Available online at www.sciencedirect.com
SCIENCE DIRECT
Field Crops Research 94 (2005) 67–75
Field Crops Research
www.elsevier.com/locate/fcr

# Effect of SWD irrigation on photosynthesis and grain yield of rice (*Oryza sativa* L.)

Xianqing Lin[a,b], Weijun Zhou[a], Defeng Zhu[b,*], Yubing Zhang[b]

[a]*Institute of Crop Science, College of Agriculture and Biotechnology, Zhejiang University, Hangzhou 310029, China*
[b]*Key Laboratory for Rice Biology, Ministry of Agriculture, China and China National Rice Research Institute, Hangzhou 310006, China*

Received 28 March 2004; received in revised form 22 November 2004; accepted 24 November 2004

**Abstract**

A study was conducted with the objective to determine the influence of (shallow water depth with wetting and drying) SWD on leaf photosynthesis of rice plants under field conditions. Experiments using SWD and traditional irrigations (TRI) were carried out at three transplanting densities, namely D1 (7.5 plants/m$^2$), D2 (13.5 plants/m$^2$) and D3 (19.5 plants/m$^2$) with or without the addition of organic manure (0 and 15 t/ha). A significant increase in leaf net photosynthetic rate by SWD was observed with portable photosynthesis systems in two independent experiments. At both flowering and 20 DAF stages, photosynthetic rate was increased by 14.8% and 33.2% with D2 compared to control. SWD significantly increased specific leaf weight by 17.0% and 11.8% over the control at flowering and 20 DAF stages, respectively. LAI of D2 under SWD was significantly increased by 57.4% at 20 DAF. In addition, SWD with D2 significantly increased the leaf dry weight (DW) at both growing stages. At all the three densities, SWD increased the leaf N content and the increase was 18.9% at D2 density compared with the conventional control. In SWD irrigation, the leaf net photosynthetic rate was positively correlated with the leaf N content ($R^2 = 0.9413$), and the stomatal conductance was also positively correlated with leaf N content ($R^2 = 0.7359$). SWD enhanced sink size by increasing both panicle number and spikelet number per panicle. The increase in spikelet number per panicle was more pronounced in the 15 t ha$^{-1}$ manure treatment than in the zero-manure treatment. Grain yield was also significantly increased by SWD, with an average increase of 10% across all treatments. SWD with D2 had the highest grain yield under the both cultivars with or without 15 t ha$^{-1}$ manure treatment, which was 14.7% or 13.9% increase for Liangyoupeijiu and 11.3% or 11.2% for Zhongyou 6 over the control, respectively.


*Keywords:* Rice; *Oryza sativa* L.; SWD irrigation; Photosynthetic rate; Stomatal conductance; Specific leaf weight; Yield

## 1. Introduction

Rice (*Oryza sativa* L.) is one of the world's major food crops and as well as for China. The area under rice in China is 31 million ha with production of 200.5 million tonnes, which accounts for 39% of the total

*Abbreviations:* SWD, shallow water depth with wetting and drying; TRI, traditional irrigation; SMC, saturated moisture content; SRI, system of rice intensification; DAF, days after flowering; LAI, leaf area index; DMW, dry matter weight

* Corresponding author.
*E-mail address:* ricecenter@163.com (D. Zhu).

0378-4290/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.fcr.2004.11.007

grain production of the country (Anon., 2001). A tremendous amount of water is used for the rice irrigation under the traditional irrigation system (TRI) termed as ''continuous deep flooding irrigation'' in the major part of the rice growing regions in China. In addition, the demand for industrial water and the consumption of urban and rural domestic water has increased continuously. Consequently, there is a decreasing trend in water resource availability year by year. The shortage of water resources has become an important issue worldwide. Growing rice using conventional irrigation requires a tremendous amount of water. Recently, much effort has been made to use water efficiently and great progress has been achieved in rice production. Some of those were adopted in certain rice growing regions, aiming to increase the water and land productivity sustainably (Mao, 1997; Mao and Xu, 1998; Peng et al., 1997; Li, 1999). The area adopted under the efficient water irrigation for rice amounts to about 5.7 million ha (Rice Research Institute of Liaoning Province, 1997). Based on the analysis of experimental data and the results of investigation from some typical rice growing regions adopting efficient water irrigation systems, (shallow water depth with wetting and drying) SWD is the best kind of efficient water irrigation system for rice in China (Li, 1999; Mao, 2002).

The relationships between plant growth and water utilization have been reported in rice and its following crop in the cropping system (Zhou and Lin, 1995; Zhou et al., 1997; Leul and Zhou, 1998, 1999; Lin et al., 2003, 2004). The main feature of SWD is the comprehensive application of shallow water depth, wetting and drying for the entire growing season of rice. SWD is similar to (the system of rice intensification) SRI in terms of the water management. The major elements of SRI can be summarized as follows: (1) raising seedlings in a carefully managed, garden-like nursery; (2) early transplanting of 8–15-day-old seedlings; (3) single, widely spaced transplants; (4) early and regular weeding; (5) carefully controlled water management; and (6) application of compost to the extent possible (Stoop et al., 2002). SWD increased grain yield of rice by 8–22% over a wide range of organic manure treatments in field experiments (Zhang et al., 1994; Yu and Zhang, 2002; Zou et al., 2003). It has been practiced widely in the southern provinces of China since late 1980s. Some reports have demonstrated the role of SWD in promoting growth of the rice plant (Mao, 2002; Wang and Xu, 2002), but little is known about the mechanism involved. One possible mechanism of increasing root growth, which favors higher nutrient uptake was proposed (Mao, 2002; Zou et al., 2003). Recently, Sabine and Sommer (2004) studied the effects of water and redox conditions in wetland soils on pedogenic oxides and morphology. Zou et al. (2003) reported that there were different photosynthetic effects in the rice plant under different irrigation treatments of paddy fields. Rice plants using SWD had better ontogenesis when the seedlings were transplanted at low densities, compared with the conventional water management from our primary experiment (Lin et al., 2004). Therefore, we selected low transplanting densities for further study of the mechanism of SWD in the present experiment.

At least 90% of the biomass of higher plants is derived from $CO_2$ assimilation through photosynthesis (Zelitch, 1982). The single-leaf net photosynthetic rate of rice plants is largely affected by stomatal conductance, leaf N content, and specific leaf weight (Peng, 2000). Photosynthetic rates at flowering stage have a positive correlation with the grain yield of rice (Cook and Evans, 1983). The growth promotion by SWD could be attributed to the increase of photosynthetic rates in single-leaf and/or whole-plant. To our knowledge, no research has been published to determine the effect of SWD irrigation on photosynthesis in rice plants. Therefore, this study was undertaken to investigate whether SWD could influence leaf photosynthesis and related characteristics of rice plants under field conditions.

## 2. Materials and methods

### 2.1. Experimental site and soil

Experiments were carried out during 2002 and 2003 at the China National Rice Research Institute farm (30°05′N, 119°56′E, altitude 6 m) in Hangzhou, China. The average annual temperature is 16 °C and the annual precipitation is 1388 mm. The soil contains 24.2 g $kg^{-1}$ organic C, 9.6 mg $kg^{-1}$ available P, 66.0 mg $kg^{-1}$ exchangeable K, and 2.27 g $kg^{-1}$ total N, with pH 6.8 (1:1, w/v, water). The rice (*O. sativa* L.) varieties used