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Short communication

Differences in elongation growth between floating and deepwater rice plants grown under severe flooding in Thailand

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ABSTRACT

To compare growth responses of floating rice (FR) and deepwater rice (DWR) to severe flooding conditions, two FR varieties, Plai Ngahm Prachinburi and Pin Gaew 56, and two DWR varieties, Prachinburi 2 and Hawm Prachinburi (RD45), were grown in the floating rice field of Prachinburi Rice Research Center in Thailand in 2007 and 2008. The water depth in the research field exceeded 1 m from September to October in both 2007 and 2008. Although the plant length of the two DWR varieties increased at a slower rate than those of the FR varieties, the DWR varieties kept parts of their foliage above the water surface. However, the survival rates of the DWR varieties were lower than those of the FR varieties under these conditions. The rates of internode elongation of the DWR varieties were slower than those of water level rise, whereas those of the FR varieties were almost equal. Consequently the tops of the uppermost leaf sheath in the FR varieties were always above the water level. These results suggest that FR can regulate internode elongation in response to rising water level so as to keep the top of the uppermost leaf sheath above the water surface.

1. Introduction

In Thailand, rice is a traditional staple crop and important export crop. In 2010, its production was 35.6 million tons and its export quantity was the world's highest at 8.9 million tons (FAO, 2010). In Thailand, rice cultivation takes place in the four ecosystems: upland rice, irrigated rice, rainfed lowland rice, and flood-prone rice. Flood-prone rice cultivation is an important cropping system in the region where severe flooding over several months regularly occurs each year. Its cultivated area was approximately 0.52 million ha in 1992, corresponding to 5.78% of the total rice cultivation area in Thailand (Charoendham et al., 1994). Much of the flood-prone rice ecosystem lies along the Chao Phraya and Bang Pakong rivers in the central plain, particularly in the central-east region (Prachinburi and Nakhon Nayok).

In the flood-prone ecosystem, common modern rice varieties cannot normally grow, owing to the water depth. Thus, deepwater or floating rice varieties that have the ability to elongate rapidly under submergence are extensively cultivated in this ecosystem. Many researchers have used the term "deepwater rice (DWR)" and the term "floating rice (FR)" without distinction in their studies. However, DWR is defined as rice grown under a water depth of 50–100 cm, whereas FR exhibits an extreme ability of stem elongation to survive in water depths above 1 m for 3–4 months (Catling, 1992). FR plants can grow at rates of 20–25 cm/d under partial submergence conditions and can reach a height of up to 7 m in water depths of up to 4 m (Vergara et al., 1976; Catling, 1992). In Thailand, various varieties of FR and DWR have been developed and cultivated depending on flooding conditions in the growing area. Bekhasut et al. (1990) characterized internode elongation in floating rice grown under natural flooding conditions in Thailand. However, few studies have addressed the differences in growth response between the FR and DWR varieties cultivated under natural flooding conditions in water depths above 1 m.

In the present study, we cultivated FR and DWR varieties in a floating rice field, where flooding to water depth above 1 m occurs each year, at the Prachinburi Rice Research Center. Our objective

Abbreviations: DWR, deepwater rice; FR, floating rice; LEI, lowest elongated internode; RIE, rate of internode elongation.

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was to compare the growth of the FR varieties with that of the DWR varieties under severe flooding conditions, and to elucidate the characteristics of the FR varieties that differ from those of the DWR varieties.

2. Materials and methods

Field experiments were conducted in the floating rice field at Prachinburi Rice Research Center (latitude 13°55′ N, longitude 101°15′ E, elevation 2.95 m), Bansang, Prachinburi, Thailand in 2007 and 2008. Two FR varieties, Plai Ngahm Prachinburi and Pin Gaew 56, and two DWR varieties, Prachinburi 2 and Hawm Prachinburi (RD45), were grown in the field. An experimental site of 20 m × 15 m with 12 subplots of 5 m × 5 m was laid out. Seeds of each variety were directly sown in three randomly arranged three subplots, respectively, at 12.5 g m^{-2}, respectively, in early May. Dates of emergence were 27 May and 13 May, respectively, in 2007 and 2008. Fertilizer was applied twice, 20 kg of N and 40 kg of P_2O_5 per hectare when the water depth reached 30 cm in the field, and 20 kg of N per hectare at panicle initiation stage.

Water depth was recorded in each subplot daily during the growing period in both 2007 and 2008. Five plants were harvested from each subplot every week from 1 August to 5 December in 2007 and every two weeks from 12 June to 27 November in 2008. Their plant length, length of upper three leaf blades, and total length of internodes were measured and the average of each subplot was calculated. The panicles of Plai Ngahm Prachinburi, Pin Gaew 56 and Prachinburi 2 emerged from late November through early December, and those of Hawm Prachinburi emerged in late December. The height of the top of the uppermost leaf sheath was calculated from the plant length and the length of the uppermost leaf blade. In 2008, the number of live plants per 50 cm × 50 cm area at each subplot was investigated at the start and end of flooding conditions to estimate the survival rate under flooding conditions.

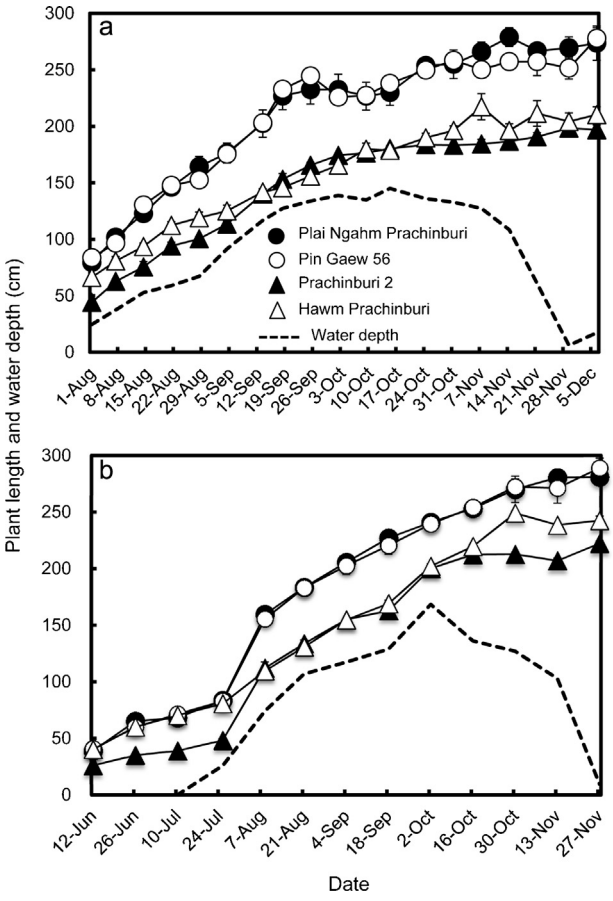

Fig. 1. Changes in plant length and water depth in 2007 (a) and 2008 (b). Data represent means ± SE of three subplots.

3. Results

In 2007, water depth was 24.6 cm on 1 August and reached 67.2 cm on 28 August (Fig. 1a). Subsequently, the depth rapidly increased and reached 127.3 cm on 18 September. On 15 October, the water depth reached a maximum of 145.0 cm and then gradually decreased to 6.1 cm on 29 November. The plant lengths of the two FR varieties, Plai Ngahm Prachinburi and Pin Gaew 56, increased in a similar manner until 25 September. The plant lengths of the two DWR varieties, Prachiburi 2 and Hawm Prachinburi, increased at a slower rate than those of the FR varieties. Furthermore, the plant length of Prachinburi 2 was shorter than that of Hawn Prachinburi until 29 August. The top of the plants of all varieties remained completely above the water surface throughout the growth period.

In 2008, water depth began to increase from 10 July and reached 25.8 cm on 25 July (Fig. 1b). The depth rapidly increased to 106.9 cm on 21 August, reaching a maximum of 168.4 cm on 2 October and then gradually decreasing to 9.5 cm on 27 November. The lengths of the two FR varieties rapidly increased from 25 July until 8 August and then continued to increase until 30 October. The length of Hawm Prachinburi (DWR) varied similar to those of the floating rice varieties from 12 June until 25 July, but that of Prachinburi 2 (DWR) was shorter than that of Hawm Prachinburi from 12 June until 25 July. However, the length rapidly increased from 25 July until 8 August, and then the length of the two DWR varieties varied in a similar manner until 16 October.

The tops of the uppermost leaf sheaths in the FR varieties were always above the water surface in both 2007 and 2008 (Fig. 2a and b). Their positions remained at 15–30 cm above the water surface during the most rapid rise in water level (from 28 August to 18 September and from 25 July to 21 August, respectively, in 2007 and 2008). The changes were almost similar between Plai Ngahm Prachinburi and Pin Gaew 56. In contrast, the tops of the uppermost leaf sheaths in the DWR varieties were submerged until the decrease in water depth.

In 2007 and 2008, the total lengths of internodes increased in all varieties during the water rising (Fig. 3a and b). However, the lengths increased more rapidly in the FR varieties, coincident with the rate of water rising, than those in the DWR varieties. In particular, during the most rapid elevation of water level in both 2007 and 2008, the internode elongation of the FR varieties occurred at a rate equal to that of the water rising, whereas that of the DWR varieties was lower (Table 1).

The survival rates under flooding condition were calculated from the numbers of plants before flooding and live plants after the water receded in a 50 cm × 50 cm area in each subplot. The survival rates of the DWR varieties were significantly lower than that of Plai Ngahm Prachinburi (Table 2). In addition, Hawm Prachinburi had a significantly lower survival rate than the FR varieties and a lower percentage of surviving plants than Prachinburi 2.

4. Discussion

In Thailand, rice cropping in the flood-prone ecosystem is usually based on the utilization of FR and DWR varieties. DWR can grow under conditions of moderate water rise to a depth of 50–100 cm, whereas FR can adapt to severe flooding conditions with water depths above 1 m (Catling, 1992). However, the differences in the elongation response of internode between FR and DWR have