THE ECONOMICS OF HARVESTING POTATOES IN STONY FIELDS USING A WINDROWER

G.C. Misener
Junior Member CSAE
Research Station, Agriculture Canada
Fredericton, New Brunswick

L.P. McMillan
Research Station, Agriculture Canada
Fredericton, New Brunswick

INTRODUCTION

The rate of output for the mechanical potato harvester in stony fields is limited to the ability of the sorting crew to handsort the stones from the potatoes. The introduction of the air harvester increased the harvesting rate by improving stone and potato separation, but excessive tuber injury resulting from high conveyor speeds (3) and high forward velocities (>0.9 m/s) (1) imposes a limit on increasing the output by higher travel speeds.

Glaves (3) developed a method of harvesting four rows with a two-row potato harvester on stone-free land. To implement this method, a two-row digger was modified to make a digger-windrower that was used to dig potatoes from two rows and deposit them between two adjacent undug rows. A two-row harvester was then used to simultaneously harvest the two undug rows and recover the potatoes deposited between them by the digger-windrower. The feasibility of this system was later studied by French (2).

This paper presents the results of a study of the possibility of harvesting four rows of potatoes simultaneously with a two-row air harvester in stony fields. Tests were conducted to determine rates of output and tuber injury, and a computer program was developed to compare the cost of the two- and four-row systems of harvesting.

EQUIPMENT AND METHODS

Harvesting rates, tuber injury, and field losses were determined in a study conducted with the cooperation of two growers. In order that a comparison could be made between the two methods of harvesting, information was collected on each harvesting system when the growers were using an air harvester to harvest either four or two rows.

In the four-row method, a two-row digger-windrower was used to dig and divide two rows of potatoes and deposit them between the two adjacent undug rows. An air harvester then dug the two undug rows and simultaneously picked up the windrowed potatoes, separated the stones from the potatoes, and conveyed the potatoes to a bulk truck (Figure 1).

With the two-row system, the air harvester dug two rows of potatoes, separated the stones from the potatoes, and conveyed the potatoes to a bulk truck.

In each instance, the forward speed of the harvester chosen by the operator was limited by such factors as vine growth, soil moisture content, clods, stones, and amount of tuber damage. The windrower speed was adjusted to the need of the harvester. No attempt was made to control or alter the parameters set by the operator. For each harvester the conveyer speed was the same for both the two-row and four-row operations.

The following is a list of the parameters measured and the sampling methods used for each of three tests involving both four- and two-row harvesting techniques:

1. Potato yield — by taking nine random
samples from 6 m of row length dug by the digger-windrower.

2. Rock population — by collecting six random rock samples from the stone-run of the harvester as it traveled 15 m.

3. Potato injury caused by the digger-windrower — by randomly collecting nine 10-kg samples from the potatoes deposited between the two undug rows of potatoes.

4. Potato injury caused by the four-row operation — by randomly collecting nine 10-kg samples from the end of the loading elevator of the harvester collecting four rows of potatoes.

5. Potato injury caused by the two-row operation — by randomly collecting nine 10-kg samples from the end of the loading elevator of the harvester digging two rows of potatoes.

6. Potato losses — by taking nine random, 1-m² samples of the deviner-run and stone-run leavings.

7. Harvester forward velocity — by measuring the time required for the harvester to travel 15 m.

In all instances the variety of potatoes was Netted Gem and a chemical vinekiller was applied 10-14 d before harvest.

Assessment of Tuber Damage

Misener et al. (5) found that flesh and crack injuries caused by harvesting and handling operations could be expressed in terms of a damage index designated trim loss. The index was obtained by measuring the weight of trim required to remove flesh and crack damage and expressing it as a percent of the original sample weight. Trimming for each injury was done in a single plane until all sign of injury was removed.

All samples of potatoes collected for the injury assessment were stored for 2-3 weeks and then evaluated on the basis of trim loss.

Duncan’s New Multiple Range test (6) was used in all comparisons dealing with tuber injury.

Comparison of Costs

To determine the economical feasibility of the four-row system of harvesting a cost analysis was conducted. Parameters such as purchase price of each machine, machine life, number of hectares harvested per year, number of operators required, rate of harvesting, and field efficiency all contribute to the cost of harvesting. The field efficiency is a ratio of the actual operating time to the total field time and is affected by loss of harvest time due to adjusting the machine, breakdowns, clogging, and turning at the end of the rows.

Liley and Smith (4) developed a computer program that can be used to calculate the probable cost of harvesting for a number of combinations of factors. Modifications were made to the program to allow for the cost of windrowing when the four-row method was implemented and for the cost of filling the storage. Changes were also added so that the number of bulk trucks required to keep the harvester busy at all times could be determined. The program allowed 12 min for the bulk truck to travel to the storage area, 18 min to unload, and another 12 min to return to the field. These times were determined from field studies.

The effect of time of harvesting was also considered because the harvesting process on the larger farms would necessitate an early start and a late finish thus causing a reduction in the marketable product. The frost-free harvest season for New Brunswick was estimated to be from 200 to 250 h; therefore, two season lengths of 200 and 250 h of work were considered in the analysis, with a linear reduction in the value of the undug crop to zero in 100 h extra for each season length.

Information for several of the factors affecting the cost of harvesting taken from the work conducted by Scott and Roberts a and Thompson (7) were used in assessing values for the study (Table I).

RESULTS AND DISCUSSION

Field Evaluation

A wide range was encountered in both field parameters and harvester performance (Table II). The four-row system of harvesting resulted in an average increased output of 57.7% over the two-row system, although the forward speed was reduced when harvesting four rows. The two systems produced little difference in potato losses in the deviner and the stone-run leavings. There was, however, a considerable difference between harvesters (test 1 employed a different machine from that used in tests 2 and 3).

There was no significant difference

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TABLE II SUMMARY OF DATA COLLECTED ON HARVESTING OPERATIONS

<table>
<thead>
<tr>
<th>Field parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test no. 1, a</td>
<td>3</td>
</tr>
<tr>
<td>Harvester</td>
<td></td>
</tr>
<tr>
<td>No. bulk trucks required†</td>
<td></td>
</tr>
<tr>
<td>two-row operation</td>
<td></td>
</tr>
<tr>
<td>four-row operation</td>
<td></td>
</tr>
<tr>
<td>Yield (metric ton/ha)</td>
<td>34.2</td>
</tr>
<tr>
<td>Rock population (metric ton/ha)</td>
<td>19.7</td>
</tr>
<tr>
<td>Harvester speed (m/s)</td>
<td>0.8</td>
</tr>
<tr>
<td>two-row operation</td>
<td></td>
</tr>
<tr>
<td>four-row operation</td>
<td></td>
</tr>
<tr>
<td>Harvester output (metric ton/h)</td>
<td>14.1</td>
</tr>
<tr>
<td>Field loss (metric ton/h)</td>
<td>0.5</td>
</tr>
<tr>
<td>two-row operation</td>
<td></td>
</tr>
<tr>
<td>four-row operation</td>
<td></td>
</tr>
</tbody>
</table>

† Calculated by program.
‡ a and b designate the two different two-row harvesters employed in the tests.

TABLE III COMPARISON OF POTATO INJURY: MEAN TRIM LOSS, % BY WEIGHT

<table>
<thead>
<tr>
<th>Windrower</th>
<th>Two-row operation (harvester)</th>
<th>Four-row operation (harvester-windrower)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.9ab</td>
<td>2.2ab</td>
</tr>
</tbody>
</table>

* Means followed by the same letter are not significantly different at the 5% probability level.

Comparison of Costs

Estimated harvesting costs per hectare for large enterprises were lower than for smaller operations (Figures 2, 3, 4). The decrease was due primarily to the fact that the fixed costs for the larger enterprises were spread over a greater number of hectares. Fixed costs were considered to be those not related directly to machine output, such as machine depreciation, insurance, and interest on investment. The variable costs such as machine repairs and operating costs remained constant for any given harvester forward speed and yield except where the harvesting operation required some of the extra 100 h in order to complete the harvest. This added a penalty charge to the variable costs.

For small operations, the four-row system of harvesting was more expensive than the two-row because of its higher initial cost, but as the number of hectares harvested per season increased, the costs of the two systems became very similar. In test 1 with the four-row operation the estimated fixed costs ranged from $150.10/ha on the 20-ha enterprise to $25.02/ha on the 120-ha enterprise. The variable costs remained constant at $30.57/h. The fixed costs for the two-row system involving only one air harvester ranged from $120.75/ha on the 20-ha enterprise to $20.13/ha on the 120-ha enterprise. The variable costs remained at $21.32/h until the penalty factor was added. This indicates that a substantial increase in the rate of harvesting by the four-row operation is necessary to lower the total costs per hectare. Similar trends were observed in the other tests.

The advantage of using the four-row method occurs when the required harvesting period for the two-row system exceeds the season length, thus necessitating the purchase of a second harvester. In test 1 (Figure 2), with 100 ha, the four-row system of harvesting represented a cash saving of $26.93/ha or $2693/yr over the two-row system involving two harvesters in a 250-h season. In a 200-h season, the saving could be substantially greater. For the operating conditions in test 1, the two-harvester system would be more economical for areas over 117 ha/yr in a 200-h season. In tests 2 and 3 (Figures 3, 4) the points where the two-harvester system would be more economical were not reached in the analyses. The higher speeds of operation for the four-row system in tests 2 and 3 increased the yearly capacity of the system as compared with test 1 (Table II).

The maximum possible harvesting rate was not used in the field evaluation. Graphs (Figures 2 - 4) were based on speeds set by the harvester operator. The effect of harvester speed on the computed cost per hectare of harvesting with the four-row operation is illustrated in Figure 5. When the speed of the harvester reached 0.8 m/s, an additional bulk truck was required to keep the harvester busy; thus an increase in the computed cost of harvesting over 0.7 m/s was obtained.

Figure 2. Cost comparison of two- and four-row harvesting systems (test 1).
An additional advantage of the four-row operation is the reduction in the harvesting time. Using the average yield and speed for the three tests, the four-row system would complete 50 ha in 38 fewer hours than the two-row system; similarly for 100 ha, 76 fewer hours. The tractors and labor force are then available sooner for other jobs than if the two-row system using only one harvester was used.

On the basis of the economical analyses, it would be feasible for the operator to plan to harvest an increase of up to 50-60% of the number of hectares his present harvester can handle in 1 yr if he implemented a four-row system. A larger increase would require the use of a second harvester.

**CONCLUSIONS**

The conclusions drawn from the study were as follows:

1. The four-row system of harvesting resulted in an average increased output of 57.7% over the two-row system.

2. There was no significant difference in total potato injury (trim loss) and field loss between the two systems of harvesting. In the four-row system less damage was done by the harvester.

3. Both the fixed costs and operating costs per hour for the four-row harvesting system are higher than for the two-row operation, necessitating a substantial increase in the rate of harvesting by the four-row operation to lower the total costs per hectare.

4. An advantage in harvesting cost is obtained with the four-row system when the two-row operation exceeds the season length, necessitating the purchase of a second harvester.

5. In addition to the potential for reduction of harvesting costs, four-row operation offers an advantage in the reduction of the number of days required to complete the harvest.

6. Factors affecting the rate of harvesting should be studied closely because of the effect of harvest speed on the cost.

**SUMMARY**

The system of employing a digger-windrower in order that four rows of potatoes could be harvested simultaneously with a two-row air harvester in stony fields was evaluated. The study found that there was a 57.7 percent increase in output with the four-row system over the conventional method of harvesting without any significant increase in potato injury or field loss. A cost analysis indicated that both the fixed costs and the operating costs per hour for the four-row harvesting system were higher than for the two-row operation, necessitating a substantial increase in the rate of harvesting by the four-row operation to effect a lower operating cost per hectare. A definite advantage in harvesting cost was obtained with the four-row system when the two-row operation exceeded the season length, necessitating the purchase of a second harvester.

**REFERENCES**

YIELD = 34.2 METRIC TON/ha
--- EXCEEDS 200-H SEASON

Figure 5. Effects of harvester speed on harvesting cost of the four-row system (harvester and windrower).


