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Raising and Transplanting Technology for Long Mat with Hydroponically Grown Rice Seedlings

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Abstract

Long mat with hydroponically grown rice seedlings (hereafter referred to as LMHS) with a mat size of 6 m in length and 28 cm in width, was designed to develop a labor-saving rice transplanting system. The rice seedlings were grown in a newly developed nursery device for about 2 weeks and the plant length reached 10 to 15 cm. The seedling mat was composed of entangled plant roots and nonwoven cloth and it was strong enough to be handled. LMHS were transformed into roll type seedlings by rolling up. The weight of a mat with roll type seedlings was about 12 kg and approximately 1/5 of that of a conventional mat with young seedlings raised in a soil bed (hereafter referred to as CMSS). A rice transplanter was designed and tested to transplant the roll type seedlings in paddy fields. The rate of damaged seedlings immediately after transplanting was 30 to 50%. However, the minimum rate of missing hills after rooting was 3%, when the number of plants per hill ranged from 7 to 8. Working rate of the transplanter was approximately 0.5 ha/h for a working speed of 1.13 m/s and a working width of 1.8 m. Rice yield in the case of LMHS was assumed to be equal to that of CMSS.

Discipline: Agricultural machinery
Additional key words: nonwoven cloth

Introduction

In Japan, the percentage of transplanting in rice production exceeds 99%. Most popular seedlings used for rice transplanting are referred to as mat type seedlings and they are grown on soil in a seedling box (58 cm long, 28 cm wide and 3 cm deep). The carriage of the seedling boxes is laborious and is associated with major problems for the following reasons: (1) the weight of one seedling box is approximately 6 kg, (2) 2,000 seedling boxes are necessary for paddy fields with an area of 10 ha, and (3) during the period from seeding to transplanting, the seedling boxes must be carried from the seeder to the nursery chamber, greenhouse, truck and rice transplanter.

The objective of this study was to reduce the weight and the carriage frequency of the seedling boxes. Specific objectives were: (1) to raise rice seedlings with long mat (6 m long) by hydroponics in a nursery device, (2) to roll up the seedlings to a small size, and (3) to develop a rice transplanter to transplant the seedlings in paddy fields.

Materials and methods

1) Outline of nursery device

The nursery device developed to raise LMHS is illustrated in Fig. 1. The nursery device which consists of a nursery bed, a liquid fertilizer tank and a liquid fertilizer pump was fixed on the ground in a vinyl house. The nursery bed fixed horizontally on the ground comprised 4 nursery trays. A nursery tray (6.5 m long, 28 cm wide and 6 cm deep) made of stainless steel was developed. The height of the nursery tray from the ground surface was set at 60 cm to work without bending the waist. Liquid fertilizer circulates in the tank and on the tray of the nursery device through a pump.

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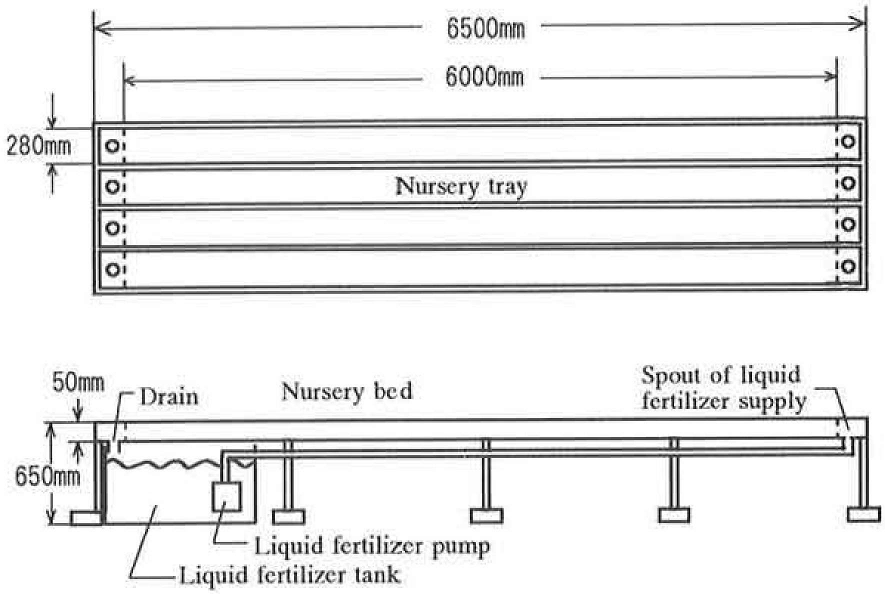

Fig. 1. Hydroponic nursery device

2) Seeding method

A nonwoven cloth was spread on the dry nursery tray and fixed at both ends on the tray with 2 plates like a comb. Liquid fertilizer was circulated in the nursery device and then germinated rice seeds were scattered on the tray with a self-propelled seeder as shown in Fig. 2. Mass of the seeds ranged from 100 to 250 g per unit area corresponding to the size of a conventional seedling box (28 × 58 cm). The nonwoven cloth was made of cotton and it was used to obtain a seedling mat sufficiently strong to be rolled up and transplanted.

3) Supply of fertilizer and air temperature in the vinyl house

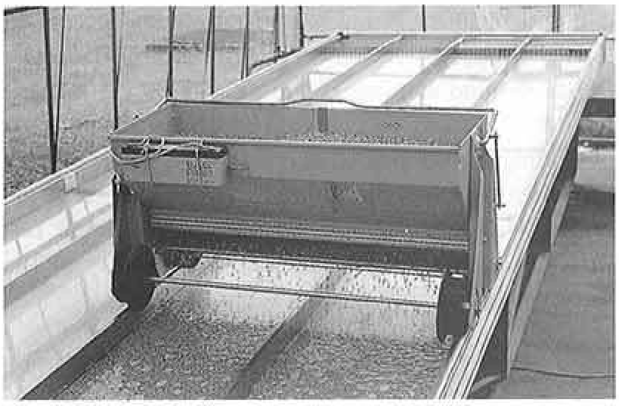

Fig. 2. Nursery device and self-propelled seeder

Water without fertilizer was circulated in the nursery device for several days after seeding. Fertilizer commercially available for hydroponically grown vegetables, Otsuka No. 1 and No. 2, was dissolved in the water in the liquid fertilizer tank on the 5th day after seeding. Electric conductivity (EC) of the liquid fertilizer was adjusted to reach values ranging from 1.3 to 1.4 mS/cm every day.

Water temperature in the nursery device was adjusted to be compatible with the raising of the seedlings by controlling the air temperature in the vinyl house with heaters or ventilators.

4) Rolling up of seedlings

Tests of rolling up of LMHS on the 6 m long mat were conducted for transfer to the paddy fields and loading on a rice transplanter.

5) Development of a rice transplanter for LMHS

A riding type rice transplanter currently manufactured was remodeled to transplant the roll type seedlings in paddy fields. The basic performance of the rice transplanter was as follows: working width of 1.8 m (6-row planter with 30 cm row spacing) and maximum working speed of 1.4 m/s.

6) Experimental methods

Experiments for raising the seedlings were conducted to investigate the relationship between plant length, root length and number of roots of the

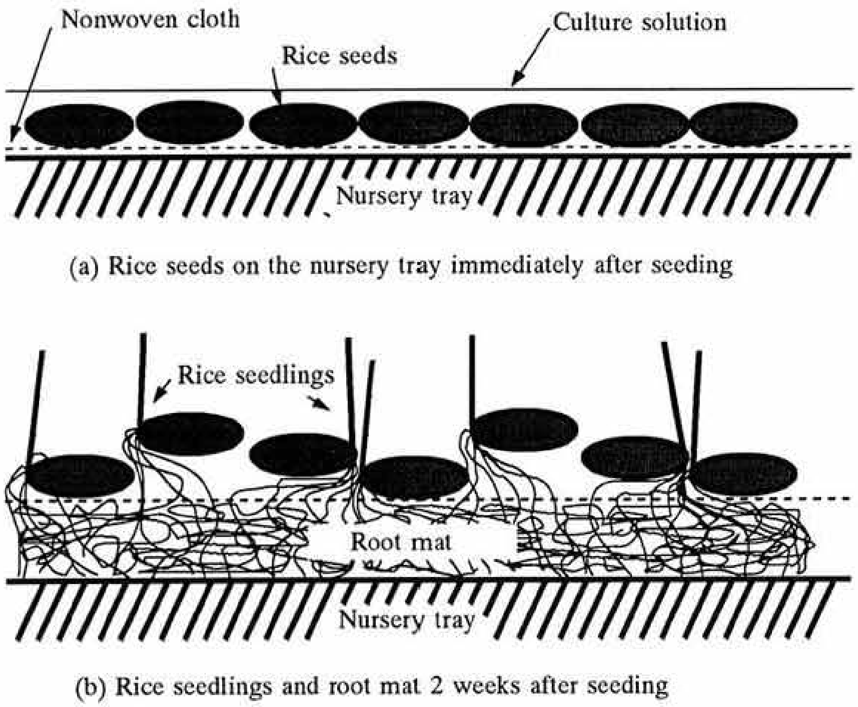

Fig. 3. Cross-section of seeds and seedlings on the nursery tray

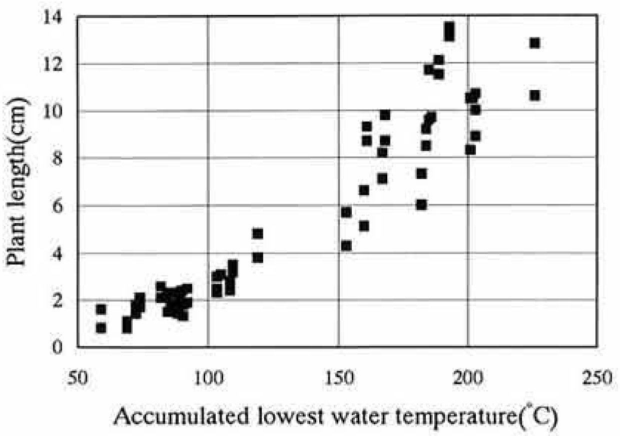

Fig. 5. Relation between accumulated lowest water temperature and plant length

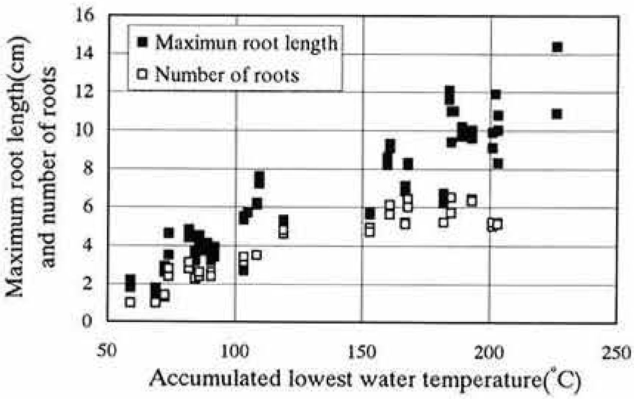

Fig. 6. Relation between accumulated lowest water temperature and maximum root length or number of roots

seedlings and temperature. Varieties of rice used were Koshihikari, Kinuhikari, Akitakomachi and Himenomochi. In this test, air temperature, water temperature, EC and pH of liquid fertilizer were measured in addition to the examination of the plant conditions.

Field experiments were conducted to determine the working accuracy and working rate of the transplanter in paddy fields. In the experiments, more attention was directed to determine the rate of damaged seedlings and missing hills after transplanting and rooting. Field tests were also performed to evaluate the rice yield in the case of the LMHS from 1996 to 1997 in 3 prefectures, i.e. Ibaraki, Saitama and Iwate.

Results and discussion

1) Raising of seedlings

Rice seeds and seedlings on the nursery tray immediately after seeding and 2 weeks after seeding are illustrated in Fig. 3. Roots of the seedlings

Fig. 4. Appearance of the seedlings on the tray at 10 days after seeding

Fig. 9. Conventional mat type seedlings

Fig. 8. Roll type seedlings

Fig. 10. Rice transplanter for roll type seedlings

became entangled after penetrating into the nonwoven cloth on the nursery tray. The mat composed of the entangled plant roots and the nonwoven cloth was strong enough to be handled. Appearance of the seedlings on the tray on the 10th day after seeding is illustrated in Fig. 4.

2) Relationship between plant length, root length and number of roots of the seedlings and temperature

The relationship between accumulated lowest water temperature and the plant length is depicted in Fig. 5 and then the relationships between accumulated lowest water temperature and the maximum root length or number of roots are depicted in Fig. 6. These data were obtained when the highest water temperatures ranged from 30 to 34°C. The plant length as well as the maximum root length reached values of 10 to 12 cm at the accumulated lowest water temperature of 200°C. The number of roots increased from 5 to 7 at the accumulated lowest water temperature of 160°C.

3) Roll type seedlings

Method of rolling up the LMHS on the 6 m long mat was eventually developed. Method of rolling up the seedlings was as follows: (1) pushing down the seedlings with a cylinder of approximately 15 kg, (2) putting a steel plate of 60 cm long, and 27.5 cm wide and a mass of 3 kg on the seedlings, (3) rolling up the seedlings on the circumference of a pipe with a diameter of 15 cm and (4) wrapping the seedlings in a cloth. These operations are illustrated in Fig. 7 and the mats with roll type seedlings are shown in Fig. 8. Diameter and weight of the mats with roll type seedlings ranged from 40 to 45 cm and 12 kg per 6 m, respectively. Comparison between the seedlings subjected to the new and conventional methods for the same length of the mat showed that the mass of the roll type seedlings was approximately 1/5 of that of the CMSS.

The number of seedling boxes for the CMSS shown in Fig. 9 was approximately 60 and the 6 mats with roll type seedlings shown in Fig. 8 corresponded to the seedling boxes shown in Fig. 9. Based on the data described above, the use of the mats with roll type seedlings enabled to reduce the weight and carriage frequency of seedling boxes.

4) Development of a rice transplanter for LMHS

A 6-row riding type rice transplanter currently manufactured was remodeled to transplant the roll type seedlings in paddy fields as shown in Fig. 10. Some equipment was developed to attach the roll type seedlings to 6 seedling platforms of the transplanter. Ability of feeding belts of seedlings increased

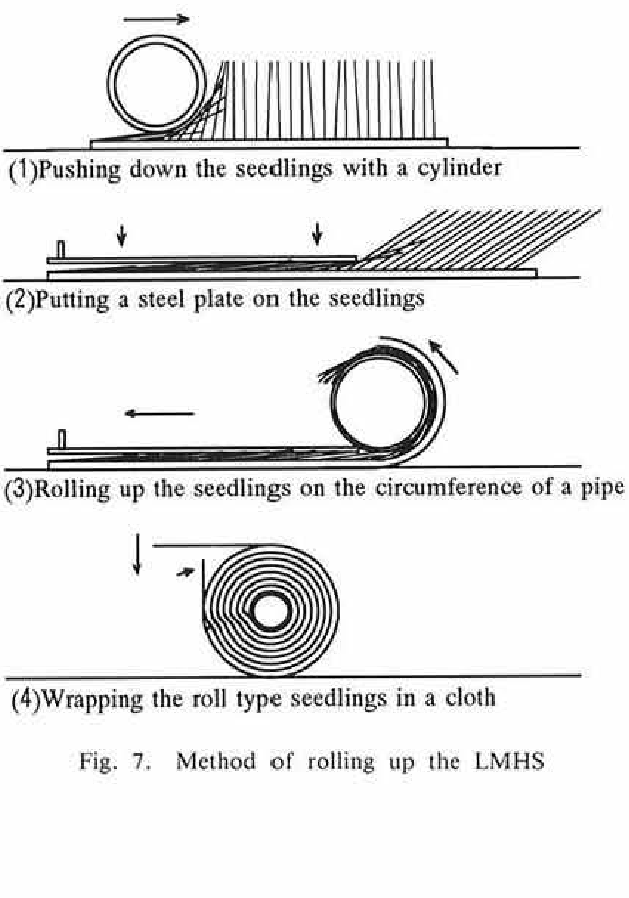

Fig. 7. Method of rolling up the LMHS

for reliable and steady feeding by the use of a driving roller in addition to the top and bottom rollers. Two seedling racks were fixed to carry 8 extra mats with roll type seedlings on both sides of the operator's seat. The capacity of the hopper of fertilizer was twice as high and enabled to reduce the frequency of supply of fertilizer to the transplanter.

5) Working accuracy of the rice transplanter

In the field experiments conducted in 1996 to 1997, the working accuracy of the rice transplanter resulted in a 30 to 50% rate of damaged seedlings immediately after transplanting and the minimum rate of missing hills after rooting was 3% when the number of plants per hill was 7 to 8. Working speed did not affect significantly the working accuracy.

The rate of damaged seedlings was not related to the working speed of the transplanter but was related to the strength of the seedling mat depending on the mass of seeds per unit area, days of raising of seedlings and variety of rice. In particular, the strength of the seedling mat depended on the mass of seeds per unit area: the larger the latter, the stronger the former. As a result, the rate of damaged seedlings increased. However, a seed mass less than 150 g per unit area (28 × 58 cm) led to a reduction of the volume of the seedling mat, resulting in the increase of the rate of missing hills. Therefore, optimum mass of seeds was considered to be 180 to 200 g per unit area.

6) Working rate of the rice transplanter

Working rate of the transplanter with one operator was approximately 0.5 ha/h for a working speed of 1.13 m/s. It took 12 min to supply 6 mats with roll type seedlings to the transplanter.

Although one operator and one helper are required, working rate of a transplanter with the same size under the same conditions when a conventional seedling box was used was nearly 0.3 ha/h. Supply of conventional seedlings to a transplanter requires a helper in addition to the operator and reduces the working rate. Therefore, the use of the transplanter for the roll type seedlings resulted in a considerable saving of labor.

7) Yield of LMHS

Rice yield in the case of the LMHS and the CMSS in 1996 to 1997 is shown in Fig. 11. Rice yield in the 2 kinds of rice seedlings varied with the years and the locations but did not show a particular tendency. As a result, rice yield in the case of LMHS was assumed to be equal to that of CMSS, although more detailed comparison will be needed in future.

Conclusion

Studies were conducted to develop a long mat with hydroponically grown rice seedlings (LMHS). The rice seedlings were grown in a newly developed

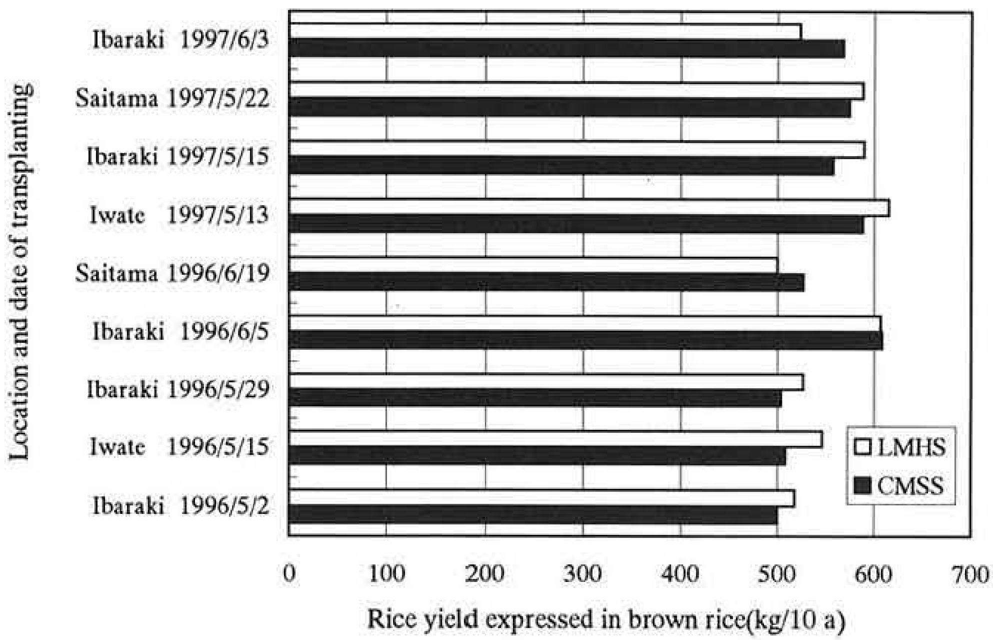

Fig. 11. Rice yield in the case of LMHS

nursery device for about 2 weeks, and the plant length reached 10 to 15 cm. The seedling mat composed of entangled plant roots and nonwoven cloth was 6 m long and 28 cm wide. The seedling mat was strong enough to be handled by using a nonwoven cloth.

Roll type seedlings were obtained by rolling up the LMHS. The weight of the mat with roll type seedlings was about 12 kg per 6 m and approximately 1/5 of that of a conventional mat with seedlings raised in a soil bed (CMSS).

A rice transplanter was remodeled to transplant the roll type seedlings in paddy fields. Working accuracy of the transplanter was as follows. Damaged seedling rate immediately after transplanting ranged from 30 to 50% and the minimum rate of missing hills after rooting was 3% when the number of plants per hill was 7 to 8. Working rate of the transplanter was approximately 0.5 ha/h for a working speed of 1.13 m/s and a working width of 1.8 m.

Rice yield in the case of the LMHS was assumed to be equal to that of CMSS, although more detailed comparison will be needed in future.

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