ANAEROBIC DIRECT SEEDER

Engineering Component of the Rice Anaerobic Seeding Technology

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ABSTRACT

Direct-seeded rice can have comparable yield with transplanted rice if its inherent problems can be solved. It is a labor-saving technology and can significantly reduce production cost because seedling nursery, pulling, and transplanting are omitted. Turnaround time between cropping is reduced hence the possibility of a third annual crop. But direct-seeded rice is very vulnerable to pest attack (by birds, rats, and golden snails), desiccation, weed infestation, and prone to lodging resulting to unstable crop establishment and inconsistent yield. These problems can be solved by anaerobic seeding (sowing pre-germinated seeds under the soil). It requires precise seed placement into the soil to optimize its benefits.

We developed a four-row anaerobic direct seeder (US$200 commercial price) for this purpose. It consist of a structural framework mounted with a drum-hopper metering device, flotation type drivewheels, spring-loaded and adjustable furrow closers, and furrow openers, and a plastic rainguard. It can sow in line pre-germinated seeds into the soil thus permitting the use of mechanical weeders for a chemical-free weed control. Its performance was comparable with the Japanese two-row anaerobic seeder (costing US$400) in terms of seed placement and crop establishment. It was tested with five cultivars. Seeding rate varied from 38 kg/ha to 80 kg/ha. Crop establishment ranged from 64 to 99 percent while grain yield varied from 3.0 t/ha to 5.4 t/ha. A six-row anaerobic seeder was also developed and adapted to a powertiller for increased capacity, field efficiency, and easier operation.

The anaerobic seeder is useful to farmers shifting to direct seeding to reduce rice production cost and to researchers conducting agronomic studies in direct-seeded rice. Blueprint of the machine is available free of charge from IRRI.

Introduction

Rice transplanting is the most common rice crop establishment method in Asia. The newly transplanted seedling has a headstart for competition with weeds, reliable, and stable. In developed countries (such as Japan, Korea, etc.) rice transplanting is highly mechanized. They developed mechanical transplanter in response to scarce and costly agricultural labor supply. It is predicted that in most Asian countries, including the Philippines, agricultural labor supply will become costly and scarce due to the rapid industrial growth in the region. Labor-saving and cost effective technologies will be needed then because there will be an outflow of labor force from the rural areas to the cities, working in the rice fields will become less rewarding and attractive. It is therefore imperative that labor-saving and cost effective methods of rice production be developed now and rice crop establishment by direct seeding is one of them. Direct seeding is a labor-saving technology in rice production because seedling preparation, pulling/uprooting, and transplanting of the seedlings are omitted and the turnaround time between the harvesting crop establishment is shortened which could allow for three crops annually under favorable conditions.

Direct seeded rice can have comparable yield with transplanted rice if the inherent problems of weed infestation, pest attack (by birds, rats, and golden snail during seedling stage), desiccation, and lodging can be solved.

Dry seeding and wet seeding are the two methods of direct seeding rice. In dry seeding, seeds are sown into the dry soil while in wet seeding seeds are sown on the surface of water saturated or flooded soil. Wet seeding can be done by manual broadcasting or using machines such as power broadcasters, helicopters or airplanes for large farms. Wet-seeded rice are very vulnerable to pest attack and desiccation during dry season and have unreliable crop establishment during rainy season. The crop is more prone to lodging (Fig. 1) because the roots are not anchored firmly into the soil. This often resulted to inconsistent and low yield. Farmers counter this problem by sowing two to three times the recommended seeding rate to give allowance for seed damages. The most common weed control is by herbicide which should now be minimized as much as possible.

Generally, in wet-seeded rice, 150 seedlings per square meter is enough to get optimum yield (Hiraoka et al. 1992). Established seedlings greater than 180/m^2 has no significant effect on yield increase but the yield decline sharply proportionate to the decrease in established seedlings if there are less than 150/m^2 seedlings. Uniform seedling establishment is important to achieved high yield. Higher yield can be attained with plant density greater than or equal to 200/m^2 (Washio, 1992).

Farmers of Thailand and Vietnam have demonstrated that the yield of direct-seeded rice is equivalent to transplanted rice if there is good water management, pest, and weed control.

Based on this backgrounds, the International Rice Research Institute in collaboration with Japan International Research Center for Agricultural Sciences engaged in the development of rice anaerobic seeding technology (**ras**) for irrigated rice to solve the problems of direct seeding and consequently lower the rice production cost. Anaerobic seeding (sowing pre-germinated seeds under the puddled soil) requires precise seed placement to optimize its benefits. The 4-row rice anaerobic seeder (**4-ras**) was developed as the engineering component of the rice anaerobic seeding technology.

Methodology

A prototype of the **4-ras** was developed (Fig. 2), laboratory and field tested. Factors affecting its seed metering performance were evaluated including the number of holes around the drum-hopper (H), diameter of the holes (D), and drum revolution (R). A 2x4x3 factorial experiment in a randomized complete block design with three replicates was conducted to examine the seed metering performance. A comparative test between the traditional direct-seeding (seeds sown on soil surface), anaerobic seeding using a two-row Japanese commercial seeder (Fig. 3), and anaerobic seeding using the **4-ras** was conducted. Another experiment was performed to evaluate the performance of five cultivars sown by the **4-ras**. Analysis of variance and linear regression were used to analyze the results.

Seeder development and description

The **4-ras** consists of a structural framework where the following major components are mounted: (1) drum metering device with holes around its circumference, (2) pair of flotation type drive wheels (ftdw), (3) spring-loaded and adjustable furrow openers, (4) spring-loaded and adjustable furrow closers, and (5) the rainguard.

The drum metering device also serves as hopper for pre-germinated paddy. Portion of its lateral surface can be opened to permit seed filling. When the drum rotates, seeds are delivered through the holes around its circumference.

The ftdw are rotatively mounted on both ends of the shaft where the drums are also mounted. It supports the system during operation and also provide rotary motion to the drum metering device when the unit is pulled by the handle. The ftdw was so designed to prevent sinking of the unit in relatively soft puddled field with deep hardpan. In normal field condition having shallow hardpan, the ftdw can be replaced with a pair of ordinary traction wheels.

The spring-loaded furrow openers and closers are attached in front and at the rear of the drum metering device respectively. These three components must be in a line such that seeds falling from the holes of the drum will fall into the opened furrow, and then covered with soil by the furrow closer. Depending on the condition of the field, the furrow opener and furrow closer can be adjusted to attain the desired seeding depth. The spring is to account for the variation on the soil surface and the vertical movement of the handle caused by the operator in motion.

The rainguard is made of small round bars and plastic sheet. It protects the seeds (in the drum) and allows operation even when raining. The handle is adjustable to suit operator's height. Total weight of the machine is about 20 kg without seeds.

Results and discussion

The interaction between the number of holes around the drum, diameter of the holes, and drum revolution on the seed metering performance of the 4-row anaerobic seeder was not significant but the interaction between the diameter of the holes and drum revolution was significant at 5% level (Fig. 4). The seeding rate was directly related to the number of holes around the drum regardless of hole diameter.

Performance of the **4-ras** was comparable to the commercial seeder in terms of seed placement and percent crop establishment (Table 1). Crop establishment using the **4-ras** was 39.8% and 37.5% using the commercial seeder with IR41996-50-2-1 cultivar while only 1.8% in surface seeding. With IR72 crop establishment was 47.0% using **4-ras**, 37.0% using the commercial seeder and 7.0% in surface seeding.

In the experiment with five rice cultivars (Table 2) sown by the **4-ras**, the seeding rate varied from 38 kg/ha to 80 kg/ha, number of seedling established ranged from $129/m^2$ to $285/m^2$, crop establishment was 64 to 99%, sowing depth range of 3.8 to 7.1 mm, and grain yield varied from 3.0 t/ha to 5.4 t/ha. The cultivar BG34-8 have the highest seeding rate (80 kg/ha), seedling establishment (285 $seedlings/m^2$) and grain yield (5.4 t/ha). Sowing depth was 7.1 mm and crop establishment was 81%. IR41996-50-2-1-3 have the highest crop establishment (99%), with the lowest seeding rate (38 kg/ha), 135 $seedlings/m^2$, and 5.2 t/ha grain yield. Average sowing depth was 5.3 mm. In general, there was no direct correlation between seeding rate, percentage crop establishment, sowing depth, and grain yield.

Users of the **4-ras** with ordinary rice cultivars (IR72, IR74, etc..) have reported better weed control (using mechanical weeders) and increased yield. Two men can sow 1 ha/day operating alternately. Downtime was high due to frequent refilling of seeds in the drum. Based on this feedbacks, a six-row powertiller-mounted anaerobic seeder was developed (Fig. 5) for increased capacity, field efficiency, and ease of operation. It can be operated by one operator continuously. The seeder was successfully adapted to the powertiller by a four-bar-linkage mechanism (Fig. 6), the only mechanism able to meet the operational requirement, i.e., the seeder frame must remain relatively parallel to the soil surface during operation regardless of the powertiller handle vertical movement. This condition allows the synchronize engagement of the furrow openers and furrow closers for uniform seeding depth.

Conclusions and recommendations

The anaerobic direct seeder for rice was successfully developed. Easy to use and maintain, cost only US$200. Its capacity is linearly related to the number of holes around the drum regardless of hole diameter. Its performance is compatible with a two-row Japanese commercial seeder (with US$400 price) in terms of seed placement and crop establishment.

Among the five cultivars (evaluated for suitability to anaerobic seeding) sown by the **4-ras**, IR41996-50-2-1 have the lowest seeding rate (38 kg/ha) but with the highest crop establishment (99%). Cultivar BG34-8 have the highest seeding rate (80 kg/ha), seedling establishment (285 seedlings/m^2), and grain yield (5.4 t/ha). No direct correlation existed between seeding rate, percentage crop establishment, sowing depth, and grain yield.

The anaerobic seeder is a solution to some problems in direct seeding of irrigated rice. It is a labor-saving technology for the future. It will be useful to farmers shifting to direct seeding to lower rice production cost. We do not recommend its use for sowing ordinary rice varieties particularly **during the wet season** because the crop might fail due to anoxia or absence of oxygen in the soil caused by standing water. Other anaerobic seeding techniques must be developed such as ridge seeding which might be applicable in the wet season using ordinary rice cultivar.

Table 1. Average comparative data of two cultivars sown by drum seeder, anaerobic seeder, and commercial seeder. IRRI 1993 Wet Season.

Cultivar	Seeding Method	Seeder	Seeding Rate (kg/ha)	Percent Crop Establishment	Planting Depth (mm)	Plant Density (no/m^2)
IR41996-50-2-1	surface	drum seeder	56	1.8	7.0	5
	anaerobic	anaerobic seeder	58	39.8	4.3	84
	anaerobic	commercial seeder	98	37.5	6.4	133
IR72	surface	drum seeder	45	7.0	7.6	14
	anaerobic	anaerobic seeder	50	47.0	7.5	99
	anaerobic	commercial seeder	79	37.0	6.4	123

Table 2. Performance of 5 rice cultivars sown by anaerobic seeder.[a] IRRI, Philippines. 1994 dry season.

Cultivars	Seeding rateb[b]		Crop establishment[c]		Sowing depth[d] (mm)	Grain yield[e] (t/ha)
	(no./m^2)	(kg/ha)	Seedling (no./m^2)	Establishment (%)		
BG34-8	354	80	285 a	81 ab	7.1 a	5.4 a
IR41996-50-2-1-3	136	38	135 b	99 a	5.3 a	5.2 a
IR72	172	41	129 b	75 b	5.0 a	4.8 a
E4129	238	59	152 b	64 b	3.8 a	3.9 b
AUS351	206	46	141 b	68 b	4.9 a	3.0 c

[a] Randomized complete block design with four replications. Means having a common letter are not significantly different at the 5% level by DMRT. Fertilizer was applied at 50, 30, and 50 kg N/ha at 21 and 42 d after sowing and heading, respectively.
[b] Estimated by measuring the weights of seeds loaded into the seeder and left in the seeder after sowing. Calculation of number of seeds sown was based on the weight of single seed. Mean of four plots of replications.
[c] Measured 3 wk after sowing.
[d] Estimated by measuring the length between seed and the portion of leaf sheath where the color changes from white to green. The 20 plants sampled for the measurement of crop establishment were used.
[e] Harvest area = 6 m^2.

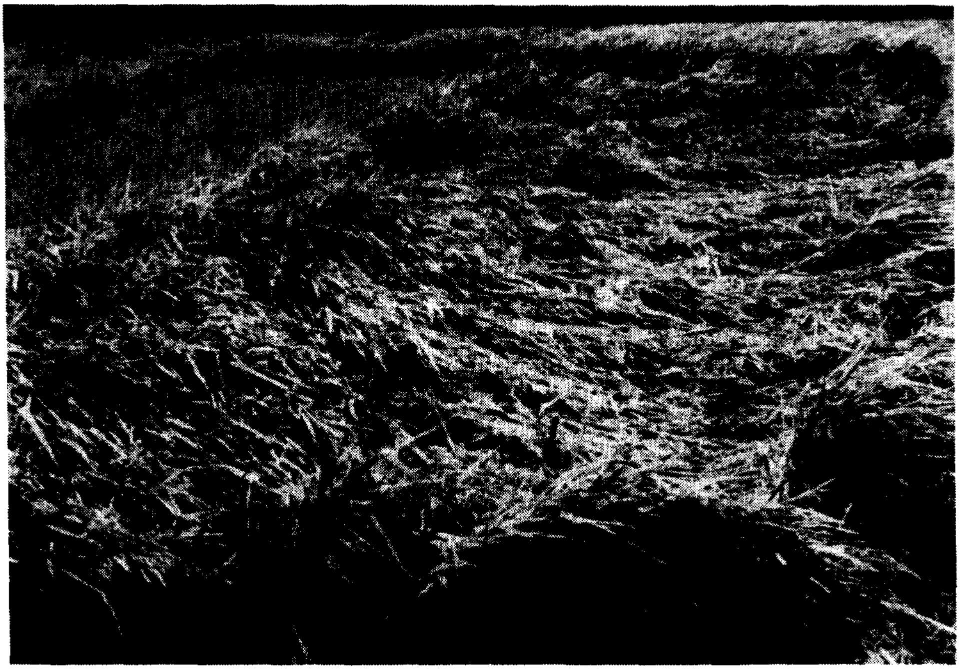

Fig. 1. Traditionnally direct-seeded rice (sown on the soil surface) are prone to lodging producing inconsistent and low grain yield.

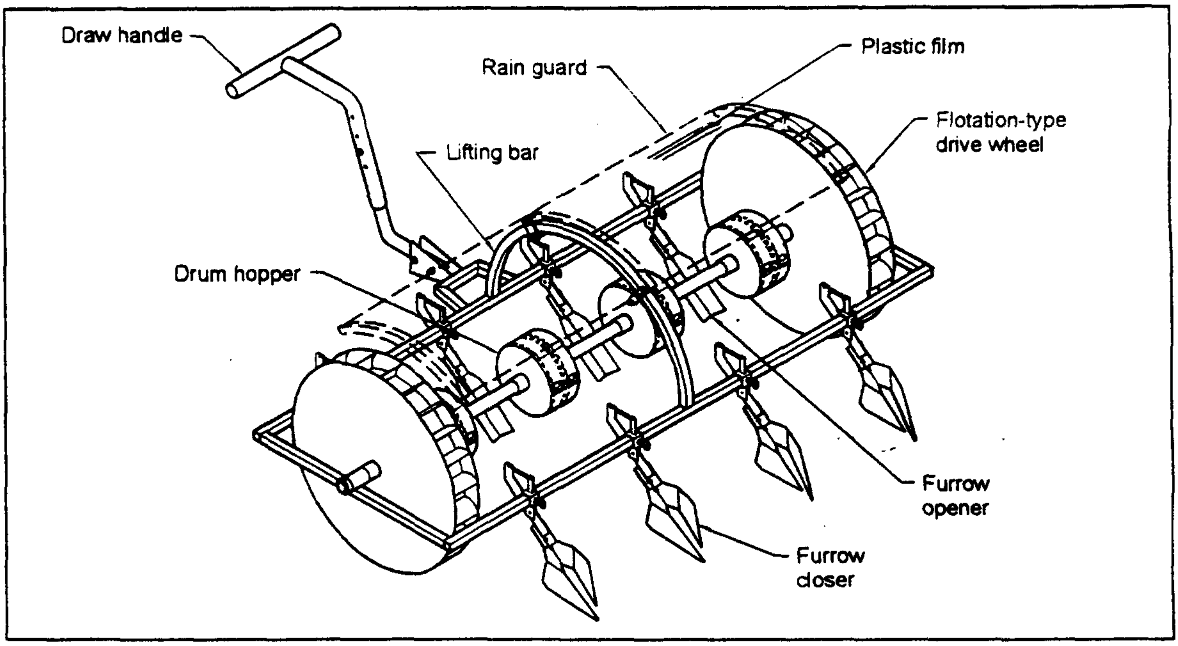

Fig. 2. Anaerobic seeder designed to put pre-germinated rice seeds under the puddled soil.

Fig. 3. The two-row Japanese rice anaerobic commercial seeder .

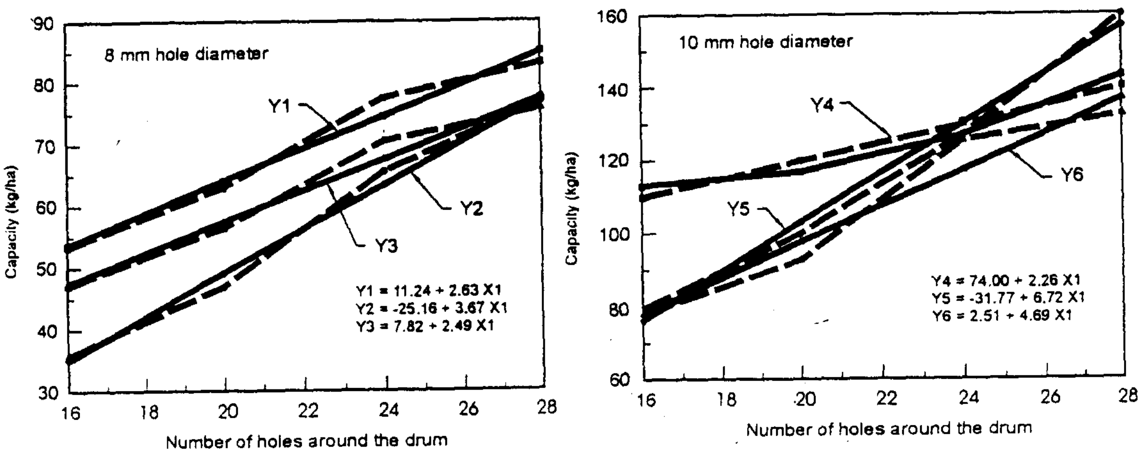

Fig. 4. Relationship between number of holes and seeder capacity, Predicted seeding rates: (A) Y1, Y2, and Y3 at 28, 37 and 46 drum rpm with 8 mm hole diameter. (B) Y4, Y5, and Y6 at 28, 37, and 46 drum rpm with 10 mm hole.

Fig. 5. The six-row powertiller-attached rice anaerobic seeder.

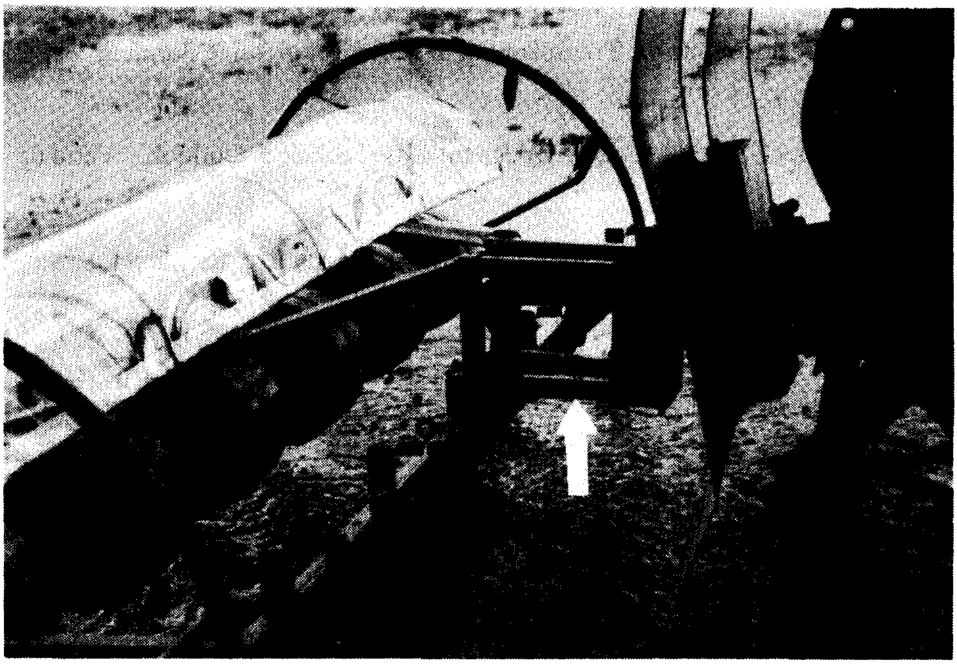

Fig. 6. Four-bar-linkage mechanism used in the powertiller-attached rice anaerobic seeder.

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