Status of Mechanization Technology for Tomato Transplanting

G. B. Hergert, L. C. Heslop, B. A. Compton
W. S. Reid and M. Feldman
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Contribution no. I-925, from Engineering and Statistical Research Centre, Research Branch, Agriculture Canada, Ottawa, Ontario K1A OC6.
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FOREWORD

M. Feldman

Most of the tomato production industry in Southern Ontario is based on bare-root transplants imported from Georgia, U.S.A., and planted with commercial transplant machines that depend on hand labor input. Various organizations are collaborating on research to develop a locally-produced seedling to compete with the imported plants. Growers have immediate concerns with the labor-efficiency of their current transplanters as well as longer term interest in appropriate mechanization for the domestic seedling if it is successful.

Through ESRC's (Engineering and Statistical Research Centre, Ottawa) ongoing mechanization activities, we have done research work and possess expertise on horticultural mechanization, including transplanting. ESRC was contacted by various individuals for advice regarding these tomato transplanting mechanization concerns. Discussions with G. Koestler (New Crop Development Fund, Agricultural Development Branch, Agriculture Canada, Ottawa) and E. Tomecek (Ontario Ministry of Agriculture and Food, Ridgetown) led to the concept of a symposium to update organizations and individuals on current activities, equipment and problems. The symposium was organized by E. Tomecek and held December 9, 1986 at Ridgetown College of Agricultural Technology.

The purpose of this report is to assemble the ESRC input to the symposium and our analysis of the proceedings, relevant to mechanization. Note that each chapter contains its own list of references and the author's post-meeting assessment.
CHAPTER 1: SEMI-AUTOMATIC TRANSPLANTERS FOR BARE-ROOT AND TRAY-GROWN TRANSPLANTS

G. B. Hergert

1.1 Introduction

Progress on research to establish locally grown tray transplants for tomatoes has prompted a review of present methods of transplanting along with various ideas to increase work rate or to reduce labor input. Most transplanters used today are semi-automatic types that have mechanisms to carry plants to the furrow, position them and firm the soil around them. Operators are required to load the mechanism plant by plant. There are several different transplanter designs, but these can be separated into two main groups: bare-root and tray plant transplanters.

1.2 Bare-root Transplanters

Bare-root transplanters grip plants in one of the following ways:

1. Folding plant pockets or grippers extending from a chain or disc that are loaded by hand, then close automatically to carry the plant to the furrow where the pocket or gripper releases the plant.

2. Flexible rubber or steel discs rotating in pairs that grasp the plant when inserted and release it in the furrow.

3. Automatic plant pick-up system where the plant is laid in a tine-bottomed box to be picked out by a plant gripper as it passes through the box, carrying the plant to the furrow.

Transplanter forward speed is limited by the rate at which the operator can load the gripping devices. In most high-volume applications using bare-root transplanters, two operators per row are used. The conventional method of building transplanters has been to drive the plant carrier from the packing
wheels. Recent improvements have included driving the plant carrier from a separate wheel, offering more opportunity to adjust speed ratios in relation to the forward speed. This allows more grippers to be used while travelling slower, so the operator has more time to pick up and separate plants and load the gripping device before it has travelled out of reach. Faster forward speeds are thereby attained.

Another method to improve the work rate of bare-root planters is to provide more plant pockets for filling at one time by the operator. This allows the operator to cycle between picking up, sorting and loading in groups of 5 to 8 plants. A multiple loading station transplanter was reported from North Carolina (Suggs 1979), where an extra long chain carrying the plant grippers was made to bend bi-directionally to allow a number of grippers to pass on a horizontal table in front of the loading operator. An ESRC review (see chapter 4) indicated that planting rates could have been inflated because of short measurement periods. Suggs' development remains to be proven as a promising method to improve performance of conventional planters capable of handling both bare-root and tray plants.

An alternate method of achieving multiple loading is used on the Super Prefer planters from France and supplied in Canada on Egedal planters (Appendix 1.2) where up to 36 plant grippers are supplied on a planting wheel. The increased number of grippers and the gripper design allows up to 8 grippers to be loaded at any time in alternate loading and sorting actions.

The use of pre-loaded bandoliers is another method to increase work rate on transplanters. Bandoliers are coiled belts that have plants inserted either in the packing shed or during harvest. The bandoliers are then transferred to a transplanter where they are uncoiled and transplanted automatically. Bandolier transplanters include:

1. Whitfield Forestry Equipment (Appendix 1.2; Fig. 1.2) plastic band planter where a mylar plastic band has notched openings that open for plant insertion when rotated over a small pulley but grip the plant when rolled on a large diameter reel.
2. Ruetenik Gardens tape transplanter (Fig. 1.2) where foam blocks were glued onto a fabric belt. The space between the blocks opens when rotated over a small diameter pulley with the foam blocks facing out but grip the plant when rolled onto the reel with the foam blocks facing in. An advantage of the foam blocks is that they can be moistened to preserve the plants (Wynia).

3. Picador System from Europe (Appendix 1.2) where plants are spaced on a separate loading chain and then rolled into a reel with cloth tapes on each side of the plants, holding the plants in position for automatic planting in the field.

4. Field loaded bandoliers where plants are fed directly from a row-type seedling harvester to a belt or tape system that grip the plants and hold them until released when the bandolier is transferred to and fed through the planter.

Bandolier planters have never come into common use, probably because with the exception of field-loaded bandoliers, they only offer a transfer of labor from the field to the packing shed. Field-loaded bandoliers would require a sophisticated marketing system for any crop where plants are sold in different areas than where grown, special planters would be required, and there would be no opportunity to sort seedlings either at harvest or at planting.

1.3 Tray Plant Transplanter

In recent years, special planters have been developed for transplanting seedlings grown in cells or trays. These planters have a bank of 4 to 10 conical cups that receive plants one at a time. The cup bank rotates from a gear drive and opens to drop the plants at appropriate spacings. The plant is controlled by a gate in the furrow opener or by tines extending from a belt (see Fig. 1.3).

Transplanters designed for tray plants work at speeds equal to or slightly faster with one loading operator than bare-root planters with two
loading operators. Increased labor efficiency is achieved by multiple station
loading and by providing easy to reach tray locations.

Automation of tray plant transplanters is receiving considerable
attention by researchers and inventors but there are no models available
commercially. Machines built in California are available for hire only. A
carousel concept is described by Compton and Reid (see chapter 3). Lannen
Tehtaat (Appendix 1.2) have prototype models using a modified paper pot
technique to provide complete automation from growing to transplanting.
Automation of tray plants is feasible because machines can work with defined
size soil blocks, especially when the soil can be enclosed as is the case with
paper pots or is held intact by a binder material.

Special planters for peat blocks are common in Europe where seedlings are grown
in pressed peat mats. The peat mats are scored during the forming operation and
are easily broken into blocks at planting time. Recent developments are toward
transplanters using only one operator for up to six rows (see Appendix 1.4).

1.4 Transplanting Tray Plants with Bare-root Transplanters

With slight modifications, bare-root transplanters may be used for
transplanting tray plants. Pocket or gripper-type transplanters require pocket
extensions; disc-type transplanters require a root ball holder to replace plant
markers (Appendix 1.1). The advantage of using bare-root planters is that both
bare-root and tray plants may be planted. The disadvantage is that labor
requirements are higher as two people will be required per row.

All transplanters require proper devices or racks to hold plant trays to
function at optimum speed, allowing the operator to pull plants with one hand.
As well, some sort of tray indexing arrangement is required to prevent
interruptions for changing trays. Tray type and seedling size can affect speed
of planting because of difficulty or ease of plant singulation.
Discussion

Sufficient mechanization is available to plant tray plants at acceptable rates. Bare-root planters may be used but minor modification is required. The advantage of using bare-root planters is that growers still have the option to plant both types of seedlings. Semi-automatic planters designed specifically for tray plants are now available and have been demonstrated to require only one-half of the labor required for bare-root planters. The increased labor efficiency offers an opportunity to offset the higher cost of tray transplants and of the planters themselves.

An economic study based on a computer model was done in Great Britain to estimate the change in profit due to using different machinery on a horticultural enterprise (Audsley 1985). The enterprise that was modeled grew a variety of horticultural crops according to marketing and crop rotation practices. This determined the amount of regular labor, casual labor, and machinery needed. Bare-root transplants were raised on the farm itself, but soil-block or container plants were purchased. Both manual and automatic transplanters were considered at various work rates.

The automatic transplanters did not appreciably improve profitability and in fact, profit for the fully automatic planter was less than that of a lower level of mechanization requiring an extra operator. The study indicated that the best profit level was for conventional high-speed planting using bare-root plants, but this may be partly due to the lower on-farm cost of the plants. Table 1.1 shows the maximum extra capital generated by the increased productivity of various machine systems, that could be invested in such a machine, compared to a base system. The study did not address the question of plant growth performance and involved conditions considerably different from the Ontario situation.

1.5 Automation

Automation may not reduce over-all costs but would alleviate the labor shortage problem. Costs for automation can be extrapolated from existing
information. Automation of bare-root transplanting is technically difficult and therefore unlikely to be done at an affordable cost; thus, automation is only applicable for tray plants. A reason for investigating automation early in the program is to include machine requirements when specifying planting tray types and media mixes.

1.6 Conclusion

Considerable attention has already been given to improving transplanter performance. Existing commercially available transplanters provide sufficient mechanization to proceed with the Ontario Tomato Seedling Replacement Program, especially considering the models developed for tray plants. The type of transplanter used will affect the over-all costs when comparing bare-root to tray-grown plants. The type and source of plants can also have an effect on profitability requiring that a study on transplanting involve an integrated approach including agronomy, mechanization and economics.

1.7 Recommendations

The following recommendations pertaining to transplanting are made to the co-operators of the Ontario tomato seedling transplant replacement program for study as part of the over-all system.

1. Time study should be carried out for properly equipped bare-root transplanters using both bare-root and tray plants, and tray-plant transplanters with tray plants only. It is of little value to study planters not properly equipped (Appendix 1.1).

2. An economist should be involved in the program to evaluate each segment of the system in the Ontario situation. Sensitivities should include:
   a. transplanter type, capacity and cost;
   b. labor required;
   c. plant stand and yield (including seedling discard rate);
   d. tray type and costs;
   e. projections for fully automatic planters.
3. Manufacturers with new or improved planters not available from co-operating growers should be encouraged to provide properly equipped test units (3-row minimum) for demonstration and data collection. Experimental planters such as the carousel planter described by Compton and Reid should be also included.

4. Evaluation of planters should include their ability to provide a good plant stand.

5. Planting tray types and seedling sizes should be evaluated for ease of removal and separation.

6. The "bottom line" for comparison of systems should be the cost of establishing a field of healthy, growing plants. Evaluations should be carried out in field size units, using at least 3-row planters and include all steps in the seedling production, supply and transplanting operation.

1.8 References


Kolk, H. 1986. Personal communication. Mechanical Transplanter Co., P.O. Box 1008B, Holland, MI. 49423.


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APPENDIX 1.1: MODIFICATIONS REQUIRED FOR USING CONVENTIONAL PLANTERS WITH TRAY PLANTS

Mechanical Transplanter Co.

1. Pocket extensions (part #482) required for each pocket or plant gripper to support the root plug.

2. Carousels are available to hold plant trays.

Powell Manufacturing Co. Inc. (Disc-type planters)

1. Wire pockets to fit in place of the disc markers (part #17-00442, left and right) required.

2. Carousels (part #10-0246) for holding plant trays in place of plant boxes.

Plant Pick-up Planters

1. No modification parts are available from the manufacturer but a grower's suggestion is to use a metal plate in the pick-up box to support the root plug until picked off by the plant gripper.

Holland Transplanter

1. Either a rubber extension (part #P-54S for small plants) or a dual fork extension (part #P-54 for root plugs up to 2 in. diameter or 2 in. square) is required for each pocket or gripper.

Delhi Transplanter

1. A pot pocket (part #P59P) required for each pocket or gripper.
## APPENDIX 1.2: TRANSPLANTER MANUFACTURERS AND ADVERTISED TRANSPLANTING RATES

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<td><strong>Comments</strong></td>
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<td>P.O. Box 10088</td>
<td>340 Edinburgh Rd. North</td>
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<td>Model 4000, tray plant (Model 1000, bare-root is up to 30% faster than old model 22)</td>
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<td>Guelph, ON</td>
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<td>U.S.A.</td>
<td>M1H 1E1</td>
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<tr>
<td><strong>Powell Manufacturing Co. Ltd.</strong></td>
<td>Agrospray Chemicals Limited</td>
<td>two 40,000 plants/day</td>
<td>#15 disc-type with carousels.</td>
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<td>Bennettsville, SC 29512-0707</td>
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<td>Delhi, ON</td>
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<td>Tel.: 519-582-2770</td>
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N/A - Not available.
APPENDIX 1.3 POST-MEETING COMMENTS AND OBSERVATIONS

Comments

1. Tray grown plants account for only 2% of the total Ontario tomato crop. Replacement of imported plants is seen as an import replacement opportunity. Obstacles include:

   - cost: greenhouse grown plants will probably cost 50% more than imported bare-root plants;
   - assurance of supply: Georgia growers have been a reliable supplier of good plants. Canadian greenhouse growers are presently interested but better-paying crops could have preference in some years.

Advantages of tray grown transplants are:
   - potential for better stand and yield;
   - possibly faster transplanting if proper planters are used;
   - more opportunity to hold the plants if weather prevents transplanting.

2. There is presently sufficient mechanization to proceed with the import replacement program. The use of Mechanical 4000 or Lannen transplanters should reduce planting costs sufficiently to pay for the extra costs of tray transplants. There is no easy solution to further mechanizing bare-root transplanting.

3. Development of the Suggs modification may bring the planting rate for bare-root transplanting to equal the rate for tray plant transplanters such as the Mechanical 4000.

4. Automatic transplanters may not offer any cost reduction because of the high capital cost but would alleviate labor problems.
5. The secret to automatic transplanting appears to be in the use of a soil binder to keep the root ball intact. Samples of tree seedlings grown in the Castle and Cooke medium could be used for badminton birds. Dr. Fred Maurer, Agassiz Research Station, Agriculture Canada, has an European peat block machine and has been doing a lot of work with transplants using different mediums.

6. Now is the time to fully investigate systems such as the ESRC carousel or other peat-block transplanters, as both require seedling trays or blocks not being considered in the Ontario Program.

Points raised during the meeting:

1. Growers are not showing interest in buying tray type transplanters if they cannot be used for bare-root. They do not appear to be committed to tray plants as yet. This would certainly preclude interest in automatic planters that cannot handle bare-root.

2. The Speedling Co. is intending to sell Florida grown tray plants in Ontario. They already sell in Ohio at prices below local greenhouse plants. This activity may help the import replacement program as growers could switch to tray plant systems and still have more than one source of supply.

3. In Ontario, it is the processors who actually buy the seedlings whether imported or locally grown. The processors control where the plants come from and what type they will be. This may also explain grower reluctance to purchase planters devoted to tray plants.

4. There was no apparent interest in improving the work rate of bare-root transplanters by Suggs' method or by trying the Reutenick bandolier which was offered for cost of transportation by Adolf Wynia from the Ontario Ministry of Natural Resources.
5. I did not perceive much interest in automatic planters.

6. There was indication that conventional planters were not modified properly when used last year for establishing field tests with experimental tray plants.

7. Paper pots were mentioned several times but comments always indicated difficulty in opening the paper blanks. I suspect that paper pots are not being given a fair try because of lack of proper equipment. Unfortunately, such equipment is expensive.

8. Discussion after the meeting indicated a lot of confusion about capabilities of transplanters.

9. The discussion period indicated diverse points of view. Growers with the blessing of the processors will probably switch to tray grown transplants if advantages are demonstrated.

10. There did not seem to be much interest in high-density tray plants. It would appear that higher plant costs might be acceptable if stands are better and growth starts sooner. There appears to be concern that small plants would suffer due to transplanting and damage from blowing soil.
APPENDIX 1.4: POST-MEETING RESEARCH ON OTHER TRANSPLANTERS

Regero Transplanter

The Regero automatic transplanter was introduced in France in 1983. The operator loads peat-block seedlings from trays onto inclined flat belts that push the blocks down slides to the opened furrow (see Figure 1.1). Belt speed controls plant spacing. Flat bottom, 4 x 4 cm peat blocks are used, which are considerably different than the tapered tray plants that are most popular in North America. The Regero plants 6 rows, at 0.3 m row spacing, with crops like lettuce. Only one person is required to keep all 6 belts filled from the supply trays. Compared to tomatoes, the close row-spacing facilitates loading by a single operator.


Rohlfing's study indicated a payback of 4.85 years for the initial planter cost of 19 000 DM ($9,500 CAN).

Manufacturer: Regero
Rue de l'Allemagne-Fédérale
Z.I. Centre de Gros, B.P. 1807
44084 Nantes, France
Tel. (40) 49.38.20

Canadian distributor: Plasti-tech
223 St. André
St. Remi, Que.
JOL 2LO
Tel. (514) 454-4659
Contact: J.G. Charboneau
Productivity comparison for 100,800 peat-block transplants

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<td>6</td>
<td>1235</td>
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<tr>
<td>(Ontario tomatoes)</td>
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Figure 1.1 Schematic diagram of Regero transplanter.
Figure 1.2 Two examples of pre-loaded bandolier systems
Figure 1.3 Two examples of tray plant transplanters using a rotating bank of conical cups (Mechanical 4000 - top; Cheecchi and Magli - bottom)
Transplanting Equipment in Europe


The use of peat block transplants for large acreage production in France started some 15 years ago and is increasing. Between 1974 and 1978, the production of peat-block transplants tripled at the expense of bare-root transplants. Peat-blocks are mainly used for lettuce, tomatoes, melons, celery, cucumbers and cauliflower.

Equipment for peat-block transplants fall into four categories:

1) Manual: a marking roller with peat block shaped projections at appropriate spacings is run over the field surface before manual transplanting.

2) Transplanting aid: the marking roller frame is extended to carry operators for placing the transplants by hand in the holes. Packing wheels assure good contact between peat blocks and soil. Some machines include soil preparation equipment (bed formers) and some have the capability of laying plastic mulch.

3) Semi-automatic transplanters: transplants are placed manually in a mechanism (finger, soft disc, or other) that carries the transplant into the furrow.

4) Automatic transplanters: the machine handles the peat block transplants from the tray to the soil.

The Dewa semi-automatic transplanter requires the operator to place the transplant between fingers that descend vertically. When the transplant reaches ground level, the machine stops travelling while the mechanism forms a hole in
the soil and places the transplants. The machine moves forward again a distance equal to the plant spacing, and the operation is repeated. This machine is particularly consistent for plant spacing.

The Exponent semi-automatic machine uses a belt system loaded manually with transplants. The belt carries the material to ground level onto a toboggan-shaped shoe, in turn pushing the transplants on the toboggan off into the furrow formed by the shoe. Plant spacing is accomplished by the difference between the tractor ground speed and the belt speed. Tests show that this system is not very consistent for plant spacing.

The Super-Prefer is more like North American transplanters. The transplant is placed upside down between fingers carried around on a disc. Half a turn later, the transplant is dropped into the furrow. Tests showed an increase of 12% in transplanting speed for this semi-automatic machine over the transplanting aid at 2420 plants/h.

On the Budzyn transplanter, the transplants are placed manually on a belt. They are then picked up by fingers mounted on a wheel which drops them into the ground. A prototype pneumatic system was developed to automatically place the transplants on the belts directly from the tray. The development was abandoned due to peat-block size variation.

A short-duration test using a 12-row transplanting aid working on three preformed beds with block holes previously formed by a roller, indicated that a seven-member crew (one tractor driver and six operators) could transplant 12 rows at a rate of 38,400 plants/h or 5500 plants per man/h. Each person handled two rows. The machine restricts the operator to placing the plants directly into the preformed holes, but provides excellent operator seating and racks for plant supply.

An experimental machine, having a segmented loading conveyor feeding a plant gripper device to carry the plants to the furrow, gave a planting rate of 3600 plants/h/row and required one operator per row. Actual field performance
was reduced to 8600 plants/h for the 4-row machine when tray loading and
turn-around times were considered.

In general, European transplanting technology is progressively moving
towards full automation using principles and mechanisms similar to the ones used
in North America. One of the problems in developing a fully automatic
transplanter lies in the size of the media block. Three different block sizes
are in use in Europe, the most popular one being 3.5 x 3.5 x 4 cm for lettuce.
The other types are 8 x 8 x 12 cm for tomatoes, cucumbers, melons, etc. The
pyramid-shaped tray plants are also gaining popularity.

Peat-block transplants were originally developed for greenhouse culture
but use is now extended to field application. The blocks are made from a
mixture of peat, vermiculite and water. They can be formed with manual
equipment or fully automatic machines delivering up to 60,000 blocks/hour.
Equipment commonly used produces 15,000 blocks/hour. Different types of seeders
are used for seeding the blocks.

The transplanting aid equipment developed in Europe is in many ways
similar to the one developed in Quebec by Plasti-tech. The Plastiplant
Super 800 can lay a plastic mulch and cut a hole through it where the transplant
is to be placed by the operator. Three people are required for a two-row
machine with a capacity of 4000 to 6000 plants/h.

LIST OF TRANSPLANTERS

<table>
<thead>
<tr>
<th>Make</th>
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<td>Dewa Demaetere</td>
<td>Baele</td>
<td>Chemin des Anglais, Mont Noir, 59270 Saint-Jans-Cappel, France</td>
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<td>&quot;Exponent&quot; Verheijen</td>
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<td>Ruffier</td>
<td>49, rue de la Gare, B.P. 4, 45530 Vitry-aux-Loges, France</td>
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<td>Budzyn prototype</td>
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<td>30580 Seynes, France</td>
</tr>
<tr>
<td>Plasti-plant Super 800</td>
<td>Plasti-tech</td>
<td>136, rue de la Gare, St-Rémi, Qué. JOL 2LO</td>
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CHAPTER 2: AUTOMATED TRANSPLANTER DEVELOPMENTS

L. C. Heslop

2.1 Introduction

Automated transplanting suggests the elimination of labor from the operation of transferring a seedling block from its tray or growth medium into the ground. Application and experience teach us how to "automate" the process wherever possible and practicable. Labor-aided mechanical transplanting speed is significantly increased when the operator can pre-load multi-plant stations rather than working at precisely the machine rate (Suggs, 1979). "Semi-automatic" transplanting is said to occur when a dozen or more plants are handled at one time (Boa, 1984). Automatic machines, where transplants are fed automatically from mechanically or manually-filled magazines, still require at least one operator on a multi-row machine.

The mechanization of field tomato harvesting has resulted in a significant increase in tomato production area per farm because of the sharp drop in harvest labor requirements (Anon., 1981). Although labor costs and availability are usually cited as reasons to "mechanize" or "automate" labor-intensive operations, final business decisions are also based upon:

- labor management costs;
- opportunity costs of labor vs machines;
- peak vs average labor requirements.

Although a defined need usually drives technological development, a solution is only defined when it achieves the cost-benefit ratio specified within the industry.

In the case of automated tomato transplanting in Ontario, the need is somewhat dynamic and without total definition. Does the industry need:
Fortunately, or perhaps unfortunately, the need is not much better defined in many other regions of the world. It is, however, universally recognized that control of transplant quality and availability reduces delays in maturity and deviation in quality. This increases control of delivery schedules which go a long way to maintain domestic market share (Lee, 1982). Also, media transplants start better in the field than bare roots and allow close control of plant products right into the field, with a resultant increase in production quality (Brewer, 1986). To this end, extensive research and development work has been carried out around the world for many years in an attempt to develop commercially acceptable bare-root and media-block automatic transplanters.

2.2 Bare-root Transplanters

Development of bare-root seedling transplanters has progressed in three major industries:

- grassland renovation and development; (Moden, 1982; Hauser, 1985);
- forestry seedlings (Graham, 1983; Ardalan, 1982; Buckley, 1978; Pretzer, 1979);
- vegetable crop production (Maw, 1985; Brewer, 1985; Maw, 1980).

Bare-root seedlings are cheaper to produce but after they are pulled, packed and shipped, they are difficult to singulate and transplant automatically. Extensive research has been carried out on singulation including optical methods (Maw, 1985), stalk diameter determination (Buckley, 1978) and cannister, drum, robotic and hydraulic servovalve sorting (Suggs, 1986) (Fig. 2.6). The greatest success has been derived from bandolier type tapes or stitching systems that pull field plants and immediately attach them to a continuous tape from which they are detached only after they are placed into the ground. In some experimental cases the plants were hand attached to the tape for experimentation. Plant size variations have affected machine performance
and devices have been incorporated to detect non-plants and simultaneously advance the tape in an effort to reduce 'misses' in the field.

An underlying theme of bare-root transplanting is the need to control seedling production from the seed to the final field transplant. Seedling uniformity, pulling and packing, shipping, quality control and final transplanting must all occur within a single controllable management system if optimal results are to be expected. Bare-root seedlings are grown to be shipped efficiently and transplanted within any vegetable production system. This defies the need to control for optimal results.

Automated bare-root transplanter development benefits from a single management system in which machine and seedling can be developed together. Seedlings grown and packed for ease of shipping from a distant location to the processor for the grower makes coordinated development difficult. A transplanter as complex as is illustrated in Fig. 2.1 demonstrates the need for coordinated development.

2.3 Media-block Transplanters

Automatic media-block transplanting requires at least as much management and control as bare-root transplanting in order to achieve acceptable results. However, media-block transplanting tends to locate the seedling grower and the vegetable grower proximate to each other. In fact in California, increasing amounts of lettuce are automatically transplanted in media blocks every year by two companies with two transplanter designs in which the transplants are sold to the grower in the field. Seedling production, shipping and transplanting are carried out by a single party (Branch, 1986; de Groot, 1986). Because of machine complexity and capital cost, there is no advantage to the individual grower in owning a transplanter.

Huang and Splinter (1968) set the stage for automated transplanting using a continuous-grid method. They also extensively researched and reported on operator performance and efficiency. The plastic tray replaced the grid system and has been used in most research because of greenhouse efficiency and grower acceptance (Pinkepank, 1980).
Other types of plant containers have been developed and incorporated in the interest of improving machine design and performance including:

- Z-folded linked paper plant cells;
- roll-feeders;
- ferris wheels, carousels and bandoliers;
- individual seedling blocks.

(Figs. 2.2, 2.3, 2.4, 2.5, 2.7, 2.8)

Individual media-block transplants have been popped, cut, slid, grasped, pushed, and pierced as they travelled from their container to the ground.

Growers transplanting in Salinas, California (Branch, 1986) (Fig. 2.9) have developed a plug transplanter that pushes celery, leaf lettuce, head lettuce, cauliflower, broccoli and pepper crops down through the tray and into the ground at rates of over 100 plants/row/minute automatically.

Bud of California (de Groot, 1986) (Figs. 2.10, 2.11) have developed a soil plug automatic transplanter for lettuce that pushes a polymer based plug out of the tray, into a pocket chain that delivers the plug and transplant to a finger chain. The finger chain transports the transplant to ground level and places it in the soil at zero relative ground speed.

Pinkepank and Shaw (Figs. 2.12, 2.13, 2.14, 2.15) reported on a soil block transfer system for tomato seedlings that used plunger rods, foliage and retention sheets, and transfer cups to transfer seedlings from the tray to the drop cup.


In nearly all successful reports to date, it is noted that:
- plant size is controlled to less than or equal to media block size;
- plugs or media blocks are cohesive;
- transplant and media block motion is controlled from the container to the soil. Direction changes and accelerations are minimized. Multiple actions and machine simplicity are apparent;
- usually the media block, but occasionally the plant stalk, is grasped to control and define motion.

Researchers including Liptay and Brewer (1986) have demonstrated, especially for tomato plants, that a short, compact, and sturdy tomato plant can be started and successfully handled in a mechanical transplant system. It is still not clear what planting densities, double-planting and thinning techniques and growth-control treatments will be economically viable and manageable in the field.

Boa (1984) indicates that the opportunity cost of labor in other more profitable activities that must be delayed or abandoned to allow labor-intensive transplanting to take place, translates into a cost advantage for automatic transplanting at an annual usage of less than 200,000 transplants. Audsley (1985) states that significantly more capital can be spent on initial transplanting ratio increment (2,000 to 3,000 plants per operator-hour) than can be spent on fully automated rates (15,000 plants per operator-hour). His results incorporate an added cost for media blocks without any added benefit and he concedes that this should be reviewed.

2.4 Conclusions

The Ontario tomato transplanting industry needs or will need an automated media-block transplanter that will transfer controlled, sturdy, compact transplants from rectangular, multi-cell, containers into conditioned soil at approximately two plants per second per row in a multi-row machine. Presently there does not appear to be a machine commercially available to perform this task nor are all the specifications clearly defined. However, the technology appears nearly complete at a price.

Specifications and support are needed to achieve such a development within the existing industry.
2.5 References


Fig. 2.1 Transplanting apparatus for depositing plants directly from a supply tape into an inclined furrow (Pretzer, 1979)
Schematic diagram of the horizontal, bandoleer feed mechanism listing its separate parts.

Side-view, schematic diagram of the vertical feed mechanism; the plants move from right to left.

Fig. 2.2 An automatically-fed bandolier transplanter (Moden, 1982)
The dibble penetrating the soil at near-zero horizontal velocity showing the plant and bandoleer cell (1), closed trap door (2), the open position of the trap door (3), and the funnel (4).

Top view of the fluted-feed mechanism showing the bandoleer belt feeding from the storage tray to the rubber roller (A) into the fluted-feed rolls (B) and the shears (C) that cut each cell free (D).

Fig. 2.3 An automatic grass transplanting machine (Hauser, 1985)
Fig. 2.4 Self-feeding transplanter, using plants grown in honeycomb cells, consisting of pairs of plant fingers or hands to grip the plant cells, tear them from the strand and place them into the open furrow (Suggs, 1986)
Fig. 2.5  Self-feeding transplanter which uses plants grown in a honeycomb of cells which unfolds into a strand or belt of cells carrying plants (Suggs, 1986)
Fig. 2.6 Machine for digging a row of plants and stitching them between tapes into a continuous strand (Suggs, 1986)
Multiple loading station transplanter utilizing cross belt and plant transfer

Fig. 2.7 Bare-root transplanter modification to supply multiple loading stations (Suggs, 1979)
Fig. 2.8 National Institute of Agricultural Engineering automatic transplanter (Boa, 1984)
Fig. 2.10 Stabilized soil plug automatic transplanter (de Groot, 1986)
Fig. 2.11 The 1984 pivoting transplanter frame. The cylinder allows the unit to float, following the bed contour. Pressure to the ground is controlled through the pressure reducing/relieving valve. The disc opener and packer wheel subframe can be quickly changed over to bed shaper with shoe (Feeder head is not shown) (de Groot, 1986)
Fig. 2.12 Sequence for transfer of plants from transfer cups to drop cups (Pinkepank, 1980)
Fig. 2.13 Side view of plant transfer areas (Pinkepank, 1980)
Fig. 2.14 Sequence for transfer of plants from the growing flat into the transfer cups (Pinkepank, 1980)
Fig. 2.15 End view of plant transfer areas (Pinkepank, 1980)
APPENDIX 2.1 - POST-MEETING COMMENTS AND OBSERVATIONS

Comments noted

- "Need for a reliable tomato transplant and a labor-saving device to plant the crop"
- "Bare-root transplants - when they're good, they're really good
  - when they're bad, they're really bad"
- "Growers tend to react to the most recent worst scenarios"
- "96% of tomatoes in Ontario are bare-root, 2% greenhouse trays and 2%
  direct-seeded in greenhouse"
- "Short term trials of plug transplanting found to be a pain!"
- "Successful media-block transplanting requires a high-management system"
- "Greenhouse operators and tomato growers are already starting to work
  together on a system"
- "Media-block transplants grown in a greenhouse, transported to the
  field and transplanted require perfect cooperation between the
  greenhouse operator and the grower. If it rains the plants must go
  back to the greenhouse and this must be built into the costing"
- "Growers are nervous about holding transplants on the farm"
- "There are many little tricks available to keep tomato transplants from
  getting tall and spindly"
- "7-8 years are required to pay off an improved transplanter"
- "More work is required to grow and look after media-block transplants
  (compared to bare-root) but they are easier to transplant"
- "Only Real Growers can grow Good Plants"

Conclusions from the meeting

1. Commercially available transplanters are not fast, require 1 to 2
   operators per row and encourage the grower to acquire multi-row
   (2-3 row) units. Double-row units covering 3 double-rows requires 6
   persons plus a tractor operator. Direct labor costs did not appear
to be the greatest concern. Social program costs and daily labor availability appeared more important. If one laborer does not appear in the morning, a 3 double-row machine cannot operate! This is perceived by the grower as a large problem.

2. Existing "improved" transplanters, as presented by Mechanical Transplanting Co., do not have the confidence of the grower and have not yet shown an increase in planting rate.

3. The processing companies 'control' the availability, type and quality of transplants by acting as the transplant supplier to the grower. Hence, the grower is not responsible for transplanting. It is difficult in this scenario for the grower to effect a change in his methods.

4. Bare-root shipping, handling, storage, and singulation results in a plant loss prior to and after planting that was not formally discussed but was estimated to be as high as 30 to 50%. This represents a significant increase in bare-root costs even in a good year. Since it was not discussed, it appears to be a non-problem.

5. From conversation at the meeting, it appears that the grower wants to transplant at a field rate several times greater than his eventual harvest rate. This may or may not be necessary but it illustrates the present opportunity cost of transplanters, labor and alternate activities.

6. The growers did not express a need for a fully-automated transplanter.

7. The major problems can be separated into the following areas:

   - The grower wants a faster, less labor-intensive bare-root transplanter now. No commercial solution appears available.
- If media-block transplants become more popular, the available transplanters are not any faster than those used for bare-root. Hence, media-block does not appear more attractive with respect to planting rate.

- The processor presently supplies the transplants to the grower who is responsible for transplanting. This makes effective development difficult.

- The grower may be reluctant to invest significantly in transplanters when he does not control the input material.

- There cannot be any grower incentive to develop media-block transplants when they do not control the supply.

- It is not clear who should take the initiative to search out, develop, or source an improved transplanter or method of transplanting
  - the grower
  - the processor
  - the government - provincial
  - federal

- Although the cost of importing bare-root transplants to Canada has been defined as significant, the need to replace imports is not perceived by the grower as an issue.

Recommendations for direction to a tomato transplanting research committee.

  a) Faster, less labor-intensive and less labor-dependent, non-automated transplanting of bare-root plants is a high priority to the grower. It does not appear to be economically attractive to industry (welding shops, manufacturers, importers) to try to satisfy this need. An engineering/economic review of the need and world-wide product availability should be considered as a high priority.
b) Media-block transplant mechanization requirements are very similar to bare-root but because of their minor importance in the field should be incorporated in the program to develop domestic media-block transplants. Relative costs can only be compared in-the-field.

c) The need for fully automated transplanting, bare-root or media-block in Canada is not sufficiently great to warrant a very high priority.

d) An organizational structure and funding strategy to carry out research, development and technology transfer must be established as a high priority, especially in light of all involved
   - grower
   - processor
   - government - provincial
     - federal.
3.1 Abstract

Media, or peat-block transplanting has traditionally been a labor-intensive and monotonous operation. Current systems utilize greenhouse-grown plants in flats that are transported to the field where the individual plants are manually removed from the flat and fed into the transplanter. The transplanter design has remained virtually unchanged for 30 to 40 years and can employ one or two operators per row. Maximum planting speed with two operators per row is in the range of 60 plants per minute.

In an effort to reduce labor requirements and increase transplanting speed while maintaining accuracy, a totally automatic transplant feeding mechanism has been developed to adapt to current transplanter systems. This mechanism eliminates the labor requirements on the transplanter and reduces container handling while allowing transplanting speed to increase to two plants per second.

A special segmented belt is wound onto a carousel, loaded with a peat mix, seeded and the plants allowed to grow to transplant size. The carousel is then transported to the field and fitted to the feeding mechanism on the transplanter. As the carousel belt travels through the mechanism, individual singulated transplants are presented to the transplanter. The mechanism is comprised of a feed carousel, indexing drive take-up carousel and sensing and triggering devices.
Testing has shown that the transplanting mechanism functions at a rate of two plants per second with a successful transplanting efficiency of 90% (with cauliflower).

This automatic media-block transplanting system was developed in response to the need to reduce labor dependence and increase transplanting speed. The design offers a labor-free transplanting system to commercial vegetable growers.

3.2 Post-meeting Comments and Observations

In my opinion, this meeting in many aspects proved to be an "eye-opener" with respect to transplanting practices, available technology and transplanting politics. The overall objectives intended to be reached within the meeting were, however not met due in part to the absence of representatives from the Processors' Group and the New Crop Development Fund.

Points emphasized by the speakers were:

1. Georgia grown transplants are inconsistent in quality.
2. Acreage per grower and overall tonnage supplied to the processor are increasing while the number of growers is decreasing.
3. Labor force required is increasing in quantity and cost and must be reduced.
4. Possibility of changing to tray or peat-block transplants from bare-root is increasing.
5. Currently 96% of all tomatoes supplied to processors are grown from bare-root transplants, 2.5% from tray-transplants, and the remaining 1.5% from direct seeding.
6. Switching to double rows or two-row beds yields an additional 4 to 7 tons/acre.
7. Bare-root planting costs are approximately $50/acre, most of which is the cost of sorting and handling on the transplanter.
8. With proper management cell sizes for tray transplants can be reduced from 1 x 1" to 5/8 x 5/8".
9. In field trials, transplants grown in reduced cell sized trays equalled or surpassed Georgia bare-root transplants in yield.
10. For tray-grown transplants, 7" is determined to be the optimum height for transplanting.
11. In a poor year, losses from Georgia transplants can be as high as 50%. Up to 35% of the available transplants are discarded as culls, and another 15% are lost after transplanting. This figure in effect doubles the real unit cost of Georgia transplants.
12. A "box" of Georgia transplants contains from 800 to 1200 plants.
13. "Speedling" offers tomato transplants in boxes guaranteed to contain 1000 transplants.
14. Transplanting technologies from the tobacco, forestry and vegetable industries can be interrelated.
15. Many transplanting aids are available but with the exception of the ESRC carousel, only one eliminates labor requirements on the transplanter. This unit, designed for forestry transplanting, uses a foam belt that must be manually loaded, thus defeating the purpose of labor reduction in the overall system.
16. The ESRC carousel emerged as the only transplanting mechanism available that substantially reduces labor requirements.

The processing tomato industry appears ready for a change especially from the growers standpoint. A realization of the potential inconsistencies and dependancy on Georgia transplants, combined with the recently demonstrated advantages of peat-block transplants, have the growers in a quandry. As I see it, there are two major obstacles in the way of any substantial change-over. The first obstacle is tradition. Most growers are hesitant to take the initiative unless on a very small scale. The main obstacle, however, is the fact that the processors call all the shots in the industry, thus any change in the overall system would have to originate with them. Apparently the processor deals directly with the transplant supplier, dictating varieties, quantities, shipping, etc., on the one hand, while contracting with the growers on the
other. No matter how much the grower would like to change, he is still under the control of the processor.

Evidence as to the interest in the transplanting industry was the attendance of the estimated 130 people (25 expected) and to the apathy of the processors where only one speaker was scheduled and didn't show up.

Not surprisingly, any attempt to identify priorities, develop strategies, or organizational structures and funding to carry out research was not forthcoming.

ESRC's input and potential impact towards this industry is, to say the least, cloudy. We currently have a mechanism, that according to some, can revolutionize the industry, but it must first be "sold" to the processors if the present rules and rulers apply. Any attempt to automate or improve efficiency of the bare-root system is in my mind treating a symptom or possibly "flogging a dead horse". This type of effort on our part would also be difficult to justify as research, as we would in fact be competing with equipment manufacturers. We must also realize that in this industry, we at ESRC are handicapped technically and geographically.

My suggestion, as to our direction, would be to put our projects on hold until a research-oriented project is defined and requested by the processors with the growers.
CHAPTER 4: SURVEY OF POTENTIAL FOR A SEMI-AUTOMATIC BARE-ROOT
TRANSPLANTING DEVICE TO INCREASE PLANTING SPEED

W.S. Reid

4.1 Introduction

The semi-automatic bare-root transplanters of the Mechanical Transplanter Co., Holland Transplanter Co., Powell Manufacturing Company Inc. and D.R. Ellis Manufacturing Co. Inc. were introduced about 30 years ago. They were described briefly by Voisey and Hergert (1973). Since their introduction, there has been no improvement in labor utilisation nor speed in the transplanting operation, at least in horticulture.

Suggs (1979) reported significant improvements in speed of transplanting with a single operator when using a modified chain and clip transplanter with multiple-loading stations (see Figure 2.7).

This report will investigate why this development has not been picked up for commercialisation by any North American transplanter manufacturer and if it is realistic to test this or similar concepts further.

4.2 Assessment

Study of Suggs' paper

Suggs (1979) stated:
"Since they (the test runs) contained only 30 plants, the individual observations were not long enough to produce fatigue but did allow the operator to approach steady state. However, it was felt desirable to have a large number of short runs rather than a few long runs. Fatigue effects may have been present in the runs toward the end of each session. During a session of repeated 30 plant runs, the fatigue state of the operators of the experimental transplanter and the conventional transplanter were probably not appreciably different."

Suggs' modified transplanter had 5 loading stations available to the operator. Summarizing the results reported, the mean operator planting speeds were 79.2, 67.8, 34 plants/minute and the mean machine planting speeds were 78.9, 54.4, 72.3 plants/minute for the modified and conventional transplanter with one operator and the conventional transplanter with two operators respectively. All planting speeds reported were adjusted to 2% misses.

Suggs again states: "The most important comparison in the data is between the planting rate for the experimental transplanter with one operator, 79 plants/min, and the conventional transplanter with two operators, 72 plants/min. One operator on the experimental machine can transplant as many plants as the two operators normally used on a conventional machine."

These rates are burst rates and do not represent the sustainable output of an operator throughout a working day.

Specialised Harvesting Services Ltd. (contact T. Windle), Corey Garth Lane, Haxey, Doncaster built a machine like this and they have been unable to sell it. (Information from A. Liptay; no direct contact with the company.)

It is interesting to note that Mechanical Transplanter Co., in their sales literature, claim speeds of 80 to 120 speedling transplants per minute with their model 4000, 4-station rotating cup transplanter.
Study of related research

No other studies were identified which attempted to increase the transplanting speed of individual operators. Suggs references work by Splinter with respect to tobacco and also with respect to the theoretical effect of multiple loading stations on transplanting speed.

There is no doubt that multiple loading stations can improve the planting rate of a single operator, but by how much under practical field conditions is uncertain and whether this results in excessive reduction of machine planting speed is not certain either.

Contacts with commercial manufacturers and research personnel

As a basis for discussion, a questionnaire was prepared and questions asked of the contact (Table 4.1) as seemed appropriate. Each question and the significant replies were as follows:

Question 1 - Are you familiar with the Suggs concept to provide a multi-station loading area for semi-automatic bare-root transplanting?

Comments: Three of the four American transplanter manufacturers and one Canadian manufacturer were not aware of this work. Mr. Kolk of Mechanical Transplanter was aware of this work and Dr. Suggs had in fact sent drawings.

Research personnel contacted were in general aware of this concept.

Question 2 - In your opinion, why has it not been adopted?

Comments: No manufacturer considered this approach of great value. The Canadian manufacturer (Sales personnel) was the most favourable. Because of the recession, two of the American manufacturers were in no position to do any development work. Only Holland were doing any
research work and this was on automation of transplanting from flats. All manufacturers sales have been hit severely in recent years.

The Canadian research workers did not think that it offers any real advantage. The U.S. personnel were somewhat ambivalent.

Question 3 - To your knowledge are there any other alternatives such as the plug mix planter that will handle bare-root transplants?

Comments: In industry, Mechanical Transplanter Co. mentioned their rotating and indexing 4-cup transplanter for speedlings. It does not handle bare-root transplants.

In research, K. Walker and Bruce Reynolds stated from their observations that the plug mix planter of Holland Transplanter Co. functioned quite well with bare-root transplants. Excessively large transplants failed to drop and small transplants were planted incorrectly.

Question 4 - Will the 4-cup, indexing planter of the Mechanical Transplanter Co. handle bare-root transplants?

Comments: Only Mr. Kolk of the Mechanical Transplanter Co. was asked this question and he said "No".

Question 5 - What is the structure of the crop production industry using transplants (e.g. tomatoes, tobacco)?

Comments: Knowledge was not deep concerning this aspect of the industry. Manufacturers had a feel for farm sizes in their area and close by. Around South Carolina, row crop acreages were large (250 acres). In Michigan, 90% of growers acreages were <50 acres with some large growers at 200. In Ontario, large operations have 30 - 80 acres of transplants.
The large variation in row crop acreages means a great variation in the level of mechanisation that the different growers can consider, unless contract planting becomes common. At present, machines are produced in 1- to 6-row configurations.

Question 6 - Would transplant users adopt more labor efficient machines?

Comments: The answer appears to be 'yes' but buyers are cost conscious and no or little loss in machine speed can be accepted. Too few interviewees were asked this question for the above answer to be definitive.

Question 7 - What is the labor availability at transplanting time?

Comments: In Georgia, there is plenty of labor and it is cheap. In South Carolina and Michigan, it is available but not good and farmers would like to reduce their dependance on this input.

4.3 Design Possibilities or Other Options

Since there is only one design concept at present, it seems appropriate to see if there are any alternatives that have equal or greater potential.

Concept 1 - Extend the conventional vertical chain to make 3 loading stations accessible to the operator, changing his/her seating position to match. This is cheaper to implement than the Suggs modification but accessibility of all three loading stations is not assured.

Concept 2 - Modify the 4-cup rotating head and planting chute of the Mechanical Transplanter Co. to handle bare-root transplants as well. It may be possible to do this using either forced air, suction or mechanical means to draw the transplant through the cup and tube to the ground. Suitable size transplants would be required. This
Modification should be quite inexpensive ($100) but the machine is already between $1280 and $1450 more expensive per row than a conventional planter costing from $645 to $710/row.

Concept 3 - Concentrate on automation of rectangular flats and/or the carousel transplanter and/or complete automation of bare-root transplanting (also a real possibility in the future).

4.4 Conclusions

There is no clear-cut case to be made for starting research on the Suggs concept for incorporation of multiple loading stations on the conventional transplanter. No other option to improve the performance of semi-automatic transplanters appears significantly better either. The outcome if research is initiated is not clear nor is it likely to result in even moderate improvements in efficiency. Thus the decision to initiate this work is not easy. Probably a better use of resources would result from attempting to completely automate transplanting from flats or the bare-root transplanting operation.

4.5 References


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CHAPTER 5: SUMMARY AND CONCLUSIONS

M. Feldman

1. The preceding chapters provide a good review of tomato transplant mechanization and related research work. Sufficient mechanization and information exists to proceed with development of new transplant programs, but there is no commercially available fully-automatic machine, for bare-root or media-block transplants, that suits the existing or perceived needs of the growers in Ontario.

2. The industry is in the process of evolutionary change. Forces for change include uncertain availability of labor, pressure to reduce production costs, and policies to support replacement of imported transplants. More development of engineering, agronomic and economic data is required to provide sufficient information for innovators to make a firm commitment and growers and processors to generally invest in new systems.

3. Growers have an immediate need for a faster, less labor-intensive means to transplant bare-root tomato seedlings. No engineering solution is readily available, and an expensive development program cannot be substantiated. Further review and analysis is warranted.

4. Engineering and economic studies need to advance along with the agronomic research to develop a media-block transplant system that suits the growers and the industry. A good base of mechanization and engineering knowledge exists to work from.

5. The ESRC prototype carousel transplanter demonstrates a fully-automatic concept for media-block transplanting, but its integration into a viable seedling and crop production system remains to be demonstrated.
6. ESRC is not pursuing further development of full-scale new prototypes for bare-root or media-block transplanting, but is available to continue collaboration on solving transplanter and transplanting questions and problems.