Study on the Tractive Characteristics of the Seed Furrow Opener for No-till Planter

Woo-Jung La

無耕作播種機用溝切器具の曳引特性についての研究

羅又禎

SUMMARY

This study was carried out to obtain basic data for the type selection of furrow openers for the no-tillage soybean planter trailed by the two-wheel tractor from the standpoint of minimum draft and good performance of furrowing. For this study, two models of furrow opener, hoe and disc type, were tested on the artificial soil stuffed in the moving soil bin. The results obtained were as follows.

In the case of disc furrow opener, the drafts were measured according to various diameters of discs under the condition of disc angle 8° and 16°, working depth 3cm and 6cm, working speed 2.75cm/sec. Minimum draft appeared when the diameter of disc was about 28cm and the drafts increased as the diameter of discs became larger or smaller than this diameter. Specific draft showed almost same tendencies as above but showed the minimum when the diameter was about 30cm.

For the purpose of controlling the seeding depth, the relationships between draft and working depths, 3cm and 6cm, were tested. The variations of draft concerning the various working depths showed linear changes and were affected in higher degree by depths than other factors.

There were general tendencies at both working depths, 3cm and 6cm, that total draft showed the minimum with the disc diameter of about 28cm and specific draft showed it with the disc diameter of about 30cm regardless of disc angle and working speed.

For the purpose of controlling the working width and speed, the relationships among drafts, disc angle and working speed were investigated and there were general tendencies that the draft increased as the angle and speed were increased and the draft was affected more by speed than by angle.

To compare the hoe-type with disc-type opener, the specific drafts of hoe openers were compared with those of disc opener of 16° angle and 30cm diameter. The specific draft of disc-type opener with the diameter of 30cm was 0.35~0.5 kg/cm², while 0.71~1.02 kg/cm² in the case of hoe type with the lift angle of 20°, which is 2 times as much as that of disc type in average value. And the furrows opened by disc openers were cleaner than those opened by hoe openers.

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INTRODUCTION

For centuries the moldboard plow has been the basic tool of agriculture breaking and turning the soil as the first step in the series of operations collectively known as tillage. It is known that in the U.S.A. more than 250 billion tons of soil are estimated to be stirred or turned each year. To plow this soil once requires 500 million gallons of gasoline or diesel fuel, costing over $100 million (10).

In recent years there has been increasing interest in minimum-tillage systems or no-tillage systems as a means of reducing row-crop production costs and improving soil conditions(29). Recently, in the U.S.A., on a large and growing area of farmland, the plow is being displaced by a system of farming that involves either no tillage or a greatly reduced amount of it(31).

In Korea, Pyeon et al. (24) conducted an experiment on soybean production using the method of no-tillage system. Kim et al. (11) conducted an experiment on the modification of the regular planter for no-tillage soybeans.

The objective of this study was to investigate the tractive characteristics of furrow opener which can be attached to the planter for no-tillage soybeans and so to obtain the data on how to reduce the draft and how to select suitable type of openers. For this study, two models of furrow opener, hoe and disc type, were tested on the artificial soil stuffed in the moving soil bin.

REVIEW OF LITERATURE

Triplett, Jr. et al. (31) reported that in no-tillage system the seeds for a new crop are simply planted in soil that remains covered with the residues of the old crop. The control of weeds, which is a prime objective of tilling, is achieved mainly by the application of herbicides but partly by the fact that the old crop cuts as a mulch, stifling the growth of unwanted plants. And the main advantages of the new methods are that they reduce the labor cost of farming and be predicted that within a few years much of the crop land in the U.S. will be planted without a moldboard plow and in most conditions planting without tillage (but with herbicides) can save labor, energy, water, and soil.

The 1973 ASAE year book defines no-tillage planting as a procedure whereby a planting is made directly into an unprepared seedbed. It is also called chemical fallow. The advantages of no-tillage are listed as early planting of a following crop, reduced labor and machine cost, reduced danger of soil blowing, and soil and water conservation. Insect buildup is controlled by the application of chemicals(29). In Korea, Kim and Pyeon carried out a study on no-tillage system on soybean (11, 24).

Abernathy et al. (1) reported that furrow area tended to be least for openers with small vertical angles and the largest furrows were made by openers with medium vertical angles and large wedge angles, and the lift and drag forces acting on furrow openers increased with increasing vertical face angle and with increasing wedge angle. Kim et al. conducted an experiment on the comparison of hoe and disc-type furrow opener and concluded that continuous studies were needed on the diameter, disc angle and weight of seeder, and experiments using planters precisely manufactured were necessary. Many theses were reported on the characteristics of various parts of planters, but the study on the draft resistances of furrow openers of hoe and disc, and the comparison between them has not been carried out yet in Korea.

Many studies were reported on dynamic characteristics of artificial soils(2, 5, 6, 18, 21, 22, 23, 25). Research results from tillage implement experiments are affected by soil characteristics as well as by implement design. Natural soils, both in the field and in the laboratory, have been found to vary widely in their mechanical characteristics.
Fig. 1 The overall system for model furrowing studies.

Major sources of variation have been those of moisture content, moisture distribution and tension hysteresis, and aggregation and aggregate-size distribution. To ascertain changes in implement performance with variation in implement design, it would be desirable to have a laboratory material with mechanical characteristics similar to natural soil, but with properties which could be maintained uniform over long periods of time and with repeated mechanical working.

The most important fact is that artificial soils simulate natural soils in tillage studies(25) but have the advantages in that the variances of physical properties are very small according to the change of temperature and humidity, and various types of soils are available by manufacturing them and the reproducibility is very good, and sufficient strength is obtained to simulate natural soil.

Artificial soils may be compounded using moistening agents such as ethylene glycol or oil, which do not evaporate rapidly and thus permit maintenance of given soil strength conditions over an extended period of time. Artificial soils compounded from clay, core sand and ethylene glycol have strength parameters similar to those of natural soils.

In tillage studies, the outdoor experiments were usually carried out, but they are very troublesome.

Fig. 2 The openers being tested.

Instead of them, recently, indoor experiments are widely carried out using soil bins(5, 13, 16, 17). Indoor experiments on tillage studies have much advantages compared with outdoor experiments. Field testing of soil-machine systems is difficult, time consuming, and costly. Controlling soil conditions for field-testing purposes is almost impossible. These difficulties suggest the use of models in a laboratory where soil conditions could be controlled. Controll of test conditions, economics, and convenience are factors which make a model tillage laboratory desirable. The comparatively low cost of such a laboratory makes it possible for more research installations to perform research on soil-machine systems. The laboratories could be small enough to be enclosed in a controlled environment and large enough for performing valid tillage and traction research. But, in Korea, no study has been done on soil bin and artificial soil yet.

EQUIPMENT AND METHODOLOGY

1. Experimental apparatus, measuring instrument and artificial soil

The equipment used for this study was a moving soil bin in which the artificial soil was stuffed.

The overall system is shown in Fig. 1 and the openers being tested in Fig. 2.
Table 1. Specifications of the experimental apparatus.

<table>
<thead>
<tr>
<th>Experimental apparatus</th>
<th>Dimensions</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>disc opener (angle, °)</td>
<td>8, 16</td>
<td>DA is simpler form for disc angle in the following figures.</td>
</tr>
<tr>
<td></td>
<td>ϑ (cm)</td>
<td>20, 25, 30, 35</td>
</tr>
<tr>
<td>hoe opener (lift angle, °)</td>
<td>20, 40</td>
<td>S-1, S-2 are simpler forms for 2.75cm/sec, 5.63cm/sec in the following figures.</td>
</tr>
<tr>
<td></td>
<td>ϑ (wedge angle, °)</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>ϑ (cm)</td>
<td>12L×3.4W×14H</td>
</tr>
<tr>
<td>soil bin (cm)</td>
<td>480L×45W×30D</td>
<td>D-3, D-6 are simpler forms for depth 3cm, 6cm in the following figures.</td>
</tr>
<tr>
<td>speed of soil bin (cm/sec)</td>
<td>2.75, 5.63</td>
<td></td>
</tr>
<tr>
<td>roller (cm, kg)</td>
<td>ϕ27×40W, 60</td>
<td></td>
</tr>
<tr>
<td>scarifier (no. of times)</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>strike-off blade (cm)</td>
<td>40W×15H</td>
<td></td>
</tr>
<tr>
<td>capacity of load cell (kg)</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>electric motor (p. s.)</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Measuring instruments.

<table>
<thead>
<tr>
<th>Items</th>
<th>Dynamic strain amplifier</th>
<th>Rapicorder</th>
<th>Soil hardness tester</th>
</tr>
</thead>
<tbody>
<tr>
<td>manufacturer</td>
<td>Kyowa Electronic Instrument Co.</td>
<td>Kyowa Electronic Instrument Co. Ltd.</td>
<td></td>
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<tr>
<td>model</td>
<td>DPM-6E</td>
<td>RMV-33N</td>
<td>Yamanaka</td>
</tr>
<tr>
<td>channel</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dimensions (mm)</td>
<td>386×307×150</td>
<td>325×210×494</td>
<td>ϕ30×200L</td>
</tr>
</tbody>
</table>

Table 3. Physical properties of artificial soil.

<table>
<thead>
<tr>
<th></th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand(%)</td>
<td>Oil content(%) Wet unit weight(g/cm³) Cohesion Angle of internal friction(°) Absolute soil hardness (kg/cm³)</td>
</tr>
<tr>
<td>48.10</td>
<td>12.55 1.51 0.10 30 5.27</td>
</tr>
<tr>
<td>39.35</td>
<td></td>
</tr>
</tbody>
</table>

Specifications of the experimental apparatus and measuring instrument are shown in Table 1 and 2.

Physical properties of artificial soil are shown in Table 3.

The gradation curve for the mixture of sand and bentonite is shown in Fig. 3.

2. Methodology

To measure the oil content, a soxhlet apparatus was used to extract oil from the artificial soil(7). The bin carriage were accelerated to the desired speed and moved past a fixed bar at a uniform speed by an electric motor. After the bin passed

Fig. 3 The gradation curve for the mixture of sand and bentonite.
the tool bar, the drive motor was turned off and the bin decelerated to a stop. Furrowing tool was attached to a mounting frame equipped with vertical and horizontal screws for coarse adjustment of tool position.

The uniformity of soil hardness in the soil bin was maintained by the method that the entire experiment was repeated after tilling the soil once by scarifier followed with the strike-off blade and then with roller passes of 4 times, and ending with measurement of soil hardness at 8 locations in the bin by Yamanaka-type soil hardness tester.

Each of the two types of furrow openers was operated at two kinds of speeds in one type of artificial soil. Drafts on the openers were recorded by oscillographic equipment connected to a force transducer.

**RESULTS AND DISCUSSION**

1. **Relationship between the diameter of discs and draft**

   To find out the diameter of disc that required least draft in the case of disc type, the draft was measured according to the various sizes of diameters. As shown in Fig. 4, there were analogous tendencies regardless of working depths and disc angles, and the diameter of disc which required the least draft was about 28 cm.

2. **Relationship between the working depths and draft**

   As shown in Fig. 5, the variations of draft according to the various working depths showed almost linear changes irrespective of working speeds and disc angles within the scope of this experiment. In the case of plow, Song(30) reported that the draft resistance was increased with increased depth of plowing and the specific draft resistances were decreased with depth to a certain point above which depths they were increased.

   As shown in Fig. 4, there were general tende-
ncies at both working depths, 3cm and 6cm, that total draft showed the minimum with the disc diameter of about 28cm; and specific draft showed it with the disc diameter of about 30cm regardless of disc angle and working speed, as shown in Fig. 7.

It was thought to be desirable that the furrowing be controlled by the adjustment of disc angles and disc diameters rather than by working depths with the end in view of reducing the draft requirements of the planter because the variations of working depths affect the draft requirements in higher degree than other factors under the same condition of experiment.

3. Relationships among the draft, disc angle, and working speed

As shown in Fig. 6, there were general tendencies that the draft increased with increasing disc angle and with increasing working speed.

Shibano(27) reported that the ridging resistance increased when the wedge angle was larger on every conditions. In general, increased forward speed increases the draft with most tillage implements, mainly because of the more rapid acceleration of any soil that is moved appreciably. Soil acceleration increases draft for at least two reasons—first, because acceleration forces increase the normal loads on soil engaging surfaces, thereby increasing the frictional resistance, and second, because of the kinetic energy imparted to the soil(10, 19, 28, 29).

As shown in Fig. 6, in the case of optimum disc diameter of 30cm, the rates of increased draft by the variations of disc angles and working speeds were compared to find out by which the draft is affected more. In the condition of working depth, 3cm and working speed, 2.75cm/sec, the drafts were about 6.2kg and 7.7kg in the case of disc angle, 8° and 16° respectively, showing little differences; but 7.2kg and 9.3kg in the case of disc angle 8° and 16°, respectively, at the working speed of 5.63cm/sec and same working depth as above; which show that draft is affected more by
working speed than by disc angle. It was thought to be desirable that the working speed of planters be reduced a little than that of ordinary tillage implements from the standpoint of draft requirement and precision planting.

4. Comparison between hoe and disc-type openers

For the purpose of comparing the draft of these two types of opener, the specific drafts of hoe-type openers were compared with those of disc-type openers with the disc angle of 16°. As shown in Fig. 7 and Fig. 8, the specific draft of disc-type opener with the diameter of 30cm was 0.35~0.5kg/cm², while 0.71~1.02kg/cm² in the case of hoe type with the lift angle of 20° which is 2 times as much as that of disc type in average value.

The movement of soil during furrowing operations were compared between the two types. With the bin level, or at zero slope, the artificial soil was furrowed, and there remained equal banks on both sides of the furrow opened by both types. But the degree of crack of removed artificial soil to both banks of furrow was greater in the case of hoe type than of disc type(Fig. 9).

Choking of artificial soil between the two discs was beside the question during the experiment, but it was thought the scrapers would be necessary to be attached between them in actual furrowing operation in the field.

A) Furrow opened by disc type.
B) Furrow opened by hoe type

Fig. 9. The furrows opened by the two types of opener.
The degree of artificial soil adhesion on the opener was greater in the case of hoe type than of disc type, and soil adhesion is not desirable because it causes the increase of friction between soil and metal face of opener.

So, considering the conservation of moisture content, draft requirement and soil adhesion, it was thought that furrow opener of disc type would be more suitable forrow opener of planter than that of hoe type.

摘 要

動力耕廘機用豆類の無耕廘播種機に附着する使用する溝切器中で所要牵引力が高くて溝切作業精度が良好なる溝切器の開発をはるまして差を因の基礎資料を供し 為の 縦動式 土壌型人工土壌を除く形板型及保全型溝切器の所要牵引力の影響を実験によって示すこととした結果 保全型の 直径16cmの溝切器の 牽引特性と比較すると 結果 直径30cm溝板型の 塃遇は 約抵抗に 0.35〜0.5kg/cm²で 比例した保全型の 塃遇は 0.71〜1.62kg/cm²となり 保全型の 牽引抵抗比抵抗に平均2倍程度に 大きく 増大して 作溝状態で溝板型の 塃遇が 大きい不良結果でなかった。

REFERENCES

no–tillage soybeans:1–2. College of Agriculture Chungnam National University.


