INVESTIGATION OF TRANSPLANTING METHODS FOR PROCESSING TOMATOES

G. B. Hergert, M. Feldman, E. J. Tomecek, M.-A. Pelletier,
A. Liptay and F. D. Sumson
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EXECUTIVE SUMMARY

A new trend in the processing tomato industry is the use of locally-grown media block seedlings (tray plants) in place of bare-root seedlings imported from Georgia. The purpose of the investigation described here was to compare the cost of labour and other inputs for transplanting bare-root and tray-grown plants using systems presently available. The information was gathered in Southern Ontario during the 1987 season.

The findings from the field study included:

1. The planting rate with conventional bare-root transplanters averaged 61 plants/min/row with two operators per row, or an average rate of 30.5 plants/min/person. Planting tray plants with a cup-type machine intended for such plants produced an average rate of nearly 70 plants/min/person, or an increase of 2.3 times in operator productivity.

2. Conventional machines using bare-root seedlings were found to spend 61% of their field time actually planting. Much of the remaining time (34%) was spent sorting and loading the seedlings. By contrast, the cup-type machine using tray plants handled on racks required only 19% of the time for loading, achieving 73.5% actual planting time. For both systems, minor amounts of time were used for turning at row ends and down-time.

3. It was found that the planters all placed the plants accurately in the soil at the expected spacings.

4. Tray-plants survived well after being transplanted. Measurements 3 weeks after planting showed a loss of 4.6% compared to 13.7% for bare-root plants.

5. The seedlings represent the greatest direct cost of transplanting processing tomatoes at $629/ha for bare-root plants and $704/ha for tray-plants. Labour costs amounted to $156/ha for bare-root transplanting, and $83/ha for tray plants transplanted with a cup-style transplanter.

Other information gathered included:

1. Exploratory trials with two European machines and one automatic transplanter showed that the tomato transplants used in Ontario were too large to be compatible with any of these mechanisms. This suggests that smaller seedlings are used elsewhere, indicating that there may be a need to evaluate the ability of smaller transplants to survive in the field.

2. Sample measurements were made of tray-plant characteristics. Plant size varied with plug size, with stem heights averaging 155 mm for
288 square cell to 182 mm for 200 square cell trays. Average tray fill was 88-96%, although some trays were only filled at 63-76%. Removal force was higher for round cell plugs than square cell plugs.

3. An estimate of the market potential for automatic transplanters can be suggested from 1986 statistics. There were 734 processing tomato growers producing 11,000 ha of tomatoes. It is suggested that 50% of those growers have in excess of 40 ha and could use a less labour-intensive method of transplanting.

4. Information was gathered on automated transplanters from other countries. An Australian machine (Williams) is being test marketed in California for introduction in 1989. Lennan from Finland and Holland Transplanter from U.S.A. are working on models for introduction in 1989. An automated transplanter has been developed in Israel and inventors are looking for partners to complete development and to market the machine. Two types of automated planters are used in California in integrated operations, but are not for sale.

5. A means of advancing introduction of the most suitable of these potential automated systems in Ontario might be to evaluate plants grown in the types of trays they use, while also providing preferred plant specifications to the respective developers for their own evaluations.
INVESTIGATION OF TRANSPLANTING METHODS FOR PROCESSING TOMATOES

G.B. Hergert and M. Feldman
Engineering & Statistical Research Centre
Research Branch, Agriculture Canada
Ottawa, Ontario K1A OC6

and

E.J. Tomecek
Plant Industry Branch
Ontario Ministry of Agriculture and Food
Ridgetown, Ontario NOP 2C0

INTRODUCTION

Processing tomatoes are grown on 11,000 ha in Ontario with 96% being established by transplanting bare-root seedlings imported from Georgia. A new trend is to use locally-produced seedlings grown in media-blocks in plastic trays (tray plants). Per plant, the locally-grown transplants cost more than imported bare-root seedlings, but this extra cost may be offset by two factors. There are indications that plant stands and therefore yields are improved with tray plants, and tray plants potentially require less transplanting labour. Other establishments have ongoing work on agronomic aspects of tomato production. A 3-year collaborative (Grower-Provincial-Federal) research project to evaluate the performance of tray plants in Ontario was initiated in 1986 under the co-ordination of E. Tomecek. The project was expanded in 1987 to include an investigation of transplanting methods, providing the Engineering and Statistical Research Centre (ESRC) with an opportunity to have engineering aspects included in the study during the 1987 transplanting season. The purpose of this report is to compare the cost of labour and other inputs for transplanting, from the engineering data gathered in 1987 (Burgoyne, 1987) on various transplanting systems presently available for both bare-root and tray plants.

Current Practice

In Ontario, processing tomato seedlings are planted using semi-automatic transplanters. The machines have either gripper pockets
or flexible discs that carry the transplants to the furrow, placing them upright at predetermined spacings. Normally, two people are required per row to place the plants into the pockets or discs. Semi-automatic transplanters can plant both bare-root and tray plants.

Until recently, most transplanters for processing tomatoes provided three single rows, one per bed spaced at either 1520 or 1680 mm. The present trend is to plant two rows 450 mm apart on each bed, by either making two offset passes with a three-row transplanter or using a preset six-row transplanter. Planting three beds at a time is preferred because weeding equipment used later must closely follow the planted rows.

Growers have expressed concern about finding and managing the size of work crew required to operate the semi-automatic transplanters. A three-row transplanter requires 6 operators, a tractor driver and one support person for transporting plants and water. The crew increases to 13 or 14 people for a six-row machine. The use of tray plants and further transplanter automation are seen as methods to overcome labour shortages and costs.

METHOD

Machines Used

The conventional machines currently used to transplant tomatoes in Ontario are semi-automatic (Fig. 1), employing pockets or grippers attached to a conveyor chain to carry transplants from the loading operators' station to the furrow. The grippers open automatically to receive the plant, close to grip the plant and open again at the furrow. The chains carrying the grippers are driven from the packing wheels with adjustments available to vary the plant spacing. Such machines are supplied by North American manufacturers including Holland, Mechanical, Delhi and Ellis*. A similar machine manufactured by Powell uses flexible steel discs, marked to show where to insert the plant, to carry the plants

* Mention of trade names is for identification purposes only and does not represent an official endorsement by Agriculture Canada.
to the furrow. These machines require two people per row for loading the grippers or discs, to achieve an acceptable planting rate. Both types are easily converted to handle tray plants by adding extensions to each gripper or disc to support the root media-block. Conventional transplanters were made available by 19 co-operating growers for the collaborative study.

The following transplanters sold in North America were considered to be different from the conventional semi-automatic planters:

**Mechanical Model 1000 (M-1000)** is very similar to conventional planters except that the chain carrying the plant grippers is driven by a floatation wheel rather than the packing wheels and 12 plant grippers are supplied instead of 10. (Mechanical Transplanter Co., Holland, Michigan, U.S.A. 49423.) Four M-4000 transplanters owned by co-operating growers were made available to the investigation.

**Mechanical Model 4000 (M-4000)** was developed specifically for tray-grown plants and has four conical cups per row into which the operator places the plants (Fig. 2). The four cups turn as a unit on a vertical shaft geared to ground speed. The cups open at the appropriate spacings to drop plants into a delivery tube leading to a furrow opener. There, a gate device pushes the plant into the opened furrow. The planters are attached to a tool-bar in the same manner as conventional planters. Recent models have a floatation wheel as used with the M-1000. Two M-4000 planters were available for the investigation - one owned by Roland Farms and mounted on a 4-wheel drive chassis with frames for holding racks of tray plants; and one rented from Chatham Ford. The latter was made available to several co-operating growers, thus permitting data collection using many experienced operators. (Mechanical Transplanter Co., Holland, Michigan, U.S.A. 49423.)

**Regero HD 4BT** was recently developed in France for use with tray plants. Each row has pans travelling on a conveyor chain to receive plants from an operator and carry them to the furrow opener (Appendix I). Potential advantages included the range of adjustment of the row spacing
and the speed that operators could load plants into the conveyor pans. Two adjacent rows could be set at 450 mm apart allowing one person to feed two rows.

*Lännen RT-2* produced in Finland uses a cup carousel, similar to the M-4000, to receive tray plants from an operator, and a unique guide for the plants as they are placed in the soil (Appendix II).

*Modified Castle and Cooke* is a prototype unit, produced by the Ontario Centre for Farm Machinery and Food Technology for planting tree seedlings, based on a design used in California for lettuce and other crops (Appendix III). Even though obviously not set up for tomato transplants, a test was considered useful to gain experience with an automated machine.

*Tray Racks* - An emerging practice is to use rectangular racks made of 38 x 89 mm wood members to handle tray plants. The racks hold 16 trays that rest on wires stretched across the wood members. Seeded trays are placed on the racks and are handled that way throughout the growing process. Special trailers are used to carry the racks of trays from the greenhouse to the field. Trailer covers protect the plants from wind and sun. As needed the racks are loaded onto supports on the planter where the trays are then distributed to the single or four-tray carousel holders in front of each operator.

Transplanter made by Checchi and Magli of Italy and distributed by *Twison* Industries, Milton, Ontario, and the Egedal transplanter distributed by *Timm* Enterprises, Oakville, Ontario, are also on the market, but were not included in these tests as they were similar to conventional models.

Plants used for this study included:

1) Bare-root seedlings field grown in Georgia, U.S.A. and shipped to Ontario in bundles ready for planting.
2) Tray plants grown in plastic trays in individual cells containing a growth media, according to a procedure described by Muehmer (1987) and Garton et al. (1987). The most common tray used is the Blackmore 288 with either round or square cells. Plants were 120 to 200 mm tall when transplanted. Various terms are used to identify these plants, such as plug plant, media-block, and others, but the term "tray plants" will be used in this report. Different plant varieties were produced in the trays, but variety was not identified for purposes of this investigation.

Procedure

Measurements were taken and observations made during on-farm transplanting operations and special tests arranged for the non-conventional transplanters. Procedures were established for project staff and growers to gather data on machine performance parameters, cultural techniques, labour requirements, and certain costs. Data collection was coordinated with the Tomecek project to include cultural aspects and avoid duplication. The detailed methods and procedures are described in a separate report (Burgoyne, 1987). In addition, information was collected, as available, on emerging transplanter technology.

FIELD STUDY RESULTS

The results presented in this section pertain to the conventional, Mechanical 1000 and Mechanical 4000 transplanters, as determined from measurements made during commercial use by growers.

Planting rates

Cup transplanter technology designed for and used with tray plants can double individual worker productivity and slightly improve overall machine planting rate (Table 1). Cup machines with tray plants achieved a rate of nearly 70 plants/min/row compared to 65 plants/min/row at most, using gripper machines with bare-root plants. Since cup machines need only one worker per row, instead of two as on the gripper machines, the
respective worker productivities were 70 and 26 to 36 plants/min.

Machine planting rate reduced slightly compared to bare-root when using tray plants in gripper machines. As well, planting rate was 55% of normal when using one operator in place of two on a gripper machine with tray plants. The industry average, measured on 19 different farms, for conventional machines using bare-root transplants and 2 operators/row was about 61 plants/min.

Of secondary interest, the M-1000 design seemed to provide a 6% increase in planting rate compared to the conventional machines, for bare-root transplants. For tray plants, the increase was over 20%, noting however that planting rate for tray plants with conventional machines was already 15% less than for bare-root. Measurements were not taken to establish the reason for the difference, but a good guess is the fact that the M-1000 has 2 more grippers, travelling at 20% less peripheral velocity than on the conventional machines.

Field Efficiency

Use of tray plants with appropriate available planting and handling mechanization provides a more efficient field operation that could mean up to 50,400 more plants placed in the ground with a 6-row machine in a 10-hour day than with conventional systems. The cup technology and the use of rack supports reduced the total time needed for planting and increased the proportion of field time actually spent placing plants into the ground (Table 2). Comparing the M-4000 with racks to conventional bare-root operations, the time to plant 1000 plants (per row) was reduced by more than 7 minutes and the proportion of time spent on planting was increased by over 12 percentage points.

Besides planting rate improvements already discussed, use of tray plants reduced the actual time and proportion of the field operation spent on sorting and loading plants. The conventional bare-root system required 9 min per 1000 plants for sorting and loading. With the M-4000 this reduced to 5.5 min with trays, and to 4 min with trays and racks. This means, as shown in Table 2, that rack and tray systems require about 20% of the field time for loading.
The remainder of the field time was taken up by non-productive travel (turning at row end) and unplanned machine downtime. Because there was no reason to expect differences between the machine systems, the variations shown (Table 2) more likely correlate with factors beyond the scope of this study. However, the results show that turn time (2.6 to 7.6%) and down-time (0 to 2.5%) absorbed a small portion only of the total field time.

Plant Spacing

Average plant spacing delivered by the transplanters being used in the field was within 3 cm of the machine setting (Table 3). No significant effect of machine nor plant type on plant spacing was detected. Similarly, there was no significant effect by the same two variables on plant spacing variation, indicated by the standard deviation.

Tray Racks

Use of racks along with appropriate trailers and supports on the transplanter improved tray handling at the greenhouse and in the field. The racks facilitate moving 16 trays at one time, but required two people to handle them. Measurements of loading time showed that a crew of 4 could load a 6-row transplanter in one-third the time if racks were used (Table 4). Similarly, handling time and convenience at the greenhouse were improved. In addition, the racks increased the plant carrying capacity of the transplanter, permitting full rounds to be made in large fields without reloading, thus improving field operations.

Further improvements in tray handling systems could be made. One example would be the use of catwalks on the transplanter, to permit a worker to circulate safely between planting units to distribute loaded trays and retrieve empties while the machine is moving. Faster tray distribution would then reduce the chance of operators running short of plants and possibly reduce the size of the crew by one person.
Field Plant Stands

Tray plants were subject to less planting error and survived considerably better after planting than bare-root plants. Plants were counted immediately after planting and again 21 days later and compared to the theoretical planting rate of the machine. Stand deficiency at transplanting, attributed to missed or misplanted plants, was 8.8% for bare-root and 6.1% for tray plants. Field loss of bare-root plants three weeks later was 21.3% compared to theoretical planting rate and 13.7% compared to planted stand. For tray plants, field loss was 10.4% compared to theoretical and only 4.6% compared to the planted stand (Table 5).

Sorting Costs for Bare-root Plants

Sorting out non-viable plants and foreign matter from the seedlings before transplanting is an integral cost of using purchased bare-root plants that is eliminated when using tray plants. The magnitude of bare-root sorting costs varies considerably with quality of the shipments and planting delays due to poor weather. Reliable data was therefore difficult to establish. Estimates indicated that the number of plants rejected could range from 5% to over 20%. Corresponding sorting productivity ranged from 5200 to 1890 plants/h/worker, showing that more time was needed to handle material with a high rejection rate.

Data collected for one operation indicated that the high level of sorting required cost $33/acre ($82/ha) (Table 6). This amounted to 10% of the total planting cost, or nearly as much as the cost of the field operation to plant the seedlings.

Supplemental Water

Common transplanting practise in Ontario is to apply about 0.1 L/plant of water, usually mixed with liquid fertilizer, to the row from tanks and plumbing mounted on the transplanting equipment. The added equipment, carrying the extra load in the field, and filling the
tanks adds to the cost of transplanting. It was observed that filling the water tanks did not extend beyond the time to load the transplants.

Since imported transplanters are not equipped for applying water, and tray plants can be watered before planting, the potential of less-cost, alternate systems should be assessed. However, there was no opportunity to obtain such data during this field study.

Premature Fruit Removal

Premature fruit often forms on bare-root seedlings and must be removed (by hand) to obtain optimum yields. This cost is variable, but estimates from growers indicated an average of $22/ha ($9/acre). The problem is not significant with tray plants, eliminating the need for this extra field operation.

Tray Plant Characteristics

Data was collected to characterize tray plants for possible use in analyzing systems and designing transplanters. From a sampling of trays, plant stand was quite variable (Table 7), ranging from 4 to 32% empty cells. Average stand was about 83%, or about the same as the proportion of good bare-root plants after sorting out rejected material. This would indicate that an automatic planter would need to detect missed plants to improve the planted stand unless a worker was provided to fill empty cells. Alternatively, improved growing techniques such as seed selection and treatment could possibly increase cell fill to a more acceptable level (James, 1987).

Samples from the same trays provided information on plant size and force to remove the plant with its root media block from its cell (Table 8). Interestingly, the force to remove plants from the round cells was 1.8 times that for the square cells.
Cost Comparison

As described earlier, tray plants offer reduction in labour only when an appropriate transplanter is used. Labour costs increased slightly, compared to bare-root, when planting tray plants with a conventional planter but dropped to almost one-half of the level when using a tray-plant transplanter (Table 9). Labour cost was further reduced by using a rack system to handle the plant trays. The use of the more efficient tray-plant transplanters required only one person for each row rather than two, but one or two extra people were required for tray handling and for planting missed plants. Better design of tool carriers to include rack supports and catwalks (Fig. 3) could again reduce the work crew by one and further increase field efficiency.

While tray plants cost about 12% more than bare-root plants (Table 9), combined plant and labour costs are less with the appropriate machine. Labour represents 18 to 19% of the combined cost with bare-root plants, but only 11% with tray plants using the M-4000.

Fully automatic transplanters may reduce the number of workers but would not eliminate the need for machine attendants completely because of the need to load new trays into the mechanism (estimated to be every 46 seconds on a six-row machine).

ANALYSIS OF OTHER MACHINES

Field Trials

Tests were conducted with the Regero, Lännen, and modified Castle and Cooke to gather information on possible use under Ontario conditions.

The Regero was not found compatible with the tray plants currently used in Ontario. The plants were too tall to fit properly into the receiving pans, as well as to pass through the planting mechanism without interference. The mechanism provided no particular advantage in operator productivity. Complete details are provided in Appendix I.
The Linnen operated successfully with Ontario transplants, provided appropriate receiving cups were installed on the cup carousel. The unit did a good job of placing plants into the ground. Complete details are provided in Appendix II.

The modified Castle and Cooke was tested by growing plants specifically to be compatible with the machine, in the appropriate trays. The trials showed that such a machine could provide a basis for an automatic transplanter for tomatoes if the required plant size and type of root media can perform adequately in the greenhouse and the field. More details are provided in Appendix III.

Automated Transplanters

Automatic transplanters have been under development for a number of years, for various agricultural crops as well as for forestry seedling nurseries. Few such machines are actually in use, and development information is not readily available due to commercial confidentiality.

The following is a list of known information as of September, 1987:

Holland Transplanter Co.
510 E - 16th Street
HOLLAND, MI 49423
U.S.A.

An automatic transplanter is under development that will use existing or very slightly modified existing trays (such as the Blackmore). Processing tomatoes, as grown in the N.E. United States, is one of the target crops in the development program. Expected introduction is 1989 at a price forecast to be under $50,000 (Can.) for six-rows.

Linnen Tehtaat Oy
SF-27820 Iso-Vimma (Säkylä)
Finland

Lännien started development of an automatic transplanter using paper-pot technology. This has been dropped in favour of a planter using special but low-cost trays similar to trays presently used in Ontario. Introduction is forecast for 1989 but price is not known.

Williams,
Hi-Tech Space International Pty. Ltd.
Warragul
Victoria, Australia

The Williams transplanter is on the market in Australia and Europe and is being test-marketed in California. The transplanter is fully automatic and uses a special cell chain that unfolds from a
rectangular tray. The machine is capable of discerning a missed cell and compensating the feed to the transplanting mechanism. Planting rate: 60 plants/min/row; cost about $65,000 (US) for 4 rows.

Instaplant Ltd.
Ram On,
19,205 D.N. Megido
Israel

This is an experimental, tractor-mounted, automated transplanter that extracts seedlings automatically from plastic trays and plants them in prepared or untilled soil. Each planting unit can handle from 1 to 6 seedlings/sec with a maximum forward speed of 4 km/h. Planting depth and density is computer monitored. The developers are looking for a manufacturer to introduce the machine on world markets (Anon.; 1986).

Growers Incorporated
Salinas, CA.
U.S.A.

A pneumatically controlled transplanter that pushes the plug out through the bottom of the tray. This machine has been used in an integrated operation for a number of years, but there has been no attempt to market the machine.

Minora Industrial Co. Ltd
447 Shimoich, Sanyo-cho
Japan

A small, automatic machine developed for transplanting onion seedlings. It uses an elastic tray fed through a curved track.

Castle and Cooke

Described in Appendix III.

ESRC Carousel
Research Branch
Agric. Canada
Ottawa, ON KIA OC6

A design approach to a low-cost automatic transplanter (Compton and Reid, 1987). The unit is experimental only.

There are many other transplanter ideas developed by universities and research organizations that have not been produced commercially. These were reviewed previously (Heslop, 1987).

Transplanter Sales Potential

Processing tomatoes are grown on over 11,000 ha of land in Ontario by about 700 growers (Table 10). It is estimated that about one-half of
these growers will have in excess of 40 ha and will already have a mechanical tomato harvester. Therefore, it could be expected that about 350 growers would be interested in higher levels of transplanting mechanization.

Total production has remained relatively constant over the last five years, but the number of growers declined from almost 1200 in 1982 to just over 700 in 1986. The trend toward fewer and larger growers is common in agriculture and can be expected to continue.

The use of tray plants should be of interest to most growers, because of the various advantages reported earlier and the potential to develop the local production industry. In Ontario, however, it is the processors that purchase the seedlings, whether bare-root or tray grown and sell them to the growers. Thus, the processors must be closely involved in any industry-wide shift in the type of transplants used. If the rate of adoption of tray plants is restricted by the processor it would reduce the market potential for the more expensive transplanters. For example, any one grower limited to 50% of his crop in tray plants may not find it feasible to invest in an expensive planter that cannot handle both bare-root and tray plants.

Availability of tray plants will also govern the rate at which new transplanters are purchased. Local production of tray plants has probably reached a limit in terms of present capacity. Further increase in production will probably require new facilities or a shift of facilities from production of other crops.

Information from growers suggests that $50,000 (Can.) might be an acceptable price for a six-row, automated transplanter. While economic analysis may find this cost too high, other factors such as a perceived lack of labour availability and the costs of hiring and managing large work crews are part of growers' considerations. Further, an automatic machine might increase returns due to timeliness as well as providing a
significant reduction in planting costs. With smaller crews on shift, for example, it may be possible to plant for 20 hours per day, not a practical option with semi-automatic machines.

Six-row transplanters to plant two rows per bed are of interest to most larger growers, as yields have proven to be advantageous even over the added cost of planting only one row per bed. Six rows can be established with a three-row transplanter by double passing, but the trend is toward six-row machines. A method of reducing labour demonstrated in Europe uses a small, self-propelled, self-steering transplanter for a single bed (2 to 6 rows) where the driver simply changes position once the transplanter is aligned on the bed and becomes one of the operators (Fig. 4). Such a concept, along with a guide system to align three adjacent beds to match cultivation equipment and planting two rows per bed, could lead to a one-man, fully-automatic transplanter.

CONCLUSIONS

1. Use of tray plants and appropriate transplanter design (cup technology) improved the field planting rate and reduced overall costs, compared to bare-root plants. More tray transplants could be planted per day, and less field time was spent in non-productive operations.

2. Tray planting permits using one person per row, rather than two, to place plants into the planting mechanism. Use of racks for the trays further improved labour efficiency in the field and in the greenhouse.

3. Tray plants provided a 10% better field stand than bare-root plants.

4. Tray plants eliminated the cost of sorting. With bare-root transplants, labour for sorting can cost almost as much as that required for field planting.

5. Tray plants eliminated the need to remove premature fruit later in the growing season.
6. Tray plants cost about 12% more than bare-root plants, but combined plant and labour costs were less. Labour comprised 18 to 19% of the combined costs for bare-root, but only 11% for tray plants.

7. Empty cells existed in the plant trays that would require manual or automatic compensatory action in a mechanized planting system.

8. Imported transplanters did not have provision to apply supplemental water during planting.

9. The three new machines available for trials did not function well because they were designed for smaller plants than the Ontario tray plants. However, with minor changes, the Lännen could be expected to become a competitive system.

10. Some work on automated transplanters is underway, but none are yet available for sale in Ontario.

11. In the current industry, 350 Ontario growers could be considered as potential customers for upgraded transplanting mechanization. Deciding factors include machine cost and method of merchandising the transplants. The trade-off cost of labour is small, but other factors such as labour availability, labour management costs, and planting timeliness represent significant advantages.

RECOMMENDATIONS

1. Economists should further assess the tomato transplanting data to quantify and compare costs and returns of mechanized systems and better define the potential market for automatic transplanters.

2. Most transplanters from other countries require a smaller transplant than those presently used in Ontario. Interdisciplinary research is required to evaluate the suitability of smaller plants under field conditions, and better define the parameters that determine optimum
transplant size. The study should include the dependance of the transplanter on the weight of the soil block to carry the plant to the furrow.

3. Interdisciplinary work is required to quantify the effect of empty cells in the plant trays on mechanized transplanting and of missing plants on harvested yield, and identify solutions. Machine solutions (Williams Transplanter) and improved germination (James, 1987) are possible.

4. More work should be done on rack systems to accommodate plant trays for improved efficiency. Planters equipped with catwalks could increase efficiency and improve safety.

5. To hasten the introduction of emerging transplanter technology for tomatoes in Ontario, special trays used on these planters should be tested locally and the specifications for the type of plant required should be supplied to the developers to ensure problems are identified and solved before introduction.

6. Sorting of bare-root transplants is indicated to be a major cost. Information collected in 1987 did not include specific studies on sorting. Further study on sorting should be conducted to establish more accurately the cost of lost seedlings and cost of labour involved.

7. Since new transplanters on the market do not facilitate applying supplemental water, research is required to evaluate the need for water with tray plants, as well as alternative methods of providing water and/or more efficient water supply systems.

ACKNOWLEDGEMENTS

This project was made possible by the following well-appreciated support:
1) Funding from the New Crop Development Fund, Agriculture Canada; Ontario Crop Introduction and Expansion Fund; and the Ontario Vegetable Growers' Marketing Board.

2) Allocation of the priority for collection of the engineering data by the Ontario Tomato Seedling Growers' Marketing Board.


4) Data collection assistance by Jeanane Kettle.

5) Data collection and analysis by Stéphane Burgoyne, as credited in the references.

REFERENCES


Table 1. Field planting rates with semi-automatic transplanters

<table>
<thead>
<tr>
<th>Machine type</th>
<th>Plant type</th>
<th>Operators per row</th>
<th>Rate per row</th>
<th>Plants/min</th>
<th>Plants/min.operator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bare-root</td>
<td>2</td>
<td>60.9</td>
<td>30.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>tray</td>
<td>2</td>
<td>51.6</td>
<td>25.8</td>
<td></td>
</tr>
<tr>
<td>M-1000</td>
<td>bare-root</td>
<td>2</td>
<td>64.7</td>
<td>32.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>tray</td>
<td>2</td>
<td>63.8</td>
<td>31.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>35.4</td>
<td>35.4</td>
<td></td>
</tr>
<tr>
<td>M-4000</td>
<td>tray</td>
<td>1</td>
<td>69.8</td>
<td>69.8</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Burgoyne, 1987)

Conditions: 1. Drivers choose forward speed at the upper limit of operators' ability to consistently place plants in the pockets or cups.
2. Planting rates shown are the number of pockets or cups opening per minute, even if some did not contain plants.
3. Rates are the average of a number of measurements during actual field operations.
4. Rates are expressed per unit time to eliminate plant spacing as a variable.
Table 2. Proportion of time (%) and total time to plant bare-root and tray transplants with different transplanters and tray handling methods

<table>
<thead>
<tr>
<th>Machine type</th>
<th>Plant type</th>
<th>Racks used</th>
<th>Plant (%)</th>
<th>S &amp; L (%)</th>
<th>Turn (%)</th>
<th>Down (%)</th>
<th>Total (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional bare-root tray</td>
<td>N/A</td>
<td>61.1</td>
<td>34.2</td>
<td>3.5</td>
<td>1.2</td>
<td>26.9</td>
<td></td>
</tr>
<tr>
<td>M-1000 tray</td>
<td>No</td>
<td>68.5</td>
<td>25.0</td>
<td>5.3</td>
<td>1.2</td>
<td>28.3</td>
<td></td>
</tr>
<tr>
<td>M-1000 tray</td>
<td>Yes</td>
<td>68.0</td>
<td>29.3</td>
<td>2.6</td>
<td>0.0</td>
<td>23.0</td>
<td></td>
</tr>
<tr>
<td>M-4000 tray</td>
<td>No</td>
<td>69.9</td>
<td>26.7</td>
<td>3.4</td>
<td>0.0</td>
<td>20.5</td>
<td></td>
</tr>
<tr>
<td>M-4000 tray</td>
<td>Yes</td>
<td>73.5</td>
<td>19.1</td>
<td>4.9</td>
<td>2.5</td>
<td>19.5</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Burgoyne, 1987)

Notes: Racks - support system for holding a stock of trays
Plant - actual transplanter working time
S & L - transplanter waiting while plants are sorted and loaded
Turn - transplanter turning at end of rows
Down - transplanter down-time for adjustments, unplugging, etc.
Total - calculated total time to transplant 1000 transplants (per row)

Table 3. Plant spacings produced in the field with different transplanters and types of transplants

<table>
<thead>
<tr>
<th>Machine type</th>
<th>Plant type</th>
<th>Test rows (No.)</th>
<th>Machine setting (cm)</th>
<th>Field average (cm)</th>
<th>Standard deviation (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional bare-root tray</td>
<td>18</td>
<td>30</td>
<td>31</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>bare-root tray</td>
<td>20</td>
<td>40</td>
<td>41</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>M 1000 tray</td>
<td>15</td>
<td>40</td>
<td>38</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>M 1000 bare-root tray</td>
<td>20</td>
<td>40</td>
<td>40</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>Tray</td>
<td>6</td>
<td>30</td>
<td>31</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>M 4000 tray</td>
<td>10</td>
<td>40</td>
<td>43</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>M 4000 tray</td>
<td>19</td>
<td>35</td>
<td>36</td>
<td>4.0</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Burgoyne, 1987)

Method: Spacing measured between 20 consecutive plants in each of the test rows (ignoring any misses).
Table 4. Effect of the use of racks on the loading of trays onto a 6-row transplanter

<table>
<thead>
<tr>
<th>Item</th>
<th>No racks</th>
<th>With racks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observd</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trays carried/trip (No.)</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>People required/trip (No.)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Time required/trip (s)</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>Calculated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trips to load 128 trays (8 racks)(No.)</td>
<td>43</td>
<td>9</td>
</tr>
<tr>
<td>Time to load 128 trays (min)</td>
<td>36</td>
<td>6</td>
</tr>
<tr>
<td>Time required for 4 people to load 128 trays (min)</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

(Source: Burgoyne, 1987)

Table 5. Surviving plant population compared to theoretical machine setting, and to actual planted population for two types of transplants

<table>
<thead>
<tr>
<th>Plant count basis</th>
<th>Bare-root plants</th>
<th>Tray plants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plants/30 m (%)</td>
<td>Plants/30 m (%)</td>
</tr>
<tr>
<td>Theoretical</td>
<td>5226 100</td>
<td>5748 100.0</td>
</tr>
<tr>
<td>At planting</td>
<td>4766 91.2</td>
<td>5396 93.9</td>
</tr>
<tr>
<td>3 weeks after</td>
<td>4115 78.7</td>
<td>5150 89.6</td>
</tr>
<tr>
<td>Lost plants</td>
<td>651 13.7</td>
<td>246 4.6</td>
</tr>
</tbody>
</table>

(Source: Burgoyne, 1987)

Notes: Lost plants = difference between "at planting" and "3 weeks after"  
Plant count = average of four 30 m rows on each of 15 farms for each type of plant
Table 6. Partition of planting costs for bare-root transplants for one grower

<table>
<thead>
<tr>
<th>Item</th>
<th>Total($)</th>
<th>$/ha</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transplants</td>
<td>11,025</td>
<td>603</td>
<td>77</td>
</tr>
<tr>
<td>Sorting</td>
<td>1,475</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>Planting</td>
<td>1,890</td>
<td>104</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>14,390</td>
<td>789</td>
<td>100</td>
</tr>
</tbody>
</table>

(Source: Burgoyne, 1987)
Conditions: planter - conventional, 3-row
plants purchased - 558255 at $19.75/1000
sorting speed - 1892 plants/h/worker
(worker salary - $5.00/h
planted area - 7.5 (in double rows) + 10.8 (in single rows) = 18.3 ha.

Table 7. Number of trays (Blackmore), in two sizes, at different amounts of fill (proportion of cells in the tray containing viable tomato seedlings)

<table>
<thead>
<tr>
<th>Proportion of cells having good plants (%)</th>
<th>Number of trays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200 cells/tray</td>
</tr>
<tr>
<td>68</td>
<td>1</td>
</tr>
<tr>
<td>72</td>
<td>5</td>
</tr>
<tr>
<td>76</td>
<td>2</td>
</tr>
<tr>
<td>80</td>
<td>1</td>
</tr>
<tr>
<td>84</td>
<td>11</td>
</tr>
<tr>
<td>88</td>
<td>7</td>
</tr>
<tr>
<td>92</td>
<td>6</td>
</tr>
<tr>
<td>96</td>
<td>7</td>
</tr>
<tr>
<td>Total trays sampled</td>
<td>40</td>
</tr>
</tbody>
</table>

Weighted Average fill: 82% 83%

(Source: Burgoyne, 1987)
Note: Trays sampled were from different shipments to various cooperating farms
Table 8. Characteristics of tomato plants grown in Blackmore square cell and round cell trays.

<table>
<thead>
<tr>
<th>Cells/tray</th>
<th>No. of plants tested</th>
<th>Stem height (mm)</th>
<th>Removal force (N)</th>
<th>Root mass (g)</th>
<th>Stem mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200s</td>
<td>15</td>
<td>182</td>
<td>1.39</td>
<td>8.0</td>
<td>3.5</td>
</tr>
<tr>
<td>288s</td>
<td>25</td>
<td>155</td>
<td>1.37</td>
<td>4.0</td>
<td>1.5</td>
</tr>
<tr>
<td>288r</td>
<td>15</td>
<td>173</td>
<td>2.58</td>
<td>3.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

(Source: Burgoyne, 1987)

Notes: 1. Values shown are averages for the samples tested.
2. Removal force includes that required to lift the mass of the root and stem.
3. Plant variety, age and plug moisture content not recorded.
4. Under cells/tray: s = square, r = round.

Table 9. Estimate of some variable costs ($/ha) for transplanting processing tomatoes during 1987 field operations in Ontario.

<table>
<thead>
<tr>
<th>Machine type</th>
<th>Plant type</th>
<th>Racks used</th>
<th>Employee cost</th>
<th>Plant cost</th>
<th>Fruit removal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>bare-root</td>
<td>No</td>
<td>156</td>
<td>629</td>
<td>22</td>
<td>807</td>
</tr>
<tr>
<td></td>
<td>tray</td>
<td>No</td>
<td>164</td>
<td>704</td>
<td></td>
<td>868</td>
</tr>
<tr>
<td>M-1000</td>
<td>bare-root</td>
<td>No</td>
<td>143</td>
<td>629</td>
<td>22</td>
<td>794</td>
</tr>
<tr>
<td></td>
<td>tray</td>
<td>No</td>
<td>133</td>
<td>704</td>
<td></td>
<td>837</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>127</td>
<td>704</td>
<td></td>
<td>831</td>
</tr>
<tr>
<td>M-4000</td>
<td>tray</td>
<td>No</td>
<td>87</td>
<td>704</td>
<td></td>
<td>791</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>83</td>
<td>704</td>
<td></td>
<td>787</td>
</tr>
</tbody>
</table>

(Source: Burgoyne, 1987)
Table 10. Production statistics over five years for processing tomatoes in Ontario

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total contracts (No.)</td>
<td>1,187</td>
<td>1,007</td>
<td>1,004</td>
<td>855</td>
<td>734</td>
</tr>
<tr>
<td>Contract area (acres)</td>
<td>27,075</td>
<td>26,779</td>
<td>31,260</td>
<td>26,163</td>
<td>27,526</td>
</tr>
<tr>
<td>Total harvested (tons)</td>
<td>520,157</td>
<td>442,473</td>
<td>593,418</td>
<td>523,198</td>
<td>539,097</td>
</tr>
<tr>
<td>Farm Value ($'000)</td>
<td>56,962</td>
<td>45,736</td>
<td>66,625</td>
<td>58,791</td>
<td>60,021</td>
</tr>
<tr>
<td>Yield (tons/acre)</td>
<td>19.2</td>
<td>16.5</td>
<td>18.9</td>
<td>20.0</td>
<td>19.6</td>
</tr>
<tr>
<td>Return ($/acre)</td>
<td>2,104</td>
<td>1,707</td>
<td>2,131</td>
<td>2,247</td>
<td>2,180</td>
</tr>
<tr>
<td>Return ($/ha)</td>
<td>5,197</td>
<td>4,216</td>
<td>5,264</td>
<td>5,550</td>
<td>7,730</td>
</tr>
</tbody>
</table>


Note: Return ($/acre) - referenced value
      Return ($/ha) - calculated value

Figure 1. A conventional, semi-automatic machine for transplanting processing tomato seedlings. (A) furrow opener; (B) packing wheels; (C) two loading operator seats per row; (D) plant grippers or pockets extending from a chain driven from the packing wheels; (E) container for seedlings.
Figure 2. A cup-style transplanter (M-4000) for tray plants, (A) 4-cup carousel; (B) packing wheel; (C) furrow opener; (D) combination floatation and drive wheel; (E) rotary tray holder for four trays.
Figure 3. A concept drawing of a transplanter with rack carrying capabilities showing: (A) Matheson style tool-bar semi-mounted on tractor; (B) a tray plant transplanter with a modification for spacing at 45 cm (18 in.); (C) cat-walk; (D) rack supports and, (E) rear swivel wheels.

Figure 4. A European self-propelled, self-steering machine with one operator transplanting 5 rows per bed.
APPENDIX I. TESTING OF THE REGERO HD B4T TRANPLANTER WITH TOMATO TRANSPLANTS

M.-A. Pelletier and G. B. Hergert
Engineering & Statistical Research Centre
Research Branch, Agriculture Canada
Ottawa, Ontario K1A 0C6

INTRODUCTION

In Ontario, most processing tomato crops are established from bare-root seedlings transplanted by machines that depend on hand labour to sort the plants and place them into the planting mechanism. Current trends to use tray plants, double-row beds and concern about labour availability are creating needs for new mechanization.

The Regero HD B4T transplanter (Fig. I.1) is manufactured by Regero, 44084 Nantes, France and is distributed in Canada by Plastitech Culture Inc., BP 750, St. Remi, Quebec JOL 2L0. Both tractor-mounted and self-propelled models are available, that can handle both bare-root and tray plants.

Features of the Regero design of potential interest in Ontario included multi-row bed planting, and a potential for reduced labour requirement to feed plants to the planting mechanism. The self-propelled version could permit one person to operate a two-row machine. The purpose of the test reported here was to evaluate the operation of a Regero machine under Ontario conditions.

DESCRIPTION

The Regero model HD B4T obtained for evaluation was a three-point hitch mounted unit, capable of planting 8 rows on a 2-m wide bed, but supplied with mechanisms for 3 rows.

The main frame comprised two sections, linked together on each side by parallel arms (Fig. I-1). The front section carried the operator's
platform, and was attached to the three-point hitch of the tractor. The second section carried the transplanting mechanisms and the ground drive roller, and was free to float independently of the front section. When lifted by the three-point hitch to the transport position, the front frame engaged the rear frame to form a rigid unit. A plant rack was located on the rear section.

Transplants were loaded by hand onto tapered trays or pans attached to inclined roller chains. As the chain for each row traveled over the lower sprocket, the pans tipped, dumping the plant root first into the planting shoe cup (Fig. I-2). With the transplant in the cup, a cable retracted the rear door as a cam-actuated rod pushed the cup rearward to seat the plant into the furrow just ahead of the packing wheels. A scraper at the front of the cup pushed the plant along with any soil or debris out the rear of the furrow opener. The mechanism then returned to the neutral position, ready to receive the next plant. The planting mechanism, including the pan conveyor, was chain-driven by the ground roller, with provision for adjustment, to achieve timing of the components and the desired plant spacing.

FIELD TESTS

Procedure

The transplanter was set up to suit Ontario conditions as follows:

1. The mechanism for one of the 3 rows was removed.

2. The remaining two rows were centered relative to the three-point hitch. Mounting lugs on the furrow opener attachment bars were added for this purpose.

3. The ground-drive roller was replaced by two low-pressure tires (21 x 11-8), with each tire running in line with a furrow opener. This was done to reduce the danger of soil drift due to pulverization.
4. Plant spacing (in the row) was adjusted to 400 mm (16 in.) by selecting the appropriate drive sprockets.

5. Mechanisms were adjusted as much as possible to accept large plants.

The machine was tested at two locations in Southern Ontario and also in Ottawa, using similar transplants, where more detailed operation could be studied.

Tilbury tests

The machine was transported to Tilbury and tested in a field having permanent beds formed at 1700 mm (66 in.) on center. Planting depth was adjusted to approximately 75 mm (3 in.) with the packing wheels set as close as possible to the cup mechanism. The tomato transplants were approximately 150 to 200 mm (6 to 8 in.) total length, including a root ball approximately 38 mm (1\(\frac{1}{2}\) in.) long.

This test resulted in the following observations:

1. The conveyor pans were too short for the transplants, slowing operator work rate because of the need for more care in loading the plants. Plants were blown sideways when operating in a slight cross-wind, indicating that the pans were also too shallow.

2. When placed in the furrow, the transplants interfered with the planting cup mechanism and were pushed forward when the reciprocating cup returned to neutral, even though the rear door was adjusted to maximum clearance.

3. The furrow openers could not cut deeply enough to permit the packing wheels to close the furrow properly. With the permanent bed, a hard-pan existed about 50-75 mm (2-3 in.) under the loose top soil. The bottom of the furrow opener is flat and approximately 35 mm (1\(\frac{1}{2}\) in.) wide x 350 mm (10 in.) long, so that it slid on top of the hard surface and didn't penetrate.
Ruthven tests

In this field, looser soil allowed deeper penetration, disclosing that the timing of the pan conveyor was out of adjustment. The plants were dropped too late to reach the bottom of the cup mechanism, and were thus planted at less than the adjusted depth and pushed flat to the ground by the mechanism as it returned to neutral.

The respective drive sprockets were adjusted to advance the transplant drop and retard the activation of the cup mechanism so that the transplants completed their fall before being pushed out of the cup. The machine performance improved, but the rear door still brushed the tops of tall plants as the cup returned to the neutral position. The root ball was placed deeply enough in the furrow to be held firmly in the ground, but many tops were leaning in the direction of travel and some plants were damaged.

Ottawa tests

Further tests showed that plants shorter than 18 cm (7 in.), including the root ball, were properly transplanted and did not show any sign of damage by the mechanism. The height of the opening at the back of the planting cup was approximately 18 cm (7 in.) but the rear door reduced this to 10 cm (4 in.). The plants would clear the cup but were struck by the rear door as it returned to the neutral position. Plants taller than 18 cm (7 in.) were also anchored properly but were leaning in the direction of travel, although they did not show any severe damage. The tests were conducted in a loose, dry, sandy-loam soil where the transplanter could achieve a planting depth of 7 to 10 cm (3–4 in.).

At all three locations, the tests were made with the packing wheels adjusted as close as possible to the furrow opener. Trials made with the packing wheels moved back approximately 7 cm (3 in.) resulted in most plants being flattened in the furrow.

Tests made with the rear door removed, with plants from 10 to 18 cm (4–7 in.) tall, showed that plant placement remained satisfactory and
that interference was reduced. As the transplant falls into the cup, the root ball sits between each side of the furrow opener. When the mechanism is activated, a scraper on the front of the cup pushes the root ball out of the shoe and cleans all soil from the furrow opener. Shorter plants require the action of the retracting door to keep them from falling over during the planting process. When the door is removed, the plant relies on the foliage to hold it upright in the cup, which was appropriate for the tall tomato plants used in Ontario.

Minor problems were encountered with plants hanging on the edge of the cup, due to being placed or blown sideways on the conveyor pans. The foliage of plants not falling straight into the cup sometimes hooked on the cup sides, causing the following plants to lodge and eventually plug the mechanism.

It was originally considered that only one person would be needed to operate the two-row planter. While this was possible, the advantage was limited by the speed at which the operator can remove plants from the trays and place them in the conveyor pans. This rate was measured at 60-70 plants/min with other planters (Burgoyne, 1987). The planting rate, therefore, for one person feeding two rows would be limited to 30 to 35 plants/min/row. The standing position of the operator did not appear to promote faster loading. The short feed plates were observed to be more difficult to load than cups on other transplanters.

CONCLUSION

The Regero transplanter was found capable of handling tomato tray transplants, but improvements are required to handle the tomato transplants presently used in Ontario, that vary from 20 to 22 cm (8-9 in.) in height. The machine handled shorter plants properly and spaced them in the furrow consistently. The Regero offers the advantage of planting two rows side-by-side, spaced at 450 cm (18 in.) on the same bed. Also at lower speeds, one operator could feed the two rows on the same bed, or 3 operators and one tractor driver for a six-row unit, making the machine attractive to smaller growers with access to only a small work crew.
To adapt the Regero transplanter for tomato transplanting in Ontario, a number of modifications and improvements should be made:

1. The conveyor pans should be made longer to accommodate plants 20 to 22 cm (8-9 in.) tall. This would require increased clearance at each end of the pans, but would facilitate faster loading and reduce the effect of wind on seedling alignment in the pans.

2. Shields or tarps provided around the machine would prevent wind from blowing transplants off the pans.

3. Both sides of the planting cup should be extended upwards and tapered outwards to prevent plants from hanging up on the edges.

4. The cup and rear door assembly should be modified to accommodate plants from 20 to 22 cm (8-9 in.) tall, including eliminating the door if not required for the taller plants.

5. Furrow openers should be redesigned to improve penetration in firm soils to achieve greater planting depth.

6. The furrow openers should be mounted on a frame that permits sliding adjustment of row spacing to match the adjustments provided for the other components of the machine.

7. The smooth drive roller should be replaced by low-pressure tires or other arrangement to reduce soil pulverization.

8. The machine should provide facilities for applying supplemental water while planting.

9. The tool bar should accommodate 6 rows to plant 3 beds spaced up to 168 cm (66 in.) on center, each with two rows spaced at 45 cm (18 in.) and centered on the bed. The operator's station should accommodate one and two workers per row.

10. Appropriate racks are required for the plant trays.
Figure I-1. Regero HD B4T transplanter from France.
(A) front hitch section; (B) floating rear section;
(C) ground drive roller (hidden); (D) plant rack; (E) feed pans attached to chains (6 rows shown); (F) packing wheels.

Figure I-2. Planting shoe used on the Regero Transplanter.
(A) sliding cup; (B) front scraper; (C) rear retracting door; (D) control cable; (E) furrow opener; (F) cam-actuated rod.
APPENDIX II. TESTING OF THE LANNEN TRANSPLANTER WITH TOMATO TRANSPLANTS

G. B. Hergert
Engineering & Statistical Research Centre
Research Branch, Agriculture Canada
OTTAWA, Ontario K1A OC6

Introduction

The Länn en RT2 transplanter (Fig. II-1) is manufactured by Länn en Tehtaat Oy of Finland and is distributed in Canada by Hakmet Ltd., 881 Harwood Blvd., Dorion, Quebec J7V 7J5. The planter is specifically designed for tray plants and is sold world-wide for vegetable and forestry transplanting. Originally, the machines were designed for transplanting plants grown in paper pots but the RT2 is an improved version that can be used for almost any type of tray plant. This report describes the planter and limited field tests.

Description

The transplanters are sold as single-row units for mounting on tool bars but can also be supplied as multi-row machines complete with attachments, particularly for forestry operations. Each planter unit consists of two main elements:

1. A vertical axis, rotary cup bank or carousel to receive the plants and release them one at a time into a delivery tube.

2. A planting system to receive the plants from the delivery tube and place them upright in the furrow.

The carousel consists of 10 cylindrical cups 60 mm diameter, angled at the bottom, and closed by a hinged flap. As the carousel rotates, levers on the flaps open each cup in turn, allowing the plant to drop through a delivery tube into the furrow opener. The carousel speed can be easily adjusted to provide various plant spacings through changing a sprocket device in the drive from the packing wheels.
The planting system consists of a stainless steel furrow opener and a unique plant guide consisting of long spring tines protruding from two V-belts driven from the packing wheels. The seedling drops from the delivery tube into an area near the back of the furrow opener, bounded by a metal tongue at the front and the tines at each side. The tines keep the plant upright and allow soil to filter through to cover the plant root ball. The tines gradually withdraw from the ground just before the packing wheels firm the soil around the plant.

The working parts of the planter are mounted through a floating, parallel-bar linkage with a clamp on a tool-bar. Each planting unit has independent depth adjustment controlled by a handwheel within reach of the operator. The operator's seat can be placed on either the tool-bar clamp or the seeder frame depending on soil penetration requirements. Each planter unit is about 500 mm (20 in.) wide. Row spacing closer than 500 mm would require a double tool-bar with the planters offset.

Field Tests

A single planter unit mounted on a tool-bar was supplied by Hakmet Ltd. for testing. In the initial trial with 18-cm tall tomato plants, the plant foliage would hook on the top of each cup on the carousel. After completing this test, Mr. Jorma Puumalainen, Sales Manager for Lännen in Finland visited us and suggested using a carousel with 8 larger (75 mm diameter) cups fitted with upper extensions. The new carousel alleviated the hooking problem, but the design of the hinged flap on each cup caused a new problem. The new flap was convex, rather than flat like those on the smaller carousel, causing the root ball to slip against either side of the tube. If the root ball moved to the outside, it would strike the edge of the delivery tube when released by the flap, interfere with the carousel, and subsequently block the opening to the delivery tube.

During the tests, the following advantages of the planter were noted:

1. The unit was capable of planting up to 120 mm deep, allowing plants to be placed into moist soil during dry conditions.
2. A wide range of adjustments were possible without disassembly.

3. There were no reciprocating parts in the planting mechanism that could jam on small stones or wear quickly, allowing the mechanism to turn freely and easily.

4. The furrow opener was made of stainless steel to reduce soil sticking, and eliminate potential rusting problems.

5. The carousel mechanism is quite similar to that on existing rotating cup planters, such as the Mechanical 4000, that are already in commercial use.

Disadvantages noted were:

1. Each planting unit is too wide for single ranking at row spacings less than 500 mm.

2. A suitable tool-bar for a three- or six-row set up complete with water tanks, to suit tomatoes, is not presently available from the manufacturer.

Recommendations to the Manufacturer

1. The Lännen RT-2 planter would be suitable for tomatoes in Southern Ontario if the problem with the convex flaps on the eight-cup carousel was eliminated.

2. While some growers will be interested in purchasing individual units for mounting on their own tool-bars, others will want to purchase a complete unit with water facilities, plant racks, tray holders and other necessary equipment for efficient operation.
Figure II-1. The Länner RT2 transplanter.

(A) rotary cup bank or carousel;  
(B) stainless steel furrow opener;  
(C) plant guidance tines;  
(D) packing wheels;  
(E) tool-bar clamp;  
(F) parallel mounting linkage;  
(G) depth adjustment wheel;  
(H) delivery tube.
Appendix III. Castle and Cooke Transplanter Tomato Transplanting Trial

M. Feldman
Engineering and Statistical Research Centre
Agriculture Canada
Ottawa, ON

A. Liptay
Research Station Branch
Agriculture Canada
Harrow, ON

F.D. Sumision
Ont. Centre for Farm Machinery and Food Technology
Chatham, ON

Purpose

Observe a feasibility trial to evaluate the capability of a "Castle and Cooke" automatic transplanter modified and in use for transplanting plug seedlings of evergreen trees.

Date and Location


Background

During 1987, the Engineering and Statistical Research Centre and others were collecting field performance data on various methods of tomato transplanting in Ontario. F.D. Sumision offered to arrange a field trial with the Forestry transplanter to add to this data base, since tomato transplants had not been tried in the original nor modified Castle and Cooke system.

Description

The machine is an 8-row, self-propelled unit using the Castle and Cooke principle, but modified to provide 16 cm row spacing, 6 cm plant spacing, and other engineering innovations required for tree seedling transplanting (Fig. III-1). Planting units are set up in two tandem, offset sets of 4, to provide the 8 rows. One tray rack is provided for each row set so that one operator installs full trays and retrieves empties for four rows (Fig. III-2). Plants are ejected from the trays one row at a time by plungers that engage the root end of the plug through holes in the tray bottom below each cell (Fig. III-3).
Procedure

1) A. Liptay prepared the transplants by growing tomato seedlings in Castle and Cooke trays and the prescribed media (Fig. III-4), to size specifications provided by Sumsion. Some trays were grown at one plant in each cell and the remainder at one plant every second cell. With the seedlings ready to plant, Liptay transported the trays to Thunder Bay.

2) The test field was a well-prepared, smooth, bare, sandy soil bed as used for transplanting tree seedlings. Soil was moist, but not sticking to soil working parts of the machine.

3) The machine was handled by the same Forestry Station operator who drives the unit for tree transplanting. Ground speed was similar to that used for the trees, in the order of 2 km/h. About 9 to 10 trays were run through the mechanism of one row of the 8-row machine (Fig. III-5).

4) The machine was operated at virtually the same settings as was being used for the trees.

Observations

1) Noting that this was a first trial, in the order of 60 to 80% of the plants were properly placed in the soil. Most misses were due to plants not being ideally placed onto the conveyor mechanism from the tray, and could be solved by adjustment (see 4, below).

2) The transplants used were approximately 50 to 70 mm tall on top of a 10 mm diameter by 45 mm high plug. This would likely be considered small as a transplant; Liptay mentioned that the plants should be taller. Still, there were indications of leaf interference problems in the machine (see below).

3) Plant spacing was about 7.6 cm (as required for trees), but double that spacing when planting from the trays with plants in every second
cell. Machine modifications would be necessary to deliver the wider spacing required for tomatoes. Plant spacing is controlled by (a) planting chain to ground speed ratio (fixed to obtain proper placement of the seedling in the soil) and (b) spacing of plant grippers on the planting chain (replacement chain required).

4) The main problems seemed to be that the plants ejected from the trays were placed too far out on the conveyor chain compartments. The plants sometimes tipped and fell off the conveyor or leaned at an angle on the conveyor causing interference. Other possible problems noted were: a) interference between the leaves of the row of plants placed onto the conveyor and those of the plants held in the next row in the tray, and b) interference between the leaves of the plants and the plant holders at the point where the holders pick the plants off the conveyor chain.

These problems should be solvable with design changes, within some upper limit of plant size.

Field Performance

Information was obtained on the performance of the prototype machine with tree seedlings, and extrapolated to estimate possible performance with tomatoes. Operation with tree seedlings includes the following comments:

1) One person handles trays for 4 rows, on the machine. The number of tray handlers required depends on planting rate.

2) One person is required to handle trays at the greenhouse and transport the containers of trays to the field, but this depends on travel distance and the type of handling and transport system.

3) Empty tray containers were removed from the machine and full ones installed, using a fork lift. This operation is part of the machine turning cycle at one end of the field.
4) The transplanter satisfactorily meets the precise criteria specified for tree planting, except for plant spacing accuracy. The criteria include:

- top surface of the seedling plug to be 6 ± 6 mm (1/4 ± 1/4 in.) below ground surface after soil packing and subsequent settling;
- plant position within 5' of vertical;
- plant anchored in the ground, to withstand a 1.96 N pull test;
- row spacing 15 cm (6 in.);
- in-row plant spacing 6 cm (2.5 in.).

5) Some performance data was available from the forestry operations, permitting further calculation and estimation of potential performance of such a machine with tomatoes, as shown in Table III-1. There is a potential for planting considerably faster than current tomato transplanters, depending on the factors that might limit forward speed.

With trees spaced at 6 cm and planted at 2 km/h, the theoretical planting rate for the 8-row machine is 266,6667 plants/h. Actual planting rate achieved was about 200,000 plants/h. Using this achieved rate and projected travel speeds of 2 to 6 km/h, planting rates for tomatoes spaced at 35 cm can be calculated and are shown in the table. Since ground speed determines planting rate, for a given plant spacing, the rate is limited by acceptable plant placement in the soil, control of the machine by the operator, or other such factors. At the same forward speed as for trees, the planting rate for tomatoes (71 plants/min/row) is similar to existing planters. However, the tree data shows that the mechanism can operate at a speed of 417 plants/min/row. Therefore, as an example for tomatoes, increasing planting rate by a factor of 3 compared to current transplanters is possible at a reasonable ground speed of 6 km/h.
Table III-1. Measured and Calculated Performance Data for a Prototype, Automatic Tree Transplanter

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Trees (actual)</th>
<th>Tomatoes (projected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of rows</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Travel speed (km/h)</td>
<td>2</td>
<td>2 to 6</td>
</tr>
<tr>
<td>Plant spacing (cm)</td>
<td>6</td>
<td>35</td>
</tr>
<tr>
<td>Planting rate (plants/h)</td>
<td>200,000</td>
<td></td>
</tr>
<tr>
<td>Planting rate (plants/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- per machine</td>
<td>3,336</td>
<td>426 to 1278</td>
</tr>
<tr>
<td>- per row</td>
<td>417</td>
<td>71 to 213</td>
</tr>
<tr>
<td>No. of operators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- driver</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>- tray handlers</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Turning time at end of field (min)</td>
<td>1 to 4</td>
<td>same</td>
</tr>
<tr>
<td>Change containers (min)</td>
<td>5.3 (one)</td>
<td>same</td>
</tr>
<tr>
<td>Proportion of time planting (%)</td>
<td>81</td>
<td>same</td>
</tr>
</tbody>
</table>

Figure III-1. Self-propelled, 8-row Castle and Cooke transplanter converted for use with tree seedlings
Figure III-2. Full tray taken from the tray rack (right side of photograph) being placed into the automatic mechanism

Figure III-3. Plungers set to enter holes in the tray bottom to eject a row of seedlings
Figure III-4. Tomato seedlings in the Castle and Cooke trays

Figure III-5. Tomato seedlings placed into one of the eight rows during the field trials