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Development of Direct-Wet-Rice-Seeding Machines in Korea

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ABSTRACT

History, achievement and future of direct-wet-rice-seeding technique in Korea and problems encountered in on-farming research were introduced. Some farmers are very eager to lower production cost and save labor. Their effort results in several direct-wet-seeding methods and seeding machines. The design problems and improvement points related to the direct-wet- rice-seeding machines were drawn out of field test.

Key Word : direct wet seeding, seeding machine, rice, Korea

1. INTRODUCTION

Rice in Korea has been considered as a fundamental for Korean culture and Korean spirit. Mechanization of rice cultivation has been fairly well proceeded with wage increase and labor reduction accompanied by economic development. The major machinery for rice cultivation are tractors, combines, transplanters. High wage, small cultivation area, and many expensive machines can not but result in high rice production cost. Our production cost exceeds more than three times, compared to that of rice-exporting countries. As international pressure to open Korean rice market increases, Korean farmer either become aggressive to seek a method to survive or give up rice cultivation. In fact, un-plowed paddy land area is increasing rapidly since late 1980's.

Direct rice seeding is one good example how much eager farmers are to survive the international production cost competition. Direct rice seeding techniques have been before transplanting techniques, which was introduced in Korea before 1400's. Current rice seedling transplanting by machines are fairly good in all respects except production cost and labor requirement. Direct rice seeding techniques do not require seedling preparation that is complicated, laboring. Direct rice seeding techniques has many good aspects as well as some problems to be solved such as weed control and side-lodging of rice plant.

Direct rice seeding can be classified into dry-seeding and wet-seeding. Korea Rural Development Administration(RDA) has been researched on direct-dry-seeding, developed machinery and finally stabilized the techniques. However, the direct-dry-seeding techniques show poor performances by their inherent limits. Farmers with muddy soil, that covers nearly half of arable soil in Korea have tried to develop direct-wet-seeding technology on their own. Their trials resulted in excellent achievements such as direct-wet-seeding on no-tilled surface, direct wet seeding on grooved soil curd, and machinery for direct-wet-seeding. Direct-wet-seeding technology

is expected stabilized soon by Korean Rural Development Administration, where breeding of new varieties suitable for direct-wet-seeding and cultivation technique for direct-wet-seeding are intensively researched.

This paper is to introduce history, achievement and future of direct wet rice seeding technique in Korea form the view of agricultural engineer. This paper is a summary of on-farming research conducted by the authors in Chonbuk, Korea in 1992 and 1993.

2. Technical differences between direct-wet-seeding and transplanting of rice seedlings

2.1 Technique of transplanting rice seedling

Transplanting rice seedling in Korea has been accomplished by machinery with 4 or 6 rows. Labor input for transplanting is between 3 and 5 hours-man per 0.4 ha. Transplanting technique require labor not only in transplanting but also preparing seedlings which normally take 30 days. Even if a new technology (young seedling transplanting) cut the preparation time down to 8 days, transplanting requires many complicated laboring work procedures, shown in Figure 1. Work procedure in Figure 1 is not fully mechanized but most widely accepted. In fully mechanized system, the technique needs rice seeding machine, soil digging machine, soil sizing machine and soil steaming machine. In addition, the time of seedling preparation coincides with time of land preparation.

As shown in Table 1, number of farm households and farmers decreases rapidly and farm sizes become larger. The transplanting technique is not feasible anymore to "wide-area-cultivation by small number of farmers", that is a government policy for rice cultivation.

Table 1. Changes of some agricultural environment in Korea from 1975 to 1990

Item	Unit	1975	1980	1985	1990
Total population(A)	1,000	35,281	38,124	40,806	42,793
Farm household population(B)	1,000	13,224	10,827	8,521	6,661
B/A	(%)	37.5	28.4	20.8	15.6
Number of farm household	1,000	2,379	2,155	1,926	1,767
Number of tractors	1	564	2,664	12,389	41.203

(Source: Rural Development Administration, 1991)

2.2 Technique of direct seeding

Direct rice seeding can be classified into direct dry seeding and direct wet seeding. Direct wet seeding also can be divided into seeding on surface(muddy water), seeding into soil, seeding on grooved soil, and seeding on no-tilled soil. Table 2 shows technical differences between direct-wet-seeding and dry seeding techniques. Even though the two seeding methods have some advantages and disadvantages, the two are not competitive but mutually supportable. When direct-dry-seeding becomes difficult by some reason, direct-wet-seeding can be used.

In direct-dry-seeding technique, rice is directly seeded into soil when paddy land is dry. Dry paddy is converted into wet paddy after rice seedlings emerge. Wet soil during shoot development of rice will cut off oxygen and prohibit growth of shoot. It has fairly many chances of rain in Spring in Korea. Inherently direct dry seeding shows poor performance in muddy soil. Also, direct dry seeding technique requires lots of water once after water is supplied into paddy field.

On the contrary, direct wet seeding is subject to bird, rats, side-lodging and poor shoot emergence in some cases. Regardless of considerable defects, direct wet seeding techniques are considered as hopes to reduce labor and production cost in muddy area such as Honam province, well known as grain storehouse of Korea. In Japan, direct-wet-seeding means coated rice kernels with CaO_2 to provide oxygen for shoot emergence of seeds(Nakamura, 1986). Coating technology is not welcomed by Korean farmers because coating procedure needs a coating machine, CaO_2, time and labor. Direct-wet-seeding with coated rice was tried only in government experimental stations.

Direct seeding methods save time for both seedling preparation and in-field work. Direct seeding take only 1 to 1.5 hours-man per 0.4 ha. Effective field capacity(ha/hr) of direct-seeding is 3 times or greater than that of transplanting. If a remote helicopter is employed, field capacity will increase more. Direct seeding method are generally known to produce less yield but some farmers get more yield with less fertilizer using a direct seeding technique.

In contrast to the above advantages, possibility of phytotoxicity increases so that weed control should be done at a specific time by specific herbicide. To prevent side-lodging, careful water management should be done to make rice get enough mass of roots reaching deep below soil surface. To reduce shoot emergence problems, extra attention is necessary when seeded by machines. (Most of the above difficulties occur in direct-wet-seeding).

Table 2. Comparison of direct wet rice seeding and dry rice seeding technology.

Type of direct seeding	Good aspects	Bad aspects
Direct-dry-seeding	Labor and cost saving High field capacity Resistent to side-lodging Good for drought in Spring	Poor in muddy soil Poor if rainy in Spring Difficult weed control Need more water when irrigated
Direct-wet-seeding	Labor and cost saving High field capacity Less fertilizer Airplanes can be used	Subject to side-lodging Shoot emergence can be serious May need CaO_2 coating Birds and rats eat seeds

(Source: Chung, 1993)

3. Methods of direct-wet-seeding in Korea and their characteristics

Direct-wet-seeding techniques have been developed in various forms because they were originated from different locations and by different farmers. Figure 2 summarizes work procedure of direct-wet-seeding methods. Each method has some advantages as well as disadvantages. Some farmers have tried to develop machines for their seeding methods. Of course, it is possible to find direct seeding methods similar to theirs in literature. The basic principles of direct-wet-seeding are to reduce shoot emergence problems and to reduce possibility of side-lodging. Table 3 shows seeding machines in each cases.

In this paper, two most influencing methods were introduced in detail.

Table 3. Direct-wet-seeding machines in Korea.

Seeding method	Seeding machines manufacturer	Prime mover
Seeding on grooved soil curd	Tae-Hong(farmer) Gold-Star(agr. mach. manufacturer) Chonbuk Provincial RDA Chang-Sik(farmer)	Transplanter Transplanter Transplanter Manual
Seeding into muddy water	Yeo-Hong(farmer) Yong-Gil(farmer) various farm mach. manufacturer	Remote helicopter Transplanter *(duster)
Seeding on roughly rotary tilled wet paddy	Yong-Gil(farmer) Hyun-Dai(farm)	Transplanter Tractor
Seeding on no tilled paddy	**	**

* : Dusters are carried by men.

**: There is not a dedicated seeding machine developed but the above seeding machine can be applicable in this case with a little change of it.

3.1 Direct-wet-seeding on grooved soil curd

This technique is aimed to reduce possibility of side-lodging instead of losing possibility of shoot emergence. Top soil of rotary-tilled paddy is composed of very fine particles and easy to collapse. Basic idea is illustrated in Figure 3. As shown in the figure, seeding machine make grooves on leveled top soil when it becomes curd as sedimentation of particles occurs, drop seeds onto the grooves, and then irrigate water to prevent bird from eating seeds. During a week or longer, the grooved top soil slowly collapse and cover the seeds by wavy motion of water. During the same time, seeds can take enough oxygen and make shoots successfully. The seed location is below 4-5cm below the soil surface. Because the rice make branches below 4-5cm below surface, center of mass is lower than that of surface-seeding and rice plant become resistent to side-lodging likewise transplanted rice. Seed amount per 10a is recommended to be 3-5kg, but farmer feel comfortable at the level of 5-8kg/10a. Depending on the seed amount per 10a, amount of fertilizer application per area should be carefully decide to prevent over-population of branches.

3.2 Direct-wet-seeding onto muddy water over rotary tilled soil surface.

This technique is aimed to secure shoot emergence instead of a little risk of side-lodging. Water in paddy field just after rotary tilling contains lots of fine particles. As shown in Figure 4, rice seeds are casted onto the muddy water. The dropped seeds continue falling down from 0.5 to 1 cm below soil surface as soil particles sediment. Seed casting is usually done by hand or a duster for fertilizer application. This method is very excellent from the views of shoot emergence and labor requirement. It is not easy to cast seeds uniformly. However, over-population is not a big problem because rice itself adjust number of branches in their given environment.

4. Development of direct-wet-seeding machines

Seeding machine developments have been started since 1986. Motivation of machine development are clearly to save labor and to manage large paddy field(2 to 3ha per farm). They found that it is very difficult to handle large area with rice planters without

help from others. Developers suffered difficulties in both machine and cultivation method development. Direct seeding machine development is very closely related to cultivation methods. Without development of proper cultivation technique, farmers will not accept the machinery. Some of the machines are molded in factories but most of them are prototypes and still under development. The seeding machines under development by farmers range from a hand-drawing machine to a remote controlled helicopter and are estimated to be commercially available in 1996.

Most direct seeding machines are developed as an attachment to a rice transplanter, which is wide-spread over the country. One reason is that once the direct seeding is adopted, a rice transplanter become needless and the other reason is, the rice seeding machine also needs a prime mover. The basic component of rice transplanters are hydraulically controlled chassis, wheels, floats, transplanting arm and seedling-mat-supplying device. In wet seeding, floating device is necessary except no-tillage seeding. The float works as a final leveling device.

All direct wet seeding machines have some common problems such as uniform distribution and consistent metering. The problems are caused by improperly cleaned seed and change of moisture content of seeds, that affects friction coefficient between seeds and surrounding wall. Most farmer use rice harvested at their own field as seeds next year. The seeds harvested by combines at regular speed, have considerable percentage of broken kernels and have debris of broken leaves and kernels with rachis. The uncleaned seeds often block kernel passage in the machines and cause mistakes in seeding. In direct seeding, germinated rice seeds are planted. Germinated seeds of which root length is longer than 3mm often block the seed passage. A long mis-seeded line is normally seeded by hand and lower efficiency of direct-seeding.

4.1 Machines for direct-wet-seeding on grooved soil curd

Structure of machines

The direct-wet-seeding machine on grooved soil curd have two main parts; metering and groove making. Metering devices adopted are shown in Figure 5. The first, most simple device drop seeds in a row and has very low possibility of mis-seeding but it can't control metering rate. Initial root length does not cause mis-seeding but, the small root of seed are subject to breakage. The second one drop seeds in a row and is easy to control metering rate and have fair chance of mis-seeding. The third, most complicated one drop seeds at a specific interval and easy to control metering rate but have relatively high chance of mis-seeding.

Groove making devices are made of V-shaped plastic or steel plate. Various groove making tools are shown in Figure 6 with dimension. In 1993, groove making devices cause lots of troubles such as bad shape of groove, shallow depth of groove, dirt gathering around the tool. The nose angle of the tool should be decreased to prevent bulldozing soils and dirts. Relative location of the tool to the float should be far enough to drop seed at location out of turbulence effect. Turbulence after the float bring considerable amount of soils and tend to cover seeds. Seeds covered with soil can't grow due to lack of oxygen. The simple tool in the figure is made of a wheel cap of a bicycle. It make nice clean shape of grooves but depth and width of the grooves are too small. The second one use a rubber plate to adjust depth of grooves and attached to the end of the float at its bottom. In field test, groove size made by this tool was good. The last one did not perform well in field. Width of the tool is thought to be small and nose angle to be large.

Field test

In 1993, over 150 prototype machines were commercially distributed and tested in field. Though the machines are prototypes, farmers are anxious enough to but seeding machines. Many expected and unexpected problems found. Some are design problems and the others are user problems. Direct-seeding technique is a labor and production cost saving technique but it is a very high

technology. Some farmers consider this method as simple labor saving techniques and did not follow given instructions. Most of reported failure cases are due to the ignorance of instructions. In 1993, direct-wet-seeding on grooved soil curd technique meets many cases of poor shoot emergence but is fairy good in side-lodging. The problems found in field test are;

1) 'soil covering just after seeding' caused by water turbulence following floats in deep region,
2) 'insufficient soil covering' by small width of groove making tool and dirts gathered around and over the groove making tool.
3) 'continuous mistake in seed metering' due to improper seed cleaning and some design factor,
4) 'seed movement' by in-flowing water.

Some improvement points are;

1) new design on groove making tool and attach method of the tool to prevent dirts gathering around it and make a clean and deep enough grooves.
2) device to reduce water turbulence after the float,
3) device to press seeds on the grooves to prevent re-float by in-flowing water,
4) a electronic sensor to alarm mis-seeding and automatic control device for seed metering to prevent continuous mistake.
5) reliable consistent seed metering irrespective of moisture content and wide span of metering rate
6) device to minimize water turbulence following float,
7) easy and reliable seed metering

4.2 Machines for direct-wet-seeding onto muddy water

Structure of machines

Machines for direct-wet-seeding on grooved soil curd as well as dusters can be used in this cases. In order to use the machines for direct-wet-seeding on grooved soil curd, attached to transplanters, the groove making tool should be removed. Main functional differences between dusters and transplanter attachments are; 1) Seed dropping height of duster is higher than that of the transplanter attachments, 2) Seed distribution by dusters is not uniform compared to that of the transplanter, 3) High speed of conveying air flow in dusters cause seed damage by high speed impact to the conveying tube wall. Direct-wet-seeding by dusters are highly effective, 0.4 hours-man/0.4ha. Structure of dusters are skipped because it is well known.

Field test

This method was wonderful in the shoot emergence stage and side-branching stage. As the harvesting time come near, rice plants with heavy ears tend to relatively easily side-lodge. However farmers who have been done very careful water management do not suffer side-lodging problems. When duster is used in paddy field filled with sufficient water, it was difficult to find out seeded region and caused overlaps in seeding. In this case, farmers performed manual thinning.

The problems of duster, found in field test are;

1) 'overlapping in seeding' caused by double seeding,
2) 'seed damage' caused by high velocity collision of seeds with the conveying tube wall however, manual seeding did not suffer seed damage.

Some improvement points are;

1) mixing some floatable material with seeds to help finding seeded region,
2) replacing tube with wavy wall by tube with smooth surface.

4.3 Problems in on-farming research for a machine development

In this research, authors were asked many times to help developing seeding machines and tried to help as much as possible. However, there was a clear limit and the followings are some problems the authors suffered.

1) Farmers think of themselves as inventors with high originality. They are not ready to give up their own design to make a better machine.

2) Farmers who developed or found cultivation technique tend to generalize their cases. In many cases, soil type, water quality, soil condition affect greatly growth of rice.

3) There are plenty of questions that can not be answered without experiments.

5. CONCLUSIONS

Direct rice seeding is surely labor saving, low cost technology but high technology. High technology means more attention and care. Changing from transplanting to seeding has great influence on rice cultivation. Therefore, research on weed control, fertilizer application and water management should be accompanied by machine development.

Development of direct-wet-seeding machines have been initiated and continued by farmers in most cases. It is time for agricultural engineers to take parts in developing more reliable machines. Engineering research should be done to improve function and reliability of metering device and to make groove making tool perform nicely irrespective of soil condition, and to reduce seed damage.

Direct-wet-seeding as well as direct-dry-seeding techniques are expected to take over 1/2 of paddy field in 2000(RDA, 1991). Reliable direct-wet-seeding machines from transplanter attachments to a remote controlled helicopter are estimated to be available in 1996.

6. REFERENCES

1. Rural Development Administration. 1991. Labor saving rice cultivation technology. Rural Development Administration, Suwon, Korea
2. Chung, Chang-Joo. 1993. Mid-term report on "A study on development of basic design technology for land reformation to enhance field capacity of agricultural machinery". Department of Agricultural Engineering, Seoul National University.
3. Nakamura, Yoshiaki. 1986. Low cost, high yield rice cultivation - Direct-wet-seeding technology. ISBN4-259-51638-8 C2061

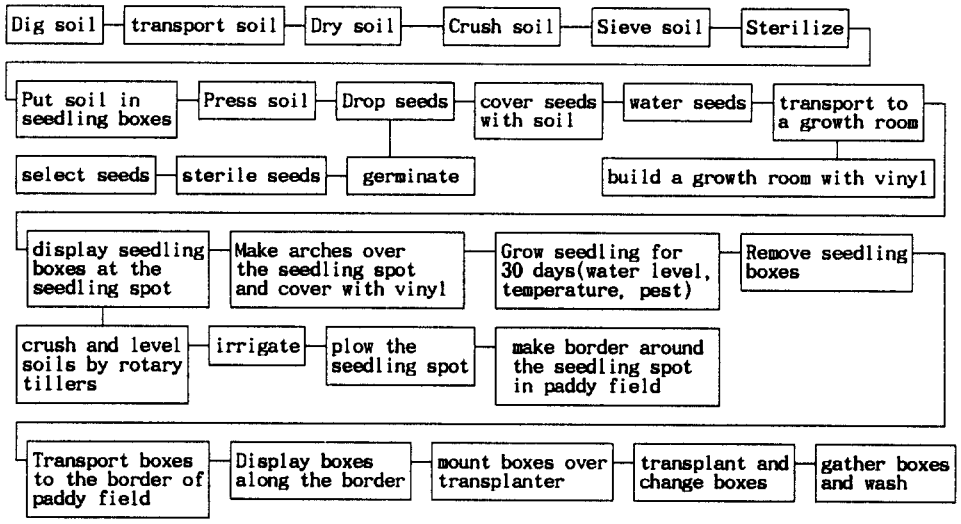
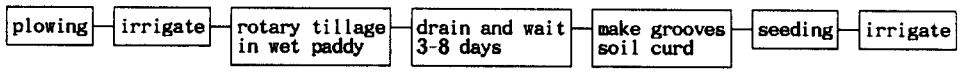
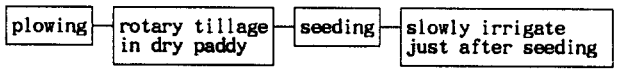


Figure 1. Work procedure of rice seedling transplanting technique.



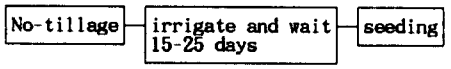
(a) Seeding on grooved curdy soil surface

(b) Seeding into soily water over rotary tilled soil surface.



(c) Seeding on roughly rotary tilled dry soil surface

(d) Seeding on roughly rotary tilled wet soil surface



(e) Seeding on no-tilled soil surface

Figure 2. Work procedure comparison of various direct-wet-rice-seeding methods.

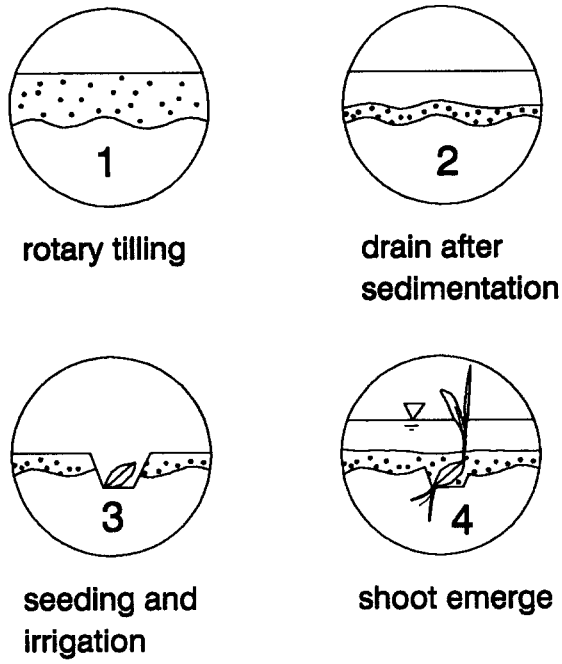


Figure 3. Principle of direct-wet-seeding in grooved soil curd

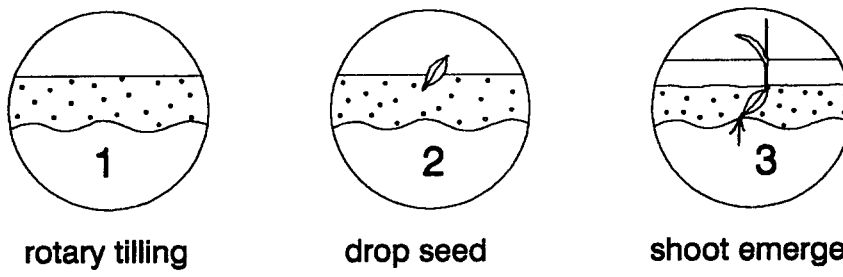


Figure 4. Principle of direct-wet-seeding onto muddy water

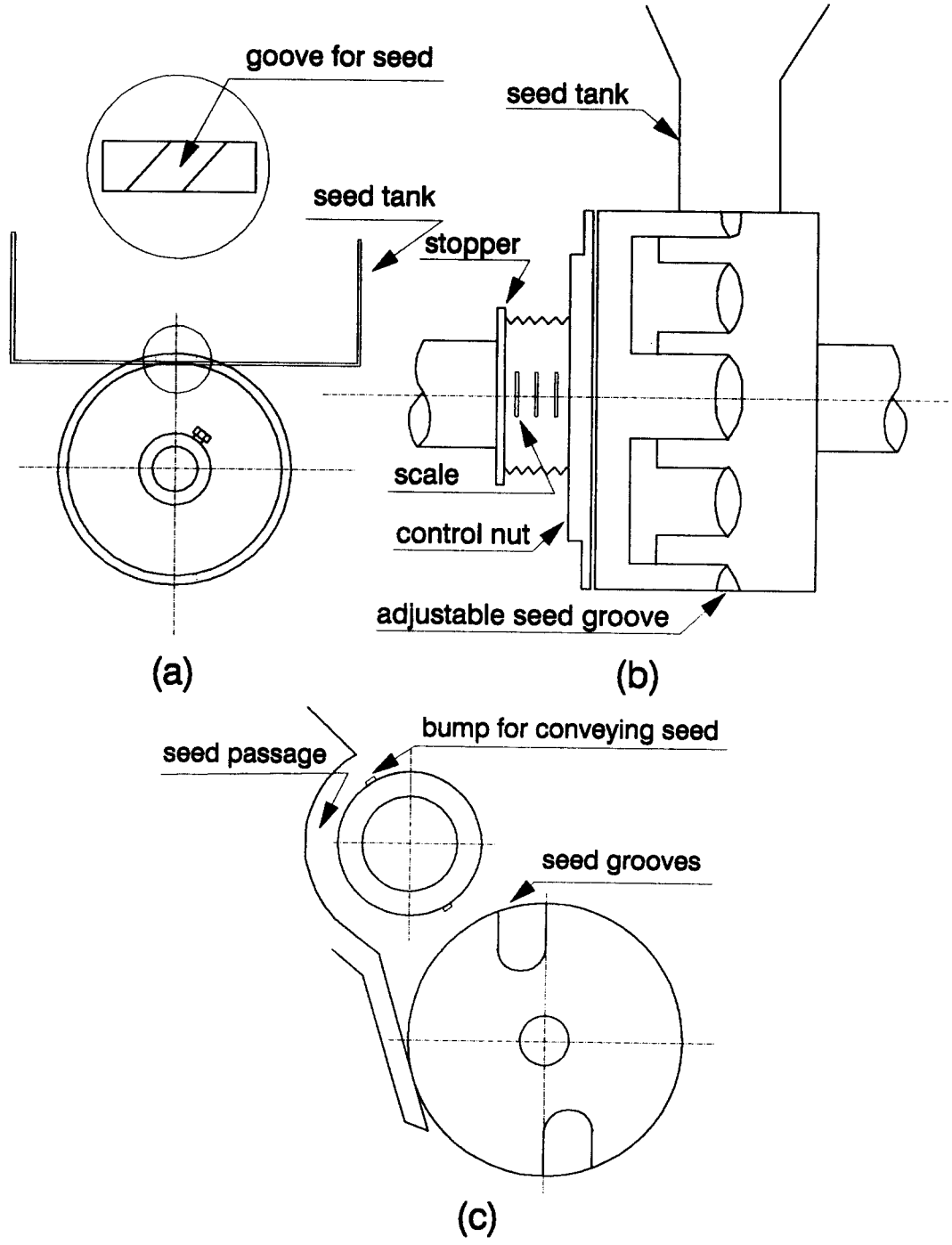


Figure 5. Seed metering devices for direct-wet-seeding

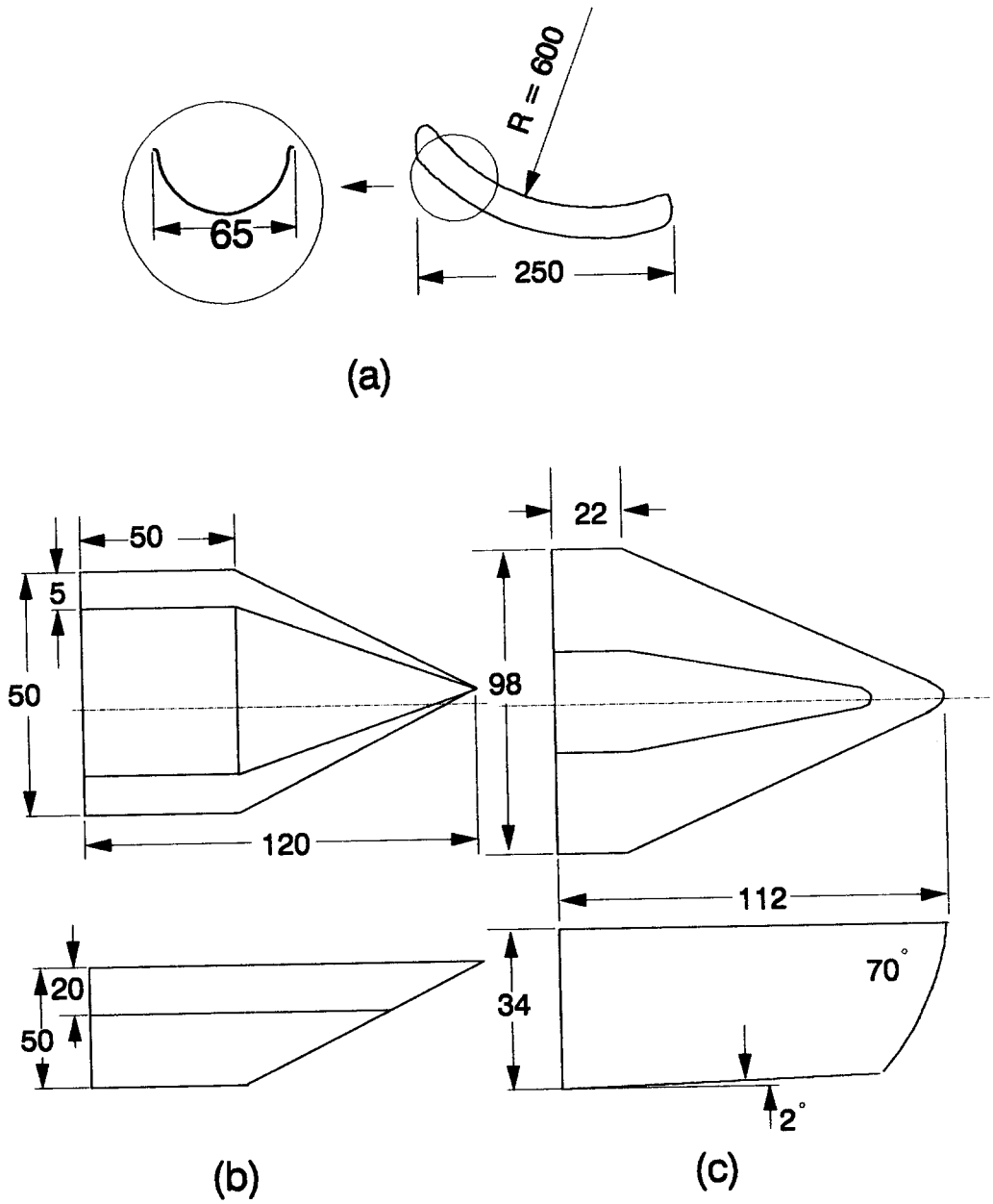


Figure 6. Groove making tools for direct-set-seeding