Rice Science, 2007, 14(1): 67-70

Relationship Between Canopy Temperature at Flowering Stage and Soil Water Content, Yield Components in Rice

ZHANG Wen-zhong[1], HAN Ya-dong[1], DU Hong-juan[2]

([1] *Shenyang Agricultural University, Shenyang 110161, China*; [2] *Ningxia Meteorological Research Institute, Yinchuan 750001, China*)

Abstract: The canopy temperature of rice at the flowering stage and the soil water content were investigated under different soil water treatments (the soil water contents were 24%, 55%, 90% and 175% at the flowering stage). The canopy temperature was lower than air temperature, and the soil water content significantly influenced the canopy temperature. The lower the soil water content, the higher the canopy temperature, the less the accumulative absolute value of canopy-air temperature difference. Moreover, the maximum difference between treatments and CK in the accumulative absolute value of canopy-air temperature difference appeared at 13:00 p.m. in a day, thus, it could be considered as a suitable measuring time. Under the lowest water content treatment, the peak flowering occurred in the first three days (about 70% of panicles flowered), resulting in shortened and lightened panicle of rice. As to the CK and the high water content treatments, the peak flowering appeared in the middle of flowering duration, with longer panicle length and higher panicle weight. Results indicated the lower the soil water content, the less the filled grain number and grain yield.

Key words: rice; canopy temperature; soil water content; yield components

Water deficit is one of the most important factors limiting crop yield, and the monitoring of crop water status is important for reasonable irrigation and water saving cultivation. Using crop canopy temperature to characterize crop water status is a new method for the monitoring. Tanner et al [1] first evaluated crop canopy temperature with an infrared thermo-detector to monitor crop water content. It has been found that canopy temperature was usually lower than air temperature under sufficient soil water conditions except noontime in wheat, maize and other dryland crops, and the daily changes in canopy-air temperature difference were gentle, while under water-deficit conditions, the canopy-air temperature difference varied largely, especially in the afternoon [2-3]. Cai et al [4] constructed a statistics equation about cotton canopy-air temperature difference with solar radiation intensity, relative humidity and the soil water content for determining the irrigation index.

Turner et al [5] studied the relationships among rice canopy temperature, water stress, leaf rolling and growth, and found that drought stress increased the canopy-air temperature difference and leaf rolling, whereas reduced dry matter of rice. Chauham et al[6], Carraty and O'Toole [7] confirmed that rice canopy temperature increased due to drought stress. The rice canopy temperature might increase 3-4℃ under severe drought stress, and the rice canopy temperature at flowering stage was significantly and negatively correlated with grain yield and seed setting rate. However, few research on the relations among rice canopy temperature, meteorological elements, soil water content and yield components has been reported in China. In current experiment, the relationships among rice canopy temperature, air temperature and light intensity under different water treatments at flowering, and their influences on flowering date, panicle length, grain weight were studied, in order to provide foundation for monitoring soil and plant water status, scheduling irrigation and improving water use efficiency for rice.

MATERIALS AND METHODS

Rice materials

Rice variety Liaojing 294 bred by the Liaoning Academy of Agricultural Sciences was employed.

Treatments and measurements

The pot experiments were carried out at the Rice Research Institute, Shenyang Agricultural University in 2004. Each pot was 26 cm in height, with inside diameter 29.5 cm, gross (pot+soil) weight 13 kg. Rice seedlings were transplanted into 30 pots on 4 June, with 3 seedlings in each pot. A mobile plastic rain-shelter was used to prevent rainfall from entering into the pot. The canopy temperature was measured with a BAU-I Infrared Thermo-Detector (China Agricultural University) at 1 cm distance side from leaves, the air temperature with a DHM-2 Aspiration Psychrometer (Tianjin Meteorological

Received: 18 December 2006; **Accepted:** 20 January 2007
Corresponding author: HAN Ya-dong (yadonghan@126.com)
This paper was translated from its Chinese version in *Chinese Journal of Rice Science*.

Instrument Works), the pot weight with an electronic balance, and the light intensity with a ZDS-10 Luxmeter (Shanghai Cany Precision Instrument Co., Ltd).

Different water treatments were made by artificial irrigation at the rice flowering stage, with the submerged irrigation with sufficient soil water supply as CK. On 17 August, eight pots of rice with similar tiller numbers were selected, and the total tiller number were retained to 30 per pot by removing extra tillers, with every two pots as a group, altogether 4 groups (R1, R2, R3 and CK). Watering treatments were started on the same day, making weight of R1, R2, R3 and CK at 14 kg, 15 kg, 16 kg and 18.7 kg, which matched volume water content of 24%, 55%, 90% and 175% in the soil, respectively. Three times of watering was conducted every day to maintain the continuous water gradients during the flowering period. Normal water supply was restored for every treatment until maturity after flowering ended (29 August).

During the whole flowering period, the flowering panicles were marked every day with plastic labels at 19:00.

Each pot was harvested separately at the rice maturity. Panicle length, number of unfilled and filled grains per panicle, panicle weight and grain weight per pot were measured.

RESULTS

Relationship among canopy temperature, light intensity and air temperature

The correlation analysis on the daily variation of canopy temperature and light intensity from 22 to 24 August showed that the canopy temperature was significantly correlated with the light intensity (coefficients of relationship were 0.9946**, 0.9839**, 0.9780** and 0.9870** for R1, R2, R3 and CK, respectively). The canopy temperature was usually lower than air temperature within the three days (Fig. 1), while that of R1 was obviously higher than air temperature at 13:00 on 23 August, indicating that the canopy temperature in lower soil water content treatment was higher than air temperature under high light intensity and temperature conditions.

The air temperature and canopy temperature were higher on 23 August than on 24 August (Fig. 1). The canopy temperature of R1 treatment was always higher than those of the other two treatments and CK, indicating that the canopy temperature increased as the soil water content decreased. The differences were significant between the canopy temperature of R1 and those of the other three treatments. The canopy temperature of R2 and R3 treatments were higher than that of CK, but without significant differences.

The crop canopy temperature was influenced not only by soil water content, but also by air temperature, therefore, the difference of canopy-air temperatures ($T_L - T_a$) could be used as an index for diagnosing the crop water status [4].

In this experiment, the canopy temperature was significantly correlated with air temperature (coefficients of relationship were 0.7859**, 0.6082*, 0.6016* and 0.8458** for R1, R2, R3 and CK, respectively) under different water treatments. The canopy temperature and air temperature all varied with time in a day period, therefore, it is critical to determine the suitable time for measuring ($T_L - T_a$). Generally, the best measuring time is when the canopy–air temperature difference is maximized, and this ($T_L - T_a$) can be used to better reflect soil water conditions [3].

The canopy-air temperature difference was also influenced by weather, in common, the difference was bigger on the sunny day than on the cloudy day. Dong et al [2] took the accumulative values of canopy and air temperature difference as the index for determining wheat water deficit:

$$S = \sum_{n=1}^{N} (T_L - T_a)$$

Where, S is an accumulative value of canopy-air temperature difference, N is the days reaching the predetermined target. They measured the canopy-air temperature difference of winter wheat at jointing-grouting stage, and suggested that wheat

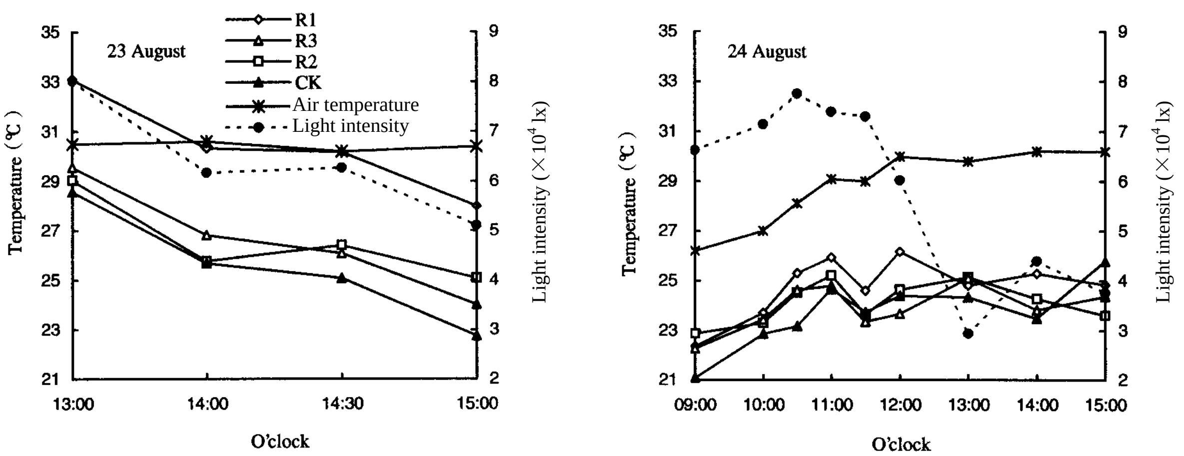

Fig. 1. Daily variation of air temperature, canopy temperature and light intensity on 23-24 August.

should be irrigated when *S* exceeded 5℃.

In contrast to wheat, rice canopy temperature is usually lower than air temperature. The accumulative values of canopy-air temperature difference were negative (Table 1). From 13:00 to 15:00, low soil water content resulted in small absolute value of accumulative canopy-air temperature difference, with the minimum value appeared at 13:00 when the largest differences were observed between treatments and CK, so it is suggested that 13:00 would be suitable for measuring canopy temperature.

Effect of different soil water treatments on plant flowering of rice

Massive inorganic and organic nutrients are consumed for respiratory metabolism at the flowering stage, and water deficit stress affects pollination and fertilization of plant flower, leading to yield loss [7]. As indicated in Fig. 2, the peak flowering of R1 treatment occurred in the first three days (about 70% of panicles flowered), while R2 treatment showed an even distribution of flowered panicles, with average five panicles flowered per day. The panicles in R1 and R2 treatments ended flowering on 24 August. R3 and CK had the similar tendency, which showed a few panicles flowered in the first two days, and the peak flowering appeared from 21 to 23 August. This suggested that low soil water content would lead to early flowering and short flowering duration.

Comparison of yield components under different soil water treatments

The effects of water deficit stress on the growth and physiological activity of rice are reflected by grain yield finally. The flowering stage is the critical period of water for rice, at which rice is very sensitive to water stress. Once water deficit stress occurred, the yield would be reduced along with the degree of water deficit stress and its duration [8]. As shown in Table 2, low soil water content caused shorter panicle length and less number of filled grains per panicle compared with the CK.

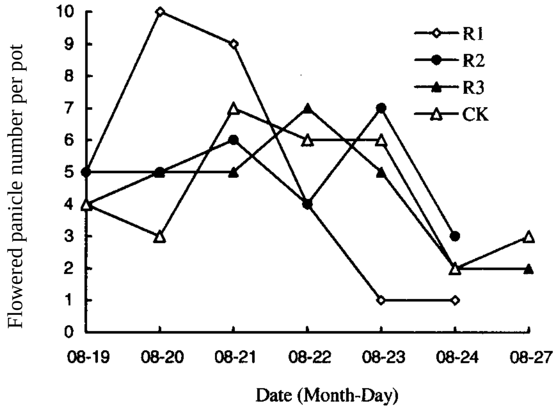

Fig. 2. Effects of soil moisture on flowering of rice.

The Chi-square test indicated that the differences in the filled and unfilled grain number per panicle between CK and R3 treatment were significant [χ^2= 91.9>$\chi^2_{(0.01,\ 1)}$], and those between R2 and R3 were also significant [χ^2=134.99 >$\chi^2_{(0.01, 1)}$], while those between R1 and R2 were not significant [χ^2= 1.530<$\chi^2_{(0.05, 1)}$].

According to the data from Table 1 and Table 2, it could be noted that lower soil water would cause larger canopy-air temperature difference at the flowering stage and lead to lower grain yield. The grain weight per pot of R1, R2 and R3 treatment reduced by 21.7%, 15.9% and 8.2% compared with CK, respectively. If we took 10% as a significant standard [9], the yield loss of R3 did not reach the significant level. Generally, pot-grown plants have better drought resistance compared with field-grown plants, therefore, the soil water content in field being controlled between CK and R3 would be helpful for enhancing water use efficiency.

Table 1. Accumulative value of $T_L - T_a$ from 22 to 24 August.

Treatment	O'clock		
	13:00	14:00	15:00
R1	-2.935	-11.947	-10.255
R2	-7.655	-16.248	-15.620
R3	-8.140	-17.430	-16.342
CK	-9.430	-17.665	-16.843

DISCUSSION

The crop canopy temperature relies on energy exchange between the crop surface and the atmosphere, which is determined by sensible heat flux and the latent heat flux in SPAC (Soil-Plant-Atmosphere Continuum). Especially the latent heat exchange is a primary cause leading to spatial

Table 2. Yield components under different water treatments.

Treatment	Panicle length (cm)	Panicle weight (g)	Unfilled grain number per panicle	Filled grain number per panicle	Total grain number per panicle	Grain weight per pot (g)
R1	15.50	2.87	7.17	107.5	114.7	81.0
R2	15.85	2.73	3.27	107.8	111.1	87.0
R3	16.45	3.47	4.97	126.1	131.0	95.0
CK	16.62	3.53	8.67	135.8	144.5	103.5

variation of canopy temperature [10]. Therefore, the crop canopy temperature closely correlated to the water deficit stress could be used to monitor crop water status, and would be regarded as one of the determinants for reasonable irrigation and drought analysis.

Among the environmental factors (light intensity, air temperature, wind speed and saturated vapor difference), canopy temperature is mainly depended on the daily air temperature, so canopy-air temperature difference has been taken as the index to determine crop water status in many crops. Liu et al [11] reported that the suitable time at which the canopy-air temperature difference could be used to reflect the water character of winter wheat was at 14:00. Cai et al [4] studied environmental factors influencing canopy temperature of summer maize, and found canopy temperature was significantly correlated with soil water content from 12:00 to 15:00. Peng et al [12] studied the trend of the canopy-air temperature difference in eggplant in a solar greenhouse, and pointed out that the most suitable time determining the canopy -air temperature difference was at 11:00 and 12:00.

The current research showed the light intensity and air temperature had a very pronounced influence on rice canopy temperature during flowering period. With the air temperature and the light intensity increasing, the canopy temperature rose. According to our observation on rice from 2001 to 2004, we concluded that water status of rice could be reflected by the canopy-air temperature difference from 13:00 to 15:00, and it was also affected by weather conditions. However, not all canopy-air temperature differences at the given time of day could be used to reflect the crop water conditions. We considered that 13:00 was the suitable measuring time at which the temperature difference could reflect the rice water conditions better. The smallest absolute value of the accumulative canopy-air temperature difference from 13:00 to 15:00 was observed. Moreover, the canopy-air temperature differences were significant among water stress treatments. The lower soil water content resulted in smaller absolute value of the temperature difference and lower yield, with less filled grain number per panicle. In addition, the lower the soil water content was, the earlier the peak flowering time was. In the lowest water content treatments, the peak flowering time occurred in the first three days, causing short panicle length and light panicle weight.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China (Grant No. 30671262) and the Natural Science Foundation of Liaoning Province.

REFERENCES

1 Tanner C B. Plant temperature. *Agron J*, 1963, **55**: 210-211.

2 Dong Z G, Yu H N. Crops Canopy Ecology. Beijing: Chinese Agricultural Publisher, 1995: 40-52. (in Chinese)

3 Liang Y L, Zhang C G. The relationship between discrepancy of canopy and air temperature and crop water deficiency. *Eco-Agric Res*, 2000, **8**(1): 24-26. (in Chinese)

4 Cai H J, Kang S Z. The changing pattern of cotton crop canopy temperature and its application in detecting crop water stress. *Irrigation & Drainage*, 1997, **16**(1): 1-5. (in Chinese)

5 Turner N C, O'Toole J C, Cruz T T, Namuco O S, Ahmad S. Response of seven diverse rice cultivars to water deficits: I. Stress development, canopy temperature, leaf rolling and growth. *Field Crops Res*, 1986, **13**: 257-271.

6 Chauham J S, Moya T B, Singh R K, Singh C N. Influence of soil moisture stress during reproductive stage on physiological parameters and grain yield in upland rice. *Oryza*, 1999, **36**(2): 130-135.

7 Carrity D P, O'Toole J C. Selection for reproductive stage drought avoidance in rice, using infrared thermometry. *Agron J*, 1995, **87**: 773-779.

8 Zhu Q S, Qu Z S. Effect of low soil water potential on rice yield. *Sci Agric Sin*, 1994, **27**(6): 15-22. (in Chinese with English abstract)

9 Wang B Y, Zhang X. Studies on optimum moisture index for high yield of crops. *Irrigation & Drainage*, 1996, **15**(3): 35-39. (in Chinese)

10 Shi C L, Guo J X, Mei X R, Zhao Q S, Lu Z G. Analysis of the factors influencing surface temperature in summer maize field. *Sci Agric Sin*, 2006, **39**(1): 48-56. (in Chinese with English abstract)

11 Liu Y, Yu Z R, Sun D F, Driessen P M, Liu Y H, Wang C Z. Study on the winter wheat canopy-air temperature difference and influence factor. *Trans Chinese Soc Agric Eng*, 2004, **20** (3): 63-69. (in Chinese with English abstract)

12 Peng Z G, Yang P L, Duan A W, He H. Research on the relationship between canopy-air disparity and the canopy temperature depression of eggplant in solar greenhouse. *Acta Agric Bor-Sin*, 2003, **18** (4): 111-113. (in Chinese with English abstract)