CHARACTERISTICS OF MINIMUM TILLAGE BY ROTARY TILLER FOR DIRECT RICE SEEDER

S. H. Park[1] , K. S. Lee[2] and C. S. Lee[1]

[1] Bio Production Division
National Agricultural Mechanization Research Institute,
Suwon, Kyunggi-Do, 441-100, Korea
E-mail : shpark@rda.go.kr
[2] Dept. of Bio-Mechatronic Engineering, Sungkyunkwan University
Suwon, Kyunggi-Do, 440-746, Korea

ABSTRACTS

A series of soil bin experiment was carried to investigate the effects of rotary blade shape, rotational direction of rotary blade, number of blade and soil cutting disk blade on the characteristics of partial tillage. Among the three types of rotary blades, rotary blade for cultivator was considered to be proper for partial tillage of direct seeder considering the torque requirements and ratio of soil breaking.

There is no need to attach so many blades to the rotary shaft. Four rotary blades were enough for efficient partial tillage by rotary tiller. Though soil cutting disk blade assisted the better formation of seedbed furrow, attachment of the soil cutting disk blade increased torque requirements.

Key word : Minimum tillage, Partial tillage, Direct seeder

INTRODUCTION

Even though main operations of paddy production are almost fully mechanized in Korea, labor requirements per hectare are three hundreds and ten hours. This value is twenty one times compared to the labor requirements in USA and represents the high production cost and low efficiency of farm mechanization systems.

To reduce the production cost, these days several methods are suggested, such as expansion of direct seeding area, expanding the transplanting area of young seedling, extend the no tillage or minimum tillage technique, reduction of chemical spraying by efficient management system, efficient water management system by improved water outlet and bulk grain harvest system.

Minimum tillage technique for direct rice seeding is to eliminate the first and secondary tillage, and to carry out the partial tillage operation by rotary tiller only for the directing seeding place. In this case seeding and covering operations are carried at same time. Thus labor requirements can be reduced drastically by eliminating the first and secondary tillage, growing seedling and transplanting operation.

Before the land preparation, there are lots of paddy and weed residues in the paddy field, so it is very important to develop the minimum tillage techniques to cut and break residues into pieces, and mix with soil, and to make the seed bed with constant depth.

Studies of minimum tillage and no tillage have started from 1950s, but until the 1970s these techniques did not come into practical use. As the herbicide is effectively used, the area of no tillage reached to the 25% of total arable land in USA. USDA report that this area will be increased 50~80% until 2010. In Korea, Rural Development of Agriculture and Chung Nam National University have carried research on the partial and no tillage, but the results were not so successful.

The objectives of this study are to investigate the characteristics of minimum tillage by rotary blade for developing the partial tillage direct seeder. The effects of rotary blade shape, rotational direction of rotary blade, number of blade and soil cutting disk blade on the characteristics of partial tillage was investigated.

MATERIALS AND METHODS

Experimental rotary blade.

Three kinds of rotary blade were selected for this experiment such as general-purpose rotary blades for the tractor and cultivator, and a leveling purpose rotary blade in the paddy field. These experimental rotary blades are selected among the rotary blades produced commercially in Korea, and table 1 and fig. 1 shows the specifications and shape factors of these blades, respectively. These blades are selected by considering 1) cutting width of the blade should be more than 40mm for cutting and breaking paddy residues into pieces and making the seed bed with sufficient width. 2) Maximum radius of rotation should be more than 150mm to keep the cutting depth as 60mm without touching the surface by rotary shaft.

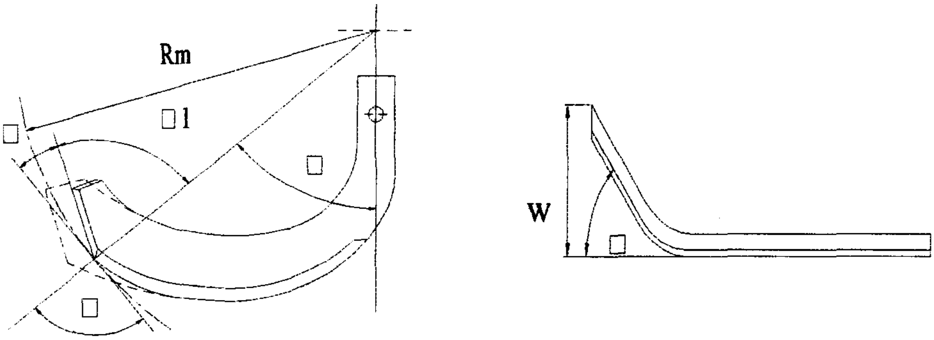

Fig. 1. Shape factors of rotary blade.

Table 1. Specifications of rotary blade.

Factors	General purpose rotary blade for tractor	General purpose rotary blade for cultivator	Leveling purpose rotary blade for tractor
Edge-curve angle(□)	90□	90□	90□
Clearance angle(□)	20□	0□	24□

Scoop angle(□1)	70□	90□	66□
Shape angle(□)	60□	36□	39.5□
Cutting width (W)	50mm	40mm	45mm
Max. Rotation radius(Rm)	200mm	240mm	168mm
Bending angle (□)	55□	60□	73□

Soil bin system

Soil bin system was used for this experiment. The USDA textural classification of experimental soil in soil bin is sandy loam

Soil hardness measured by SR-2 type cone penetrometer ranged from 2.5 to 14.7kg/㎠. Soil moisture content was 34.6%(d.b.) and this value is a little higher for sowing rice. The physical properties of experimental soil are shown in table 2.

Table 2. Physical properties of experimental soil

Soil	Hardness(kg/cm^2)					Moisture content (d.b.%)	Composition(%)		
	5cm	10cm	15cm	20cm	Avg.		Sand	Silt	Loam
Sandy loam	2.5	2.8	9.5	14.7	7.4	34.6	56.5	27.5	16.0

Measuring system

Tilling torque of the rotary blade was measured using the test carriage of the soil bin system. Strain gauge was attached to the driving shaft of the rotary tiller attached to the test carriage of soil bin system. Torque measuring system was composed of amplifier, oscilloscope and computer based data acquisition system as shown in fig. 2. Torque value was calculated by output voltage calibrated by equation as shown in fig.3.

Soil cutting and movement was recorded by Kodak high speed camera with shutter speed of 998 frame/sec. Recorded picture was stored to a computer as a file, and also stored to a S-VHS video system.

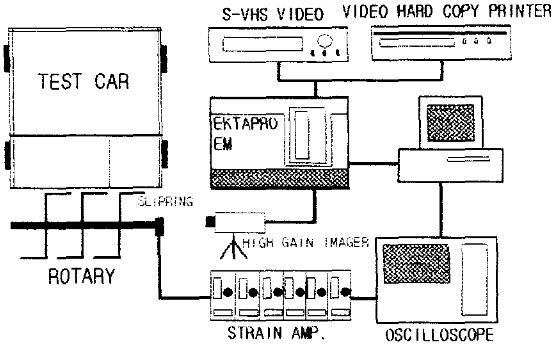

Fig. 2. Schematic Diagram of Measuring System.

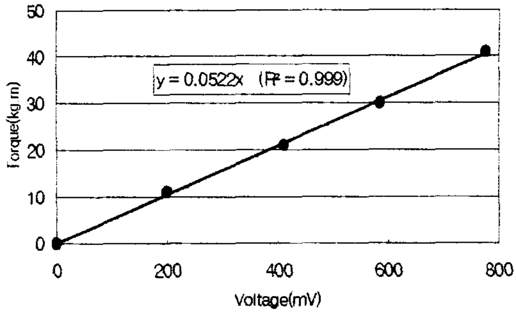

Fig. 3. Relationship between torque and voltage

Experimental methods

The effects of rotary blade shape on the characteristics of partial tillage were investigated by using the three different type of rotary blade as shown in table 3.

Also the effects of rotational direction of rotary blade were investigated by changing the direction of rotation, or down cut and up cut. By changing the number of rotary blade from one to ten, the effects of number of blade on the characteristics of partial tillage was investigated. Soil cutting disk blade was attached to the both side of rotary shaft to investigate the effects of disk blade on the formation of seedbed. Tilling width was kept about 6cm and the speed of rotary blade shaft was 234rpm. Three levels of tilling pitch were 4.0, 7.0 and 11.0 cm. For measuring the ratio of soil breaking, soil was sampled from the 30 × 30cm square and calculated using the following equation 1.

$$R_{SB}(\%) = (W_{TS} - W_{OS}) / W_{TS} \times 100 \quad \cdots\cdots (1)$$

R_{SB} = Ratio of soil breaking

W_{TS} = Weight of total soil per unit area

W_{OS} = Weight of soil diameter 2cm or more

Table 3. Experimental conditions

Items	Conditions
Type of rotary blade	3 types(general purpose rotary blades for the tractor, and cultivator, and a leveling purpose rotary blade in the paddy field
Direction of rotation	Down cut and up cut
No. of rotary blade	1, 2, 4, 6 and 10
Soil cutting disk blade	Use or not use

RESULTS AND DISCUSSION

The effects of rotational direction on the Characteristics of rotary tilling

Two rotary blades for cultivator attached to the rotary shaft and this rotary tiller was used to investigate the effects of rotational direction on the characteristics of rotary tilling. Tilling pitch and depth were 7.0 cm and 6.8 cm respectively for this experiment. Fig. 4 shows the tilling torque of rotary shaft with two blades and ratio of soil breaking as the rotary shaft rotate 180 degree during the process of up cut and down cut. Torque requirements of a rotary blade during the down cut process were higher than that of a rotary blade during the up cut process. This results shows a good agreement with the results, reported by Grinchuck, that torque requirements of rotary shaft during the up cut process was 12~16% less than that of the rotary shaft during the down cut process. Considering only the torque requirements, up cut process of a rotary blade would be advantageous. But as shown in fig. 5, during the up cut process tilling soils were scattered out of the seeding furrow and seedbed was not formed. So up cut process was not considered to be proper for the partial tillage of a direct seeder. Ratio of soil breaking was 11.6% during the up cut process and 5.5% during the down cut process.

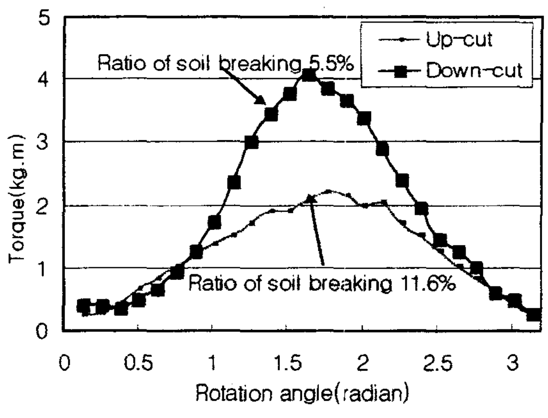

Fig. 4. Torque and ratio of soil breaking during up cut and down cut.

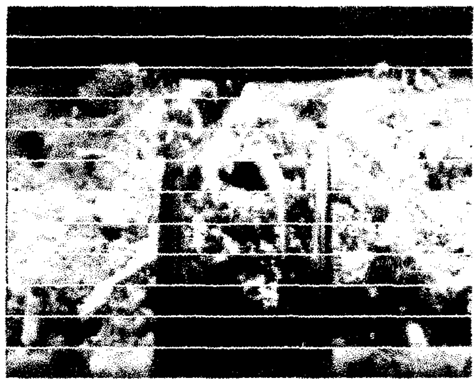

Fig. 5. Shape of soil cutting and broken soil by up cut rotary.

The effects of rotary blade shape on the Characteristics of rotary tilling

Each of the two rotary blades for cultivator and tractor, and two leveling purpose rotary blade in the paddy field were attached to the rotary shaft respectively and these rotary tiller were used to investigate the effects of rotary blade shape on the characteristics of rotary tilling. Tilling pitch was 7.2 cm and tilling depth was 7.0cm. Fig. 6 shows the tilling torque of rotary shaft as the rotary shaft rotates 180 degree during the down cut process. Tilling torque of rotary blades for the tractor was the highest one among the three types of rotary blades. Not so big differences were not found between the torque requirements of rotary blades for the cultivator and leveling purpose rotary blade.

Ratio of soil breaking was 11.6% for the cultivator rotary blades, and this value is the highest one among the three types of blades. Torque requirements depend on the maximum radius of rotation and tilling width of rotary blade. Considering the above results, rotary blade for cultivator would be a proper one for partial tillage of direct seeder. Fig. 7 shows results of soil cutting and breaking by rotary blades for cultivator.

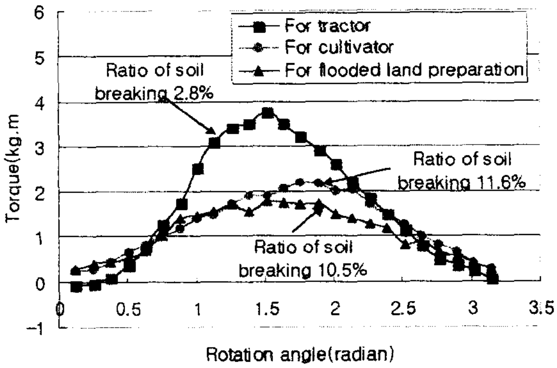

Fig. 6. Torque and ratio of soil breaking by rotary blade shape.

Fig. 7. Shape of soil cutting and broken soil by cultivator type rotary blade.

The effects of number of blade on the characteristics of partial tillage

By changing the number of rotary blade from one to two, four, six and ten, the effects of number of blade on the characteristics of partial tillage was investigated. Rotary blade for cultivator was used for this test. Tilling pitch was 4.1 cm and tilling depth was 7.0cm. Fig. 8 shows the tilling torque of rotary blades as the rotary shaft rotates 360 degree during the down cut process. As the number of rotary blade increased, torque requirements also increased. Torque requirements of rotary shaft with ten rotary blades was highest in comparison to the rotary shaft with one, two, four, and six of rotary blades.

For the rotary shaft with four rotary blades, torque requirements of rotary shaft was lowest because the rotary blades was attached with 90 degree each other and the value of soil cutting width is getting bigger one time and is getting smaller the other time in turns. Thus rotary tiller with four rotary blades appeals to be optimum for partial tillage of direct seeding. Ratio of soil breaking was 24.4% for the rotary tiller with four rotary blades. Fig. 9 shows results of soil cutting and breaking by rotary tiller with four rotary blades.

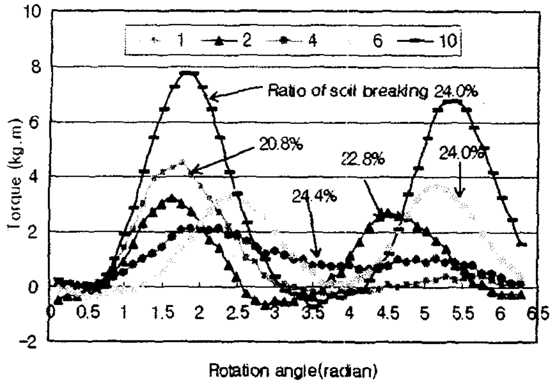

Fig. 8. Torque and ratio of soil breaking by number of blades.

Fig. 9. Shape of soil cutting and broken soil with four rotary blades.

The effects of disk blade on the characteristics of partial tillage

Soil cutting disk blade was attached to the both side of rotary shaft to reduce the soil cutting resistance and to assist the formation of seedbed furrow. Fig. 10 shows torque requirements of rotary shaft with soil cutting disk blade when the rotary shaft rotate 360 degree as up cut process. Tilling pitch was 4.0 cm and tilling depth was 6.0cm. Torque requirements of rotary shaft with soil cutting disk blade were much higher than that of the rotary shaft without soil cutting disk blade. Though soil cutting disk blade assisted the better formation of seedbed furrow, increase in friction between the disk blade and soil block brought about the higher torque requirements. Fig.11 shows results of soil cutting and breaking by rotary tiller with soil cutting disk blade.

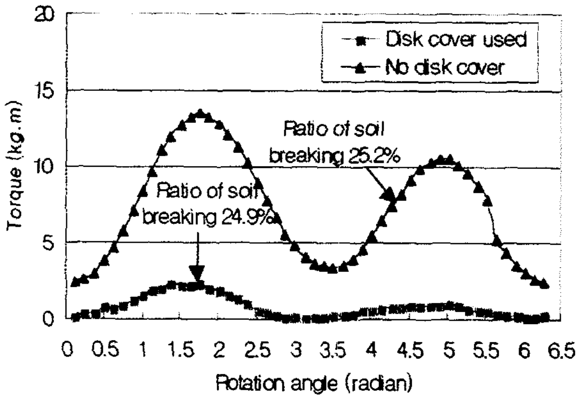

Fig. 10. Torque and ratio of soil breaking by soil cutting disk blade.

Fig. 11. Shape of soil cutting and broken soil with soil cutting disk blade.

CONCLUSIONS

This study was carried out to investigate the characteristics of partial tillage of rotary blade before the development of optimum rotary tiller for the partial tillage of direct rice seeder. The effects of rotary blade shape, rotational direction of rotary blade, number of blade and soil cutting disk blade on the characteristics of partial tillage was investigated. The following conclusions were derived from the study.

During the up cut process of rotary blade, tilling soils were scattered out of the seeding furrow and seedbed was not formed. So up cut process was not considered to be proper for the partial tillage of a direct seeder.

Among the three types of rotary blades, rotary blade for cultivator was considered to be proper for partial tillage of direct seeder considering the torque requirements and ratio of soil breaking.

For the rotary shaft with four rotary blades, torque requirements of rotary shaft were lowest and ratio of soil breaking was highest with the value of 24.4%. So it was concluded that not so many blades are required for efficient partial tillage by rotary tiller.

Through soil cutting disk blade assisted the better formation of seedbed furrow, increase in friction between the disk blade and soil block brought about the higher torque requirements.

REFERENCES

1. S. S. Kim, Y. S. Lee and J. K. Woo. 1997. Study on the Improvement of rotary blade-Tilling Load Characteristic Analysis of the Three Kinds of Rotary Blade. Journal of Korean Society for Agricultural Machinery 22(4) : 391 ~ 400.

2. S. H. Park, D. K. Choe, J. Y. Kim, W. K. Park and D. H. Lee. 1999. Characteristics of Partial Tillage for Partial Tillage Rice Seeder. Proceedings of the KSAM 1999 Winter Conference 4(1) 38 ~ 44.

3. Unger, P.W. 1980. System advances in agriculture. Agronomy 33 : 1 ~ 58.

4. Cannel, R. Q. 1985. Reduced tillage in northwest europe a review. Soil & Till. Res. 5(1) : 129 ~ 177.

5. Karahashi, M. 1990. Development of a new up-cut rotary tiller with rake-type filtering screen. JARQ 17(4) : 248 ~ 254.

6. Koichiro, O. 1990. Development of a new no-till seeder for soybean in west-southern districts of Japan. Agricultural Technology 45(3) 49 ~ 53.

7. Lee. Y. R. 1985. The tilling energy requirement and rice yield by the various tillage methods. Ph. D. dissertation, Won Kuang Univ.