A belt-roller mechanism for soil clod reduction on a potato harvester

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INTRODUCTION

The formation of soil clods during potato production is generally caused by the smearing and compacting during the ridging operation (McRae 1980). These operations are often conducted under adverse conditions in eastern Canada which further aggravate the problem. At harvest, the separation of clods from potatoes is difficult and the mechanisms employed for separation can severely injure the potatoes (Campbell 1980). Some clod removal is obtained by means of agitation on the primary bed where the weaker clods are frequently broken into smaller pieces. However, the efficiency with which loose soil is sieved between the bars of the primary bed of a harvester is inevitably reduced by the presence of clods as they reduce the effective web area openings (Campbell 1980).

MATERIALS AND METHODS

Machine description

The two row test machine consisted of a share and full width primary bed approximately 2 m in length. At the rear of the primary bed, a cross conveyor was positioned similar to the configuration on a conventional windrower but without a secondary conveyor or deviner. The clod crusher-elevator was mounted to receive the material from one of the two rows of potatoes. Positioned at 45° to the horizontal, it delivered the product to a second cross conveyor similar to the device described by Sorokin and Maksimov (1979). This arrangement allowed one row of potatoes to be sampled at the end of the cross conveyor similar to a conventional windrower and the adjacent row to be sampled after the clod crusher-elevator.
The clod crusher-elevator consisted of a flat rubber belt 600 mm wide over which two rubber covered foam rollers rotated at the same surface velocity as the belt. The elevator was inclined at 15° for the first 400 mm portion where it was in contact with the first foam roller. After contact with the first roller, the belt was inclined at an angle of 45°. A second foam roller was placed on the belt a further 1200 mm up the slope from the first roller. The rubber belted conveyor extended beyond the second roller 1200 mm. By adjusting the speed of the belt and the foam rollers, the potato, clod, and soil mixture could be accelerated such that the mixture would convey up the slope of 45°. The vertical velocity component of the product approached zero at the top of the conveyor. The potatoes were elevated an additional 1.7 m when compared to the conventional arrangement. A schematic view of the assembly is presented in Fig. 1.

The rollers were constructed from foam rubber rings 330 mm in outside diameter and 150 mm thick. Several rings of the foam rubber were placed on a 76 mm diameter tube. The ends of the roller were capped with 19-mm-thick plywood (330 mm diameter) to provide a surface for the roller to ride on the belting without compressing the foam. The assembly was covered by a natural rubber tube and sealed against moisture infiltration.

**Fig. 1. Schematic diagram of clod reducing device.**

During the second year of testing the length of the 45° sloped belt was reduced to 1000 mm. The lower foam roller remained in its original position. The distance between the two foam rollers was reduced to 500 mm, leaving the belt extended past the top roller 500 mm. A 750- mm-wide, 42-mm-pitch rubber covered draper chain, 1000 mm long, was added at an angle of 15° to the horizontal to receive the tubers from the rubber belt and continued to move the product to the rear cross conveyor. The same cross conveyor used in the previous year was repositioned to receive the material from this draper chain. With this arrangement, the additional height from the conventional arrangement that the potatoes were elevated was 1.0 m.

The test machine was operated with the same operational parameters in both years with the exception of the speed of the inclined belt (Table 1). The primary conveyor operated at 0.91 m/s and the cross conveyors at 0.75 m/s. In year one, the clod crusher-elevator belt was operated at 4.0 m/s. This was reduced to 2.7 m/s in year two. The draper chain conveyor added in year 2 was operated at 1.2 m/s. The three forward speeds of the harvester during the tests were 0.45, 0.90, and 1.35 m/s. Each test was replicated four times.

**Table I. Machine operational parameters**

<table>
<thead>
<tr>
<th>Machine parameter</th>
<th>Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1</td>
</tr>
<tr>
<td>Forward speed</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>1.35</td>
</tr>
<tr>
<td>Primary conveyor</td>
<td>0.91</td>
</tr>
<tr>
<td>Clod crusher-elevator belt</td>
<td>4.00</td>
</tr>
<tr>
<td>2nd draper conveyor</td>
<td>N/A</td>
</tr>
<tr>
<td>Rear cross conveyors</td>
<td>0.75</td>
</tr>
</tbody>
</table>

**Experimental procedure**

For both years of the two-year study, processing potatoes (cv. Russet Burbank) were grown at the Fredericton Research Centre following standard crop management practices. A vine killing treatment was applied in mid-September. The chemical desiccant diquat was applied at 0.75 kg/ha. Potatoes were grown in solid blocks for harvest with the test machine. Plots were organized on a completely random basis along the potato rows. A canvas sheet was placed on the ground to collect all material from the lower cross conveyor. A plastic container was held on a sliding bracket to collect material from the upper cross conveyor. As the machine travelled across the field, two rows of potatoes were dug and the material was deposited back to the ground. When the sample plot was approached, material was deposited on the ground sheet and into the plastic container, respectively. This procedure was repeated for each forward speed and each replication.

The field operations were performed in Fundy clay soil, which is compact clay in the upper horizons with an underlying clay subsoil starting at 400 mm depth (Rees and Fahmy 1984). The samples were tagged and sorted into component parts (soil, clods, stones, tubers, and vines). To determine the make up of each sample collected, a sieve was constructed from a 42- mm-pitch draper chain. The chain rods were 11 mm diameter with an opening of 31 mm between the rods. The samples were gently placed on the sieve and clods and tubers were collected while allowing soil to drop through the openings to a collection tray. The potatoes were stored at room temperature for an additional two weeks before they were evaluated for mechanical injury.
For mechanical injury assessment, the method of Thornton (1969) was employed. Tuber damage was determined by using a potato peeler to remove a slice of approximately 3 mm thickness. Damage was classified as: (a) undamaged, (b) scuffed or skinned - skin only broken, (c) slightly or peeler - flesh damage removed by a 3-mm-deep stroke of the peeler, (d) severely damaged - damage to flesh which was not removed with one peeler stroke, and (e) black spot. A damage index was calculated based on the percentage of tubers in each category multiplied by 0, 1, 3, 7, and 5, respectively. The values were then added to give a total damage index (Robertson 1970; McGechan 1980).

The pressure that the foam exerted on a tuber as it passed between the foam roller and belting was measured in the laboratory. Tubers of various sizes were pressed into the foam and the compressive force measured. A foam roller was positioned on the base of a Universal Testing Machine, model MC3000 (Nene Instruments Inc., Wellingborough, England). A flat piece of rubber belting with a metal backing was attached to a 1 kN load cell on the movable head of the testing machine. The belting was covered with a non-drying layout dye, 35v Prussion blue (Permatex Limited, Orangeville, ON). A tuber was positioned on the foam roller and covered with a soft paper towel. The movable head was lowered at a fixed speed of 500 mm per minute until the tuber was compressed into the foam roller a distance equal to its diameter as would be the case on the clod crusher. The resulting compression force was recorded on a computer using software provided with the testing machine. The paper towel was removed after raising the movable head. The dye on the belting resulted in a stain on the paper towel equal to the contact area between the tuber and the belting. This area was measured by tracing the stained area with a digitizer pad, model GraphicMaster 11 (Numonics Corp., Montgomeryville, PA) connected to a personal computer using AutoCAD, Ver. 13 software (Auto desk, Sausalito, CA). Twenty tubers were selected with an average mass of 233.6 ± 69.8 g.

RESULTS AND DISCUSSION

The performance of the clod elimination apparatus in field conditions was monitored over the two year study. In general, the clod crusher-elevator functioned well and adjusted to varying soil conditions. It was observed that the mixture of potatoes, clods, and soil leaving the primary bed flowed evenly into the roller-belting device and moved without hesitation up the inclined belt conveyor. Material was deposited on the adjacent conveyor in an efficient manner. Vines were also effectively pulled in by the roller-belting device and moved up the inclined conveyor. Sufficient pressure was developed between the rollers and potatoes to achieve acceleration of the soil, clods, and potatoes.

The effectiveness of the clod crusher-elevator at reducing the percentage of clods is given in Table II. In all tests, there was a reduction in the percentage of clods and the amount of soil collected when compared with the standard harvester arrangement. The higher moisture content (20.2%) of the soil in the third test in the first year resulted in less soil removed as compared to the other tests. Clods were totally eliminated at the slow forward speed (0.45 m/s) during the second year of the study; whereas, only 33.2% were eliminated at a forward speed of 0.45 m/s during the first year. The lower soil

Table II. Summary of performance data

<table>
<thead>
<tr>
<th>Year</th>
<th>Forward speed (m/s)</th>
<th>Soil moisture content (%)</th>
<th>Mechanical injury (damage index)</th>
<th>Clod reduction (%)</th>
<th>Soil reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Standard Clod crusher</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>364.4a 203.9ab</td>
<td>90.7ab</td>
<td>63.6ab</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>243.2c 264.9a</td>
<td>91.7ab</td>
<td>76.3a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>286.9abc 109.8b</td>
<td>87.1ab</td>
<td>69.0ab</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different at the P=0.05 level according to Duncan’s Multiple Range Test

**Clod or soil reduction was determined by**

\[
\text{wt of clods (standard)} - \text{wt of clods (clod crusher)} \times 100
\]

**wt of clods (standard)**
moisture content during the second set of tests of the first year of the study suggests that the clods had a higher strength than at the higher moisture content. Decreasing the distance between the two rollers did not appear to have any effect on the performance of the device in eliminating clods.

One disadvantage with the device appears to be the increase in the level of mechanical injury of the potatoes. On average, mechanical injury increased by 69.8% over the standard arrangement. However, the level of mechanical injury was lower than that found on commercial harvesters. Misener et al. (1989) found that the average injury index was 368.6 for commercial harvesters operating in eastern Canada. The average index for the clod reducing device was 297.3. Reducing the distance between the rollers did not affect the level of mechanical injury (Table II).

Mohsenin (1965) found that a mean normal pressure range of 241 - 326 kPa was required before skinning was initiated by potatoes rubbing against each other. Average pressure between the rollers and potatoes was measured as 181 kPa ± 55 kPa which was less than the normal pressures required for skinning. The amount of stones mixed with the potatoes (mean 11.4%) may have contributed to the injury of potatoes as they passed between the rollers and belting as well as at the transition points between conveyors.

CONCLUSIONS
The clod crusher-elevator device performed well under field conditions for reducing both the number of clods and the amount of soil on the test harvester. The key components of the device were a pair of foam rollers which operated on a belted conveyor to facilitate acceleration of the material and the breaking of soil clods. The amount of soil clods was reduced by 79.9% when compared to the standard harvester. Similarly, the amount of soil reaching the final cross conveyor was reduced by 48.6%. During the process, the potatoes were elevated an additional 1.7 m and 1.0 m by the first and second prototype units, respectively, when compared to the conventional arrangement. However, mechanical injury increased by 69.8%. Work needs to be directed towards reducing the level of mechanical injury caused to potatoes by the clod reducing device.

REFERENCES


Rees, H. And S. Fahmy. 1984. Soils of the Agriculture Canada Research Station, Fredericton, NB. Agriculture Canada Land Resource and Research Institute, Fredericton, NB.


