LeBoeuf

PLUG TRANSPLANTING AUTOMATION

FOR PROCESSING TOMATOES

(a report on a study supported by
Ontario Tomato Seedling Grower's Marketing Board)

R. Lloyd Arnold 1989

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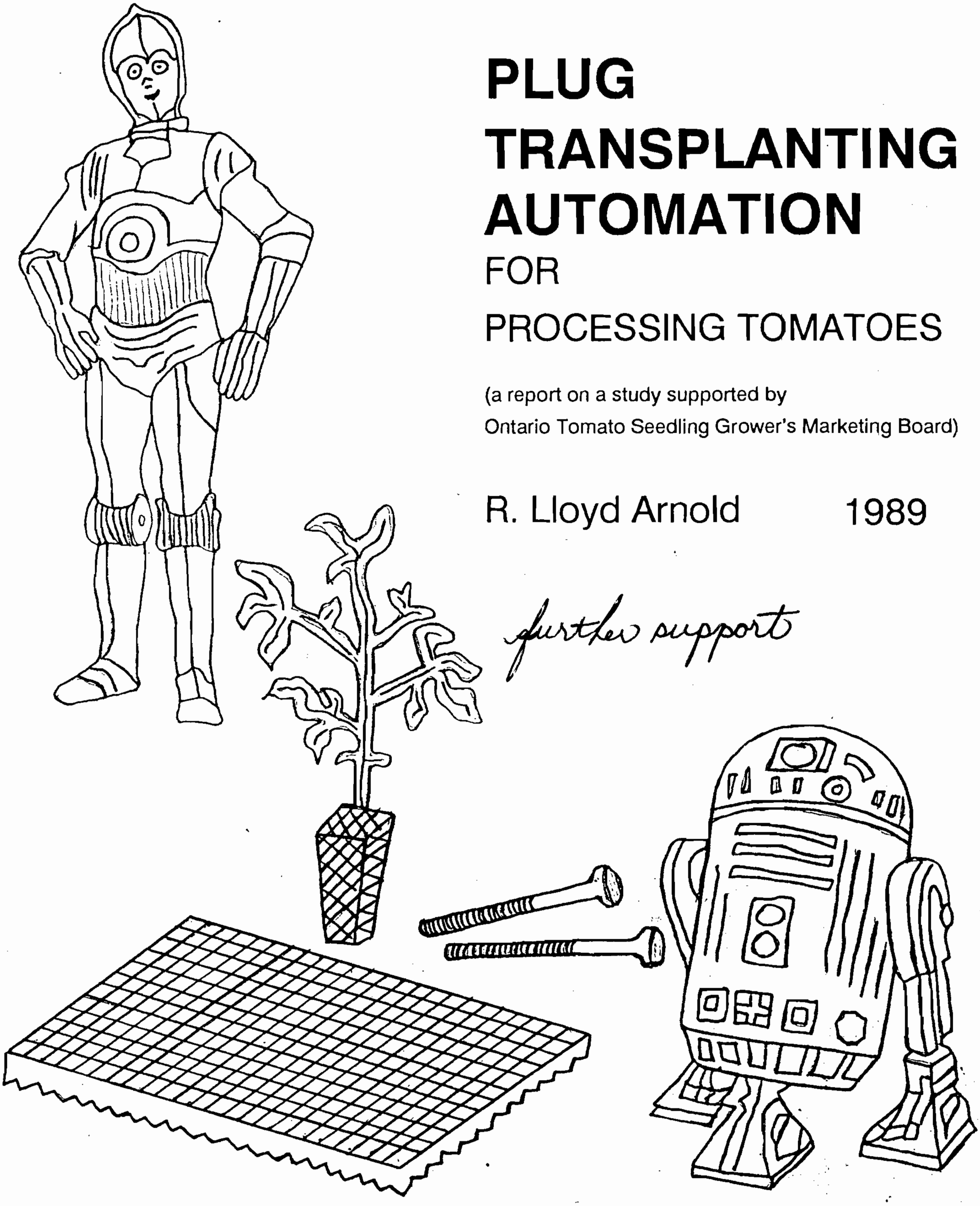

APRIL 1990

DEVELOPMENT OF TRANSPLANTING AUTOMATION TECHNOLOGY AND VOLUME HANDLING SYSTEMS FOR PROCESSING TOMATO PLUG PLANTS IN ONTARIO

R. LLOYD ARNOLD

ONTARIO TOMATO SEEDLING GROWERS MARKETING BOARD

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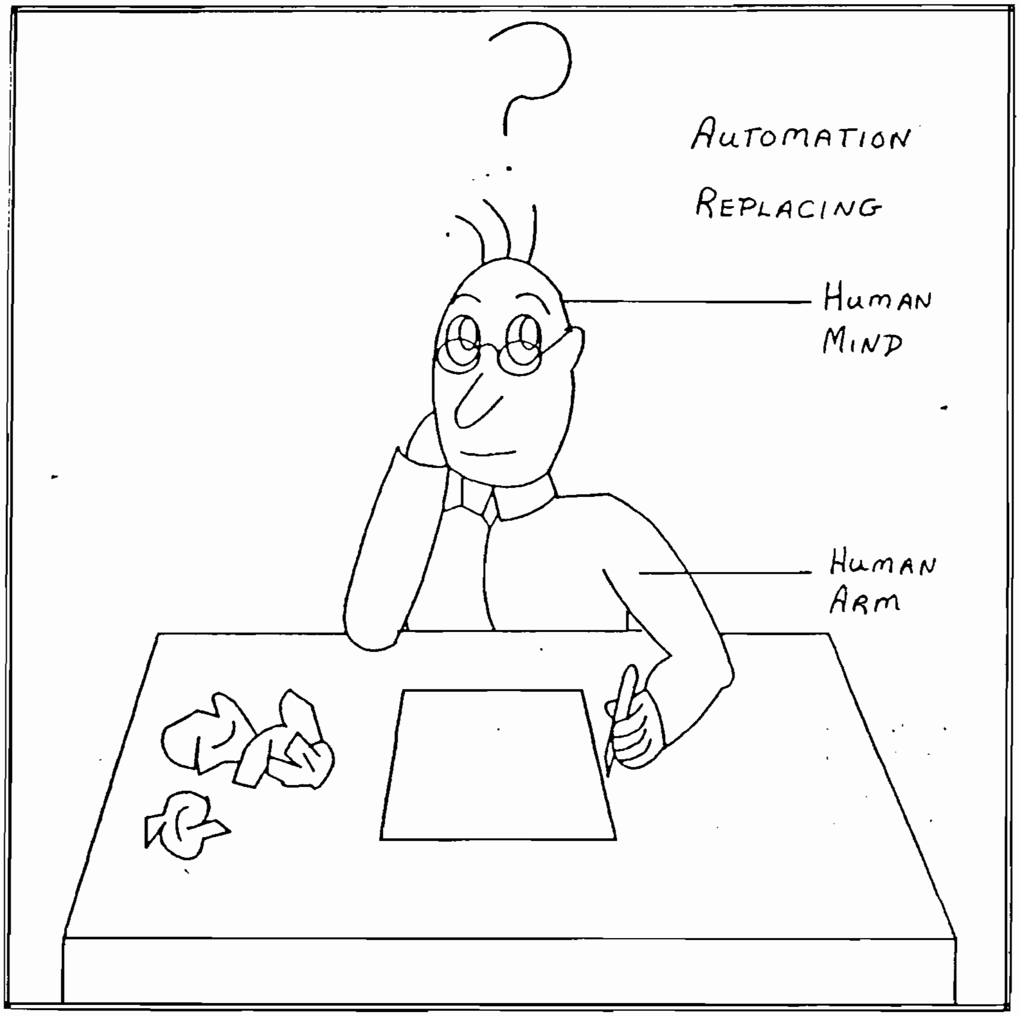

AUTOMATION
REPLACING
HUMAN MIND
HUMAN ARM

EXECUTIVE SUMMARY

The uncertainty of labour availability, a fervent desire to reduce planting costs, timeliness of crop establishment and the current trend in the processing tomato industry to the use of locally-grown media block seedlings (tray plants) have prompted growers to examine alternative transplanting methods such as the applicability of automatic transplanters.

The initial purpose of the study described here was to evaluate the field performance of a prototype-version of an automatic transplanter under development, by Clay-Mill Technical Systems (Windsor, Ontario) and accelerate the commercial introduction of this technology to Ontario's processing tomato industry.

Commercial introduction (fall 1989) of the Lannen Automatic transplanting unit, capable on utilizing the higher density 256-cell Plantek tray, provided the project with the opportunity to evaluate its performance.

Study findings on both units are discussed below:

CLAY-MILL PROTOTYPE:

1) Extraction of plug transplants from the common 288-cell tray, as desired by the seedling industry, was achieved by a series of grasping fingers or grippers.

2) Extraction rates from <u>manually</u>-filled trays, was in the range of 92% completion. Successive emptying of numerous trays under field conditions and automatic mode was never satisfactorily achieved with the current prototype version.

3) Excessive unit weight and uneven weight distribution created unique complications that re-design and downsizing would have to address for commercial scale development to occur.

4) An innovative approach to the use of air propulsion to propel plants down to the furrow and reducing free fall gravity dependency was unique. Air consumption rates required per venturi; however, presents a concern of adaptability under field conditions especially with a 6-unit functional automatic transplanter. Pulsing of air blasts may be one solution to alleviate the problem of high air requirement rates and supplementation.

5) A device attached to the tray holder, designed by Clay-Mill to singulate the contents of each tray cell and reduce root-binding problems, was also creative.

Lack of tray standardization created cell alignment and resultant extraction problems.

6) Considerable variation in the 288-cell trays supplied during the project made it apparent that a standard tray is mandatory when using automatic transplanting, as the machine returns to the same position after completing each cycle of plant extraction and ejection.

7) Missing cell detection and compensation was not successfully achieved before termination of development .

8) A maximum planting rate of 1.6 plants per second was achieved with the prototype but far from the transplanting rate of 3 plants per second (180 plants/min/row) perceived necessary to support automation. Increasing planting accuracy at the 2-2.5 plants/sec/row rate with current industry-wide greenhouse technology and expertise however may be a valid trade-off at this time.

9) The prototype unit was most comfortable with plants 6" or less but the concept of air propulsion allowed the delivery of plants 8" in height to the plant furrow without requiring trimming or chemical retardation.

10) The apparent design complexity obviously was a product of Clay-Mill's expertise and precision tolerance characteristics as applied to automotive automation mechanisms. Many of the mechanical systems would need re-design or replacement prior to final production because of dirty field conditions. A major reduction in complexity will not only reduce production costs but most importantly could allow the unit to be marketable to the tomato farmer.

LANNEN AUTOMATIC:

1) The Lannen Automatic successfully planted tomato plug plants from plastic trays of two different densities (144-cell and 256-cell) with labour only required for loading of trays into tray holders.

2) Plug plant quality and tray fill percentage had a marked effect on field stands as this unit was not equipped with any compensatory mechanism for missing cells.

3) Presently, in Ontario, the Lannen system lends itself only to a vertically-integrated system where the tomato grower produces his own plant requirement.

Reducing tray costs and transplanter unit costs, especially with twin row planters, would help to increase overall market potentiality.

4) Construction and subsequent field research of a fully functional twin row planter, equipped with six Lannen Automatic units, rack carrier, water supplying devices and other accessories will allow the seedling industry a further opportunity to fully evaluate this new transplanting technology and its commercial acceptance in Ontario.

INVESTIGATION OF TRANSPLANTING AUTOMATION TECHNOLOGY FOR PROCESSING TOMATO PLUG PLANTS

INTRODUCTION

Although the harvesting of processing tomatoes in Ontario has been automated considerably in recent years, the degree of mechanical automation in the field transplanting operation has lagged somewhat behind but now appears to be in the pioneering stage of development. Serious concerns about the high labour input required during field transplanting and related costs, and the trend to growing tomatoes at higher densities in twin rows has led growers to study and utilize alternative transplanting methods such as improved semi-automatic (carousel) or completely automatic transplanters.

To complement and make these alternatives realizable, the development and utilization of media block seedlings (plug plants) grown in multi-celled plastic trays in local greenhouses has occurred. The gradual impressive growth of the seedling industry (Table 1) suggests their acceptance by both processors and growers. Several collaborative research projects with growers - both field and greenhouse, food processors, governments - both federal and provincial, and equipment manufacturers and their retail distributors have been intensively performed to study the agronomic performance of plug plants and examine their economics (Hergert et al.1988,1989). Well-documented results suggest that despite the fact that plug plants are more expensive to purchase than southern bare-root plants, because they require more expensive growing facilities such as greenhouses, there are several operational advantages with plug plants especially in the areas of labour savings and plant survivability.

Many transplanter ideas developed by universities and research organizations that have not been produced commercially have been reviewed Heslop, 1987, while transplanters which are commercially available or under various stages of development have been documented in a report by Hergert et al., 1988.

TABLE 1 . Plug plant usage in Ontario (* million)

	1985	1986	1987	1988	1989	Projection 1990
Volume of domestic sales ('000,000)	0	2	17	30	54	105+

Transplanting represents one of the major costs of producing tomatoes in Ontario and for growers of processing crops to compete in the fiercely competitive world market, every possible and cost-effective avenue of reducing these costs must be researched diligently and implemented based on their merit and economic feasibility.

Processing tomatoes are grown on over 28,000 acres (>11,000 hectares) of land in Ontario by about 600 growers (Table 2). It is estimated that about one-half of these growers will already have a mechanical harvester. Therefore it could be expected that about 250-300 growers would be interested in higher levels of transplanting mechanization if this new technology was to be offered at a cost-effective level and performed adequately.

The objective of this study was several fold:

(1) to accelerate the testing and development of automatic transplanting technology for plug plants,

(2) to develop a labour and cost efficient large volume plant handling technology from the greenhouse to the automatic transplanter in the field and,

(3) evaluate the feasibility and economic impact of the entire system for the growers of processing crops in Ontario.

TABLE 2 . Production statistics over 5 years for processing tomatoes in Ontario.

	1985	1986	1987	1988	1989	5 yr avg
Number of growers	734	637	620	533	477	600
Contract acres	26,163	27,526	28,824	31,490	29,182	28,637
Acres per grower	35.6	43.2	46.5	59.1	61.2	47.8
Tons contracted	519,184	532,839	576,359	610,210	601,629	568,044
Tomato harvested	523,198	539,097	549,167	570,293	572,734	550,897
Tons marketed/acre	20.0	19.6	19.0	18.1	19.6	19.2

From: 46th Annual Report, The Ontario Vegetable Grower's Marketing Board Feb. 1987.

Note: 1985 Contract acres
1986-1989 Measured acres
1989 Tons harvested includes 3,074 U.S. tons
Acres/grower - calculated value

MATERIALS

PLANTS

Plug plants for the project were grown and supplied by cooperating growers, using normal growing regimes and practices (Garton et al, 1987, Muehmer, 1987).

The planting schedules were arranged so as to supply several flats of plug plants weekly from a time period of mid-April until mid-October to allow extensive testing and modifications to occur during the normal and extended planting season. The utilization of plants at the 114.3 - 152.4 mm (4.5 - 6 in) growth stage was strove for. Weather inclemency, machine modification, parts manufacture and/or acquisition and other delays resulted, at times , with tall plants , 177.8 - 203.2 mm (7 - 8 "), and increased root binding problems occurred but studies were developed to quantify how the automatic prototype-transplanter performed under these imposed conditions.

TRAYS

The most common size of plastic multi-celled tray presently in use for processing tomatoes in Ontario, is the 288 cell tray holding 1830 plants/m2 (170 plants/ft2). The utilization of these trays, rather than specifically designed trays, was initially deemed preferential as greenhouse growers already owned large inventories of existing 288-celled trays and obsolescence was not overly appealing. Individual cell size was approximately 20.6 mm x 20.6 mm (13/16" x 13/16") for all trays but variations occurred in overall tray dimensions and in cell depth which ranged from 25.4 mm (1") to 47.6 mm (1 7/8") depending on the supplier's mould design. However, the non-standardization in plastic 288 cell trays between the different manufacturers' mould designs was noted and perceived that it could create a problem with cell alignment in the cell singulation mechanism, designed by Clay-Mill Technical Systems, to reduce the root binding and entanglement problems.

Plug plants used in the Lannen springtime demonstration were grown in 144-cell Plantek trays, 40 x 40 cm , (15.8 in x 15.8 in) , whereas the fall planting evaluation was conducted using the higher density 256-cell tray of the same exterior dimensions. These trays are specifically designed to work with the Lannen automatic transplanter. The Plantek 256-cell tray (manufactured by injection moulding) as compared to the commonly used 288-cell (manufactured by vacuum extrusion) differ greatly in several aspects: overall dimensions, cell depth, cell numbers, rigidity, cost, absence/presence of exterior flange, and lifetime expectancy. These factors and their relationship to total system integration will be discussed later.

TRANSPLANTERS

The project involved field testing with two different types of automated planters:

1) A commercial fully-automated unit , manufactured by Lannen (Lannen Tehtaat Oy, Iso-Vimma, Finland),and demonstrated by Janzen Farm Equipment (Ruthven, Ontario)

2) A prototype, currently under development at Clay-Mill Technical Systems (Windsor, Ontario).

During the 1989 field trials of the prototype and initial demonstrations of the Lannen, the automatic planters were not fitted with all the accessories needed to meet the requirements of tomato growers in Ontario. Commercially-sized versions of these planters however, would have to include more extensive supplemental water delivery and storage devices, plant-tray-rack handling facilities, heavier frames and hydraulics, catwalks for safety and other numerous amenities.

Both transplanters were presented as one-row units mounted on a three-point hitch A-frame, lifted and powered by small to medium sized farm tractors.

CLAY-MILL AUTOMATIC (PROTOTYPE)

The basic underlying premise of the prototype unit involved the testing and workings of several key principles:

1) two tray holders which held plastic trays in a horizontal plane facing each other

2) extraction of plugs from 288-cell trays by a common set of grippers mounted on a slide between the two tray holders

3) mechanism designed to reduce the problems of plug root-binding between the cells of plastic trays

4) two plant indexing mechanisms which held plugs in proper alignment for delivery to shoe and plant furrow

5) air propulsion technology to propel plugs down to the plant furrow and reduce gravity dependency

6) programmable linear controller integrating and directing all machine functions

For matters of expediency, the extraction and tray holding assembly was mounted atop the lower base components of a commercially available planter (packing wheels, frame and plant kicker) realizing further modifications and enhancements could be made before total commercialization of an automatic transplanter took fruition.

LANNEN AUTOMATIC (COMMERCIAL)

The Lannen commercial unit employs a plunger to push the plug out from the bottom of the tray and onto a pair of rigid needles. The needle pair holding the transplant then rotates 90 degrees from horizontal to vertical where another pair of adjustable rubber covered fingers wipe off the plant into the delivery tube to the planting furrow. This further transplant travel is gravity dependent (Figure 1).

Lannen automatic transplanter using Plantek 256 mould-injected trays

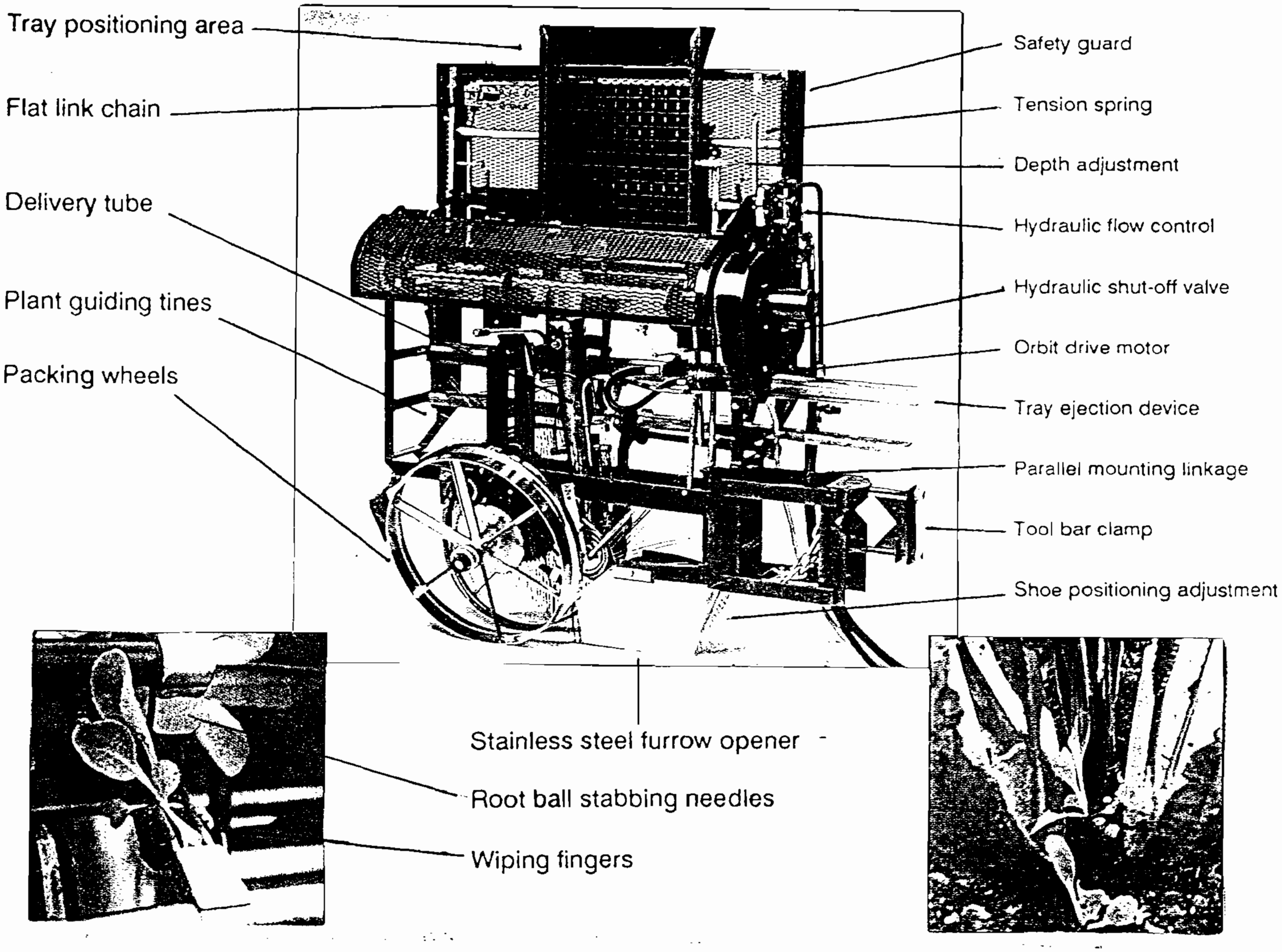


FIGURE 1. Commercial version of Lannen Automatic transplanter introduced into Ontario in 1989 capable of planting plug seedlings of a variety of vegetable crops.

METHOD

CLAY-MILL PROTOTYPE

Initially the project was designed to intensively field test a second generation prototype-transplanter whose mode of operation was to include simple computer regulated robotic features. Several evaluation criterion was to be noted on this unit such as:

a) effect of various soil types on planter performance, e.g. field sites typical of those used in commercial production within Essex and Kent counties

b) soil moisture condition and preparation

c) weather conditions impact on planter performance

d) accuracy of plant spacing and soil orientation

e) depth placement of the plug plant in the soil

f) plant survival and yield performance at harvest

g) impact of plant and plug size variations

h) economic assessment

An equally detailed and ambitious agenda by the management and technical staff at Clay-Mill Technical Systems was in place to further develop the prototype toward commercialization.

Several of the detailed tasks under study and development by Clay-Mill were:

1) tray placement system designed to a) support the trays during the travel of the machine in the field b) take the tray from its storage area and feed it to the seedling ejection mechanism and c) collect emptied trays.

2) tray positioning - an automated indexing mechanism to position the trays for seedling extraction and ejection.

3) missing seedling detection and compensation

4) neighbouring seedling interference separation

5) root entanglement interference separation.

6) seedling extraction system utilizing grippers.

7) seedling propulsion system to furrow and furrow opening.

8) transplant water and fertilizer injection.

9) depth adjustment.

10) development of fault-tolerant software to integrate and sequence the various machine functions.

Development delays of the research prototype at Clay-Mill through the summer and the termination of active development in the early autumn by Clay-Mill unfortunately interfered with the collection of the full project data. However, many positive(innovative) and negative(non-implementable) concepts and observations were noted which can only be treated as very valuable in helping the tomato industry strive towards less labour intensive automation at reasonable costs.

LANNEN AUTOMATIC (COMMERCIAL UNIT)

The project was fortunate to have the opportunity to evaluate, on a limited basis, the Lannen automatic transplanter and its' planting capabilities. The late fall shipment to Canada of the new model capable of handling the more competitive 256-cell style of tray delayed the intensive testing normal to many research endeavours but once again much valuable information and perceptual knowledge was gained by all involved.

RESULTS AND DISCUSSION

CLAY-MILL PROTOTYPE

As this was a prototype model, data collection was performed at several stages of machine development so as to document the areas of positive performance and areas where it was deemed that modification to the machine would enhance the completion of tasks. After a field evaluation was completed, the prototype would be returned to the shop area at Clay-Mill where the technical staff would correct any problems encountered and alter the machine. Another field trial would be scheduled to assess if the modifications had solved the problem and if so, successive trials would be scheduled.

EXTRACTION RATES

For any machine to successfully plant tomatoes and have a high field stand percentage, every good plug plant grown in a tray must be extracted. The inability to grasp and extract all the plants would reduce initial plant stands significantly. Slippage of the moist seedling stem while in the grasp of the gripper fingers can result in the errant delivery of the plug to the plant indexing mechanism. Positive grasping capabilities of the steel grippers were greatly enhanced with the application of rubberized coating material that (1) increased plant extraction rate from trays (26% improvement) and 2) enabled better alignment of plugs into plant indexing mechanism (Figure 2).

Although quantitative measurements of the force applied to the seedling stem by each closing gripper were not made, no visual bruising was observed, either after extraction from the trays or after transferral to the soil and subsequent growth. The cylindrical shape of the stem, by nature, appears to be capable of withstanding varying levels of externally applied forces until the extreme limit at which the outer cell membrane is broken or the stem is crushed. These levels appear to far exceed the removal force required when pulling plants from plastic trays. The occurrence of root binding between cells does increase the resistance to extraction and plant slippage in the grasp of the grippers, and management techniques to avoid this problem should be exercised.

Despite the visual perception of a large number of usable seedlings per tray when a grower selects and loads trays onto the planter, a startling revelation as to the number of full cells retaining peat after extraction clearly emphasized a very important fundamental difference between semi-automatic and automatic planters (Figure 3).

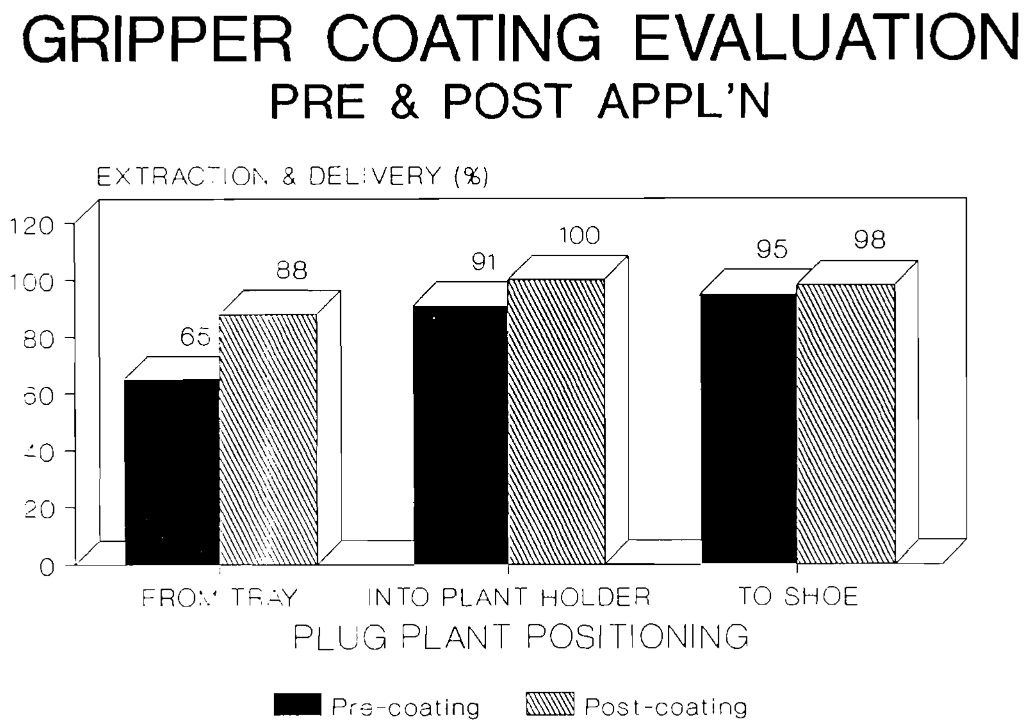
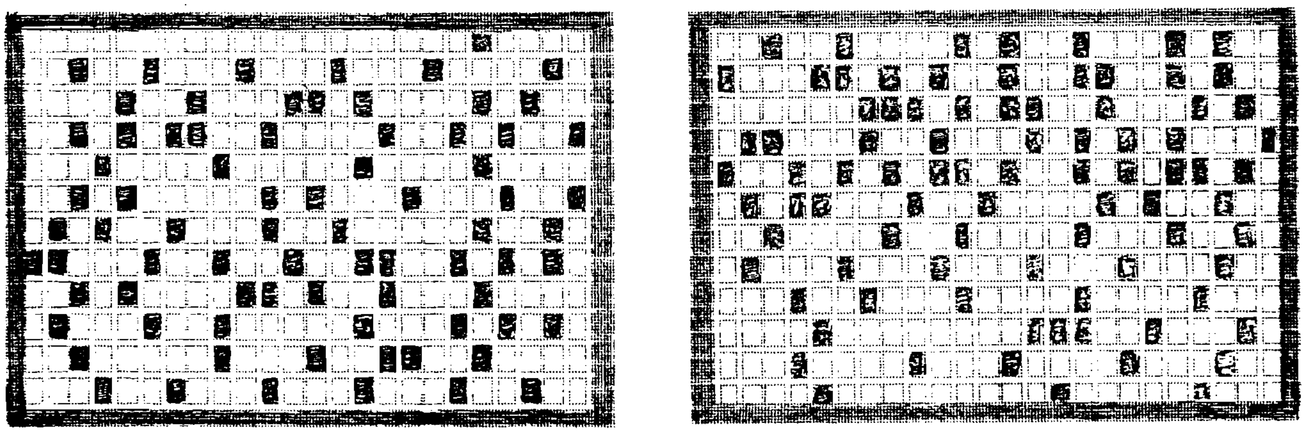


Figure 2.

MANUALLY-LOADED TRAYS

FIGURE 2. Improvement in extraction removal percentages from 288 cell trays with the application of rubberized coating material to the surface of each gripper.



Tray in right tray holder

Tray in left tray holder

Figure 3. Two trays after gripper extraction showing full and empty cells further emphasizing the need for horticultural uniformity and trays containing a large number of usable plugs.

TRAY MAPPING

Tray mapping is explained here in detail because of the prototype nature of the Clay-Mill planter. Determining accurately if the reduction in extraction rates attained with certain trays was the fault of the grippers or that missing or weak plants were the culprit was only possible if the number and tray location of these plants were known.

In order to isolate the operation of extraction by the grippers designed by Clay-Mill the contents of several trays were counted and recorded. The matter was further complicated by the fact that groups of 12 plants were alternately extracted from the tray held in the right tray holder and then from the left tray holder.

EXTRACTION SEQUENCE

The first 12 plants initially loaded into the plant holding mechanism were extracted from the first row of the tray held in the right side tray holder. The next 12 plants were extracted from the first row of the tray in the left tray holder. The gripper slide would be returned to the right side of planter, then shifted laterally to extract the remaining plants in row one. The next 12 plants would be extracted from the cells remaining in the tray in left tray holder. After cycle completion and removal of the plants from row 1 of both trays, the trays would be indexed downward so plants in row 2 of both trays could be extracted. Results of a tray mapping and extraction trial are presented in Table 3.

RIGHT SIDE (R)			LEFT SIDE (L)	
	row			row
24x12=288 cells	12		24x12=288 cells	12
	:			:
1.................24	1	cell location	1.................24	1

First 12 plants(A)="1AR"	Second 12 plants(A)="1AL"
(1-3-5-...-19-21-23)	(1-3-5-...-19-21-23) SHIFT
Third 12 plants(B)="1BR"	Fourth 12 plants(B)="1BL"
(2-4-6-...-20-22-24)	(2-4-6-...-20-22-24)

A = pre-shift location of gripper slide
B = post-shift location of gripper slide

Table 3. Results of cell extraction of mapped trays held in right and left tray holders on the Clay-Mill prototype automatic transplanter.

ROW #	EXTRACTD PLANTS TO PL HOLDER	MISPLACED PLUGS IN HLDR	EMPTY TRAY CELLS	FULL TRAY CELLS	PL ROOTS EXTRACTED FROM PLUG	CELLS NOT GERMNTD	TOTAL CELLS	
1	19	0	17	7	2	5	24	
2	19	0	14	10	3	7	24	
3	18	1	15	9	6	3	24	
4	20	1	15	9	5	4	24	
5	21	2	12	12	6	6	24	
6	20	0	16	8	1	7	24	
7	17	1	18	6	3	3	24	
8	16	0	18	6	2	4	24	
9	18	1	19	5	2	3	24	
10	18	0	18	6	2	4	24	
11	16	1	19	5	2	3	24	
12	16	1	21	3	2	1	24	TRAYS ON:
TOTALS:	218	8	202	86	36	50	288	RIGHT SIDE
	212	9	211	77	31	46	288	LEFT SIDE (IDENTICAL EVALUATION

EXPERIMENT RESULTS	TRAYS RIGHT SIDE	TRAYS LEFT SIDE
% PLANT EXTRACTION:	91.6%	87.6%
% PROPER PLANT PLACEMENT:	96.3%	95.8%
% TRAY GERMINATION:	82.6%	84.0%
# OF EXTRACTABLE PLANTS:	238	242
% OF EMPTY CELLS	70.1%	73.3%
% NON-GERMINATED CELLS:	17.4%	16.0%
% PLANTS WITH POOR ROOT DEVELOPMENT:	12.5%	10.7%

Although cells with peat remaining in them after extraction were perceived to have not contained seedlings initially because of poor germination, further study showed that some small under-developed seedlings had germinated but had been dislodged from the root ball because of poor root development (Figure 4).

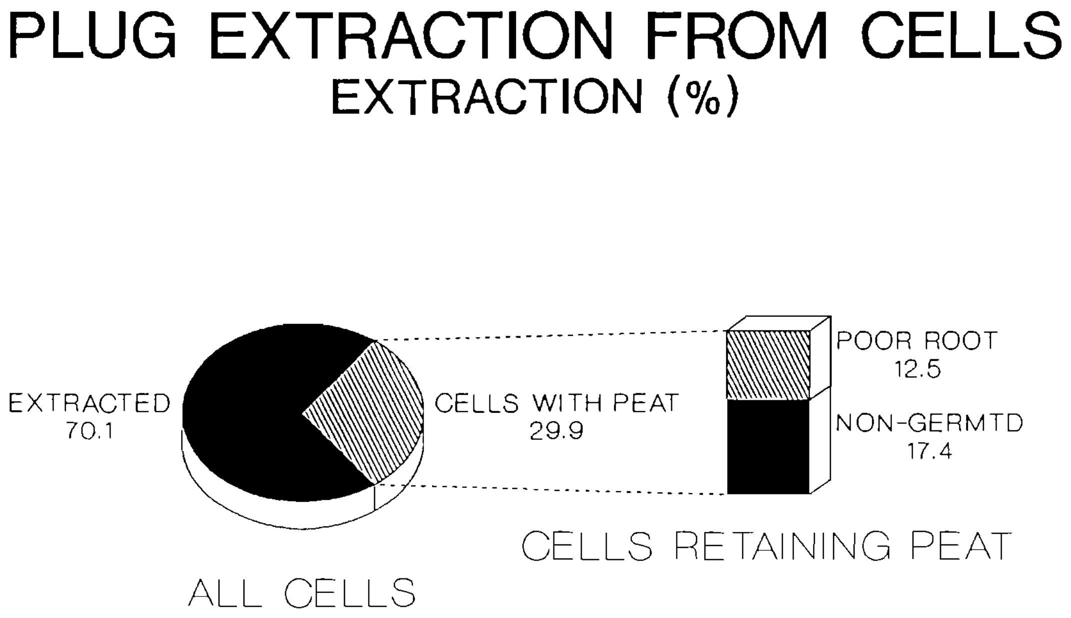


Figure 4.

SEEDLING GERMINATION IN TRAY 82.6%

FIGURE 4. Analysis of full cells remaining in trays after extraction showing that a percentage of perceived non-germinated cells did contain seedlings which were pulled from the root ball as a result of poor root development.

A field study to measure the overall planting success rate of the Clay-Mill prototype with <u>manually-filled</u> trays (ensuring 100% tray fill) was conducted. The results (Table 4) indicated that for this trial 88.2% planting success was achieved, derived from extracting 92.4% of all available plug plants and successfully transferring 95.6% of these seedlings to the planting shoe.

However, it is apparent that this success rate would decline proportionally to the percentage tray fill of the trays supplied to the planter. Trays containing 80-90% uniform, usable plants would lower this rate unless a mechanism for detecting and compensating for missing cells is available. An initial field stand of 85% in a double-row system may be acceptable to some growers but under a single-row regime the acceptability of this stand percentage is questionable due to the corresponding reduced number of plants per acre.

Table **4**. Evaluation of Clay-Mill prototype for planter accuracy and task completion from extraction of plugs from trays to resultant field spacing.

ROW LABEL	PLANTS /TRAY ROW	PLANTS TO INDEXING MECHSM	ROW TOTALS	TRAY EXTRACT'N SUCCESS RATE %	PLANTS TO SHOE (IN-ROW)	EXTRCT /SHOE SUCCESS RATE %	OVERALL EXTRCT/ PLANTING SUCCESS RATE %	PLANTING DISTANCE (FT)	MEASURED SPEED (MPH)	CYCLE TIME (SEC)	PLANT SPACINGS(IN) POTENTIAL (/24)	PLANT SPACINGS(IN) ACTUAL (# IN ROW
1AR	24	11	23	95.8%	21	91.3%	87.5%	38.6	1.55	17.0	19.3	22.0
1BR	24	12										
1AL	24	11	21	87.5%	21	100.0%	87.5%	38.3	1.53	15.5	19.3	21.9
1BL	24	10										
2AR	24	10	21	87.5%	21	100.0%	87.5%	37.2	1.47	17.2	18.6	21.2
2BR	24	11										
2AL	24	11	23	95.8%	20	87.0%	83.3%	37.1	1.42	17.8	18.5	22.3
2BL	24	12										
3AR	24	12	24	100.0%	24	100.0%	100.0%	38.2	N/A	N/A	19.1	19.1
3BR	24	12										
3AL	24	10	21	87.5%	20	95.2%	83.3%	38.3	N/A	N/A	19.2	23.0
3BL	24	11										
		AVERAGE:		92.4%		95.6%	88.2%	37.9			19.0	21.6

PLANTING RATES

Plant spacings were controlled by the programmable controller receiving signals from a counter mounted on the front packing wheel. Changing the number of signal counts required to advance the plant indexing mechanism resulted in a variance in plant spacings (Figure 5).

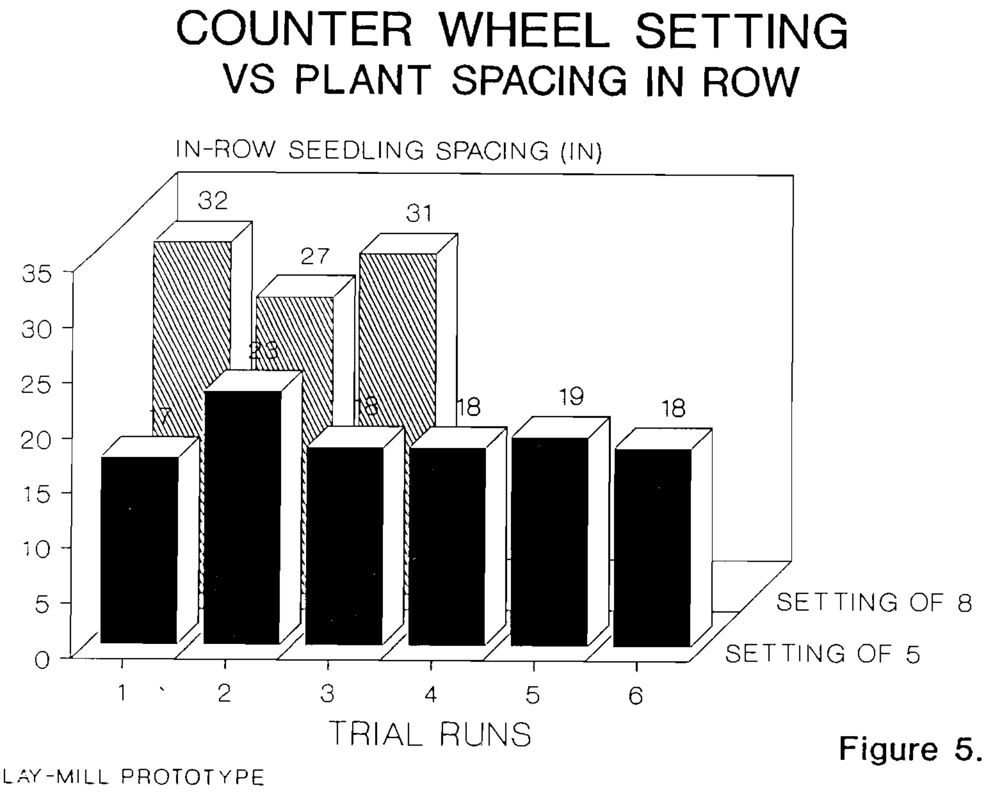


Figure 5.

FIGURE 5. Resultant changes to in-row plant spacings after adjustment to the count that directed the programmable controller to advance plant indexing mechanism.

Varying ground speed (Figure 6) as expected did affect the planting rate (plants per second) while maintaining plant spacing at a near constant level. Tray fill level (100% manually-filled in this experiment) would obviously have a dramatic effect on planting rate and spacing as missing plants in trays would result in lower planting rates and gaps in field stands or plant spacings. To achieve higher planting rates (Figure 7), the planter must complete its respective functions more rapidly. The faster the planting rate, the more rapidly the machine functions must cycle. Consistent and continuous cycling must be engineered into a successful automatic planter. The Clay-Mill prototype's capability is unknown.

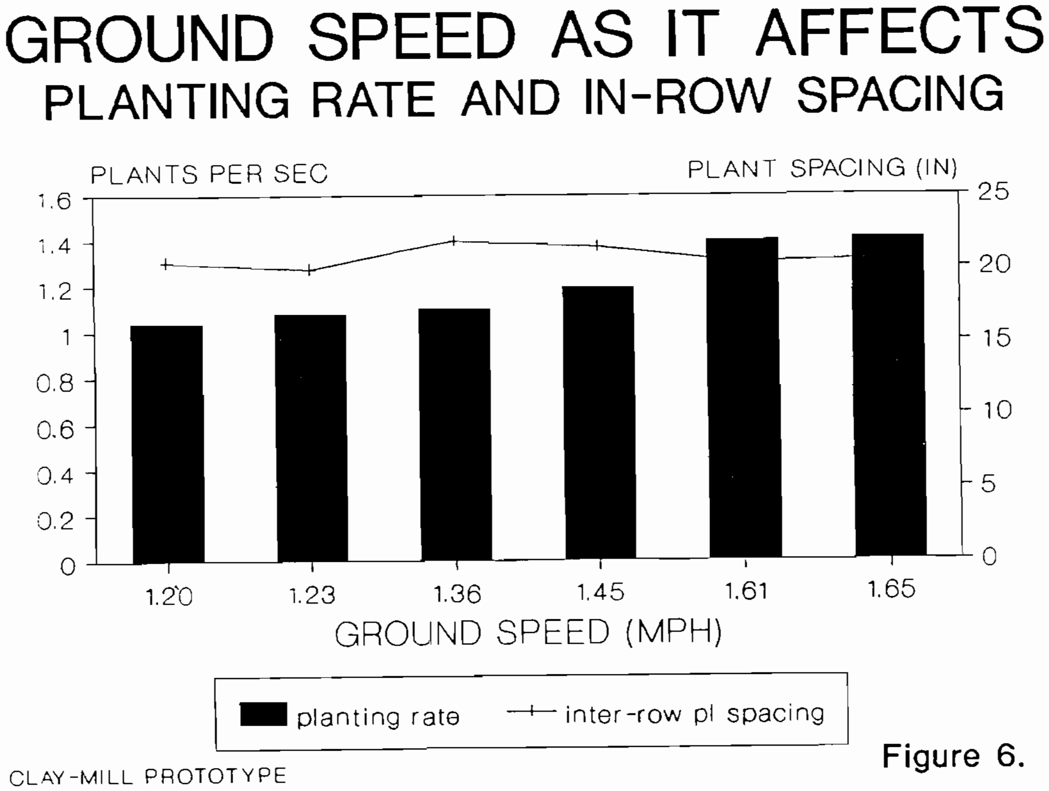
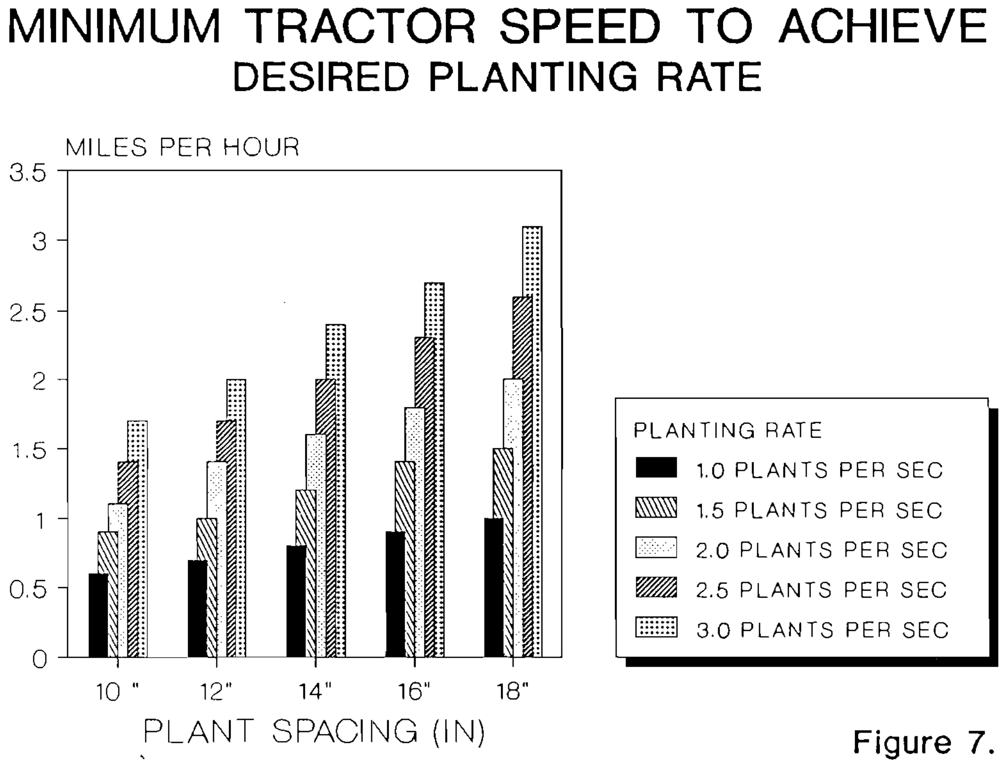


Figure 6.

FIGURE 6. Plant spacings and planting rates produced in the field test area at Clay-Mill at varying forward ground speeds.



1 MPH = 1.467 FT/SEC

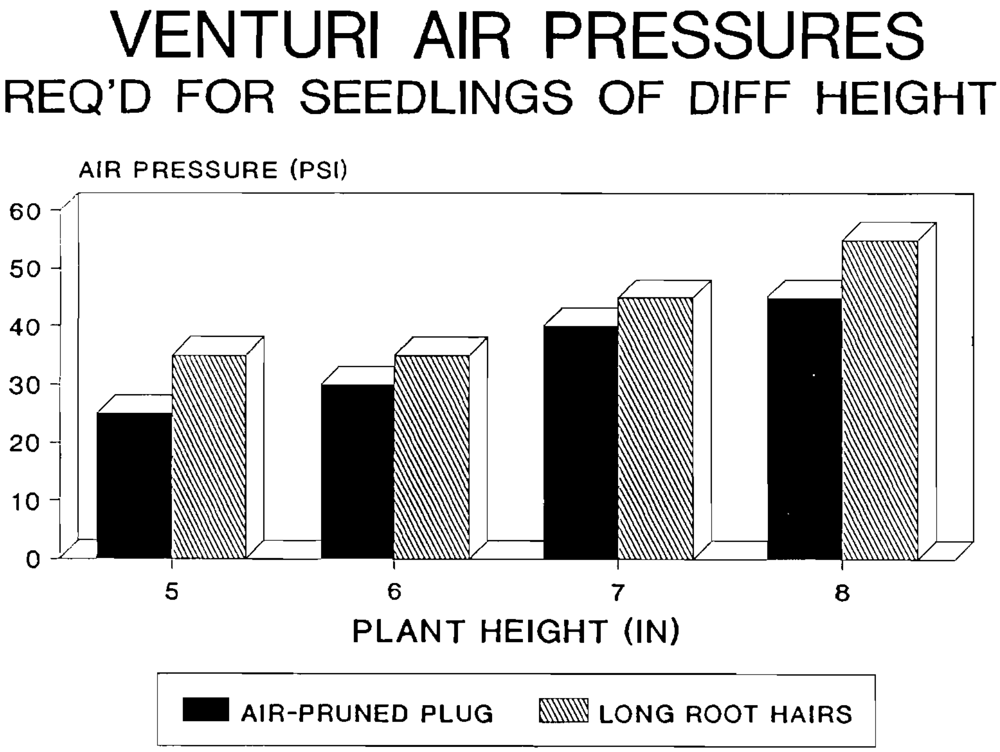
Figure 7.

FIGURE 7. Calculated minimum tractor speeds required to achieve various desired planting rates between 1.0 and 3.0 plants per second.

AIR PROPULSION PLANT DELIVERY SYSTEM

A unique plant propulsion concept was utilized by the Clay-Mill prototype. The addition of air propelling the plant down the delivery tube reduced the problems associated with gravity dependency when planting tall plants (6-8 in). Inclement weather and other delays often resulted in plants growing to heights that would be unacceptable for semi-automatic planters without clipping.

Increasing plant heights required higher air pressures (Figure 8). Foliar entanglement of plants in the indexing mechanism was the main reason for increasing line pressure to the venturi. Plants which had aged past normal maturity stages and had developed less uniform root balls because of dangling root hairs required higher rates of air delivery than the corresponding plant with air-pruned plugs.



CLAY-MILL PROTOTYPE

Figure 8.

FIGURE 8. Venturi air pressures required to propel plants of various heights down to the planting shoe in the shop trials at Clay-Mill.

LANNEN AUTOMATIC (COMMERCIAL)

A field trial to evaluate the field performance of the new Lannen Automatic transplanter was conducted at Janzen Farm Equipment, Ruthven, Ontario. With 1989 being the introduction year of this model capable of planting 256 cell trays of tomato plug plants, experiments with only a 1-row unit were performed. Due to the limited nature of the trial, quality and maturity of the plants, and existing data by the manufacturer this study was designed to test the upper limits of planting rate and accuracy to see if a rate of 3 plants/sec was achievable.

Time motion studies (Table 4) indicated that the unit was capable of planting at the manufacturer's claim of 1.66 plants per second and theoretical rates above this could be achieved but with decreased planting accuracy in actual field stands.

TABLE 5 . Field trial to measure tray consumption rates and test the upper range of planting accuracy of Lannen automatic unit

	256-cell Plantek tray				
Cell Extraction Tray Ejection Time/(Sec)	Theoretical Planting Rate		Actual In-Row Rate		Planting Accuracy
	Plants	Plants/Sec	Plants	Plants/Sec	(%)
163	256	1.57	250	1.53	97.7
148	256	1.73	247	1.67	96.5
125	256	2.05	222	1.78	86.7
123	256	2.08	206	1.67	80.5
				ave. 1.66	90.4

Actual planting rates reflect the number of plants that were present in the trays and successfully placed in the soil. Theoretical rates represent what the achieved planting rate would have been based on the measured times required to empty the 256 Plantek trays and 100% tray fill.

Extrapolations, based on the data collected (Table 5) were calculated to determine what the daily planting rate of this automatic unit would be and comparing it to the measured rates of a carousel semi-automatic planter (Hergert et al 1988). Further field trials using a commercial 6-row unit are required to evaluate actual planting rates.

TABLE 6. Measured and Calculated Commercial Field Performance Data for Lannen Automatic Transplanter Compared to Other Commercial Units Planting Plastic Tray Plug Plants

PLANTER TYPE	SINGLE OPR PL/MIN	PL/ SEC	(A/DAY)	PLANT RQMNT	TRAY RQMNT 250/TRAY	RACK RQMNT 16 TRAYS
CONVENTIONAL GRIPPER 10 POCKET	25.8	0.43	.....	.....	.....	.....
CONVENTIONAL GRIPPER 12 POCKET	35.4	0.59	.....	.....	.....	.....
M-4000 (semi-automatic) CAROUSEL	69.6	1.16	11.30	147,714	590.9	37
LANNEN AUTOMATIC	99.6	1.66	14.69	192,028	768.1	48 *
			25.71	336,081	1344.3	84 **

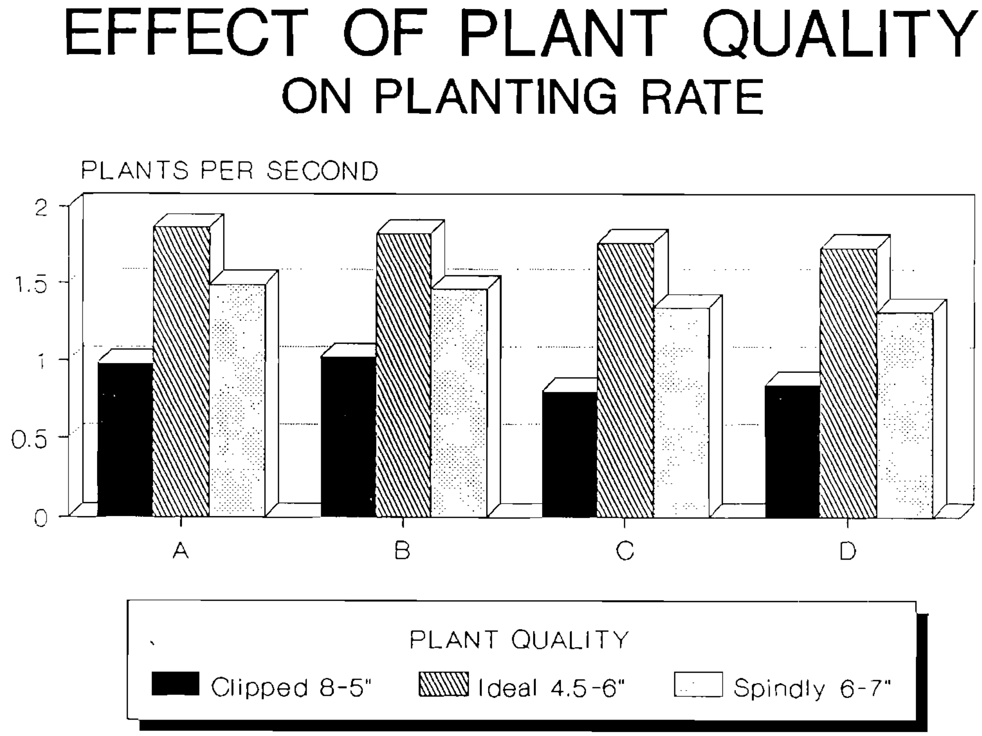
CALCULATION ASSUMPTIONS: (* - 8 hour planting day)
(** -14 hour planting day)

1) Conventional and carousel planter rates source: Burgoyne 1987
2) Total calculated time to transplant 1000 transplants per row (includes actual planting time, sorting and loading, turning on headlands, down-time for adjustments, loading racks, repairs etc) = 19.5 minutes
3) Lannen planter rates source : Arnold 1989
4) Row lengths of 610 metres (2000 feet)
5) Twin rows , 60 " beds and 13,072 plant population per acre

LANNEN AUTOMATIC: OBSERVATIONS AND MACHINE ADJUSTMENTS

Despite the limited amount of data collected on this unit, several observations were made relating to the planters' performance :

1) Plug plant quality had a very noticeable effect on planter performance. Compact, well-defined plants 114.3 - 152.4 mm (4 1/2 -6") were planted with no difficulty, but tall, spindly crocked-stemmed and clipped plants presented problems resulting in lower planting rates (Figure 9).



LANNEN AUTOMATIC

Figure 9.

FIGURE 9. Relationship of horticultural uniformity and plant quality of plug plants to the ability of the Lannen Automatic in producing different planting rates.

Most problems occurred at the top of the delivery tube where the extracted plugs would catch and subsequently affect the rate of gravity fall of following plants.

2) Positive drive of the unit was achieved by a hydraulic orbit motor controlling the rate at which the plugs were pushed from tray onto needles and then wiped off these needles down the plant delivery tube. Once the hydraulic flow rate was set, field plant spacing became a function of forward ground speed (slower speed giving closer plant spacing).

3) Percentage tray fill (number of healthy plug plants per tray) had a <u>direct</u> effect on planter performance as this unit did not have the capability of detecting and compensating for missing plants in the tray cells. A missing cell (cell containing no plant) or small under-sized plant resulted in a gap in field stand because of its absence or the small seedling was buried in the plant furrow by the packing wheels and shoe depth pre-determined setting. The machine did perform well when trays with high plant counts were used, further emphasizing the horticultural demands for consistency and uniformity that mechanical automation requires.

4) Adjustment of the delivery tube in relationship to the packing wheels and forward ground speed were found to be important factors. With faster planting speeds the delivery tube is moved away from the packing wheels towards the front of the shoe because soil is flowing around the heel of the shoe faster and this adjustment allows the plug to reach the bottom of furrow in sufficient time before it encounters soil being moved around the root ball. Slower ground speed has the delivery shoot being moved back toward the packing wheels away from front of shoe so that the plug has less time to tip over in plant furrow as soil is not flowing in around the plug as fast.

5) Depending on soil type, extensions to the planting shoe may be required especially if the soil is loose and friable and the soil flows in too fast around the root ball before the plant properly orients itself in the furrow.

6) The rubber fingers that wipe the plant off the needles were adjustable to account for variations in length of plant stem and foliar growth.

7) Root entanglement with root hairs growing between the tray cells impeded planter performance, further illustrating the need for precise management care at the greenhouse level during the tray filling process ensuring

that soilless mixture is not over-applied to the tray and singulation of each cells is achieved.

8) Root development and firmness of the root ball is important since it is <u>root ball</u> that is <u>pushed</u> from the Plantek tray rather than the stem being grasped by finger mechanisms or grippers. Smaller plants which have not developed an extensive root system in the tray cell, were the cells where the plunger pushed through the ball resulting in poor extraction and delivery to planting furrow.

9) Watering the trays prior to planting would provide a heavier plug to be extracted from the trays and result in a faster drop time to the planting furrow and shoe by gravity. Soggy over-watered plugs with insufficient root development allowed for poor extraction as the plunger pushed easily through these root balls.

10) Tray indexing and the successful transition from the recently emptied tray to the next full tray was accomplished without problems. The absence of flanges (Figure 10) on the Plantek 256 tray compared to the 288 cell tray (Figure 11) eliminates the requirement with 288 cell trays that double indexing in the tray holder occur when the last row of the first tray and first row of next tray are encountered.

TRAY COST COMPARISON

The Lannen Automatic transplanter was designed to use rigid Plantek trays with sufficient strength to accommodate the pushing of the tomato seedling from the back of the tray by a plunger. By requiring a more costly tray than the common 288 tray, increased tray costs would be expected to be reflected in higher plants costs. Increased planting rates quite substantially different from the semi-automatic planters would be required to offset these costs.

SCENARIO: Greenhouse grower using Lannen Plantek 256 cell trays, required by Lannen Automatic, and the comparative costing of using 288 cell disposable trays to grow 1,000,000 plug plants for sale or on-farm usage.

ASSUMPTIONS:

Tray costs: Plantek 256 - $6.00 each
288 - $0.75 each

Tray longevity:
Plantek 256 - 10 years use period (1 use/year)
288 - 2 year use period (1 use/year)

Salvage value - none

Depreciation - new value - salvage value/life of trays

Interest - (new value + salvage value) x interest rate/2
- 12% interest rate

Germination or tray fill:
86.8% resulting in 222 usable plants per 256 cell tray
" resulting in 250 usable plants per 288 cell tray

To raise 1,000,000 plants greenhouse grower would require
a) Plantek 256 - 1 million plants/222 plants/tray
= 4505 trays @ $6.00/tray
= $27,030 tray inventory for a 10 years use period

b) Common 288 - 1 million plants/250 plants/tray
= 4000 trays @ $0.75/tray
= $3000/2 year use life
= $15,000 tray costs for a 10 years use period

ANNUAL OVERHEAD COST: 1,000,000 plants

Plantek 256 Tray		288 Tray	
Depreciation =	2703.00	Depreciation =	1500.00
Interest =	1621.80	Interest =	360.00
	4324.80		1860.00

Tray cost per 1000 plants :
= 4.32/1000 plants = 1.86 [redacted]/1000 plants

Difference= $2.46 [redacted] per 1000 plants produced

The difference in tray costs of $2.46 [redacted] per 1000 plants produced suggests that a more cost-effective tray would enhance the market potentiality of this growing system. Actual years of documented usage are required to substantiate the longevity of either tray and resultant costs.

PLANTER COST COMPARISON

Cup Carousel(A) vs Lannen Automatic(B)

1) Plant Population (60" beds-twin rows 16" in row spacing
18" between rows)
= 13,072 plants per acre

2) Planting rate: 1.16 plants/second/row - Carousel
(Actual) 1.66 plants/second/row - Lannen Automatic

Source: (A) Hergert et al, 1989.
(B) Arnold, 1990.

Loading and turning adjustment factor:
(A) Cup-carousel x 73.5% efficiency
(B) Automatic x 70.0% efficiency (increased loading times with fewer people)

Effective planting rate:
(A) 1.16 pl/sec/row= 25,056 pl/hr/6row x 73.5% efficiency
= 1.41 acres/hour

(B) 1.66 pl/sec/row= 35,856 pl/hr/6row x 70.0% efficiency
= 1.92 acres/hour

3) Labour cost: A) 6 people + 1 driver = 7 People @ $6/hr
= $42/hr planting

B) 2 people + 1 driver = 3 people @ $6/hr
= $18/hr planting

Labour Comparison: Planting
Semi Automatic - $42/hr /1.41 A/hr = $29.79/A
Automatic - $18/hr /1.92 A/hr = 9.38/A
$20.41/A savings

<u>Annual</u> <u>fixed</u> <u>overhead</u> <u>costs</u> (depreciation, interest, repairs, housing, insurance)

	Dollars/acre		
	150A	200A	250A
6-row carousel valued @ 20,000 = $3520	23.47	17.60	14.08
6-row automatic valued @ 75,000= $13200	88.00	66.00	52.80

Annual overhead cost calculations suggest that for a labour savings of $20.41/A for semi-automatic planting versus automatic planting, the cost of an automatic transplanter may presently be too high at a $75,000 initial purchase price.

Planting with the more costly Plantek trays will add another $32.16/A due to higher plant costs.
($2.46 increase/1000 plants x 13,072 plants per acre)

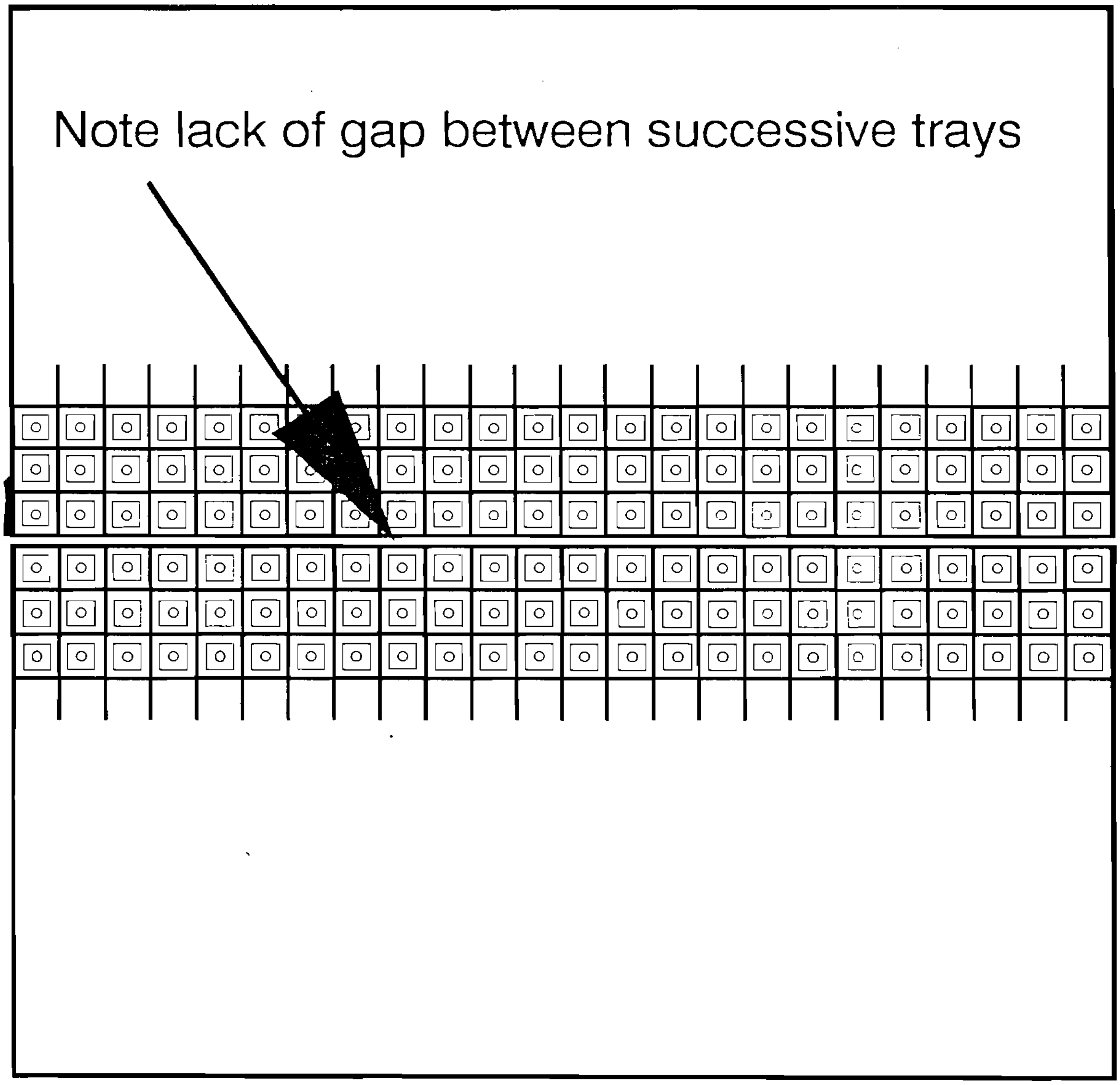


FIGURE 10. Bottom view of trays similar to Plantek 256 trays. These trays fit flush together, eliminating a gap between rows of cells facilitating tray feeding.

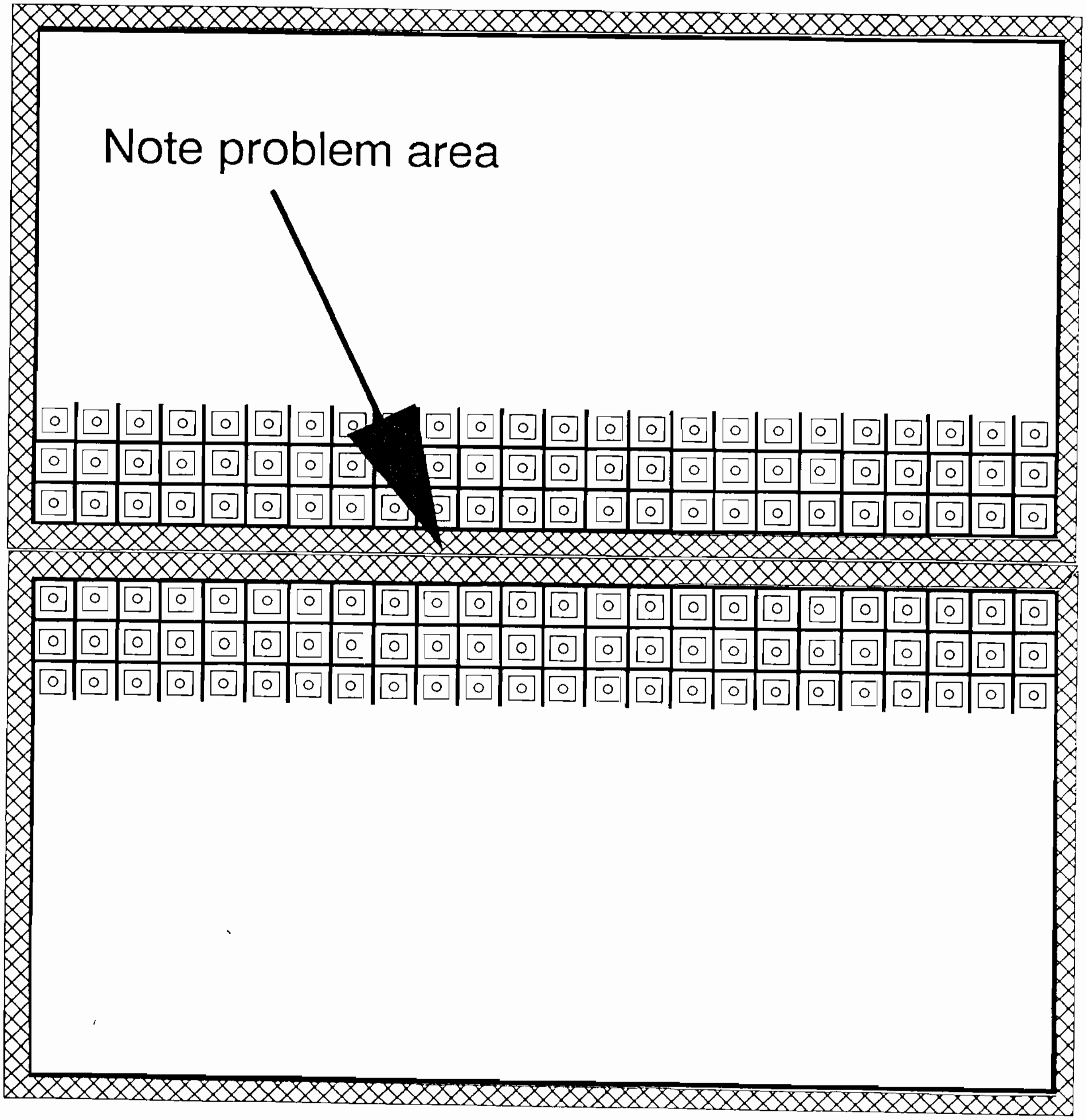


FIGURE 11. Bottom view of 288 cell plug trays. The gap between rows of cells at the edges of adjacent successive trays causes an interruption in the feeding of trays and transition between empty and full trays in the automated transplanter.

CONCLUSIONS

1). Paramount to the success of transplanting automation is the ability of the plug plant greenhouse industry to supply growers with sturdy, horticulturally uniform transplants consistently. Greenhouse management techniques must be refined to the highest possible levels of expertise through all operations (tray filling, seeding, germination, fertilization and watering etc.)

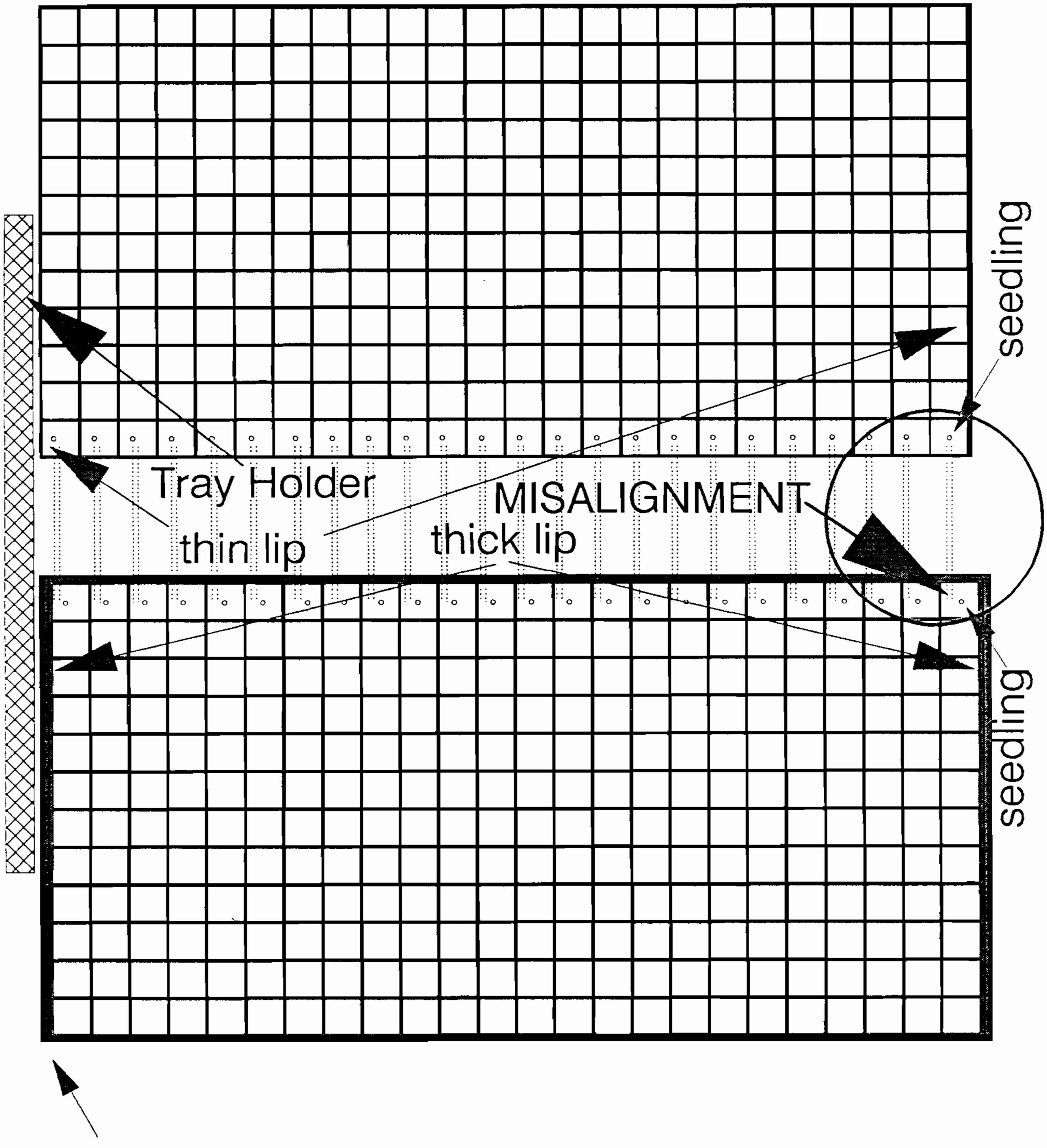
2). Automation in the automotive industry is successfully achieved because the materials handled are a) normally 100% <u>present</u> or compensated to be and b) <u>consistent</u> in composition and handling characteristics or are treated as rejects and discarded automatically. In greenhouse plug plant production the task of producing a biological entity (seedlings) as uniform and complete as precision machined auto parts is a formidable assignment.

3) Plant extraction from the cells of high density plastic trays can be accomplished either by plungers pushing the root ball out of specialized designed trays or by grasping the stems of seedlings from trays in common use. However, the former is the mode of cell extraction that is commercially available now in Ontario by the Lannen Automatic.

4). The effect of tray cells containing non-viable or missing plants had a profound effect on automatic transplanting performance. Tolerance levels to reduced stands at the initial stage of transplanting will become a function of the acreage level of each individual grower, productive capabilities of the selected varieties, growers' ability to secure labourers to re-set plants at reasonable costs, and the row system (double or single) in the growers' management regime.

5). Standardization of mould designs of 288 cell trays will be beneficial if the tomato industry is to adopt automation in transplanting operation. Problems arise in the areas of tray holding and, cell singulation and extraction if overall tray dimensions and tray configurations (e.g. ribs in trays for strength, width of exterior flange, individual cell sizes) vary slightly. Also the intermingling of different trays of different design would further compound the problems, (Figure 12).

6). Stacking capabilities and facilitating the transition from empty to full trays while held in the planter's tray holder is very important. The absence of flanges on the Plantek tray allows for smooth indexing and transition as no gap exists between stacked Plantek trays that is experienced between stacked empty and full 288 cell trays



Note thicker lip on bottom tray

FIGURE 12. Problem with cell singulation and seedling alignment due to variability in the thickness of the outer lip on the 288 tray. This indicates the need for standardization of tray design for use with automatic transplanters.

7). The cost of the Plantek tray is a drawback in terms of initial investment, depreciation and interest costs. Important considerations will be the effect of tray warping with age on planter performance and the incidence of disease build-up to the long-term use of these more costly trays. These items may or may not be valid concerns, but require further investigation.

8). Transplant water requirements would affect the design consideration of a 3 point hitch or trail-type model of an automatic planter. Required volumes exceeding 1820 L (400 gal) and fields of considerable lengths dictate that tanks supplying the transplant water be situated on the planter frame rather than in saddle tanks on the tractor.

9). Reducing inter-row spacing down past a certain level dictates that the planting units are placed in a staggered configuration on the planter. Extra planter length plus the addition of a rack handling device attached to the planter for additional trays will put a demand on the grower to make the headlands in his field wider to accommodate machines requiring larger turning radius. Self-propelled planters rather than tractor-drawn may offer an alternative.

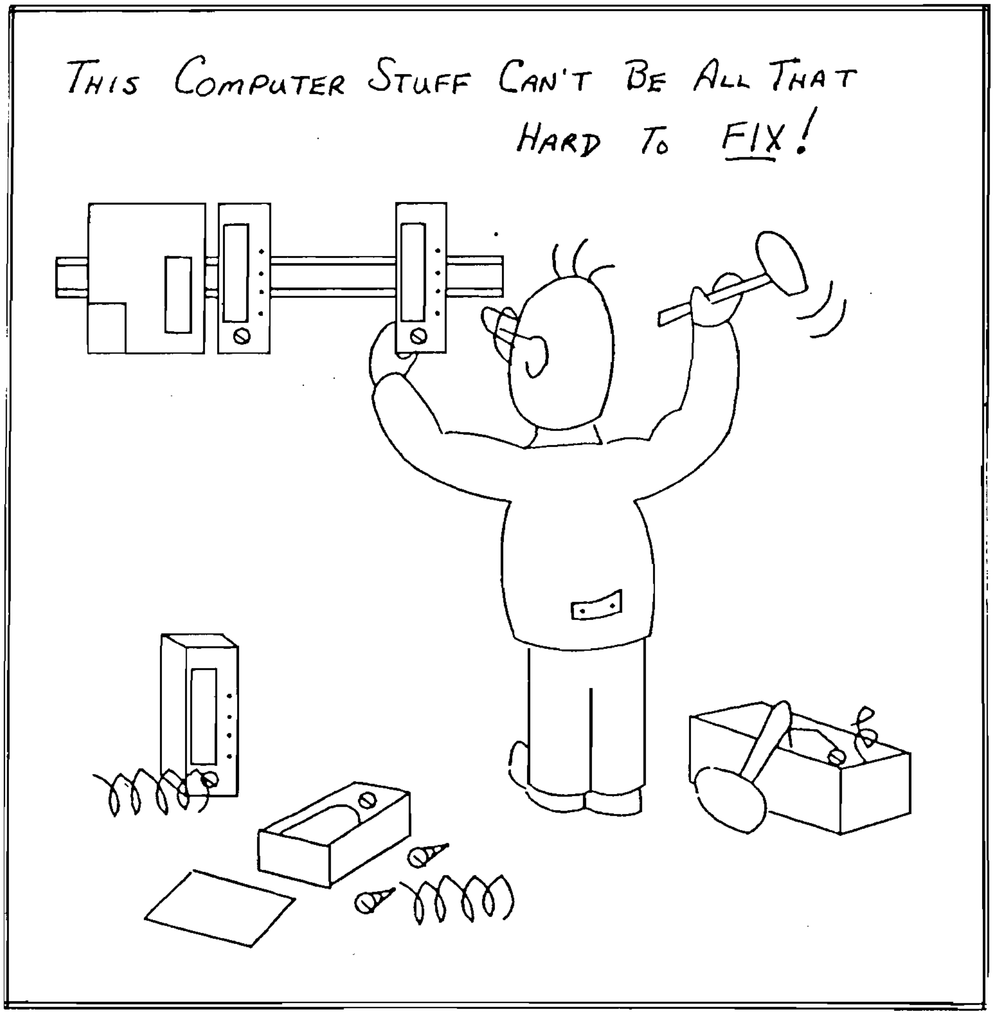
10) Planter enclosures made of tarps and similar material would be beneficial to reduce any effect of wind and add comfort to the surroundings of workers loading trays into the planter during any adverse weather.

11) Crew sizes involved with most semi-automatic planters and tomato harvesters, equipped with electric eyes, are presently at 6 persons and reducing this number is possible with transplant automation. However, will the loss of springtime planting jobs to migrant and local labour forces represent a further adjustment to the operation of hoeing and harvesting and affect our ability to attract labourers for these highly seasonal activities.

12) Processor involvement and commitment is critical in any industry-wide shift in the adoption and usage of automatic transplanters. Acreages must be of sufficient size to make it feasible for growers to afford this new technology or facilitate the co-ordination of plant allotment to individual growers to allow custom planting. Repetitive, longer work days (14-16 hours/day) which are not feasible for a semi-automatic transplanters may provide a basis for justifying automation costs.

13) Increased daily planting rates and tray consumption rates in the field by automatic planters places a further emphasis that a well co-ordinated, volume rack handling system from greenhouse to field be in place.

14) Complexity of operation, planter durability, dependability and cost must be important considerations in commercializing automatic planters for use by tomato growers in Ontario. Market potential exists for automation in the transplanting operation but must be presented to growers in a cost effective manner which reduces his overall planting costs and compliments the rest of his tomato growing operation.


THIS COMPUTER STUFF CAN'T BE ALL THAT HARD TO FIX!

RECOMMENDATIONS

1) Work on missing cell detection and compensation to be incorporated into existing technology would further enhance the perfection of planting and improvement in field stands.

2) Improving plant counts in trays through the use of high germination seed lots and fine tuning greenhouse practices will provide better planter performance until such time a cost-effective solution to missing seedlings in plastic trays is perfected.

3) A consensus regarding the use of a standard tray should be adopted if automation is to occur industry wide. This design may or may not be the same as presently in use for semi-automation but must be addressed before automation can proceed. Costly obsolescence of present facilities used in the planting and handling of plug trays and tray inventories can be avoided if proper planning and coordination is adopted early.

4) The optimum tray design, cell size and plant density for plug transplant production is still not known. These questions must be answered before an automated transplanting system can been properly developed. Alternatively, transplanter manufacturers must design their equipment with enough flexibility to accommodate a range of different transplant tray designs, if this is possible.

5) Plug plants grown in higher density trays (e.g. 406 cell) offer a means of greenhouse growers reducing overhead costs per 1000 plants sold and satisfying processor's requirements for insurance plantings but the reduced weight of the root ball associated with these smaller seedlings may present problems of delivery to planting furrow by gravity. Reducing delivery heights that the plant has to travel to the plant furrow or utilizing some form of air propulsion should be investigated.

6) Research is needed to determine transplant water requirements for optimum establishment of plug transplants. In general, the prototype automatic planters have been demonstrated without watering systems. Integration of watering systems will be an important component of automatic transplanter design.

7) Increasing demand for plug transplants by tomato growers could create a scenario where sufficient greenhouse space is not available to meet the demand. In order for the Ontario tomato seedling industry to meet the demand for local transplants, new production sources will have to be developed. Construction of new greenhouses, specifically

for transplant production, and conversion of facilities producing other crops (e.g. greenhouse cucumbers) will have to be explored. Transplant producers must continue to produce high quality, disease-free plants if the expansion of the local transplant industry is to continue and flourish.

Dedicated, qualified greenhouse growers growing uniform quality plug plants is **MANDATORY** for transplant automation to succeed.

ACKNOWLEDGEMENTS

The project was made possible by the following well-appreciated support :

1) Funding from the Ontario Crop Introduction and Expansion Fund; the New Crop Development Fund; and the Ontario Tomato Seedling Growers' Marketing Board.

2) Administration and allocation of the priority for collection of horticultural and engineering data by the Ontario Tomato Seedling Growers' Marketing Board, Gene Woodsit, Secretary-Manager, and Linda Baird, Secretary, Leamington Ontario.

3) Seed supplied by the H. J. Heinz Co. Ltd., Leamington Ontario, and Primo Foods Ltd., Ruthven Ontario was gratefully appreciated.

4) Special thanks to co-operating growers - Hank and Art Vander Pol, Roland Farms Ltd., Blenheim Ontario; Mr. and Mrs. Joe De Lellis, DeLellis Farms, Leamington, Ontario, and Mr. and Mrs. George Bicrel for their tomato seeder.

5) Agriculture Canada, Harrow: Dr. Albert Liptay, Nick DiMenna, Tom Jewitt, and Ron Garton
   Agriculture Canada, Ottawa: Gary Hergert and Lorne Heslop.

6) Clay-Mill Technical Systems, Windsor, Ontario: Clayton Pearce, Keith Arner, Doug McTagart, Dave Demers, Rob McCallum,
   Janzen Farm Equipment, Ruthven, Ontario: Ron Janzen and staff and,
   Lannen Inc., represented by Marty Verkkunin of Hakmet, Dorion, Quebec.

7) Clerical assistance by Dixie Buchanan, Dresden and Geri Guyitt, Plant Industry Branch, O.M.A.F. was sincerely appreciated.

8) Very special thanks to Ed Tomecek, Plant Industry Branch O.M.A.F.

9) Lastly the author would like to acknowledge the good working cooperative spirit and the innovativeness of the whole tomato industry.

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TRANSPORT SYSTEMS FOR PLUG PLANTS GROWN FOR TRANSPLANTING PROCESSING TOMATOES

INTRODUCTION

The increased plant consumption rates by automatic planters when fully developed, and the desire to satisfy the needs of plug plant customers at greater distances from the traditional greenhouse areas have prompted the investigation of transportation systems capable of handling large volume of plants in a labour and cost-efficient manner.

The rack system already developed in Ontario, as outlined in an engineering study by Hergert et al 1988, has shown its advantages for reducing labour for both the greenhouse operator and the tomato grower. Supplying markets at significant distances depend on an efficient method of transporting the tray-grown plug plants on trucks, which must include maximizing payloads and reducing loading times. Special requirement for transportation are required to protect the growing plants and to allow multi-tiered stacking.

In Ohio, a box system for transporting large quantities of plastic trays exists. Each box (steel reinforced, plywood-covered) contains 10 shelves of 16 trays each. The boxes are handled by fork-lifts for loading and unloading. When placed on a flat bed trailer, with open sides to the centre, the boxes create a closed environment for the plants. Twelve of these boxes loaded on a 45 foot (13.7 metre) trailer gives a shipment capacity of 480,000 plants (250 plants/tray). Major drawbacks to this system are the requirement that the trays be placed on each individual shelf by hand and the substantial measured height of the upper shelves from the flat floor surface of the trailer.

The purpose of this report is to suggest and evaluate a plug plant transportation system that would allow growers to ship plants on the same racks presently used in the growing regime in a number of Ontario greenhouses.

EXISTING PLANT HANDLING METHODS FOR TRANSPORTATION

The most common tray used in Ontario for tomato transplants is the Blackmore 288 (or equivalent) tray which holds 288 plants in individual cells and measures 11 x 22 ins. (28 x 56 cm) and has a plant density of 170 plants/ft 2 (1830 plants/m2). The racks, either a) 2 x 4 wooden racks with wires stretched across the wood members or b) steel 1 x 1 x 1/8 angle iron construction hold 16 trays.

Seeded trays are placed on the racks and are handled that way throughout the growing process. Specially-built trailers (Figure 13) are used to carry the racks of trays from the greenhouse to the field. Trailer covers protect the plants from damage by wind and dehydration by the 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.

ADVANTAGES
- racks can be handled in the field with 2 people with no fork-lift required.
- plants easily unloaded, 16 trays at time to place in a holding area should transplanting be postponed;
- racks suit an already developed seedling production and delivery system from greenhouse to transplanter;
- cost savings for all segments of seedling production and transplanting.

DISADVANTAGES
- trailers do not have capacity for long distance delivery of large orders.
- larger daily plant requirements in supplying an automatic planter would require a much larger time commitment for road travel

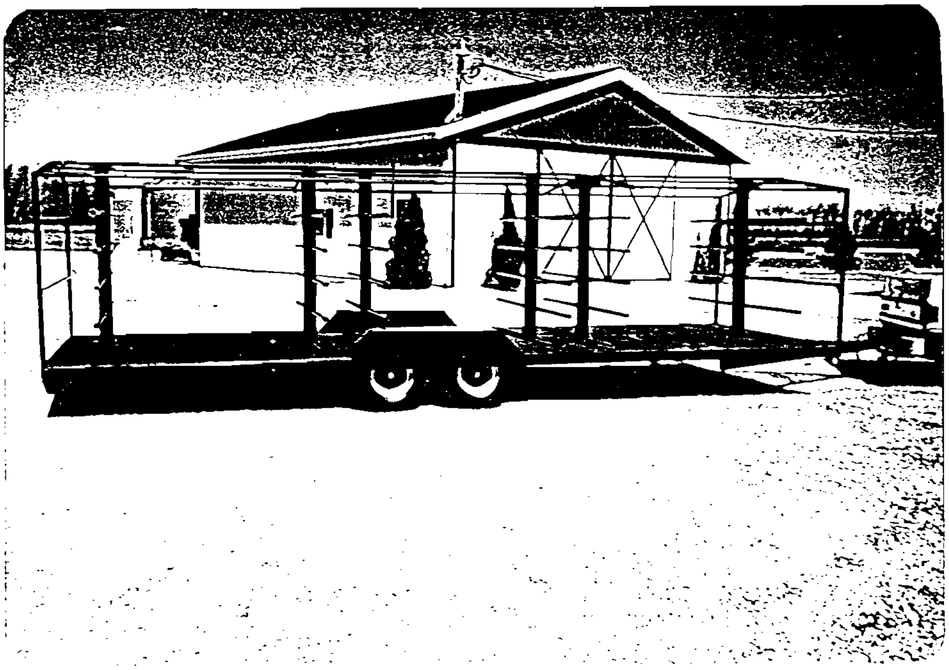

Figure 13. Specially-designed and built rack trailer for hauling plug plants within a 50 mile radius of a greenhouse

PROPOSAL - Boxes to suit the racks used In Ontario

The following discussion will describe the prototype transport boxes designed and built by Roland Farms Ltd., Blenheim, Ontario. Racks used by this commercial greenhouse operation are the wooden construction style. Efforts to have a cooperating greenhouse operator using angle iron racks design and build boxes to handle this style of rack proved unsuccessful. Angle iron construction offers a more efficient tiering situation to increase the plant capacity of the box but mention of the style of rack is for identification purposes only and does not represent an endorsement of one version over the other. Design and utilization of specific racks in a greenhouse operation seems primarily a personal reference by each individual grower incorporating them into a system he feels most comfortable with.

BOX DESIGN STRATEGY

1. Assumptions
   Tray size - Blackmore 288 (or equivalent)
   Rack size - present racks were designed to hold 16 trays. The loaded dimension is 88 in (224 cm) by 44 in. (112 cm)

Highway Trailer Size - drop-neck trailer (8-8 1/2' x 48'or 2.4-2.6m x 14.6m) to allow for tiering of 2 boxes and remain within legal height restrictions while maximizing payload

Plant Height - 6 in. (150 mm) from top of tray

2. DIMENSIONS (Figure 14)
   Exterior Overall- TOP: 95 1/2" X 45 1/2" (243cm X 116cm)

   SIDES: 64" x 45 1/2" (163cm x116cm)

   BACK: 95 1/2" X 64" (243cm X163cm)

3. Theoretical Capacity of a Typical truck Load
   Each box holds 1) 6 wooden 2 x 4 racks
   2) 16 trays/rack
   3) 250 plugs/tray (86.8% tray fill)

   = 6 boxes/side x 2 sides
   = 12 boxes x 2 tiers
   = 24 boxes/load @ 24,000 plug plants/box
   = 576,000 plants/shipment

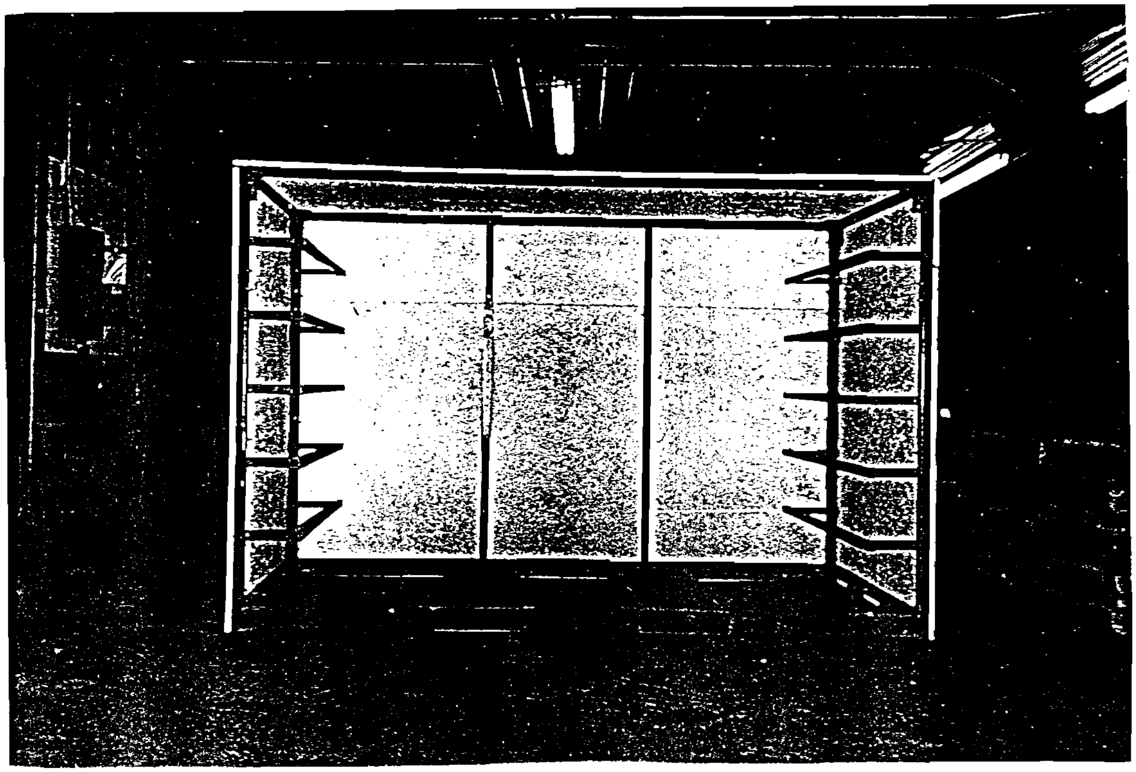

Figure 14. Prototype box designed to hold 6 wooden racks for an approximate capacity of 24,000 plug plants per box.

POSSIBLE PROBLEMS DURING TRANSPORT

1) Racks bouncing and dislodging from support - Be sure that racks are long enough that they cannot fall if they slide to one side.

2) Racks slide out of box while in truck. Be sure boxes are pushed against one another and secured with straps.

3) Racks sliding out of box while on fork-lift. If the fork-lift is sufficiently strong, the operator has to be sure that the boxes are tipped to prevent racks sliding. If the fork-lift is marginal or if being manipulated with a front-end loader without self-leveling devices, sheathing should be strapped to the open side of the box to prevent such accidents.

4) Trays bouncing from racks. The design of the racks should prevent trays bouncing completely out but as a precaution, trays should be watered to their maximum holding capacity to maximize their weight. Driver should be aware that severe bumps can cause problems.

ECONOMIC ASSESSMENT

1. Box costs were based on the prototype costs of manufacture and the following parameters.

2. - Life of transport boxes - 10 years
   - Salvage value - 10%
   - Depreciation - (new value - salvage value)/life
   - Interest - (new value + salvage value)/2 x interest rate
   - Repairs - new value x 1%
   - Insurance and housing - new value x 1%

CONSTRUCTION COSTS:

48 boxes @ 1019.93 per box = $48,956.64

Materials	363.68
Labour	656.25
	1019.93 per box

Cost of the prototype boxes would be reduced proportionately by mass assembly.

Fixed overhead costs:

Depreciation - 4406.10
Interest @ 12% - 3231.14
Repairs - 489.57
Insurance and housing - 489.57
8616.38 (annual costs)

ASSUMPTIONS:

1) 48 boxes will be constructed so that sufficient boxes are available for return trips and re-loading
2) tray fill of trays 250 usable plants/tray (250/288 = 86.8% tray fill)

LABOUR COST COMPARISON FOR LOADING

OHIO BOXES: Loading
9 men x 2.5 hr/man x $6/hr to load 480,000 plants
= $135.00/480,000 plants
= 28.1 cents/1000 plants shipped

PROTOTYPE BOXES: Loading

1.5 minutes/rack x 6 racks/box = 3.6 hours/24 box load
2 men x $6/hr x 3.6 hr/load = $43.20
1 man x $6/hr x 4.0 hr/load = $24.00 (fork-lift operator
$67.20 & securing load)
$67.20/576,000 plants
= 11.7 cents/1000 plants shipped

Cost of handling the trays on racks versus handling the trays individually shows a slight advantage. Market potential and annual usage will be important considerations before construction of these boxes.

ADVANTAGES

1). Trays are not handled individually and therefore better plant quality and tray life should be achieved.
2). Efficient use of greenhouse labour outside of times when local plant orders are being filled.
3). Expanded market potential for greenhouse growers in the future.

DISADVANTAGES

1). Construction cost of boxes.
2). Racks not returned.
3). Trucks returning empty and having to return later for box and rack pick-up.

CONCLUSIONS

The rapid growth of tomato plug plant production in the last three years is providing opportunity for many plant growers. An efficient plant handling has evolved using racks to hold the plant trays.

A transportation system for out of area sales may not be as important at this time until local supply exceeds demand. However, a standardized system developed now will help lead to long-term export possibilities as the move toward plug plants and improved semi-automatic and automatic transplanters continues.

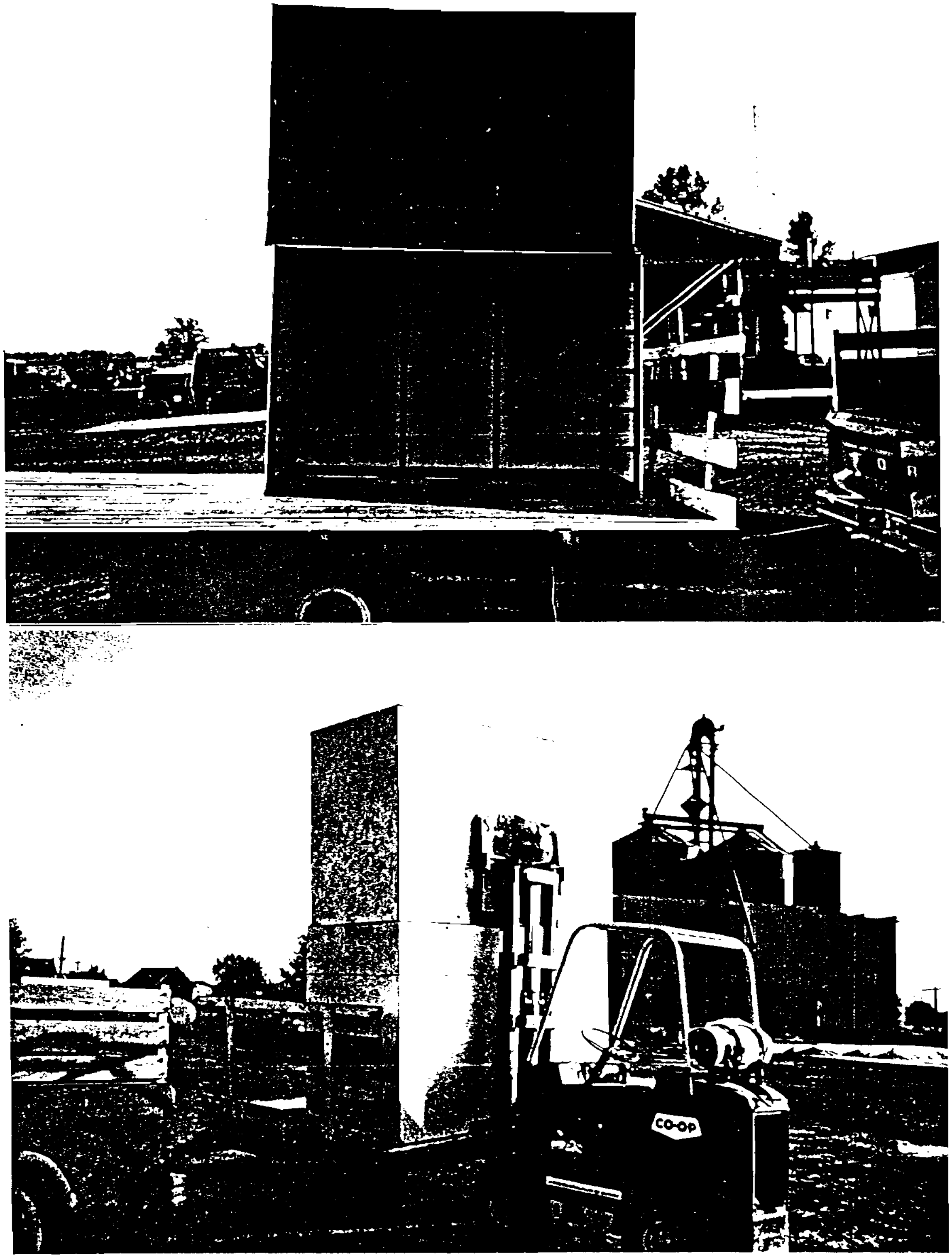

Figure 15. Interior and exterior view of prototype transport boxes stacked on a flat bed trailer.

FEASIBILITY OF PLANTEK TRAYS ON WOOD RACKS USED FOR 288 TRAYS

The greenhouse industry is presently using 2 different styles of racks based on grower preference a) wooden 2x4 racks covered with woven wire fabric and b) angle iron racks 19mmx19mm (3/4"x3/4"). Both styles of racks require different supporting structures above the greenhouse floor, so that unwanted excess root development under trays is controlled by air movement.

With every different tray mold design, there is a compensatory need to change the support structures that the racks rest on. Proper alignment of angle iron racks used for the common 288 may not perform as well with the outer dimensions and cell configuration of the Plantek 256 tray. Therefore the rack system designed by Lannen in their plant growing system should be used.

Large number of seedlings per square metre on foot of greenhouse space is the key to profit. Greenhouse space is expensive to build and maintain. The larger the number of seedlings in a greenhouse the higher the potential profit.

The following is a brief discussion showing why the wooden racks used for setting 288 cell trays on do not work well with the different tray configuration of the Plantek 256 tray. Calculations were made to show the effect of the use of existing racks versus converting to the rack system designed by the Lannen growing system.

Wooden rack dimensions: 88" x 42.5"
(223.5cm x 108.0cm)
Outer tray dimensions of 288: 21.25" x 11"
(54.0cm x27.9cm)

Oter tray dimensions of 256: 15 3/4" x 15 3/4"
Plantek (40cm x40cm)

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16

Existing 16 tray rack: 288- 8 x 11" = 88" length
2 x 21.25"= 42.5" width
16 trays/rack

Plantek 256- 8 x 15.75 = 126" length
2 x 15.75 = 31.5" width
16 trays/rack *

Plantek 256- 5 x 15.75" = 78.75" length
2 x 15.75" = 32.5 width
10 trays/rack *

NOTE: The tray configuration of the Plantek tray does not allow for more than 10 trays being placed on existing wooden racks.

ASSUMPTIONS: 288 cell/tray x 86.8% usability = 250 usable plants/tray

256 cell/tray x 86.8% usability = 222 usable plants/tray

250-222 x 100% = 11.2% less usable 250 plants/tray

16 trays/rack x288 cells x 86.8% usability = 4000 plants/tray

10 trays/rack x 256 cells x 86.8% usability = 2222 plants/tray

$\frac{4000-2222}{4000}$ x 100% = 44.4% less plants/rack

The calculations make it obvious that greenhouse growers contemplating the growing of seedlings in Plantek 256 trays are well advised to adopt the rack system specifically designed for these trays rather than try to make existing racks work.