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Plant Type and Its Effects on Canopy Structure at Heading Stage in Various Ecological Areas for a Two-line Hybrid Rice Combination, Liangyoupeijiu

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Abstract: A two-line hybrid rice combination, Liangyoupeijiu, was used to estimate several factors of plant type, and environmental models for these factors at the heading stage were established using the data of eight ecological experimental sites in 2006 and 2007. According to climatic data from 1951 to 2005, the differences in those factors and their effects on plant canopy were analyzed for four rice cropping areas in China, including South China, the middle-lower reaches of the Yangtze River, Sichuan Basin, and river valley in Yunnan, China. The thickness of leaf layer (the distance from pulvinus of the third leaf from the top to the tip of flag leaf) and distribution of leaf area could be used as candidate indices for the plant type of a rice canopy.
Key words: hybrid rice; plant type; model; ecological area; canopy structure; index

Rice plant type consists of morphological characteristics including leaves, stem, panicle, etc. Plant type at the heading stage is a key ingredient for final rice grain yield. Plant type is closely related to the sunlight receiving efficiency of canopy. Rice with ideal plant type would be able to effectively utilize radiation transmission through the reconstruction of canopy structure, and adjust the relationship between accumulation and consumption of photosynthetic products, thus promoting the net photosynthetic efficiency.

Rice plant type is an interaction among heredity, physiological characteristics, cultivation techniques and growth conditions. In the past decades, research on rice plant type mainly focused on following areas: (1) models for canopy radiation transmission (Yu et al, 1998; Gao, 2004; Hardy et al, 2004; Jonckheere et al, 2004; Leblanc et al, 2005); (2) plant ideotype based on exploration of relationships among source, sink and flux through analyzing synthesis and translocation of dry matter (Matsushima, 1959; Zhang et al, 1990; Ling, 2000; Gao, 2004); (3) canopy structure and photosynthetic characteristics (Yao et al, 1999; Zou et al, 2003; Liu et al, 2005; Lu and Zou, 2005); (4) effects of certain plant type on grain yield (Yang et al, 2001; Ma et al, 2007; Hu et al, 2009); (5) components, interactions, inheritance and ecological characteristics of plant type factors (Pan et al, 2003; Lu et al, 2005). So far, there are few reports on the difference in plant type of rice varieties with the same genetic background under various environmental conditions. Obviously, it is important to understand how the environmental conditions affect rice plant type so that the optimum canopy of a rice variety can be planned. In this study, a two-line hybrid rice combination, Liangyoupeijiu, which possesses erect leaf, small leaf angle and moderate leaf curvature, was used to investigate the characteristics of plant type under eight typical ecological conditions in 2006 and 2007. The environmental models for plant type factors were established, and the characteristics, difference and effects on canopy structure of plant type factors were analyzed based on parallel analysis of plant type factors and environmental conditions in the eight ecological sites.

MATERIALS AND METHODS

Experimental sites and sowing date

Liangyoupeijiu (Pei'ai 64S/9311) is a two-line super hybrid rice combination released by the Jiangsu Academy of Agricultural Sciences, Nanjing, China (Lu

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and Zou, 2005). During the last decade, the combination was widely planted by about seven million hectares ranging from north latitude of 0° to 35° in China and Southeast Asian countries such as Vietnam, Philippines and Indonesia.

Five sites of single-season rice areas in China were selected from planting regions of Liangyoupeijiu: Yangzhou, Jiangsu Province (32.39ºN, 119.42ºE, 14.7 m altitude), Youxi, Fujian Province (26.17ºN, 118.17ºE, 126.7 m altitude), Wuhan, Hubei Province (30.52ºN, 114.31ºE, 27.0 m altitude), Taoyuan, Yunnan Province (25.98ºN, 100.37ºE, 1170 m altitude), and Jiangyou, Sichuan Province (31.78ºN, 104.70ºE, 531.8 m altitude). In addition, three sites of double-season rice areas located in Guangzhou, Guangdong Province (23.17ºN, 113.32ºE, 4.1 m altitude), Haikou, Hainan Province (20.03ºN, 110.35ºE, 18.0 m altitude), and Nanning, Guangxi Zhuang Autonomous Region (22.84ºN, 108.33ºE, 73.7 m altitude) in China were also selected.

Seeds were sown twice a year for each site. In the single-season rice areas, the seeds were sown at the optimum sowing date and 15 days later. In the double-season rice areas, the sowings were conducted at the optimum sowing dates of the early and late seasons. The area of each plot was approximately between 700 m^2 and 800 m^2.

Measurement

For plant type, the upper three leaves of 30 big culms were chosen to determine leaf indices at the heading stage, including length (L), width (W), angle (A), interval (h, distance between pulvini of adjacent leaves), and leaf curvature [C, (1–distance between two edges of a leaf)/Width]. For flag leaves, the interval is the distance between pulvinus of flag leaf and panicle neck node.

The dates of sowing, booting, heading and milky ripening were recorded. Number of panicles per m^2 (M), number of spikelets per panicle (N), seed setting rate (P), 1000-grain weight (G), and panicle length (h_0) were investigated. The leaf area index (LAI) at both booting and heading stages was also determined.

The corresponding climatic data including daily average (T), minimum (T_m) and maximum (T_M) temperatures, sunshine hours (SH), rainfall (RF), and relative humidity (RH) were provided by the weather stations of local counties. China National Meteorological Administration contributed the historical climatic data from 1951 to 2005 for 32 cities of the key rice growing areas in China.

Method for establishing environmental model of plant type factors

By surveying effective factors and using step-wise regression method, we explored the environmental model of plant type factors. Since rice plant type was mainly formed during booting and heading stages, the critical period from 10 days before booting to 10 days after heading was chosen to establish the environmental model. Effective factors and periods were surveyed using corresponding climatic data of average value of 10 d with a space of 5 d in step-wise forward moving. The factors included 10 indices: T, T_M, T_m, ΔT (T_M–T_m), SH, RF, RH, latitude (θ), longitude (ρ), and sun radiation angle (Φ). Effective period was denoted by footnote, and '0' denoted heading, while '–' and '+' represented before and after heading. For example, $T_{M\text{-}20\sim0}$ denotes the maximum temperature of the period from 20 d before heading to heading. For the non-linear relation, T^2 and RF^2 were adopted for the selection of plant type factors. In several models, the interrelated biologic elements were considered, and the average values of the two years were employed.

Effect of leaf factors on canopy thickness (D_Q)

At the heading stage, rice plant usually holds four leaves that senesce along with the process of grain filling, resulting in a change in canopy structure. Because of the importance of the upper three leaves, the canopy thickness was denoted as the distant from the top of the first leaf to the base of the third leaf (D_Q) in the present study as the following equation:

$D_Q=h_3+h_2+L_1\cdot\cos A_1$.

Effect on leaf density (M_Y)

In this study, the leaf density (M_Y) was determined at a 10-cm interval of plant height. The calculated method could be described by dividing a leaf into three segments as trapezoid, rectangle and triangle from base to top, and the area of a leaf was taken as $0.8\times L\times W$. For an individual leaf, it was assumed to be cut into segments by an interval of 1 cm, and the area