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Correlation of Leaf and Root Senescence During Ripening in Dry Seeded and Transplanted Rice

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Abstract: Dry seeding is a resource-saving rice establishment method. With an equivalent yield, dry seeded flooded rice (DSR) has been considered as a replacement for traditional transplanted flooded rice (TFR). However, the differences in leaf and root senescence during grain filling between DSR and TFR were seldom identified. In this study, the root length, root tip number and leaf senescence of rice varieties Huanghuazhan and Yangliangyou 6 during ripening were compared between DSR and TFR. Results showed that top three leaves in DSR had the characteristics of relatively lower SPAD value, lower N content and premature leaf senescence. In addition, both the total root length and total root tip number of DSR were significantly lower than those of TFR. In conclusion, premature and quick leaf senescence was related with inadequate root length and root tip number during ripening, which might result from the deficiency of nitrogen supply in DSR. Techniques on improving leaf nitrogen status and delaying the leaf senescence during grain-filling in DSR should be developed in future researches.

Key words: dry seeded rice; transplanted flooded rice; SPAD value; leaf senescence; root length; root tip number

Direct seeded rice has gradually been accepted by farmers worldwide. Rao et al (2007) reported that nearly one quarter of rice in the world are produced through direct seeded rice. With suitable water management and efficient weed control, direct seeded rice significantly minimized water and labor requirements without compromising yield production, especially dry seeded rice (DSR) (Sudhir et al, 2011; Liu et al, 2015; Tao et al, 2016). Acreage of direct seeded rice is growing, and thus its yield stability and yield potential have played increasingly important roles in food security.

Top three leaves play a critical role in biomass and grain yield accumulation in rice (Ray et al, 1983). Large leaf area and prolonged leaf functional duration promote panicle development and grain filling (Yoshida, 1981). Majority of carbohydrates are assimilated in the top three leaves during ripening stage, and then transferred into panicles during leaf senescence (Zhang et al, 2003). Park and Lee (2003) documented that premature senescence of top three leaves reduced grain yield of rice. Functional stay-green rice varieties have higher crop growth rates during the late grain filling period than other varieties, which can be beneficial for consistent grain filling (Fu et al, 2009).

Leaf senescence in rice is generally accompanied by the reduction in nitrogen transportation from stem to leaf (Mae and Ohiro, 1981). The decrease in leaf nitrogen content is the primary cause of lower single leaf photosynthesis, which can reduce dry matter accumulation and decrease grain yield (Peng et al, 1995). Yoshida (1972) reported that dry matter accumulation during ripening contributes around 70% of the final grain yield. However, no study presenting the influence of premature leaf senescence on yield composition of DSR is found. During the growing season, leaf SPAD (Soil and Plant Analysis Device) reading provides a good estimation of leaf N content on a leaf-area basis (Peng et al, 1993, 1996), and thus it can be used to monitor the leaf functional status.

Root is the most important organ for water and nutrients

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absorption (Seiler, 1998). Zhang et al (2009) reported that root activity has a great influence on dry matter accumulation and translocation during the whole growing season, thus affecting grain yield. The comparison on root development between flooded and aerobic culture has already been studied (Beyrouty et al, 1988; Sakaigaichi et al, 2007; Kato and Okami, 2010). The effect of water management on root growth is also well understood in both aerobic and flooded culture (Beyrouty et al, 1992; Ramasamy et al, 1997).

Although both the root development and leaf senescence are related to grain filling, few researches are conducted to clarify the characteristics of leaf and root senescence and examine the relationship between these two traits at critical stage under field conditions in DSR system. Moreover, destructive root sampling methods are used to analyze the root growth in most of the previous studies, which are time-consuming and tedious, and may easily lead to root growth variation (Richardson-Calfee, 2004). In recent years, an *in-situ* and non-destructive method, minirhizotron, has been developed, and is available for directly studying roots. It permits the original measurement of fine root production, which cannot be accomplished by destructive root sampling approaches (Majdi, 1996).

In our previous research, we explored the possibility of DSR as an alternative of transplanted flooded rice (TFR) on different aspects, including grain yield, water use efficiency, nitrogen use efficiency and so on (Liu et al, 2015). No yield difference between DSR and TFR was observed in the study, even though leaf senescence happened earlier after flowering in DSR than in TFR. However, the possible reasons underlying the leaf premature senescence after flowering in DSR have never been identified. The objectives of this study were: to compare the characteristics of root and functional leaf senescence after flowering between DSR and TFR, and to understand the relationship between leaf senescence, and the length and tip number of roots during grain filling.

MATERIALS AND METHODS

Site description

The experiment was conducted at Zhougan Village (29º51′ N, 115º33′ E), Dajin Town, Wuxue County, Hubei Province, China, during the growing seasons of 2012 and 2013. In the experimental site, rice was mainly planted as single or double cropping. In recent years, DSR is gaining popularity among farmers in central China because of reduced irrigation requirement and cost for crop establishment, and conduciveness to mechanization. The meteorological data were collected from a weather station (CR800, Campbell, USA) near the experimental field and presented in a previous publication (Liu et al, 2015). The total nitrogen (N), available phosphorus (P), potassium (K), organic matter, clay, silt and sand of the upper 20 cm soil were 1.75 g/kg, 30.4 mg/kg, 80.7 mg/kg, 17.7 g/kg, 10%, 64% and 26%, respectively.

Experimentation and data collection

Two rice cultivars and two planting patterns were included in this study, which was laid out in a split plot in randomized complete block design with three replications. Planting patterns of DSR and TFR were assigned to main plots while subplots (6 m × 5 m) were two *indica* cultivars: inbred rice Huanghuazhan with growth duration of 117 d, and hybrid rice Yangliangyou 6 with growth duration of 132 d. Both cultivars are mega varieties commonly grown by rice farmers in central China.

To minimize the seepage losses, the main plots were separated by triple bunds to avoid the flow of water between DSR and TFR plots. In DSR plots, the soil was dry-ploughed and harrowed without puddling. Dry seeds were sown manually during the first week of May in both years with a row-spacing of 25 cm. The seeding rate for both cultivars was 60 kg/hm^2. TFR plots were flooded ploughed, harrowed and puddled. Seedlings were started preparing in a bed nursery at the same week of dry seeding. During soil preparation, 125 mm water was used in the main plots with an area of 60 m^2 during soil ploughing, harrowing and puddling in both years. At the end of May, 25-day-old seedlings were transplanted at a hill spacing of 25.0 cm × 13.3 cm with three seedlings per hill.

DSR plots were rain-fed until 5th leaf stage, and the total rainfall during this period was 275 mm in 2012 and 248 mm in 2013. Flooded irrigation was applied to DSR plots after the 5th leaf stage. In TFR plots, 1–3 cm water layer was maintained on the first week following transplanting. A depth of 5–10 cm standing water was maintained until one week before harvested in all flooded plots including both DSR and TFR.

A fertilizer dose of 150:40:100 kg/hm^2 of N:P_2O_5:K_2O was applied to all treatments. All the phosphorus pentoxide, 26% N and 50% K were applied as base fertilizer. The remaining N was equally split at middle tillering stage and panicle initiation stage. The rest potassium (K_2O) was top-dressed at panicle initiation at a rate of 50 kg/hm^2. Zinc sulfate was applied to the soil at the rate of 5 kg/hm^2 Zn as the base fertilizer. To avoid the unpredicted side effects of herbicides, weeds were manually removed in both DSR and TFR. Diseases and insects were intensively controlled.

After flowering, five productive tillers with similar panicle sizes from each plot were randomly selected and marked to measure SPAD (chlorophyll meter) values of the top three leaves (flag leaf, top 2nd leaf and top 3rd leaf) with leaf chlorophyll meter [SPAD-502, Soil Plant Analysis Dev. (SPAD) Section, Minolta Camera Co., Osaka, Japan], which can be used to reflect their leaf chlorophyll content (Watanabe et al, 1980). SPAD values of the same plants were recorded every 4 d, until one day before harvested or when the leaf got rolled.

Because of the differences of SPAD value between DSR and TFR at the flowering stage, a common standard is needed to compare SPAD decreasing rate between DSR and TFR. For this reason, SPAD value was normalized to the SPAD value of each leaf at flowering (relative SPAD value = SPAD value / SPAD value at flowering).