Changes Needed to Facilitate Automatic Field Transplanting

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Although automatic transplanting of several field-grown vegetables is a reality, some changes in seedling production are necessary if the full potential of automation is to be realized. In automatic transplanting machines (ATMs) that are available, containerized seedlings such as lettuce, cauliflower, and celery are removed from the seedling trays and planted into the ground without human intervention. The advantages of containerized transplants from a crop production perspective are widely recognized. It is time to recognize and emphasize the features of this growing system that aid in the engineering of automatic transplanting systems.

From an engineers perspective, containerized seedlings are in an orderly array, in a configuration that is repeated again and again, unlike bare-root seedlings, which come in random bunches. Each seedling tray can be treated like a gun-cartridge magazine and fed through an ATM, which removes the seedlings and then places them individually into the ground. Alternative arrangements for presenting seedlings to an ATM include connected paper cells (Nippon Beet Sugar Manufacturing Co., 1985), bandoliers (Boa, 1978) strips of seedling cells (Williams, 1986), and cells within trays (Brewer, 1990). Recently, several engineers from around the world used rectangular seedling trays, with some variations, for their ATMs.

Transplanters using trays

In California, Growers Transplants, Inc., has custom-planted >1.5 billion seedlings for 9 years with their fleet of ATMs (Hartshorn, 1990). In their system, the bottom of the seedling trays are removed first and the seedlings are pushed downward through the cell bottoms by plungers. Each ATM plants eight rows at a time and requires two

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to three operators to handle the trays and drive the tractor (Branch, 1986).

The ATMs recently developed for Bud of California use conventional seedling trays of injection-molded plastic (deGroot, 1990). Plungers push seedlings held vertically in trays into top grippers that then carry the seedlings to the ground at a speed of up to four seedlings per second per row.

Lannen (Lawson, 1989), in Finland, used several conventional seedling trays on an ATM that employed a plunger to push each seedling out of vertical trays onto pins that speared the root ball. These pins rotated the seedling to a vertical orientation, and then the seedling was pushed off the pins into a furrow opened in the soil.

In England, the Plantway Transplanter (Cooley, 1991) also handles conventional seedling trays vertically, but the seedlings are blown out the top of individual cells with air jets. Each seedling is directed into an upright orientation while it is falling through a drop tube into a furrow.

Other ATMs are under development, and most of them use some type of seedling tray, but as yet there are no "standard" trays.

Designing a standard tray

Even though seedling trays are probably the most-suitable supply system for new ATMs, lack of tray standardization has complicated the situation. To improve the overall handling of the seedlings from seed to the field, particular engineering design features of the trays need to be emphasized.

Standardization of dimensions. A major problem for ATM design is the myriad of seedling trays used by transplant growers. It is questionable if they are all needed by the industry and, from an engineering perspective, the variety makes ATM design difficult. Tray width and length, at a minimum, should be standardized because this would make the ATMs simpler to design and more economical to manufacture. It is recommended that the cell spacing within seedling trays be some multiple of ANSI standard roller chain, which has pitch increments of 0.125 inches (3.176 mm).

Strength and rigidity. Growing trays need to withstand the wear and tear of repeated handling, resist breakage, and protect the seedlings during transport and loading into ATMs, and fit precisely into the ATMs. Precision-injection-molded plastic trays (Fig. 1) have been selected by several engineers for their ATMs, and this may be the best type of tray for mechanical transplanting.

Configuration. Conventional seedling trays have inverted and truncated conical or pyramid-shaped cells with drainage holes that permit air-pruning of the seedling roots. Cell drainage holes need to be no less than 10 mm in diameter for removal with plungers. With smaller drainage holes, the stiletto-like plunger can impale the roots, but fail to remove any plants.

Fig. 1. Injection-molded plastic trays designed for use on automatic transplanting machines.

It is desirable to remove whole rows of seedlings simultaneously at a moderate speed to maximize an ATM's productivity, rather than removing individual plants at a traumatic rate. Like the original Todd "Speedling" tray (Todd, 1972), the trays need to have cells in a rectangular array and not in offset rows. Seedling removal should be accomplished as simply as possible to reduce the cost of the original machine and to minimize time-consuming adjustments in the field.

Desirable plant characteristics

In automatic transplanting, certain seedling characteristics will determine the success or failure of ATM handling. Most commercial transplant growers need to consider these requirements for automatic transplanting. With some current ATMs, the seedlings are grasped by the stems. If the seedlings are to pass through high-speed ATMs, seedlings need to be uniform, short, and sturdy. Short seedlings reduce the problem of entanglement that can occur when whole rows of plants are removed together.

Cell root volume needs to be large because singulation is easier with short, sturdy seedlings growing in large cells. In addition, some ATMs handle seedlings by their roots and use prongs or needles to penetrate the root mass.

Seedlings transplanted by hand or ATM need to be stress-tolerant. In transplanting with high-speed ATMs, this requirement is especially important for tolerance of transport to the field, the trauma of rapid handling on the machines, and survival after field planting.

Handling empty cells in trays

Some ATMs handle three to four seedlings per second per row unit. It is impractical, therefore, to detect empty seedling cells and compensate for

missing plants during field transplanting. Equipment that detects dead or missing seedlings and fills gaps is too expensive to incorporate into ATMs. At least one ATM was developed that detects missing seedlings, but it is very complicated and has a slow planting rate. Even with this detector, field workers still have to follow the ATM to fill in missed spaces in the field. In England, Plantway (Cooley, 1991) confronted this problem by assigning an operator to monitor the seedlings flowing from conventional trays to transplanter and to compensate manually for missing seedlings.

For efficiency and ease of handling, seedling trays must be full when delivered to the ATMs in the field. Ideally, the trays first must be filled by workers or automated machines before leaving the greenhouse rather than in the field. The trays can be scanned and seedlings replaced at any time in the production stage from plant emergence until departure to the field.

Research and development work still attempts to perfect robotic machines with electronic means for detection of missing seedlings and to fill the voids in trays. Detection accuracies of up to 95% have been reported (Aoyama et al., 1992). This sophisticated equipment can be operated day and night and not just during field operations. This equipment also will function better in greenhouses with solid foundations, which will not be subjected to the shocks and jolts of field machines.

Tray handling systems

ATMs need to handle full trays efficiently as well as empty trays during the field operation. Because fewer field workers will be needed with ATMs, mechanized tray-handling systems are mandatory to avoid delays for reloading in the field.

One labor-saving device used by several growers at present is a rack that holds ≈ 250

growing trays. A forklift can be used to load the seedling trays en masse on the rack for transport from the greenhouse to the field. In the field, a forklift is used to place the racks on the ATM. The use of racks is one way to reduce reloading time and increase field operating efficiency.

Summary

Several automatic transplanting systems are presently in commercial use by vegetable growers, and all of these systems are based on some type of greenhouse seedling tray. Thus, the tray system, which has been adopted widely by commercial transplant growers, can be used from the initial seeding, through the greenhouse growing period, to automatic transplanting in the field.

Some minor design changes and standardization in trays are needed to best use high-speed field transplanters, but the answers to these problems will be forthcoming. Integration of tray handling systems from seeding in the greenhouses to ATM will help growers remain competitive in spite of increased labor costs.

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