	0.933 **	0.916 **	-0.216	
Grain wt	-0.928 **	-0.941 **	0.340	-0.956 **

** = Significant at 1% level, R^2= 0.940, n=8

Where,
P_N = Photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$)
Cond = Conductance ($mmolH_2Om^{-2}s^{-1}$)
Trmmol = Transpiration rate ($mmolH_2Om^{-2}s^{-1}$)
WUE = Water use efficiency

Table 4. Grain dry weight and microclimatic parameters of rice varieties under water Stress

Treatment	P_N	Tleaf^{0}C	RH_S%	PARi	CO_2S_µmol
Control	21.27 a	35	75	1335	328
Water stress	14.05 b	37	69	1300	326
Variety					
Binadhan-5	18.69 a	35	74	1304	329
Binadhan-6	17.77 b	36	72	1273	329
Binadhan-7	16.88 d	36	73	1371	325
Iratom-24	17.29 c	37	69	1322	323

Values having common or without letter(s) in a column do not differ significantly at $p \leq 0.05$ by DMRT

Where,
Pn = Photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$)
Tleaf^{o}C = Temperature of leaf thermocouple (C)
RH_S% = Relative humidity in the sample cell (%)
PARi = Photosynthetically active radiation in-chamber quantum sensor ($\mu molm^{-2}s^{-1}$)
CO_2S_µmol = Sample cell CO_2 ($\mu molCO_2mol^{-1}$)

Table 5. Grain dry matter and microclimatic parameters of rice varieties from fertilization to grain maturity

Days after fertilization	P_N	Tleaf^{0}C	RH_S%	PARi	CO_2S_µmol
0	22.33 a	35	76	1270	318
4	19.99 b	36	74	1291	325
8	18.84 c	36	71	1333	328
12	18.06 d	36	72	1323	324
16	17.09 e	36	70	1280	336
20	15.84 f	37	71	1367	322
24	14.92 g	36	72	1332	329
28	14.19 h	37	71	1344	331

Values having common or without letter(s) in a column do not differ significantly at $p \leq 0.05$ by DMRT

Where,
Pn = Photosynthetic rate (µmol$CO_2$$m^{-2}s^{-1}$)
Tleaf^{o}C = Temperature of leaf thermocouple (C)
RH_S% = Relative humidity in the sample cell (%)
PARi = Photosynthetically active radiation in-chamber quantum sensor (µmol$m^{-2}s^{-1}$)
CO_2S_µmol = Sample cell CO_2 (µmol$CO_2$$mol^{-1}$)

Table 6. Correlation matrix of microclimatic parameters with photosynthetic rate of rice varieties

	Tleaf	RH_S	PARi	CO_2S
RH_S	-0.624			
PARi	0.759 *	-0.504		
CO_2S	0.407	-0.786 *	0.016	
Pn	-0.766 *	0.753 *	-0.716 *	-0.569

*= Significant at $p \leq 0.05$, R^2= 0.840, n=8

Where,
Pn = Photosynthetic rate (µmol$CO_2$$m^{-2}s^{-1}$)
Tleaf^{o}C = Temperature of leaf thermocouple (C)
RH_S% = Relative humidity in the sample cell (%)
PARi = Photosynthetically active radiation in-chamber quantum sensor (µmol$m^{-2}s^{-1}$)
CO_2S_µmol = Sample cell CO_2 (µmol$CO_2$$mol^{-1}$)

Table 7. Photosynthetic rate and grain growth parameters of rice varieties from fertilization to grain maturity

Days after fertilization	P_N	Dry wt per grain (mg)	Grain growth rate (mg g^{-1}grain-^{1}d^{-1})	Relative grain growth rate (mg g^{-1})
0-4	19.99	4.49	0.385	272
4-8	18.84	12.03	1.885	130
8-12	18.06	17.66	1.407	68
12-16	17.09	19.92	0.565	53
16-20	15.84	21.80	0.470	47
20-24	14.92	23.56	0.440	44
24-28	14.19	23.61	0.125	42

Where, P_N = Photosynthetic rate (µmol$CO_2$$m^{-2}s^{-1}$)

Table 8. Correlation matrix of photosynthetic rate with grain growth parameters of rice varieties

	P_N	Grain growth rate	Relative grain growth rate
Grain growth rate	0.541		
Relative grain growth rate	0.811 *	0.085	
Dry wt. per grain	-0.929 **	-0.322	-0.964 **

* = Significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$, R^2= 0.997, n=7

Where, P_N = Photosynthetic rate (µmol$CO_2$$m^{-2}s^{-1}$)

REFERENCES

Baker J, Allen L (2005) Rice growth, yield and photosynthetic responses to elevated atmospheric carbon dioxide concentration and drought. Abstract, American Sos. Agron. Branch Meeting held on June 21, 2005.

Huqu Z, Shuqing C, Jianmin W, Rongxian Z, Wei L, Liangbi L, Tingyun K, Shaokai M, Defeng Z, Shihua C (2002) Relationship between leaf photosynthetic function at grain filling stage and yield in super high yielding hybrid rice (*Oryza sativa* L.). *Chinese Academy of Sciences*. 45(6), 637-646.

Muchie EH, Yang J, Hubbart S, Horton P, Peng S (2002) Are there association between grain filling rate and photosynthesis in the flag leaves of field-grown rice*? J. Exp. Bot*. 53(378), 2217-2224.

Pieters AJ, Nunez M (2008) Photosynthesis, water use efficiency, and $\delta^{13}C$ in two rice genotypes with contrasting response to water deficit. *Photosynthetica*. 46(4), 574-580.

Yoshinobu K (2005) Photosynthetic rate, transpiration rate, leaf conductance for leaves of rice plants. *Japanese J. Crop Sci.* 56(4), 563-570.