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Modeling and analyzing rice canopies of different cultivars and densities by 3D digitizing method

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INTRODUCTION

Rice is one of the most important crops in the world and it is the main crop in Zhejiang Province, China. It is important for breeding high yield cultivars and improving rice cultivation level to quantify rice spatial architecture. Studies on morphogenesis and development of rice plant structure have been carried out (Watanabe *et al*., 2005; Zheng *et al*., 2008, 2011). In the 3D model (Zheng *et al*., 2008), rice canopies were measured in the field using a 3D digitizer and reconstructed. Light distribution in the canopy and the photosynthesis capacity could be computed. The model seemed useful to evaluate the rice cultivars and to design the cultivating strategies, but the measuring work was huge.

In this study, we did the experiments with different cultivars and densities, computed blade area and light distribution of rice canopies with the 3D model and analyzed the influence of cultivars and densities with the structural model. Also we wanted to study the advantages and disadvantages of the model if it was used to evaluate rice breeding and cultivation.

MATERIAL AND METHODS

Field experiment

Field experiment was conducted in 2012 at the experimental station of Xiaoshan Institute of Agricultural sciences in Hangzhou, Zhejiang province, southeast of China (30°19' N, 120°30' E). Three cultivars of hybrid rice (*Oryza sativa* L.) were planted. They were “Nei2You6”, “Nei5You8015”, “Liangyoupeijiu”, and we noted the cultivars as G6, G7 and LY for simple in this study. All these cultivars were newly-bred, high-yield and broadly planted in China for the recent years. For each cultivar, the rice was planted with three densities, which were high density (HD, the space was 16.7 × 14.3 cm), middle density (MD, 16.7 × 23.3 cm) and low density (LD, 30 × 23.3 cm), respectively. The experiment was determined by the randomized blocks design of three replications. The tiller number was dynamically recorded for each treatment through the growth period and the sampling number is 12 in each replication. The length and largest width of blade at different rank for each treatment were measured.

Nine plants (3 rows × 3 columns) for each treatment were chosen as the canopy at the dough stage (Oct.11-18). The plant organs, such as leaves, stems, and panicles, were measured by collecting their coordinates with a 3D digitizer (FastCAN Scorpion, Polhemus, USA). The blade length and width towards midrib were measured and the blade shape was modeled. The diameters of stems and the shape of rice spikes were measured after digitizing. With the data being checked, interpolated and modeled, the 3D canopies of these 5 treatments were reconstructed in Matlab software produced by the Mathworks Inc (Fig.1).

Each blade was divided into 200 triangles (see Wang *et al*., 2006; Zheng *et al*., 2008). The area of each triangle, as well as its inclination angle and azimuth angle, was calculated according to the 3D coordinates of the facet. Canopies were vertically divided into several layers with 5 cm interval. We calculated the leaf area distribution in the vertical profile. Also the leaf distribution in different inclination angle and azimuth angle was computed. In this study, the volume of stems and spikes were ignored.

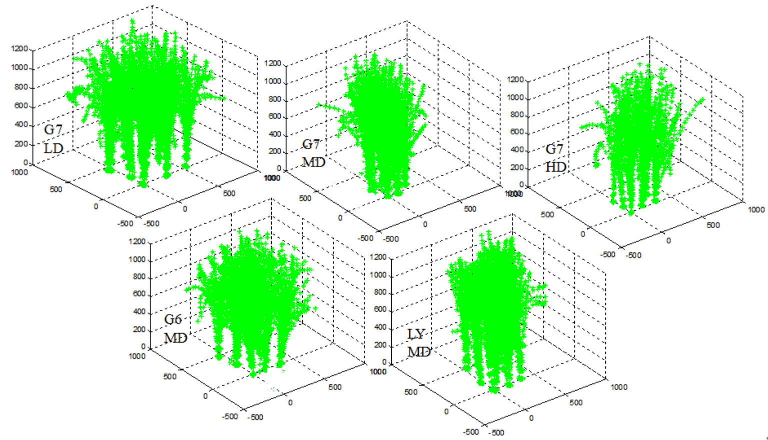

Fig 1. The visualization of the 5 treatments with blade midrib and stems and each organ were divided into 5 cm long sections. G6, G7, LY represented different cultivars and HD, MD and LD denoted different densities.

Before 3D digitizing measurement, light response curve (Pn-PFD) of different position leaves for all the treatments were measured using CIRAS-2 instrument (PP Systems, USA).

Results

During the late growth stages, the tiller number was great influenced by rice density. The density was higher, and the tillers for each plant were fewer. For all these cultivars, the difference between densities was significant (Fig.1). For the three cultivars, at the heading stage, the tiller number of LY cultivar was much larger than other cultivars, which has no significant difference from each other. However at the dough stage, there was no significant difference between the three cultivars (Fig.1).

There was no significant difference in the SPAD value for all the treatments. The net assimilation rate of LY at the measuring time was larger than the other cultivars for the flag leaf (Blade1 from up to bottom). The value was quite stable between densities with the same cultivars (Fig.2a). At the same time, the net rate was quite different for blades on different position in the same stem (Fig.2b). The difference between blades on different position was much larger than in different cultivars.

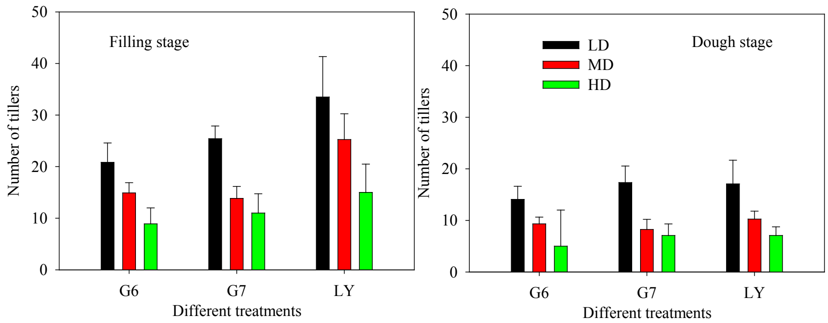

Fig. 2. Tiller number of the 3 cultivars and 3 densities of different stages.

The canopies for different treatments were reconstructed and visualize (Fig.1 show just stem and the midrib of blade). Based on the 3D model, the distributions of leaf inclination angle, azimuth angle and leaf area in the vertical profile were computed for different treatments. For the MD treatment, the blades of G6 were more concentrated and the total blade area was larger than the other cultivars. LY had a few more erect blades

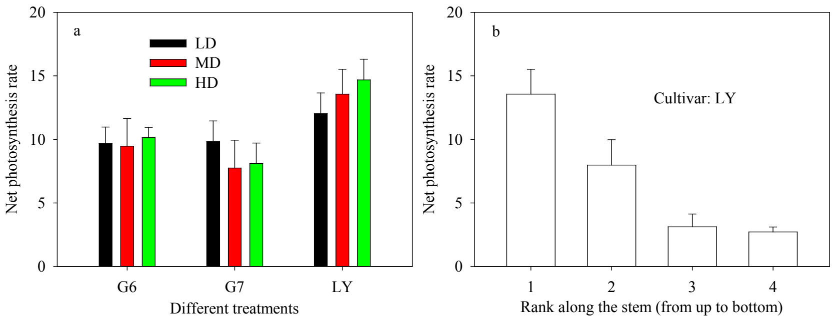

Fig. 3 Net assimilation rate for different treatments (a, blade1) and for blades on different positions (b).

DISCUSSION

Based on 3D digitizing, the rice canopies of different treatments were 3D visualized. And the vertical profile for leaf inclination angle, azimuth angle and leaf area distribution could be calculated and the difference between treatments could be analyzed by this model. Zheng compared the difference with three cultivars, one was bred 30 years before and the other two were bred recently. The light distribution was similar of the two modern high yield cultivars (Zheng *et al.*, 2008). In this study, all the three cultivars were modern rice cultivars and the difference is not significant, just as the modern cultivars used in the previous study.

In this study the net assimilation rate of the canopy could not tell the difference of the plant yield because the light would distribute in a different way if the solar altitude (time) changed even if the canopies kept stable for all the time. Moreover, the canopies changed a lot irregularly for different cultivars because tillers changed in the different way between LY and G6/G7.

Also in the field experiment, the plant cannot be planted in a precise density and grow uniformly, especially for rice, whose tillers vary a lot between plants. And the total growth periods for the three cultivars were different (G6 138 days, G7 133 days and LY 145 days). They were not in the exactly the same stage. We also cannot make the statistical analysis of the potential photosynthesis because the measuring work is huge and there cannot be many replications of the digitizing plant canopies.

In the future, we will consider the diffuse radiation and improving the calculation of net assimilation by using the Farquhar model (Farquhar et al., 1980). But we think the 3D model will not be broadly used in rice breeding and cultivating until all these disadvantages were considered and solved.

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