

Mechanism of seedling establishment of direct-seeded rice (*Oryza sativa* L.) under lowland conditions

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Abstract. The mechanism of seedling establishment under lowland conditions is an important factor for the improvement of direct seeded lowland rice culture. To explore this mechanism, 36-hour-old seedlings of ASD1, IR41996-50-2-1-3, Mahsuri and IR72 were grown in both lowland and drained soil conditions in the IRRI phytotron (29/21°C) for 10 days. The coleoptile tips of the genotypes ASD1 and IR41996-50-2-1-3 were able to penetrate the reduced soil layer to the oxygenated water by 4 days after seeding to allow an O₂ transport system to be established. This was followed by the growth of the mesocotyl and first leaf, while the root growth remained inhibited up to 6 days after seeding. ASD1 and IR41996-50-2-1-3 essentially followed the same sequence of growth, but there was an apparent difference in the tolerance of their tissue to oxygen deficit. Mahsuri and IR72 could not elongate their coleoptiles up to the oxygenated water and thus failed to establish prolonged seedling growth under lowland conditions.

Keywords: Anaerobic stress; Coleoptile; Direct seeded rice; Lowland rice; Mesocotyl; Seedling establishment.

Introduction

The adoption of a direct-seeded method for lowland rice culture would significantly decrease the cost of rice production in South East Asia (Flinn and Mandac, 1986). However, at the same time, no varieties have been specifically developed for this purpose. The existing varieties used for lowland culture do not appear to be well-adapted for seedling growth in an initially oxygen-depleted microenvironment. This causes farmers to adopt the costly practice of increasing the seeding rate by 2–3 times. There is therefore an apparent need for varieties which would allow seedling emergence and growth from a soil flooded with a few centimeters of water. The overall pattern of seedling development in rice under conditions of oxygen restriction has been extensively studied (Kordan, 1974a, 1974b, 1975, 1976a, 1976b, 1977a, 1977b; Tsuji, 1972; Turner et al., 1981). Low oxygen conditions severely restrict the growth of roots and leaves on rice seedlings while allowing the growth of the coleoptile and mesocotyl of the shoot. There is some evidence for genotypic variation in this sensitivity to oxygen deprivation (Yamauchi et al., 1993; Turner et al., 1981). While these studies have generated considerable information on the pattern of seedling establishment, very specific data will be required to allow the development and selection of varieties giving a uniformly high rate of establishment

under lowland conditions. This study describes the precise pattern and sequence of growth of four rice varieties in an attempt to evaluate developmental characteristics that would help the establishment of direct-seeded lowland rice.

Materials and Methods

The experiment was conducted in the phytotron (29/21°C) under natural light conditions at the International Rice Research Institute, Los Baños, Philippines in 1993. Two superior genotypes (better seedling establishment under lowland conditions), ASD1 (traditional plant type) and IR41996-50-2-1-3 (modern plant type), and two control genotypes (poor seedling establishment under lowland conditions), Mahsuri (traditional plant type) and IR72 (modern plant type), were grown as a subplot factor of 4 replicated split plot designed experiment. The main plots were assigned for either lowland or drained conditions. Seeds collected from the 1992 harvest and stored at 5°C were used for the study. Table 1 presents the data on seed quality. The germination percentage and germination rate index were calculated as described by Krishnasamy and Seshu (1989) and Yamauchi et al. (1993). Fifteen seeds per unit treatment were soaked with 4 ml of water in a 50 mm plastic petri dish lined with filter paper and allowed to germinate in the dark at 30°C for 36 h. Maahas clay soil of the IRRI farm, passed through a 'forty mesh' sieve and mixed with 0.125% corn starch to enrich organic matter, was used for this experiment. Plastic pots 69 mm in diam and 85 mm high were used as the experimental unit. Pots were partially filled to within 25 mm of the top with 190 gm of soil. To simulate lowland conditions, soil

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Table 1. Quality of seeds used for the study, wet season, 1992.

Genotype	Germination (%)	Germination rate index
ASD1	100.0	1.00
IR41996-50-2-1-3	94.3	1.00
Mahsuri	96.0	0.95
IR72	100.0	0.99

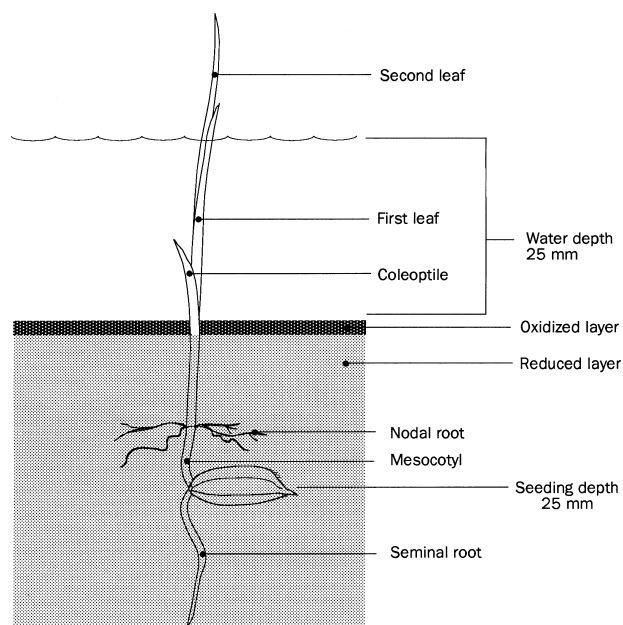
was poured in each of the pots containing 100 ml of water. In contrast, the pots, simulating drained conditions, did not have any water during initial preparation. Moreover, each of the pots was provided with a 5 mm pore at the bottom, concealed by a filter paper to prevent the soil from oozing out and to allow water absorption through it when it was placed in a plastic tray (490 mm × 360 mm × 125 mm) containing 5 mm of water. The pots assigned for lowland conditions were submerged in a plastic tray of the same size mentioned above. The water level above the pots was maintained at 25 mm. Every unit treatment was repeated in five pots for five random samplings every two days up to 10 days after seeding (DAS). For four replications, four trays were used for lowland conditions and the remaining four for drained conditions. The moisture percentage of the drained soil was around 22 at 10 DAS. All the 10 seedlings per unit treatment were considered for every observation. Percentages of coleoptile emergence, seedling establishment, and the length of each coleoptile, mesocotyl, first leaf, the plant height, longest nodal root and seminal root (Figure 1) were measured at two day intervals up to 10 days. The dissolved O₂ concentration was measured by Aquameter (Model:WQC-1A, TOA).

Results and Discussion

Seedling establishment was characterized by the ability of a genotype to produce a first leaf while coleoptile emergence was characterized by the appearance of a coleoptile tip above the soil. In lowland soil, coleoptile emergence in ASD1 and IR41996-50-2-1-3 was 100% whereas in Mahsuri and IR72 the emergence was 55.0 and 72.5%, respectively. In drained soil, no differences were observed between the superior and control genotypes. In lowland soil, the seedling establishment was 97.5% in ASD1 and 65.0% in IR41996-50-2-1-3, significantly different from each other. The control genotypes did not establish plants under lowland conditions. In drained soil,

there were no significant differences in seedling establishment among the genotypes (Table 2).

Two superior genotypes ASD1 and IR41996-50-1-2-3 established well under lowland conditions. Figure 2 presents their growth patterns as schematic diagrams. The coleoptile tips of the superior genotypes were able to penetrate the reduced soil layer to the oxygenated water at 4 DAS. The dissolved O₂ concentration in this experiment was 3–7 ppm at 1400 h at 5 and 6 DAS. Therefore, an O₂ transport mechanism as described by Kordan (1974, 1976a) was established by 4 DAS. The coleoptile growth in the control genotypes still remained far below the soil surface (0 level) even at 10 DAS. Before the coleoptiles reached the oxygenated water, the seedlings were growing anaerobically. This seemed to be the most critical stage in seedling development, the time when a genotype had to tolerate a preliminary shock due to anoxia or hypoxia (Figure 2) although rice coleoptiles are considered tolerant to anoxia (Vertapetian et al., 1980). Enhanced coleoptile and mesocotyl growth due to CO₂, C₂H₄ and other growth regulators, simulating more or less lowland conditions, have been studied by various authors

**Figure 1.** Prototype of a seedling establishment in a direct seeded lowland field.**Table 2.** Coleoptile emergence and seedling establishment under lowland and drained soil conditions (10 DAS).

Genotype	Coleoptile emergence (%)		Seedling establishment (%)	
	L	D	L	D
ASD1	100.0 a	97.5 a	92.5 a	100.0 a
IR41996-50-2-1-3	100.0 a	100.0 a	65.0 b	100.0 a
Mahsuri	55.0 c	87.5 a	0.0 c	92.5 a
IR72	72.5 b	95.0 a	0.0 c	97.5 a

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

L = Lowland conditions; D = Drained conditions.

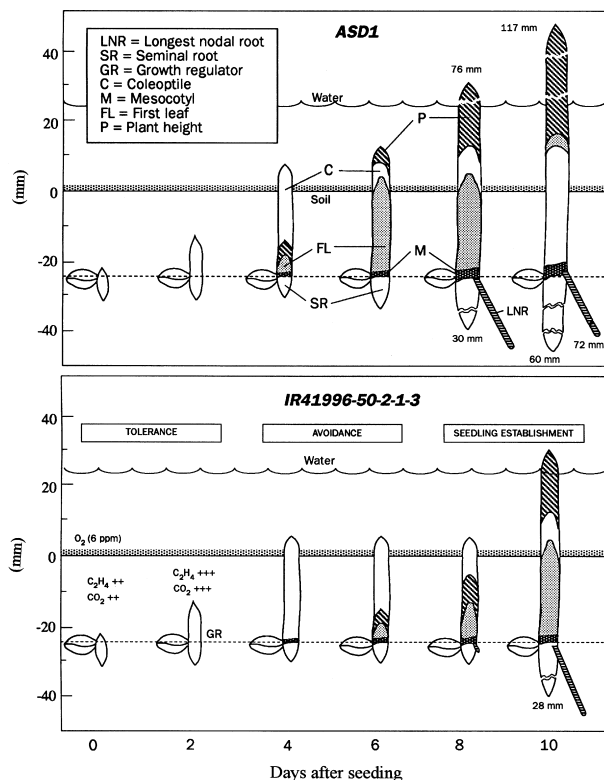


Figure 2. Schematic diagram of the growth and development of ASD1 and IR41996-50-2-1-3.

(Takahashi, 1984; Ishizawa and Esashi, 1984; Horton, 1991). From 0-6 DAS, root growth was completely inhibited. The root growth may be blocked in seeds that germinate under water until shoots have been produced, thereby providing a mechanism to conserve energy during the early phases of seed germination when oxygen is limited (Cobb and Kennedy, 1987). This is an avoidance strategy and allows initial seedling establishment by initiation of mesocotyl and first leaf then by root growth and development (Figure 2).

Some genotypic variation in response to anaerobic stress (low land conditions) was evident from the study. Though ASD1 and IR41996-50-2-1-3 followed essentially the same pattern and sequence of growth, there was an apparent difference in the tolerance of their tissues to oxygen deficit.

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