16. TECHNICAL PROBLEMS ON THE DIRECT SEEDER AND TRANSPLANTING MACHINE IN RICE CULTURE

TAMOTSU MIURA*

Preface

From a viewpoint of the seeding method, the rice culture in Japan is grouped into two, direct seeding and transplanting cultivations. And predominating at present is the latter. The former is adopted only in a very small part, 1% or so, of the rice acreage. Though there are many factors preventing the direct seeding cultivation, which is more labor-saving than the transplanting cultivation, from popularization, the main reasons are as follows:

1) Farmers accustomed to the cultivation by transplantation are uneasy about the adoption of the reformative technique, direct seeding.

2) In the direct seeding culture, the seeding emergence rate is a little variable according to environmental conditions, so farmers have a faint sense of uneasiness about the yield which may be less stable than that in the transplanting cultivation.

3) The weeding technique by means of herbicides is not yet complete under bad weather, and if a chance of the application of herbicides is missed, much labor will be needed to weed by hand.

4) In some regions, the transplanting cultivation is necessarily to be adopted by reason of an intensive use of farms, where the days required for growth of rice plants after the harvest of the preceding crop are too short to adopt the direct seeding cultivation.

5) Any effective measures to prevent damages caused by birds have not yet been established, so if direct seeding is practiced in restricted parts of farms, the parts will be greatly damaged by a concentrated attack of birds.

On these accounts, direct seeding is practiced at present only in some areas where the direct seeding cultivation is better than or equal to the transplanting cultivation in yield, though many kinds of seeders are on the market. But it seems that the direct seeding method must be widely adopted in future to cope with labor-shortage and to reduce the production cost of rice.

In the transplanting cultivation now widely practiced, seedlings are gathered from nurseries by hand when they reach a stage of 5–6 leaves and are planted in the field after washing off the soil covering the roots. Two types of rice transplanting machines are now on sale and partly in practical use as a result of recent advances in the study of these machines. One of them is used for the seedlings with washed roots. It is designed for the transplanting seedlings at a stage of 5–6 leaves after washing the roots as mentioned above. And the other is the machine for the seedlings with soil-covered roots devised for the transplanting seedlings grown in nursery boxes at a stage of 2–2.5 leaves as their roots are covered with bed soil. It is not long since the debuts of these machines, so that the number of them in practical use is rather small throughout the country at present: about 3,000 for the machine of a washed-root type and about 90,000 for that of a soil-covered-root type. But these machines are expected to be fairly

* Chief, 1st Division of Research, Institute of Agricultural Machinery, Omiya, Saitama, Japan.

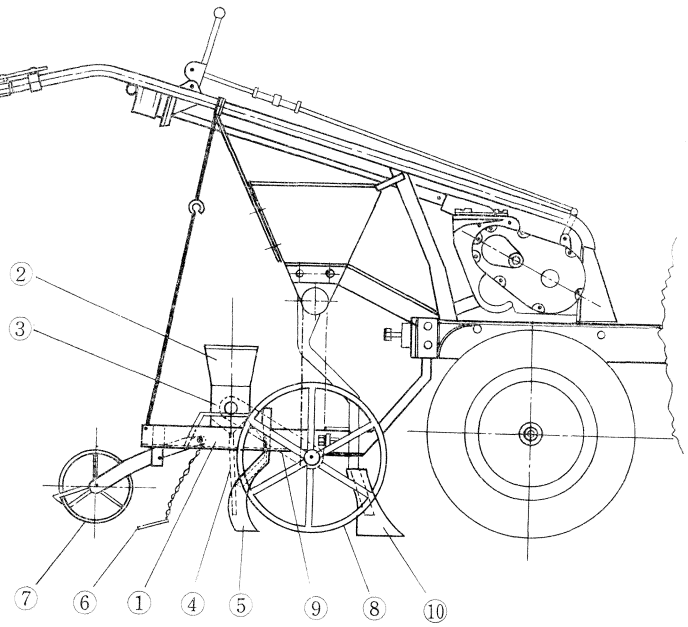
popular in future.

Direct Seeder

Two types of seeders are now in use in Japan. One is the direct seeder for dry fields after plowing, harrowing and preparation. The other is the direct seeder used for seeding wet fields after plowing, harrowing, flooding, puddling and preparation.

(1) Direct seeder for dry fields

Fig. 1 shows a seeder of this type which is in common use at present. This seeder



1 . Main frame
2 . Hopper for seed
3 . Seed discharging roll
4 . Seed tube
5 . Opener for seed
6 . Coverer
7 . Press wheel
8 . Driving land wheel
9 . Driving chain
10. Opener for fertilizer.

Fig. 1. Direct seeder for dry fields.

can do such works as furrowing with an opener, sowing the seeds sent out of a hopper through a pipe into the furrow thus made and covering the seeds with soil by the action of a mulching apparatus. For the sending out of seeds, there are two methods: sending out at regular intervals for planting, and continuous sending out for drilling. The direct seeding of this type, however, has some of the following difficulties:

1) Restriction by the atmospheric temperature: The direct seeding in dry fields can not be practiced in a place where the temperature is lower than a certain limit. In such a place, it is necessary to keep warmth by flooding the field. The use of vinyl sheets has been studied for the same purpose recently.

2) Restriction by water leakage: The direct seeding in dry fields is difficult to practice in a place where much water leaks and also in an ill-drained place where water is kept throughout the year. Therefore, the seeding is popular in a region where the

field is dry in winter and easy to plow (autumn plowing)and has a high level of undergrown water in summer. To practice the seeding, it is necessary to improve the soil for the betterment of irrigation and drainage.

3) Restriction by rain: In the warm region of Japan where direct dry field seeding is practiced, the seeding time falls on the rainy season, called "tsuyu". And if it rains just after plowing and harrowing, the seeding work will be unable to be done for 2–4 days and the schedule will result in being interrupted. In case of unplowed fields, however, the seeding can be practiced even soon after a rainfall if there is no water on the surface of the soil. Therefore, a minimum tillage by which seeding is done simultaneously with plowing and harrowing, as ridge sowing and shallow sowing, is thought to be hopeful in future, and many methods have been put to traial. The ridge sowing is a method to sow seeds on the surface of unplowed soil and cover them with the soil obtained by making furrows at regular intervals as shown in Fig. 2. In

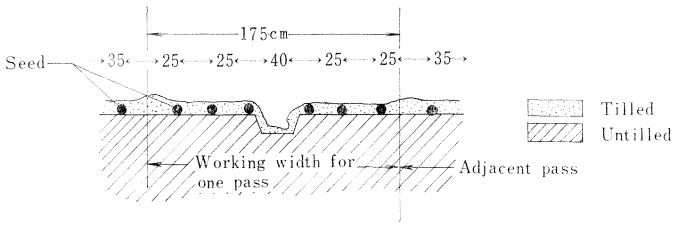


Fig. 2. Direct seeder for untilled fields.

the shallow sowing method, the machine seeds while plowing the soil 2-3 cm deep to mix the seeds with the plowed soil.

4) Restriction by harrowing: The seeder shown in Fig. 1 does not work well when there are many clods of soil, 20 mm or more in diameter, in the field. Therefore harrowing must be done carefully. For heavy clayer soil where a sufficient harrowing is often difficult, it is recommended to use a seeder of the type shown in Fig. 3. This seeder makes holes on the surface of the soil with the ragged lugs and sows seeds in

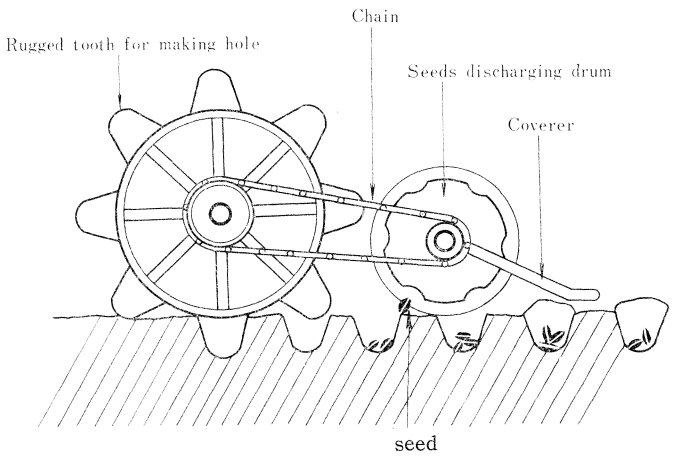


Fig. 3. Direct seeder for dry fields.

the holes. In this method, the seeding work is scarcely affected by the size of soil clods. Powered and manpowered machines of this type are on sale at present, and the distance between the lugs can be changed in some of them.

(2) Direct seeder for wet fields

The direct seeding in wet fields has the following advantages: it can be practiced not only in a cool region and in a field where water leakage is heavy but also in a time when the direct dry field seeding is useless owing to long-continued rain. However, this seeding method also has some difficulties: if seeds are buried too deep in the soil, their germination is inhibited by a deficiency of oxygen, and when seeds are only put on the surface of the soil, they may be removed by waves or other movements of water. Though it must be desirable to keep the seed half in the soil and half in the water, such a seeding is very difficult to do.

For the direct seeding in wet fields, the seeders of the planting type (Fig. 4) are

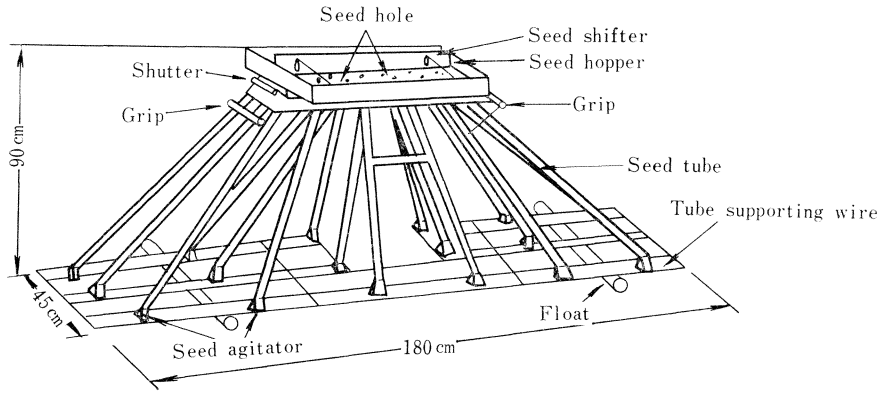


Fig. 4. Direct seeder with divided seed tubes for irrigated fields.

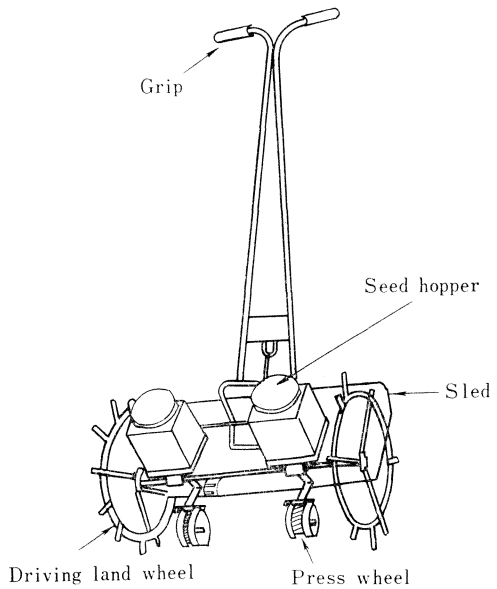


Fig. 5. Direct seeder for drain fields (pull type).

in use at present. In flooded fields, to avoid the movement of sowed seeds, which results from the agitation of water by rotating wheels, etc., this type of machine is lifted up with both hands when moved. The seeder shown in Fig. 5 is of another type which is used when the surface of soil has been made sufficiently hard to bear it by drainage following puddling. The hardness of the soil surface, however, is not easily controlled.

As mentioned above, the seeds directly sowed in wet fields are located near the surface of soil, and there is the possibility that rice plants grown from them will lodge in the harvesting season. It is known experimentally that this type of lodging is fairly prevented by mulching about 2 cm deep at a stage of 3–5 leaves, but this method has a practical difficulty that causes an increase in cultivating work.

Fig. 6 shows a seeder made for trial by the Fukuoka Agricultural Experiment Sta-

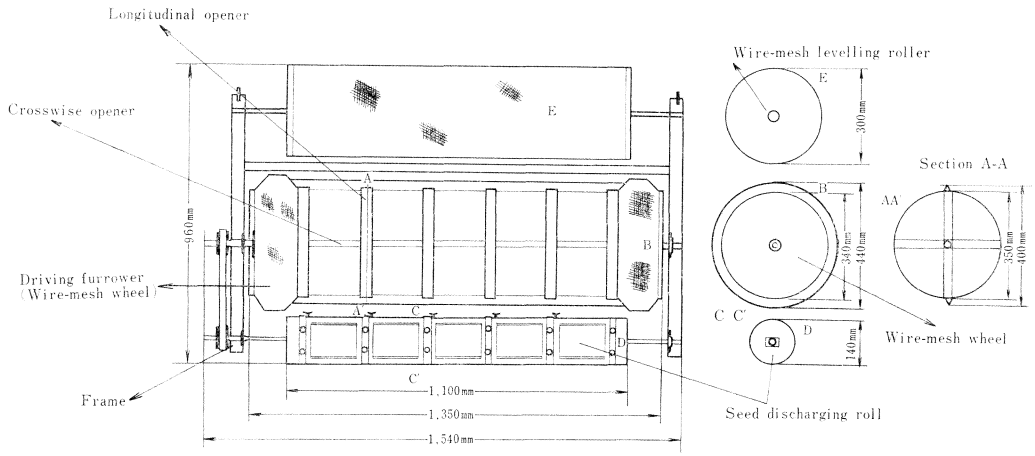
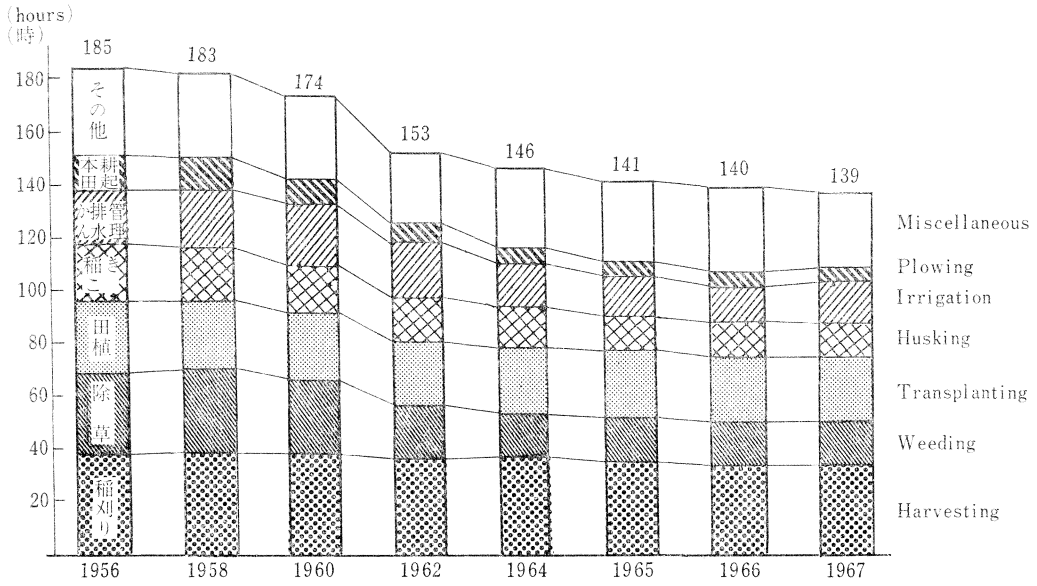


Fig. 6. Direct seeder with ditch maker for wet fields.

tion. It furrows with an opening wheel and sows seeds in the furrows. This machine was designed for the prevention of seeds from moving by making use of furrows and for the protection of rice plants from lodging during the growing period by natural mulching due to the falling in of soil from the edge of the furrows.

Transplanting Cultivation

The number of transplanted rice seedlings per hill is three in average at present, and the number of stumps is 16–23 per m^2 of the field. And it takes a worker 6–10 hours to gather a sufficient number of seedlings from a nursery for planting 0.1 ha of the field. The wide variation of the time necessary for gathering seedlings is due to many factors: the time varies with the type of nurseries and the hardness of the soil of nurseries: the easiness in removing the soil from roots is different according to the characteristic of soil; and the number of hills per m^2 of the field is different. On the contrary, to plant 0.1 ha of the field by hand at a rate of 18 hills per m^2, it takes a laborer 12–14 hours, being fairly variable according to the method of planting and the skill of workers. The time necessary for rice culture has been reduced now by the mechaniaztion of various works, but the time for planting seedlings remains unchanged as shown in Fig. 7. Therefore, to reduce the total working time of rice culture, the mechanization of planting work is the most necessary. And this is also helpful to cope with labor-shortage in farm works. Studies of rice planting machines have made



Source: Survey Report of Cost of Rice Production, Ministry of Agriculture and Forestry

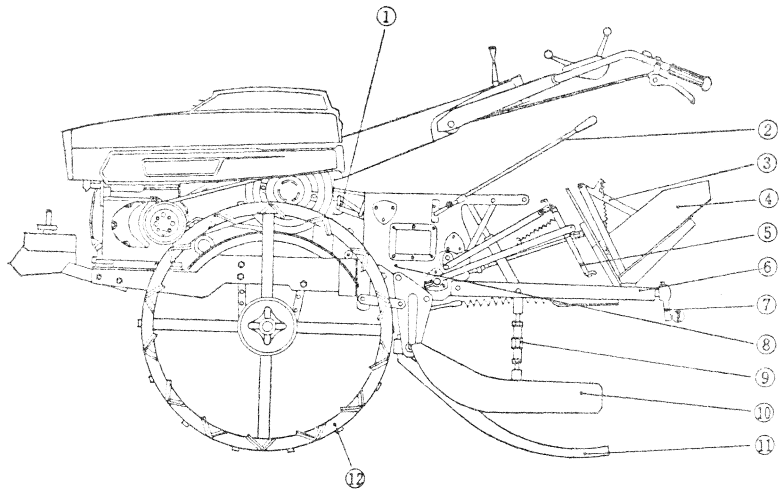
Fig. 7. Labor input by farm operations and by year.

progress under these circumstances, and planting machines of the washed-root type and soil-covered-root type are now on sale, gradually coming into wide use. The performance of these machines, however, is influenced by many factors, and they can work as correctly as handwork only under certain limited conditions of seedlings and soils. At present, they are not useful at all when the conditions are a little unfavorable. These problems will be pointed out below, making references to the directions of studies on them.

(1) Rice planting machine of a washed-root type

This type of machine was developed by the mechanization of planting actions by hand and has a long history of studies. In the course of their development many machines were made for trial, but it was not easy to put them to practical use, because they caused many missing hills and did much damage to seedlings. And also the transplantation of seedlings with those machines was inefficient by reason of the fact that a time consuming work for the prearrangement of seedlings was necessary before supplying seedlings to the machines. A kind of powered transplanting machines for two rows (Fig. 8) was first put on sale in 1965, and four kinds of similar machines different in mechanism from one another are now on the market through continuous improvement. The seedlings planted with this type of machine are not so different in their condition from those planted by hand, that farmers can master them on the basis of their techniques accumulated until now. Therefore, if machines of good efficiency are produced, they seem to spread rapidly among farmers. But they are so popular at present owing to the following reasons.

1) Seedling pluckers have not yet been completed: Rice transplantation consists of two main works, plucking seedlings and planting seedlings. If a transplanting machine as shown in Fig. 8 is used, planting can be done at a rate of 0.1 ha per 2.5–3



1. Tension pulley
2. Clutch lever
3. Conveyor lever
4. Seedling box
5. Holder
6. Chassis
7. Sledge control lever
8. Transmission
9. Levelling board adjusting turnbuckle
10. Levelling board
11. Sledge
12. Steel pipe wheel

Fig. 8. Rice transplanting machine of a washed-root type.

hours, about 1/5 of the working hours in handplanting. However, so far as plucking is concerned the work must be done by hand, because there is no seedling plucker completed at present. The transplanting machine now in use can not work correctly when seedlings have roots 5 cm long or more or their roots are entangled with each other. Accordingly transplantation by means of these machines requires additional working hours for the pretreatment of seedlings which planting by hand can spare. As it takes a worker 10–12 hours to prepare seedling for 0.1 ha of the field, a full work with a transplanting machine requires 4–5 workers for plucking seedlings. And yet the total time necessary for transplantation by the machines is only 1/2 less than that for planting by hand. These results show that the development of seedling pluckers is the most necessary for the practical use of transplanting machines. A plucker has been made for trial to pluck upland seedling grown in drills. This machine is capable of plucking the seedlings for 0.1 ha of the field in about one hour when a nursery is in dry or flooded condition, and the roots of the obtained seedlings are covered with little soil. But these seedlings are not sufficient in their separability into individuals and in the lineup of their roots in the seedling box of pluckers. Studies are now in progress to quickly improve these defects. For the plucking work in wet nurseries, and the bed-making with a net are also under study. In this method, a net is spread on a nursery bed, and is pressed against soil surface and seeds are sown on it, and seeds are covered with soil to grow seedlings. To pluck seedlings, the seedlings are lifted up with the net and are separated from it. As the net becomes too heavy to lift up by hand when seedlings grow to the stage of 6 leaves, various lifting machines have been made tentatively. At present, the plucking by this netting method takes 2–3 hours to get the seedlings for 0.1 ha of the field.

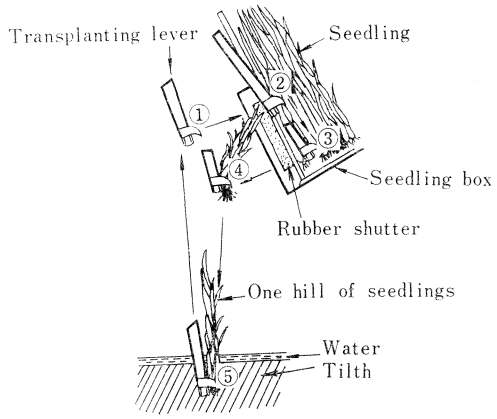


Fig. 9. Transplanting mechanism.

2) Damage to seedlings: Seedlings are sometimes folded during the process of pulling them out of the seedling box of a transplanting machine (An example is shown in Fig. 9) and in the process of inserting their roots into the soil. The folding seedlings are late in rooting, so that their reduced growing period occasionally causes the decrease in yield in cold districts, and also in warm districts the time of spraying herbicides is delayed by their retarded growth, so that weeding becomes difficult.

The folding of seedlings during the pulling out process occurs: when seedlings are held with the holder at an upper part of the stem owing to an inadequate adjustment of machines; in case seedlings are not well separated from each other, and other seedlings are pulled out together with the ones held with the holder; and if the soil of the field is too hard. Studies are now in progress of improvement to make the adjustment of machines easy and to check the coming out of seedlings other than the ones held with the holder.

(2) Rice transplanting machine of a soil-covered-root type

Machines of this type are mostly designed for transplanting rice seedlings grown in nursery boxes (Fig. 10) at a stage of 2.0–2.5 leaves. The manpowered machine for

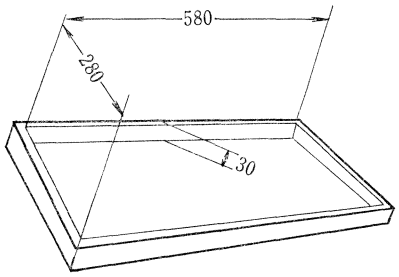
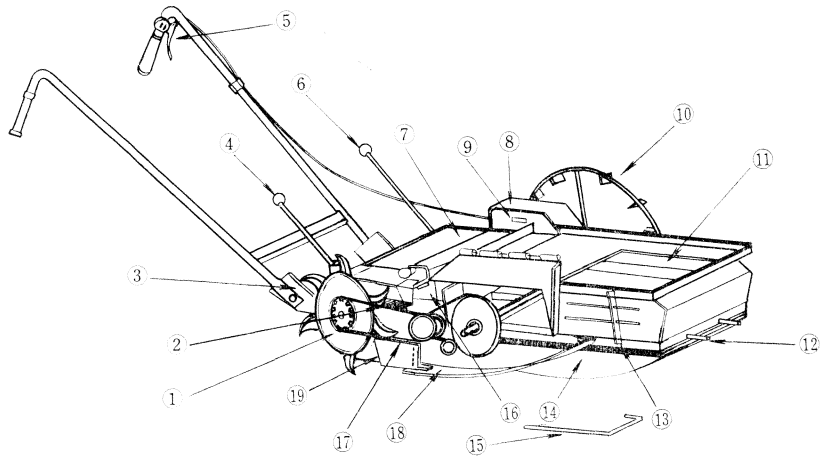


Fig. 10. Nursery box.

one row (Fig. 11) was first put on sale in 1966, being followed by every year's improvement, and 50,000 machines are in use at present throughout the country. The powered transplanting machine for two rows was put on sale in 1967, and eight kinds of these machines different in mechanism from one another are now on the market.



1. Star wheel: to cut and plant seedlings
2. Conveyor belt: to carry seedlings
3. Handle-bar controller: to adjust the angle of handle-bar to the machine body
4. Float controller for vertical direction
5. Seedlings flow control lever: to control seedlings flowing out from the seedling box
6. Wheel adjuster: to adjust sinking of the wheels so as to run machine smoothly
7. Seedlings guiding board
8. Device for carrying out seedlings
9. Fixer of roller
10. Wheel: to drive other rotating parts
11. Seedling box holder
12. Handle-bar
13. Marker (1): to adjust the spacing between rows on which seedlings are planted. (Holes from bottom upward on the guide board show those of marker respectively for the spacings of 24, 27, 30, 33, and 36 cm.)
14. Float
15. Marker (2): to be fixed to Marker (1)
16. Gear-box
17. Chain
18. Levelling board: to level the surface of field where rice seedlings are to be transplanted
19. Blade

Fig. 11. Rice transplanting machine of soil covered-root type.

These machines are used for transplanting the young seedlings at a stage of 2.0–2.5 leaves in the field. Therefore, the new rice cultivation different from old practice in planting time and fertilization, etc. has been necessary to be improved and the new cultivation techniques have been nearly established. The main reason why these transplanting machines came into popular use inspite of the need of new techniques unfamiliar to farmers must be: The time required for plucking the seedlings for 0.1 ha of the field is only 0–30 minutes, and the time necessary for planting the seedlings is 2.5–3.0 hours when a manpowered machine for one row is used and 1.5–2.0 hours

in case of a powered machine for two rows. That is, the use of these machines reduces working time for rice transplantation to about 1/9 of that in the old hand-planting method, resulting in a considerable labor-saving. Studies made on the production of the seedlings with soil-covered roots for machine-planting are as follows.

1) Method of the growing of seedlings: Three methods are now in use for this purpose.

(a) Band seedling method: A comb is set in each nursery box as shown in Fig. 12,

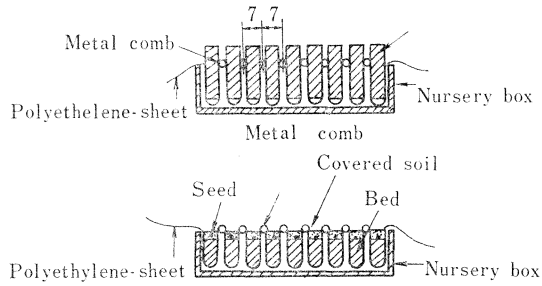


Fig. 12. The process of nursery making in a box.

and a polyethylene sheet is put on the comb to make wavy folds in the sheet by pressing it into each space between the teeth. Bed soil is put in the depressed parts, and seeds are sowed there and covered with soil to grow seedlings. In this method, seedlings are obtained in the form of individually separated bands, which are put on a transplanting machine as they are contained in a nursery box. And when the polyethylene sheet is pulled up with the sheet roll of the machine, the bands can be taken out at regular intervals and no special time is required for plucking seedlings. These bands of seedlings, however, are not suitable for the powered transplanting machine, because the separated bands of seedlings must be connected with each other during the operation of machines.

(b) Continuous band seedling method: In this method, each band of seedlings in a box is separated from those with septa as shown in Fig. 13. But it is connected

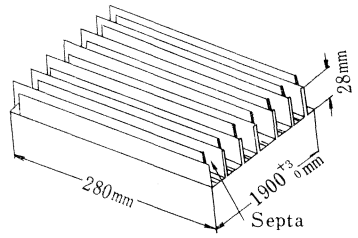


Fig. 13. Undulating septa for making the continuous band of seedling.

with the neighboring ones at both ends, respectively, so that all the bands in a box make one continuous band as a whole. To prevent the breaking of the band, it is desirable to use some reinforcement. The weak points of this method are: the septa and reinforcement are expensive; it takes 2–3 hours to seed nursery boxes to obtain the seedlings for 10 a of the field.

(c) Mat seedling method; Seeds are sowed in the bed soil contained in nursery boxes and covered with soil to grow seedlings. The time required for seeding to obtain seedlings for 10 a of the field is only about 30 minutes, and the nursery box is inexpensive. However, the seeds sowed in the box are often raised up from the surface of the bed, and seedlings grown in such a condition can not be correctly transplanted. The prevention of this raising up of seeds by irrigation and direct piling up of the boxes has been studied. When the bed soil is sandy loam, the correctness of transplanting work is reduced.

The above-mentioned methods of seedling production were developed in the order of a), b) and c) and are useful in their own way. Studies are yet going on to establish less expensive and more labor-saving methods for the production of seedlings.

2) Bed soil: About 60 kg of bed soil is needed to grow seedlings for 0.1 ha of the field. Therefore, it is estimated that the facilities for cooperative growing of seedlings now under investigation will need a huge amount of the bed soil which must be uniform in quality from a viewpoint of the management of the nursery. To meet the difficult situation of obtaining a necessary amount of bed soil, studies on substitutes for soil (carbonized materials and urethane resin, etc.) are being made.

3) The transplanting machine for older seedlings with soil-covered roots: at present, young seedlings are transplanted at a stage of about 10 cm long at the longest, so they are apt to be submerged in the water if the field is not sufficiently even. And to avoid the submersion, it is necessary to spend many hours in leveling the surface of soil. It is also necessary to transplant young seedlings earlier than the older ones. However, early planting is not practicable in some districts by reason of irrigation, weather or the preceding crop. Under these circumstances, studies are being carried out on the method to rear them to a stage of 5–6 leaves without changing the amount of seeds to be sowed per unit area of nurseries.

The above mentioned is an outline of studies made in Japan on the direct seeder and transplanting machine for rice culture.

Discussion

A. U. Khan, IRRI: Is any work being done on sowing pre-germinated paddy on the puddled soil in Japan? If so, at which institutoin?

Answer: Yes, some work is being done at the Institute of Agricultural Machinery, Omiya. We attempted to sow the seeds with their buds 2 to 10 mm long at the depth of 10 to 30 mm for the purpose of making uniform the seedling establishment and of preventing the lodging. But the attempt is kept in temporal abeyance because the lack of oxygen was found out. We now have under consideration the way of coating the seeds with oxygen exhaling matter.