International Scholars Journals

African Journal of Agricultural Economics and Rural Development ISSN 2375-0693 Vol. 2 (6), pp. 001-010, March, 2014. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Effect of photosynthetic characteristic and dry matter accumulation of rice under high temperature at heading stage

X. J. Xie[1,2]*, S. H. H. Shen[1], Y. X. Li[1], X. Y. Zhao[1], B. B. Li[1] and D. F. Xu[1]

[1]Jiangsu Key Laboratory of Agricultural Meteorology, Nanjing University of Information Science and Technology, Nanjing, Jiangsu Province, Peoples Republic of China.

[2]College of Applied Meteorology, Nanjing University of Information Science and Technology, Nanjing, Jiangsu Province, Peoples Republic of China.

Accepted 09 March, 2014

The dry matter of rice grain mainly originates from photosynthetic outcome. The relationships between photosynthetic characteristic and dry matter accumulation were measured based on room experiments with two rice varieties (Yangdao6 and Nanjing43) under different high temperature stress of heading stage in 2007 and 2008. The results showed that grain yield, chlorophyll content, net photosynthetic rate (NPn), superoxide dismutase activity (SOD) and leaf area index (LAI) suffered a sharply decline. On the other hand, relative conductivity and malondialdehyde content (MDA) increased gradually with the elevation of stress temperature and extension of stress time. The increasing rate (reducing rate) of some physiological and biochemical indexes in Yangdao6 were lower than that in Nanjing43 compared with the CK under the same temperature stress. It was shown that response of Nanjing43 to high temperature was bigger than that of Yangdao6. According to the correlation analysis, grain yield showed a positive correlation with NPn and LAI at 0.01 level, the correlation coefficients of them were 0.94 and 0.88 respectively. The correlation between grain yield and DW after initial at mature stage, the export percentage of the matter in stem-sheath (EPMSS) and the transformation percentage of the matter in stem-sheath (TPMSS) were not significant. It was showed that grain yield under high temperature stress originated mostly from the photosynthesis and LAI of leaves after heading stage.

Key words: Dry matter, heading stage, high temperature stress, photosynthetic characteristic, rice.

INTRODUCTION

Photosynthesis is the foundation of dry matter production in plants (Sultana et al., 2001). In rice, 90% of grain yield originates from the photosynthetic production of leaves after heading, especially from flag leaf. Although, photosynthetic characteristics and their effects on dry matter accumulation and grain yield have been reported for different rice varieties in recent years, but it has up till now been rarely reported for the relationship between dry matter accumulation and photosynthetic characteristics of flag leaf, under high temperature stress at home and abroad (Tong et al., 2008; Zhu et al., 2008). With growing changes of presently global climate, resulting in a continual occurrence of extreme and sustained high temperature in summer, the frequency of high temperature damage in rice and damage content in Yangzi river basin of China are thus increased, which further causes increasing damage severity for rice yield (Zheng et al., 2007).

As is well known, the heading stage is the most temperature sensitive period during growth and development of rice (*Oryza sativa* L.). High temperature at heading stage, usually over 35°C, often causes floret sterility, which results in yield reduction at maturing stage. Many reports have focused on the mechanisms of high temperature-induced sterility, the effect of high temperature on seed setting and yield, as well as the differences in response among varieties, but mechanisms of high temperature-induced photosynthetic characteristics

*Corresponding author. E-mail: xxj_200210@yahoo.cn.

of flag leaf under high temperature stress at heading stage are still not clear (Tang et al., 2005; Morita et al., 2005; Matsui et al., 2007; Guo et al., 2000). In this case, Yangdao6 and Nanjing43, widely planted in Yangtze River Basin were selected as research objects, and then after those selected rice were subjected to high temperature stress at heading stage, photosynthetic characteristics and the amount of dry matter accumulation in flag leaves, as well as yield were respectively measured. This result could supply an important reference for cultivation of high yield and breeding in Yangtze River basin.

MATERIALS AND METHOD

Experimental design

Experiment was conducted in the experiment station of Jiangsu Academy of Agricultural Sciences, Nanjing, China in 2007 and 2008. The test samples were Yangdao6 (conventional Indica rice, 138 days for total growth stage) and Nanjing 43 (conventional Japonica rice, 160 days for total growth stage). Two samples were raised as follows: sowed on May 15, transplanted to plastic cases with specification of 30 × 20 × 10 cm on June 18, six hills for each case, and double seedlings per hill, as well as the cases were positioned in a mesh room. Yangdao6 started for heading at August 18, and Nanjing 43 at September 1.

When the two aforementioned rice cultivars were at heading stage, five cases of rice were randomly selected to be transplanted to the model RXZ microclimate-controlled culture case, and treated with high temperature of 35 and 39°C respectively for 3 and 5 days, and 5 h per day (09:00 to 14:00), after that, placed back to the natural condition after high temperature stress. The temperature error of RXZ microclimate-controlled culture case was ±0.5°C, and the natural condition was used as the control (CK).

Measurements and analysis

Net photosynthetic rate (Npn) and chlorophyll content of flag leaves

Representative plants with high temperature stress were labeled for measuring Npn and chlorophyll content of flag leaves at 3 and 5 days after heading stage. The NPn of flag leaf was measured in clear morning from 8:30 to 11:30 using LI-6400 portable photosynthetic system (Gene Co.Ltd., USA) under the conditions of light intensity of 1000 $E.m^{-2}.s^{-1}$ and chamber CO_2 concentration of 380 µmol mol^{-1}. Each measurement was repeated for 5 times with different plants. The methods for measuring chlorophyll content were measured according to Li (2000).

Leaf area index (LAI) and dry weight of above-ground biomass

LAI was measured using LI-6400 portable leaf area meter (Delta-T Devices, US), and computed as the leaf area per unit land area. Dry weight of leaves, stems and spikelet at heading and maturing stage was determined by oven drying at 80°C until a constant weight was attained. The export percentage of the matter in stem-sheath (EPMSS) and the transformation percentage of the matter in stem-sheath (TPMSS) were measured according to Yang et al. (1997).

EPMSS (%) =(A-B)/A*100%

TPMSS (%) =(A-B)/C*100%

Where A is dry weight of stem at heading, B is dry weight of stem at maturing, C is dry weight of spikelet.

Light intensity- Npn response curve

Npn response curves of flag leaves to light intensity in Yangdao6 and Nanjing43 were measured using LI-6400 portable photosynthetic system. The order of light intensity of chamber was set at 0, 30, 50, 100, 200, 400, 800, 1000, 1200, 1500 and 2000 µmolm^{-2} s^{-1}, and chamber CO_2 concentration of 380 µmol mol^{-1}. Each measurement was repeated 5 times with different plants.

Relative conductivity, malondialdehyde content (MDA) and superoxide dismutase activity (SOD)

The methods for measuring relative conductivity, MDA content and SOD activity content were measured according to Li (2000). MDA content assay was performed by thiobituric acid (TBA) method, and SOD activity assay was performed by nitroblue tetrazolium (NBA) method.

Harvest

Two rice cultivars were harvested in cases and inspected at maturing stage. Spikelet number per panicle, filled grain, seed setting and 1000-grain weight were determined. Actual yield was determined by all harvested hills per case.

Statistical analysis

Analysis of data was carried out using Data Processing System (DPS).

RESULTS

Rice grain yield and yield components

The grain yield of Yangdao6 and Nanjing43 after high temperature stress of heading stage decreased significantly compared with CK (Table 1), and the grain yield of two rice cultivars suffered a sharp decline with elevation of stress temperature and extension of stress time. The difference of grain yield of two rice cultivars was not significant at 35°C/3 days stress, the difference of other three high temperature stress were significant at 0.01 and 0.05 levels compared with CK. The decreasing rate of the two rice cultivars was different, and the decreasing rate in Yangdao6 was more than that in Nanjing43. The yield reduction rate in Nanjing43 and Yangdao6 were 6.4, 26.6, 3.9 and 20.2% respectively at 35°C/3 days and 39°C/3 days.

The yield components of two rice cultivars under high temperature stress decreased significantly compared with CK, but the difference of seed setting rate and filled grain was significant at 0.05 level, the difference of 1000-grain weight and spikelet number per panicle was not significant. It was shown that, seed setting rate and filled

Table 1. Grain yield and its components of rice under high temperature stress during heading.

Rice cultivars	High temperature stress	Spikelet number per panicle (number)	Filled grain (number)	1000-Grain weight (g)	Seed setting rate (%)	Yield (kg hm^{-2})	Yield reduction rate (%)
	CK/3 d	180.0 ^{a}±3.5	170.2 ^{aA}±3.3	26.5 ^{a}±0.8	95.5 ^{aA}±1.5	7614.2 ^{aA}±203.1	
	35°C/3 d	169.0 ^{a}±29	148.2 ^{bA}±2.5	24.9 ^{a}±0.7	87.8 ^{bB}±1.6	7312.1 ^{aA}±180.3	4.0
	39°C /3 d	154.0 ^{a}±1.7	103.4 ^{bB}±1.1	24.1 ^{a}± 0.9	68.1 ^{cC}±1.3	6075.3 ^{bA}±120.1	20.2
Yangdao6	CK/5 d	176.0 ^{a}±2.4	165.4 ^{aA}±1.9	26.0 ^{a}±1.1	95.4 ^{aA}±2.0	7920.4 ^{aA}±200.5	
	35°C/5 d	151.0 ^{b}±2.0	120.3 ^{bB}±1.6	23.4 ^{a}±0.5	80.8 ^{bB}±1.1	6883.3 ^{bA}±159.3	13.1
	39°C/5 d	149.0 ^{b}±1.9	72.6 ^{cB}±0.9	24.2 ^{a}±1.1	50.1^{cC}±0.9	5668.1 ^{bB}±182.4	28.4
	CK/3 d	172.0 ^{a}±2.2	163.1 ^{aA}±1.9	24.5 ^{a}±0.9	95.4 ^{aA}±1.5	7182.1 ^{aA}±215.7	
	35°C/3 d	166.0 ^{a}±2.1	141.1 ^{bA}±1.3	23.1 ^{a}±0.8	85.0 ^{bA}±1.4	6724.1 ^{aA}±146.8	6.4
	39°C/3 d	146.0 ^{a}±1.5	107.8 ^{bB}±1.2	23.5 ^{a}± 0.7	74.5 ^{cB}±1.3	5275.1 ^{bB}±156.7	26.6
Nanjing43	CK/5d	169.0 ^{a}±3.0	155.3 ^{aA}±1.5	24.1 ^{a}±0.8	94.5 ^{aA}±1.6^{aA}	7303.0 ^{aA}±224.3	
	35°C/5d	162.0 ^{a}±3.2	130.1 ^{bA}±2.0	22.5 ^{a}±1.0	80.9 ^{bB}±1.5	6269.1 ^{bB}±197.4	14.2
	39°C/5 d	140.0 ^{a}±1.9	68.7 ^{bB}±0.8	25.7 ^{a}± 1.2	49.1 ^{cC}±0.5	4900.1 ^{cC}±126.8	32.9

Differences between values followed by the same small letter and the same capital letter are not significant, different small letter represent significant difference at 0.05 level, different capital letter represent significant difference at 0.01 level.

grain were the important factors for affecting grain yield, and 1000-grain weight and spikelet number per panicle were slightly affected by high temperature.

Photosynthetic production

Transportation and distribution of photosynthetic outcome

EPMSS-the export percentage of the matter in stem-sheath, TPMSS- the transformation percentage of the matter in stem-sheath. Difference between values followed by the same small letter is not significant. Different small letter represent significant difference at 0.05 level. Production and accumulation speed of rice dry matter decreased and thus, the accumulation amount of dry matter reduced under high temperature stress (Table 2). EPMSS and TPMSS of two rice cultivars increased distinctly after high temperature of heading stage compared with CK. The difference between 35°C/5 days, 39°C/5 days stress and the CK in Nanjing43 was significant at 5% level, the difference of other treatments was not significant.

EPMSS and TPMSS increased sharply with elevation of stress temperature and extension of stress time. Compared with CK, at 35°C/5 days and 39°C/5 days stress, there were the increasing rate of EPMSS of Yangdao6 by 4.5 and 10.7%, one of TPMSS of Yangdao6 by 10.6 and 21.0%, one of EPMSS of Nanjing43 by 33.3 and 43.0%, and one of EPMSS of Nanjing43 by 50.1 and 68.4%. It was shown that the production of ground dry matter after heading stage mainly maintained the growth of rice leaves and stems under high temperature stress, and the proportion of distributing to grain was lower. It was usually possible for self-adjusted and maintaining the growth of rice.

The chlorophyll content, Npn and LAI

The chlorophyll content in the flag leaves is an important index for photosynthetic capability. The chlorophyll content of Yangdao6 and Nanjing43 under high temperature stress was significantly reduced compared with CK; the difference in all treatments was significant at 0.05 level. Compared with CK, the chlorophyll content of two rice cultivars in the flag leaves suffered a sharp decline with elevation of stress temperature and extension of stress time, but the decreasing rate of two rice cultivars was different. The decreasing rate in Yangdao6 and Nanjing43 were 9.1, 8.0, 8.6 and 9.9% respectively, at 39°C/3 days and 39°C/5 days stress (Figure 1). NPn of two rice cultivars under high temperature was distinctly lower than that of the CK (Figure 2). It was shown that, high temperature affected rice photosynthesis. The difference between 35°C/3 days stress and the CK in two rice cultivars were significant at 0.05 level, and the differences of other treatments were significant at 0.01 level. But the decreasing rate of two rice cultivars was different compared with CK. The decreasing rate of Yangdao6 and Nanjing43 was 5.7, 21.0 and 9.5, 24.7% respectively at 35°C/3 days and 35°C/5 days stress. The decreasing rate in Nanjing43 was higher than that in Yangdao6, under the same stress.

LAI of two rice cultivars under high temperature was also distinctly lower than that of the CK (Figure 3). The decreasing rate inYangdao6 was 1.7, 8.2, 2.6 and 12.6% respectively at 35°C/3 days, 39°C/3 days, 35°C/5 days and 39°C/5 days stress, and the decreasing rate in

Table 2. Dry matter accumulation and transportation of rice under high temperature stress at heading stage.

Rice cultivars	High temperature stress	Dry weight (g plant^{-1})			Transport of culm and sheath		
		DW of culm and sheath at initial heading stage	DW of culm and sheath at mature stage	DW of spike at mature stage	DW after initial at mature stage	EPMSS (%)	TPMSS (%)
Yangdao6	CK/3d	42.6	25.6 ^{a}±2.1	50.7 ^{a}±3.1	36.6 ^{a}±1.8	40.0 ^{a}±2.1	33.5 ^{a}±0.9
	35°C/3d		23.1 ^{a}±1.5	48.9 ^{a}±2.1	27.1 ^{b}±1.1	45.7 ^{a}±2.2	39.8 ^{a}±1.2
	39°C/3 d		23.1 ^{a}±1.2	47.1 ^{a}±1.9	30.2 ^{a}±1.5	45.8 ^{a}±2.4	41.4 ^{a}±1.1
	CK/5d		22.3 ^{a}±1.3	49.1 ^{a}±2.0	28.5 ^{a}±0.8	45.2 ^{a}±2.3	39.2 ^{a}±1.1
	35°C/5d		22.5 ^{a}±1.1	46.4 ^{a}±2.2	27.4 ^{a}±0.7	47.2 ^{a}±2.2	43.3 ^{a}±1.3
	39°C/5 d		21.3 ^{a}±0.9	44.9 ^{a}±2.5	20.0 ^{b}±0.8	50.0 ^{a}±2.5	47.4 ^{a}±1.4
Nanjing43	CK/3d	37.0	23.8 ^{a}±1.1	46.2 ^{a}±2.1	25.5 ^{a}±1.4	35.7 ^{a}±1.5	28.6 ^{a}±0.7
	35°C/3d		23.0 ^{a}±1.0	44.8 ^{a}±2.1	20.2 ^{a}±0.8	37.8 ^{a}±1.7	31.2 ^{a}±0.5
	39°C/3 d		22.5 ^{a}±0.8	43.2 ^{a}±2.0	25.5 ^{a}±0.7	39.2 ^{a}±1.5	33.6 ^{a}±0.9
	CK/5d		23.5 ^{a}±1.2	45.1 ^{a}±2.5	11.8 ^{a}±0.2	36.4 ^{b}±2.0	29.8 ^{b}±1.1
	35°C/5d		19.1 ^{a}±0.5	40.0 ^{a}±2.3	12.0 ^{a}±0.5	48.4 ^{a}±2.1	44.7 ^{a}±1.5
	39°C/5 d		17.8 ^{a}±1.2	38.2 ^{b}±2.0	10.0 ^{a}±0.5	52.0 ^{a}±2.9	50.2 ^{a}±2.6

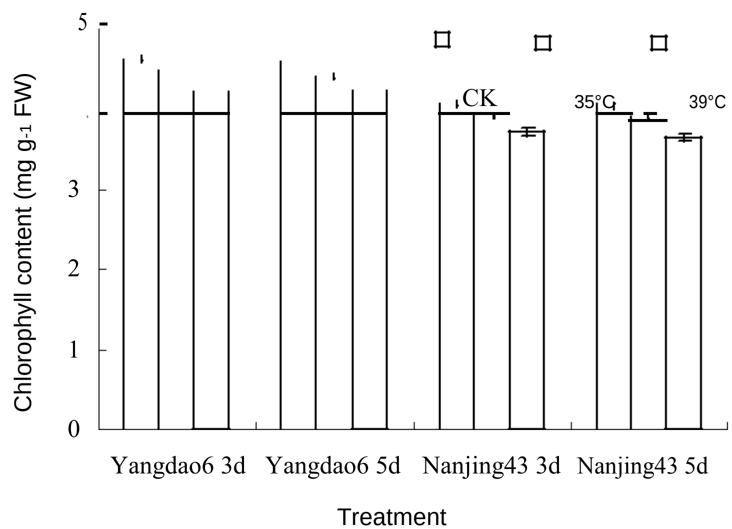

Figure 1. Effect of high temperature stress on chlorophyll content of flag leaves in rice at heading stage.

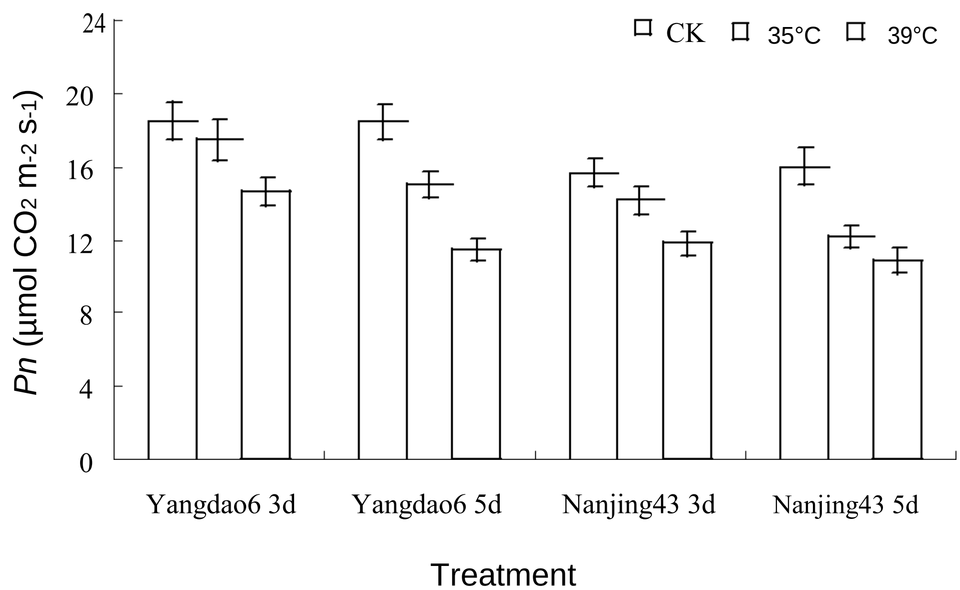

Figure 2. Effect of high temperature stress on net photosynthetic rate (NPn) of flag leaves in rice at heading stage.

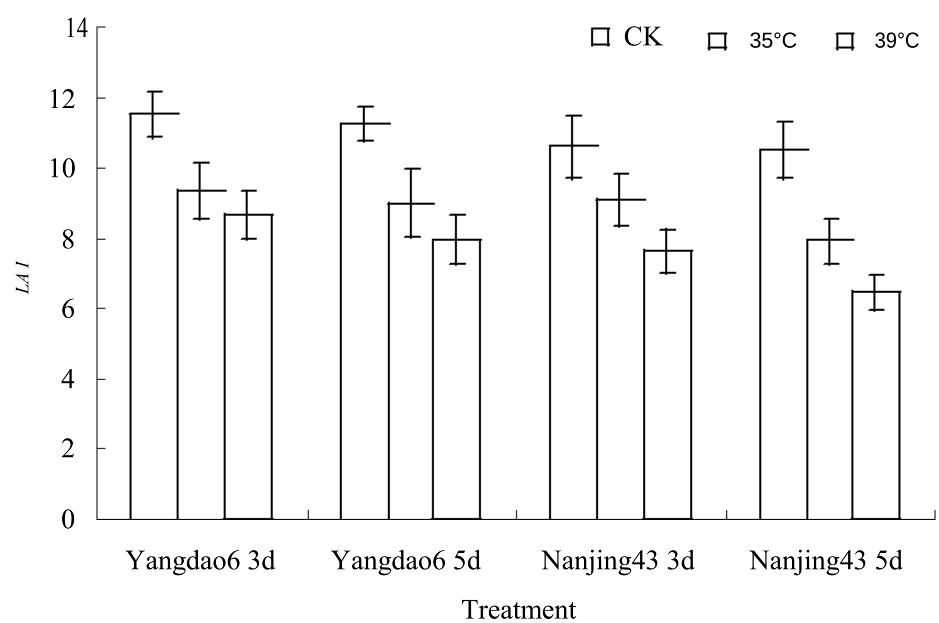

Figure 3. Effect of high temperature stress on leaf area index (LAI) of flag leaves in rice at heading stage.

Nanjing43 was 5.5, 10.5, 6.0 and 15.1% respectively at the aforestated stress. It was shown that, high temperature affected rice LAI, but the difference between high temperature stress and the CK in two rice cultivars were not significant.

Response of light intensity to Npn

Figure 4 showed the response of NPn to light intensity under high temperature stress; as an example of two cultivars rice at 5 days stress. The maximum NPn of Yangdao 6 in flag leaves is 16.9 μmol CO_2 m^{-2} s^{-1}, and the maximum NPn of Nanjing43 in flag leaves is 15.2 μmol CO_2 m^{-2} s^{-1}. NPn raised rapidly with elevation of light intensity under light intensity of 1000 μmol E $m^{-2}s^{-1}$. NPn raised to the peak value at the light intensity of 1200 μmol E $m^{-2}s^{-1}$ and then descended slowly. Compared with CK, NPn of two rice cultivars in the flag leaves declined

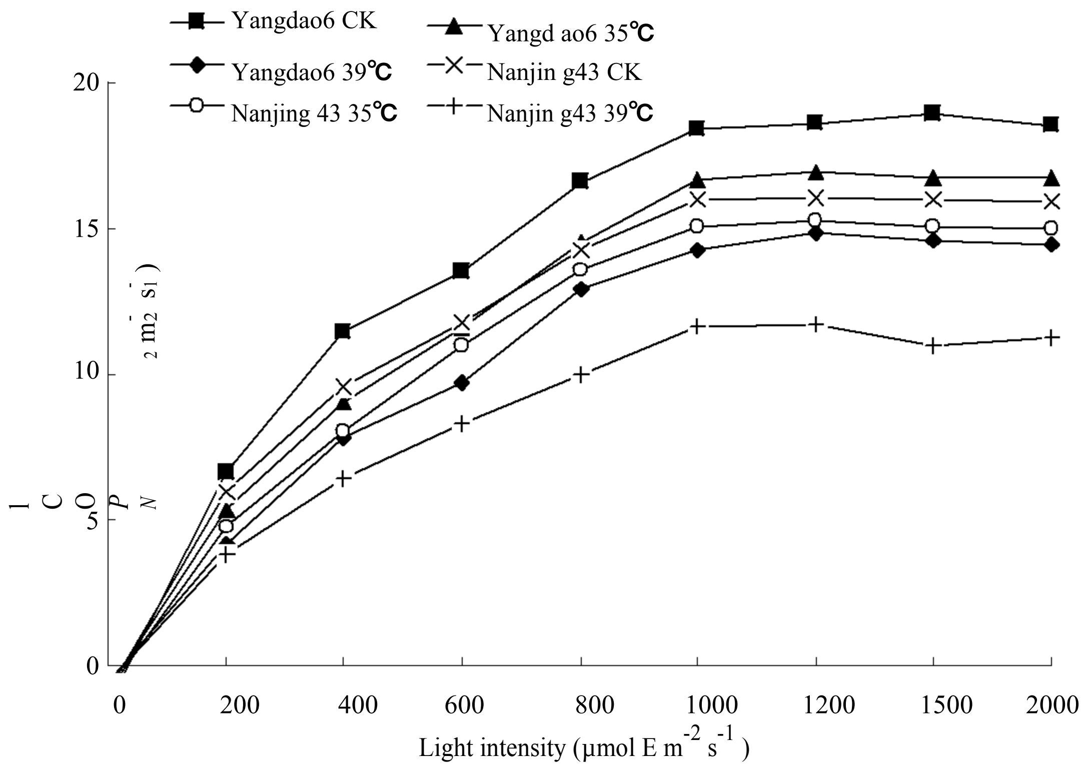

Figure 4. Effect of high temperature stress on the response of net photosynthetic rate (NPn) to light intensity in rice at heading stage.

significantly.

The rate of reduction of 39°C stress was higher than that of 35°C stress. Light saturation point of Yangdao6 and Nanjing43 under high temperature stress was lower than that of the CK. Many researchers considered that, an advance of photosynthetic production capability need advance apparent quantum efficiency of photosynthesis. High apparent quantum efficiency was high photosynthetic efficiency cultivars. The order of apparent quantum efficiency of 6 treatments was the following model: CK of Yangdao6 > 35°C stress of Yangdao6 > CK of Nanjing43 > 35°C stress of Nanjing43 > 39°C stress of Yangdao6 > 39°Cstress of Nanjing43. It was shown that, the adaptive faculty of two rice cultivars was different under different treatments, and the photosynthetic production capability of them was also different.

Relative conductivity, MDA content and SOD activity

Cell membrane permeability would be changed or lost under stress conditions (e.g. water stress, drought stress and low temperature stress, etc). Damage degree of cell membrane and stress resistance of plant could be reflected by measuring the relative conductivity of infiltrated liquid. The relative conductivity of two rice cultivars increased sharply with elevation of stress temperature and extension of stress time, but the increasing rate of different rice cultivars was different. The decreasing rate of Yangdao6 and Nanjing 43 was 15.2, 34.2, 16.3 and 48.3% respectively at 35°C/3 days and 35°C/5 days stress compared with CK (Figure 5).

MDA content of leaves under high temperature stress was different. MDA content of leaves increased gradually with extension of stress time, but the different of leaves MDA content under different treatments were distinct. The increasing rate of MDA content in Yangdao6 and Nanjing43 were 6.3, 6.9, 7.5 and 13.1% at 35°C/3 days and 39°C/3 days stress respectively compared with CK. The increasing rate in Nanjing 43 was distinctly higher than that in Yangdao6 (Figure 6). Figure 7 showed that, changes of SOD activity of the CK leaves were not obvious, but changes of SOD content under high temperature stress were different. SOD activity of two rice cultivars leaves was subjected to a sharp decline with elevation of stress temperature and extension of stress time. The increasing rate of SOD activity in Nanjing43 was higher than that in Yangdao6.

Correlation of grain yield and photosynthetic characteristic

Table 3 showed that the positive correlation between

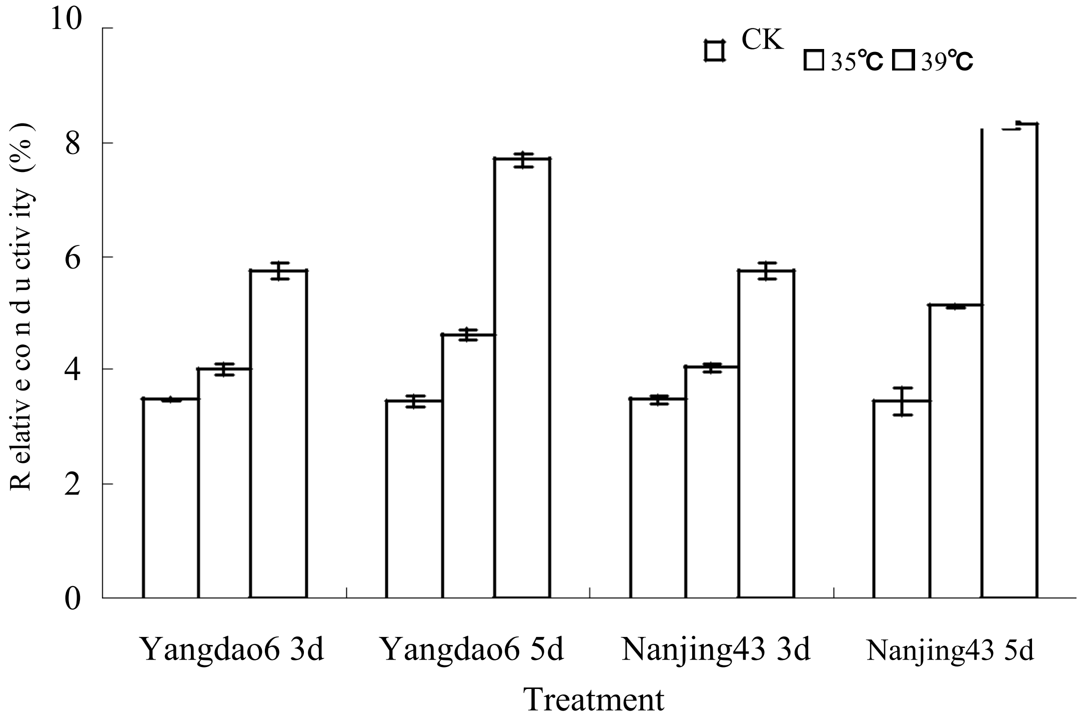

Figure 5. Effect of high temperature stress on relative conductivity of flag leaves in rice at heading stage.

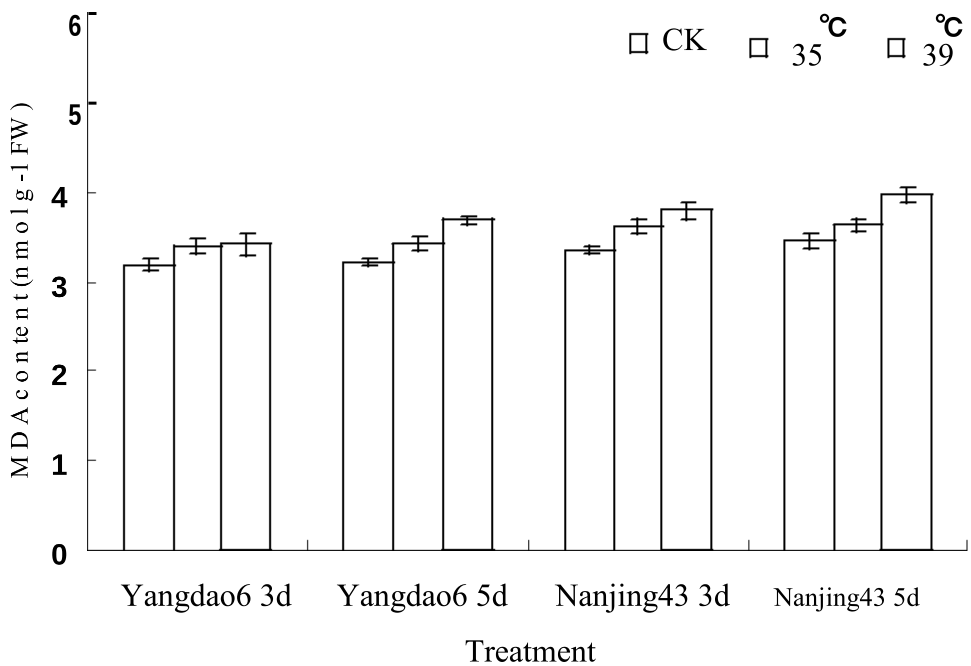

Figure 6. Effect of high temperature stress on malondialdehyde content (MDA) of flag leaves in rice at heading stage.

grain yield and Pn, and LAI were significant at 0.01 level, as well as their correlation coefficients which were 0.94 and 0.88 respectively. Further, the correlation among DW after initial at mature stage, EPMSS, TPMSS and grain yield were not significant. The correlation coefficient of NPn and DW after initial at mature stage was 0.63 at 0.05

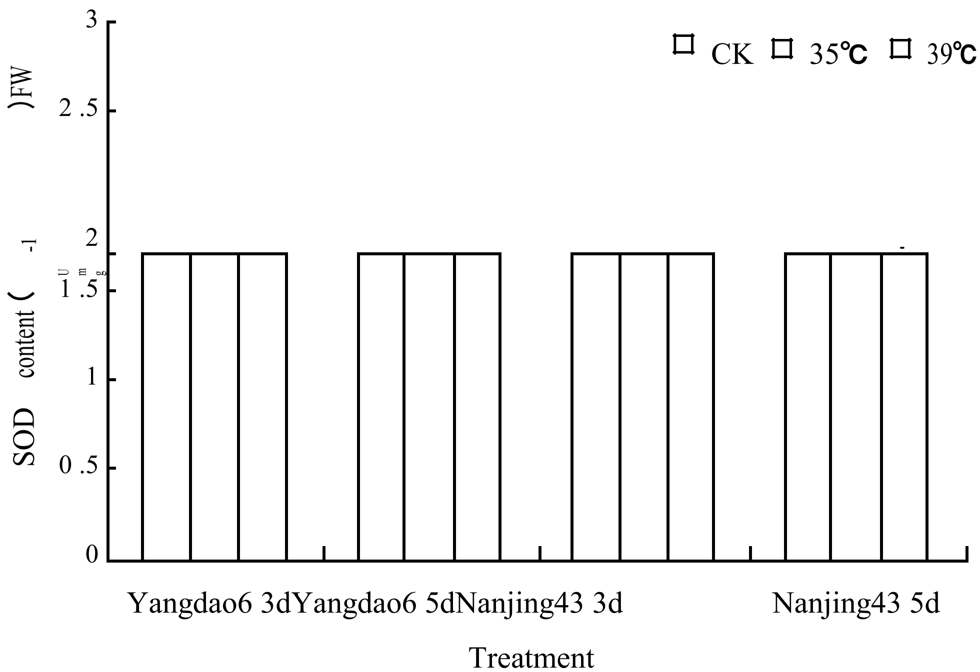

Figure 7. Effect of high temperature stress on superoxide dismutase **activity** (SOD) of flag leaves in rice at heading stage.

Table 3. Correlation coefficients among the indices related with grain yield.

Index	Grain yield	NPn	DW after initial at mature stage	EPMSS	TPMSS	LAI
Grain yield	1					
NPn	0.94**	1				
DW after initial at mature stage	0.46	0.63*	1			
EPMSS	-0.46	-0.41	-0.23	1		
TPMSS	-0.53	-0.49	-0.28	0.98**	1	
LAI	0.88**	0.94**	0.75**	-0.60*	-0.65*	1

NPn-net photosynthetic rate. EPMSS-the export percentage of the matter in stem-sheath. TPMSS-the transformation percentage of the matter in stem-sheath. LAI- leaf area index.*p<0.05, **p<0.01.

level, the correlation coefficient of NPn and LAI was 0.94 at 0.01 level, and the negative correlation among EPMSS, TPMSS and grain yield were not significant.

Also, the correlation coefficient of DW after initial at mature stage and LAI, was 0.75 at 0.01 level, the negative correlation coefficient of EPMSS, TPMSS and DW after initial at mature stage were not significant. Furthermore, the correlation coefficient of EPMSS and TPMSS by 0.98 at 0.01 level, correlation coefficient of EPMSS and LAI by 0.60 at 0.05 level, and correlation coefficient of TPMSS and LAI by -0.65 at 0.05 level.

DISCUSSION

The dry matter of rice grain mainly originates from the photosynthetic outcome of leaves after the heading stage (Cao and Yang, 2001). High temperature stress seriously limits photosynthetic production capability of rice, which mainly originates from the higher reducing rate of leaf photosynthetic velocity under high temperature stress. This is an important factor for reduction of grain yield. Chlorophyll is a vital pigment of absorbing, transferring and transforming photosynthetic capability (Yao et al., 2007). There is a close correlation between photosynthetic capability and chlorophyll content. It was shown in the present study that, the chlorophyll content of flag leaves reduced distinctly compared with CK under high temperature stress, which more affected the photosynthetic efficiency of the crop at the stage. The reasons of reduction of the chlorophyll content under high temperature stress were in two probabilities (Tewari and

Tripathy, 1998). On one side, high temperature may affect the biosynthesis of 5-aminolevulinic acid (ALA) and protoporphyrin LX (PPIX), which are two intermediate products of the chlorophyll biosynthesis. This reduces and debases the productivity of the chlorophyll. On the other side, productivity of active oxygen of the crops increases under high temperature stress which accelerates oxidation of cell membranes. This was a main reason for the reduction of the chlorophyll content, which had been attempted to be improved by this study. As is well known, SOD is one of the important antioxidative enzymes in plants. SOD has important functions in avoiding oxidation of cell membrane, lightening damage of cell membrane and delaying aging of the plants under adversity conditions. MDA is the final product of membrane lipid peroxidation, and the amount of MDA content is an important indicator for membrane lipid peroxidation (Smirnoff, 1993; Cao and Zhao, 2008). It was shown in the present study that, under high temperature stress, SOD activity decreased, on the other hand, MDA content increased.

Therefore, the content of active oxygen of two rice cultivars increased with high temperature, which led to a reduction of the chlorophyll content in rice, and accelerated leaf senescence. In addition, it was also shown that, the relative conductivity of two rice cultivars increased under high temperature stress compared with CK, the increasing rate of the relative conductivity increased correspondingly with elevation of stress temperature and extension of stress time. The relative conductivity of leaves can directly reflect the damage degree of cell membrane and stress capability of selecting plants. Usually, the strong relative conductivity of leaves is corresponding to unstable structure of cell membrane, and weak stress capability of the plants. Therefore, high temperature stress disturbed osmotic equilibrium of leaves cell membrane home and abroad, destroyed the structure and function of cell membrane, which finally affected normal physiological metabolism. The increasing rate (reducing rate) of SOD activity, MDA content and relative conductivity in Yangdao6 was lower than that in Nanjing43 under the same temperature stress. It was shown that, the response of Nanjing43 to high temperature was higher than that of Yangdao6.

It was also found that, the chlorophyll content and net photosynthetic rate of Nanjing43 was lower than that of Yangdao6 under the CK, which was mainly determined by own characteristics of rice. But the reducing rate of the chlorophyll content and Npn of Nanjing43, was higher than that of Yangdao6 under high temperature stress. It was proved that the response of Nanjing43 to high temperature was higher than that of Yangdao6 again. In addition, LAI of two rice cultivars reduced gradually with the elevation of stress temperature, but the difference of different treatments were not significant. It was shown that high temperature also affected the growth of plants, accelerated reduction of leaf LAI. The correlation of grain yield and photosynthetic characteristic was analyzed. It was found that the positive correlation between grain yield and Pn, LAI was significant at 0.01 level, the correlation between EPMSS, TPMSS and grain yield was not significant. It was shown that, grain yield originated mostly from the photosynthesis and LAI of leaves after heading. Promoting at early stage, controlling at middle stage and supplying at evening stage in rice were adopted in practice in summer high temperature area, especially appropriate fertilization would be emphasized, which prevented the premature senile of the plants, better provided a guarantee for preponderant production at evening stage.

Conclusion

In conclusion, according to results, the important factors of reduction of grain yield in two rice cultivars were the reduction of filled grain and setting seeding, spikelet number per panicle and 1000-grain weight were slightly affected by high temperature. Infection degree of different rice grain yield by high temperature was different. It is the same to SOD activity, MDA content and the relative conductivity. The reducing rate of grain yield in Yangdao6 was lower than that in Nanjing43 under the same stress. This showed that, the stress capability was closely correlated with the grain yield of stress. Selecting rice cultivars of high temperature-resistant and adopting proper cultural practices had an important practice meaning for realizing high yield and stable yield in rice high temperature area at heading stage.

ACKNOWLEDGMENT

This work was supported by a Project Funded by the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD), the National Science and Technology Supporting Foundation of China (2006BAD04B04), the National Nature Science Foundation of China (40901257) and Nanjing University of Information Science and Technology Science Foundation of China (20080330).

REFERENCES

Sultana N, Ikeda T, Kashem MA (2001). Effect of foliar spray of nutrient solutions on photosynthesis, dry matter accumulation and yield in sea water-stressed rice. Environ. Exp. Bot., 46: 129-140.

Tong P,Yang SM, Ma J, Wu HZH, Fu TL, Li M,Wang MT (2008). Photosynthetic characteristic and dry matter accumulation of hybrid rice varieties under different light conditions. China J. Appl. Ecol., 19: 505-511.

Zhu P, Yang SHM, Ma J, Li SHX, Chen Y (2008). Effect of shading on the photosynthetic characteristic and yield at later growth stage of hybrid rice combination. Acta Agron. Sin., 34: 2003-2009.

Zheng JC, Sheng J, Tang RS, Shi CL, Chen LG (2007). Regularity of high temperature and its effects on pollen vigor and seed setting rate of rice in Nanjing and Anqing. Jiangsu J Agric Sci., 23:1-4.

Zhang GL, Chen LY, Zhang ST, Liu GH, Tang WB, He ZZ, Wang M (2007). Effects of high temperature on physiological and biochemical characteristics in flag leaf of rice during heading and flowering period. Sci Agri Sin., 40: 1345-1352.

Tang RS, Zhang JC, Chen LG, Zhang DD, Jin ZQ (2005). Effects of high temperature on grain filling and some physiological characteristic in flag leaves of hyrid rice. J. Plant Physiol. Mol. Biol., 31: 657-662.

Morita S, Yonemaiu JI, Takanashi V (2005). Grain growth and endosperm cell size under high night temperature in rice. Ann. Bot., 95: 695-701.

Matsui T, Kobayasi KM, Hasegawa T (2007). Stability of rice pollination in the field under hot and dry conditions in the Riverina region of New South Wales. Australia Plant Prod Sci., 10: 57-64.

Guo PG, Li RH (2000). Effects of high nocturnal temperature on photosynthetic organization in rice leaves. Acta Bot Sin., 42: 673-678.

Li HS (2000). Experimental principle and technique for plant physiology and biochemistry. Beijing Higher Edu Press, 1: 167-261.

Yang JC, Zhu QS, Wang ZQ (1997). Photosynthetic characteristics, dry matter accumulation and its translocation in intersubspecific hybrid rice. Acta Agron Sin., 23: 82-88.

Cao SQ,Yang TQ (2001). Studies on photosynthetic rate and function duration of rice germplsam resources. China J Rice Sci., 15: 29-34

Yao YC, Wang SH, Kong Y (2007). Characteristics of photosynthesis mechanism in different peach species under low light intensity. Sci. Agric. Sin., 40:8 55-863.

Tewari AK, Tripathy BC (1998). Temperature stress induced impairment of chlorophyll biosynthetic reations in cucumber and wheat. Plant Physiol., 117: 851-858.

Smirnoff N (1993). The role of active oxygen in the response of plants to water deficit and desiccation. New Phytol., 125: 27-28.

Cao YY, Zhao H (2008). Protective roles of brassinolide on rice seedlings under high temperature stress. Rice Sci., 15:63-68.