Development of a New No-Till Seeder for Soybean

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The background and purpose of the research

In Japan paddy fields have been devoted to rice production for two thousand years. Since the 1970's, however, the situation has changed. Part of rice fields has to be converted to upland fields for growing other crops, because over-production of rice occurs every year. To alleviate the supply-demand imbalance of rice the government has planned to convert about 0.8 million ha of paddy fields into upland fields to grow wheat, soybeans, and other crops to be used for silage. Because rice culture offers higher income to farmers than any other crops, it is necessary to grow two upland crops a year on the fields converted from paddy fields. Double cropping a year such as wheat followed by soybean must be practiced with high productivity and low cost. This is the background of the present study.

In the Kanto region, wheat is harvested by the middle of June, whereas sowing of soybean has to be finished at least by the end of June. Switching from wheat to soybean needs to be done in a very short period. In addition, this period is in the rainy season, and hence plowing and sowing are often disturbed by rains or too wet soil condition. Even after sown, the soybean seeds are often spoiled by soil crust formation which is popular in paddy fields in Japan.

Therefore, we tried to develop a new system of soybean cultivation by using the no-till seeder. The use of the no-till seeder will enable us to (1) eliminate plowing and soil-breaking works before sowing, (2) sow seeds in moist and heavy soil, and (3) avoid retarded emergence caused by clay crust formation.

The present study was carried out by the group of the Research Project on "Diversified use of paddy fields" of the National Agriculture Research Center.

No-till seeding

In U.S.A., the original main purpose of the "no-till" practice which was said to date from the 1950's, was to reserve stubbles and straws of the preceding crops on the field in order to protect the field against soil erosion[3,8]. Recently, however, in a part of the East where wheat-soybean double cropping is practiced experiments on no-till seeding of soybean as a simple method of seeding after wheat harvest were conducted[6,7].

In Japan, an early study on no-till seeding aiming at good emergence of soybean in wet soil was made in 1972[2]. Later, only a few studies have been made on the soybean culture with no-till seeding, as a result of much progress which had occurred in mechanization of tillage.

Development of a fully mechanized no-till seeder for soybean was carried out earlier at

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Plate 1. The newly developed no-till seeder in operation

the Chugoku National Agricultural Experiment Station[1]. This machine intended to perform wheat harvesting and soybean sowing at the same time to save labor. Many tests of this seeder, mounted on the Japanese type (head feeding) combine, were conducted with good results. But, it was difficult for this machine to prepare seedbeds (grooves) on the remaining stubbles of wheat rows. Therefore this machine is incompatible with the cultural method of wheat such as random sowing or narrower row sowing which increases wheat yield[4]. In addition, having the structure of combination of harvester with seeder, this machine showed lowered efficiency of the combine, lowered accuracy of the seeder, and increased operator load when a high speed combine like foreign type is used. Regarding the no-till seeding, in general, Sunohara[5] emphasized the necessity of developing a slit opener which enables to make grooves in the soil surface layer for seeding.

On the other hand, the National Agriculture Research Center initiated the research based on the concept to device a no-till seeder for soybean by using a powered slit opener

Plate 2. Rows of soybean seedlings sown by the no-till seeder

in 1984[7]. The machine developed on this concept has reached the stage for practical use in the fields, and its outline is presented here (Plate 1).

The new no-till seeder

1) Structure

It is shown diagrammatically in Fig. 1. This seeder is composed of four sections (each for a row), and performs sowing of seeds one by one with simultaneous application of fertilizer and insecticide to the rows. By changing the working device from the slit opening disk to the tillage blade, this machine can be used as a cultivating machine.

The principal components of each section are the seeding units (seed hopper, seed-feeding plate and tube, and attachment for soil covering of seeds, the slit opener unit driving mechanism, and regulator). In addition, this machine has units for application of fertilizer and insecticide. The frame of the seeder mounted on four pneumatic tires (land wheels) is a tubular welded construction.

The slit opener unit which is suspended from a frame is a disk which has corrugated protrusions arranged radially on the surface of the disk. Each protrusion extends from the portion 9.5 cm to the portion 1.5 cm apart from the periphery of the disk. This disk obtains its drive from the power-take-off (PTO) shaft of a tractor through a reducer and a chain drive. When the seeder travels, the slit-opening disks rotate in the direction of travel cutting the soil surface to form grooves (slits) for seeding. The disk surface thrusts the soil aside so as to make precisely V-shaped grooves. This function of the disk makes the operation of this seeder possible even on the field with many stubbles remaining and even when the soil is moist and

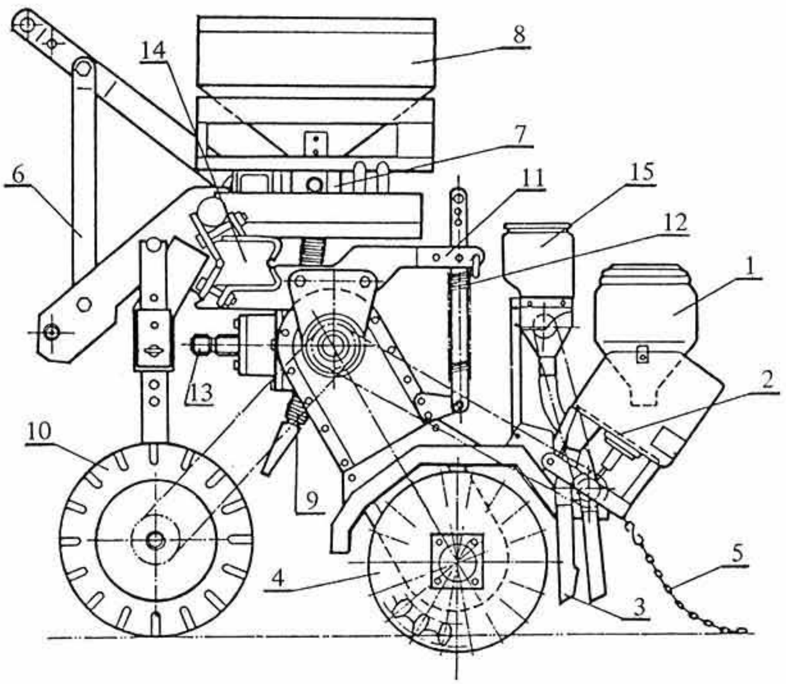

Fig. 1. Schematic diagram of the newly developed seeder
1: Seed hopper, 2: Feed plate, 3: Feed tube, 4: Slit opening disk, 5: Soil-covering device, 6: Hitching elements, 7: Fertilizer distributor, 8: Fertilizer hopper, 9: Fertilizer drill tube, 10: Land wheel, 11: Support rod, 12: Spring, 13: PTO shaft, 14: Beam (frame), 15: Insecticide hopper.

heavy. This opener penetrates better than twin disk openers or single disk openers without axle, and hence, it is suitable for compact soils. The cutting depth of it is regulated by changing the tension of a spring mounted on the support rod.

Seeds stored in the seed hopper are transferred to the seed tube and funnel by the feeding mechanism and gravity. The seed funnel is placed just behind the slit opener, and the seeds are distributed into the grooves one by one at an equal interval.

The fertilizer is applied, forming the continuous row with a width of 10–20 cm along the seed row. The fertilizer flows by gravity from the hopper to the fluted roller with a horizontal axis of rotation. By the rotation, the fertilizer is discharged into the drill tubes, and spread in front of the slit-opening disk. Shafts of the seeder and the fertilizer distributor are driven by the axle of land wheels through chain and sprocket.

Since each section of this machine is independently suspended, power requirement of the tractor is very low, so that it is easy to increase the number of sections (rows). Furthermore, due to no tillage, it is possible to increase further the labor efficiency and cropping area of soybean.

Now, this machine can be manufactured with inter-row spacing of 60–80 cm and working width of 2.4–3.2 m, and may be hitched to a 30–50 PS class tractor.

The major specification of this machine is given in Table 1.

2) Performances

In the course of designing, a large number of basic experiments were carried out on the groove shape, seeding accuracy and percentage of seedling emergence as related to various factors such as soil type, soil moisture content, traveling velocity, the ratio of the peri-

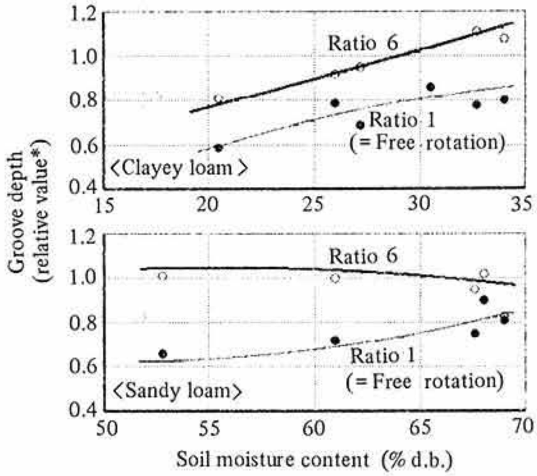

Fig. 2. Effect of soil moisture content on the depth of grooves formed at different driving ratios of the disk
* Relative value, taking the value of the ratio 3 as 1.0.

Table 1. Specification of the newly developed seeder

Model	No-till seeder with driven furrow disk opener
Type	4-wheel tractor mounted type (3-point hitch)
Dimension	
Overall length	1,380 (mm)
Overall width	3,400 (mm)
Overall height	1,170 (mm)
Weight	550 (kg)
Rotation of slit-opening disk	100—200 r/min in the direction of travel
Planting unit	Inclined axis of rotation plate feeder
Fertilizer distributor	Fluted roller
Chemicals distributor	Vertical axis disk feeder
No. of planting rows	4
Inter-row spacing	60— 80 (cm)
Flow rate of seeds	150—160 (no./ha (×1000))
Traveling velocity	1.4—3.0 (km/hr)
Efficiency	0.3—0.5 (ha/hr)

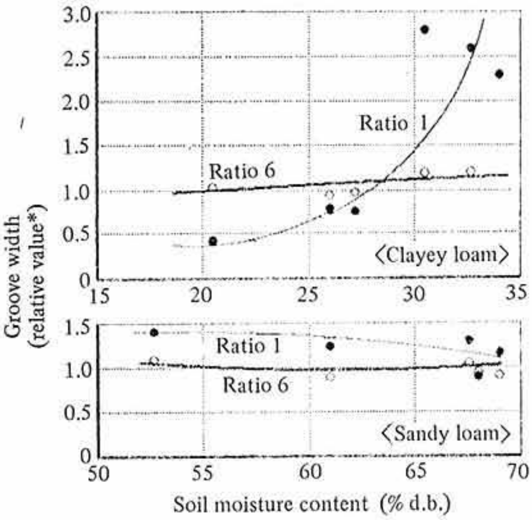

Fig. 3. Effect of soil moisture content on the width of grooves formed at different driving ratios of the disk
* Relative value, taking the value of the ratio 3 as 1.0.

pheral velocity on a disk divided by the ground speed (driving ratio of disk), etc.

Figs. 2 and 3 show the influence of soil conditions on the groove depth and width, respectively.

At different soil moisture conditions, traveling velocity did not much influence the groove shape. The groove depth and width depended on whether the disk was driven or not. In case of free rotation, the disk hardly penetrated in the soil. In wet conditions, sticky soil like clay adhered to the disk and was dug up on to the soil surface, causing difficulty of making good grooves for seeding. On the other hand, when the soil moisture is especially high, the shape of grooves became deeper and wider as driving ratio of disk became higher, and this tendency was remarkable in clayey soil.

Next, under the same conditions, we also tested the difference of seeding accuracy (Fig. 4) between the no-till seeder and the combination seeder which consists of a rotary tiller and an inclined plate rotate seeder.

The seeding depth fluctuated very much in case of free rotation of the no-till seeder, while the combination seeder gave the best

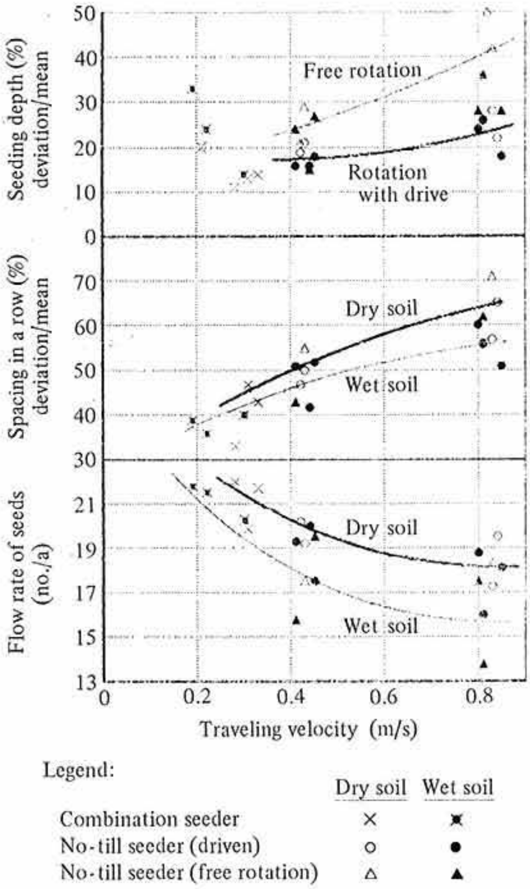

Fig. 4. Effect of traveling velocity on seeding accuracy as related to different ways of tillage and soil moisture condition

result. But in wet soils, when large soil particles remained after rotary tilling, the deviation of seeding depth for the combination seeder was the same as that for the no-till seeder. The spacing between seeds in a row and the flow rate of seeds tended to fall into disorder as traveling velocity increased. However, emergence percentage was quite high (over 90%) even in wet conditions and the difference between the no-till seeder and the combination seeder was not clear (Table 2). Moreover, there was no difference in initial growth, when seeding was done by the end of June.

From these results, we considered that the traveling velocity of the no-till seeder should be 0.5 m/s (1.8 km/hr) in wet conditions, and also driving ratio of disk should not be so

Table 2. Emergence and initial growth of soybean sown with conventional tilling (using a rotary tiller) or without tilling (1986)

Date planted	Soil[1)]	Soil moisture	Tillage	Seeds sown no./ha(×1000)	Plants emerged no./ha(×1000)	Percent emergence %	Dry weight /plant[2)] mg(×100)
June 18	A	Very wet	No-till	148	139	93.7	3.9*
	B	Very wet	No-till	169	163	96.6	3.7*
			Conventional	186	179	96.2	3.3*
June 19	A	Dry	No-till	183	182	99.3	4.6*
			Conventional	221	214	96.8	3.8*
	B	Dry	No-till	194	187	96.3	3.0*
			Conventional	200	193	96.4	2.9*
June 20	A	Dry	No-till	176	172	98.0	3.5*
			Conventional	214	207	96.7	3.6*
June 27	A	Adequate	No-till	186	182	98.1	5.7**
			Conventional	214	214	100.0	—
	B	Adequate	No-till	194	188	96.9	6.4**
			Conventional	207	200	96.6	4.9**
July 3	A	Wet	No-till	187	170	91.1	5.2**
			Conventional	214	214	100.0	6.3**
	B	Wet	No-till	185	180	97.5	4.6**
			Conventional	207	179	89.3	3.7**

1) : Soil texture A is clayey loam, and B is sandy loam.
2) : Dry weight was measured on July 8 (*) and July 23 (**).

high (not much exceeding 3). But in field conditions good for the tractor traveling, seeding is done quite well, without disturbing emergence. In conditions of dry fields, seeding is done fairly well at high driving ratio of disk.

The other important factor influencing the performance of the no-till seeder is the adaptability to quality and quantity of straw residues scattered on the field at harvesting of wheat. If the adaptability could be improved to be highly flexible, this machine will become the better one for sowing in a short period.

Practical usefulness of the no-till seeder in the wheat-soybean double-cropping system

An experiment of wheat-soybean double-cropping was carried out in a paddy field of 0.3 ha. Early wheat cultivars, "Nishikaze-komugi" and "Asakazekomugi", were sown after rotary tilling late October to early November. The crops were harvested using a head feeding combine in the middle of next June. At the time of harvest, wheat straw was cut into 5–15 cm pieces, and scattered on the ground. The wheat yields were 5.5–5.6 t/ha.

Table 3. Emergence and grain yield of soybean sown with conventional tilling (using a rotary tiller) or without tilling

Method of seeding	Year	Place of straw residue	Percent emergence (%)	Length of main stem (cm)	Width of basal stem (mm)	100 seeds weight (g)	Yield (kg/ha)
No-till	1986	Soil surface	94.8	59.2	7.1	36.0	3,760
No-till	1987	Soil surface	93.0	50.9	7.4	35.4	3,460
Conventional	1986	In the soil	98.5	58.0	8.0	38.2	3,580

Following the harvest of wheat soybean was sown, using a 30 PS class tractor on which the no-till seeder of four rows was mounted. The tractor ran at a speed of 0.5 m/s, and at the same time the compound fertilizer, containing 3–10–10% of N, K_2O and P_2O_5, was applied at the rate of 30 kg N/ha on the soil surface. The seeding rate was 65 kg/ha, and the seeding depth was 1.5–4.5 cm from the soil surface (Plate 2).

The advantage of introducing the no-till seeder

The use of the no-till seeder can increase labor efficiency. There is a serious competition among different farm works for labor during a very short interval between wheat harvest and soybean sowing. The no-till seeder alleviates the competition and enables to sow soybean at the suitable time, resulting in increased yields of soybean. It can also increase the area planted with soybean.

These advantages were demonstrated as follows, using the computer simulation. In case that we intend to grow soybean on 5 ha of field, after the harvest of wheat from 10 ha of field, we can begin the soybean sowing 14 days earlier by using this machine, and, as a result the soybean yield was higher than that obtained with the conventional tillage by more than 450 kg/ha. It means that the increase of the total yield is 2.3 tons, equivalent to about ¥700,000 (the production cost is the same for both culture). Besides, additional ¥230,000 can be obtained due to the expansion of cropped area from 5 to 10 ha. The total profit is about one million yen of the income increase.

At present, this machine is still expensive (1.6–1.7 million yen) because not being produced on the line. It is, therefore, advisable that the machine should be used on a large scale field more than 10 ha.

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