W 1235

THE ROLE OF AUTOMATION IN ADDRESSING THE NURSERY INDUSTRY LABOR SHORTAGE

PART II: ADVANCES IN AUTOMATION WITHIN TASK

Karl McKim, Extension Assistant, Department of Plant Sciences, University of Tennessee
Amy Fulcher, Professor, Department of Plant Sciences, University of Tennessee
Alicia Rihn, Assistant Professor, Department of Agricultural and Resource Economics, University of Tennessee
Laura Warner, Associate Professor, Department of Agricultural Education and Communication, University of Florida
Anthony LeBude, Associate Professor, Horticultural Science, N.C. State University
Margarita Velandia, Professor, Department of Agricultural and Resource Economics, University of Tennessee
Natalie Bumgarner, Associate Professor, Department of Plant Sciences, University of Tennessee
Susan Schexnayder, Senior Research Associate, School of Natural Resources, University of Tennessee

"*Advances in Automation within Task*" is part II of an Extension publication series in which we examine the portion of a given task that is mechanized or automated at nurseries in the United States and compare that to previously reported levels. This series was developed as a resource for the nursery industry, Extension agents, and automation manufacturers who serve the green industry to use as they consider options for automation as a means to increase production efficiency and reduce labor needs in the face of an increasingly scarce labor force. Part I of this series, "Current Automation Adoption," describes the use of a range of container- and field-production automation technologies. In "Part III: Outcomes from Adopting Automation and Perceived Helpfulness Analysis," we will examine perceptions held by nursery producers about the helpfulness of specific pieces of automation and outcomes from using automation.

A detailed description of the survey and data collection are described in Part I. In short, the survey was conducted in 2021 and asked individuals in decision-making roles at U.S. nurseries about their use of mechanization and automation technologies in 2020. Completed surveys were returned by 189 nurseries. The average annual sales reported was $10.7 million, and the median reported annual sales was $1.4 million. Results discussed in this publication are for mechanization and automation unrelated to irrigation. Results for irrigation-related mechanization and automation will be reported in a separate publication. In Part II of this publication, we report responses to the following question (Table 1):

*"Please indicate the **percent of each task that is automated** at your nursery on a per year basis. Responses do not need to sum to 100%. If you do not use automation to complete that task, please record 0%."*

% Automated Task	% Automated Task
_____ % Potting into containers	_____ % Pruning/trimming
_____% Planting in the field	_____ % Inventory tracking
_____% Weed control - mechanical removal, chemical control, mulching, etc.	_____ % Labeling
_____% Pest monitoring/control/applications to control insects and diseases	_____ % Mixing and loading container substrate
_____% Employee training	_____ % Irrigation
_____% Harvesting	_____ % Pulling orders
_____% Transporting plant material (e.g., moving and spacing plants)	_____ % Shipping
_____% Fertilizer application	_____ % Other (Please list:_____)

Table 1. *Respondents were asked to indicate the percentage of each task that is automated at their nurseries annually.*

We compare our national survey results for predominately container production nurseries with those from an interview-based survey conducted in the southeastern U.S. over several years (Posadas, 2018). We refer to that regional survey as being administered in 2006 and to mechanized and automated tasks synonymously as "automation" throughout the article for simplicity.

The level of automation of a given nursery task varies by task and type of production system (Table 2). In field production nurseries, **harvesting** was the most automated task at 56% (Figure 1). Harvesting trees by hand requires a great deal of labor, and the resulting balled and burlapped trees can weigh hundreds of pounds. Therefore, while it is not surprising that various elements of this task are automated, there is room for additional automation in this process. Hand-digging many shrub crops, which are smaller and lighter than trees, is still relatively common.

Figure 1. *Mechanically digging field-grown shade trees still requires many workers.*

Nursery task	Average percentage of each task that is automated at field nurseries in 2020	Average percentage of each task that is automated at container nurseries in 2020	Average percentage of each task that is automated at container nurseries in 2006	Difference	% Increase
Harvesting	56	-	-		
Weed control (mechanical removal, herbicide applications, mulching, etc.)	51	35	-		
Fertilizer applications	49	47	16	31	194
Planting into the field	49	-	-		
Monitoring pests, pesticide applications	47	27	25	2	8
Transporting plant material (e.g., moving and spacing plants)	46	39	32	7	22
Shipping	24	23	11	12	109
Pruning	23	25	13	12	92
Inventory tracking	21	27	-		
Labeling	21	20	-		
Employee training	19	17	-		
Pulling orders	13	16	8	8	100
Mixing and loading substrate	-	55	29	26	90
Potting into containers - includes filling containers and placing plant liners	-	47	38	9	24
Moving containers from potting to transport vehicle for movement within the nursery	-	-	15		
Spacing plants	-	-	4		
All tasks	35	33	18	15	83

Table 2. *Percent of task automated at field and container nurseries based on surveys conducted in 2006 and 2020. Percentage increase is red to indicate a low increase in automation, yellow to indicate a modest increase in automation and green to indicate a strong increase in automation.*

Figure 2. *Loading substrate is one of the most automated tasks in container production.*

Figure 3.
Automated potting machines can improve efficiency and consistency when planting liners.

In container-production nurseries, the tasks with the highest levels of automation were related to **mixing substrate and loading substrate** (Figure 2). Collectively these processes were 55% automated in 2020 as compared with 29% for **mixing substrate and filling containers** in the 2006 survey. The next most automated task in container nurseries was **potting into containers** (Figure 3), which increased from 38% automation in 2006 (29% **filling containers** and 9% **placing plant liners into containers**) to 47% automation in 2020. Automated potting has a significant advantage in that it can improve crop uniformity. Both planting depth and centering the liner within the container may be done more consistently and accurately when using a potting machine. Additionally, a potting machine will generally put the same volume of substrate in each container of a given size, leading to more uniform substrate bulk density. Because bulk density impacts how much water a container holds and how quickly it drains, filling containers to the same bulk density can dramatically affect crop growth, uniformity, and irrigation needs.

Transporting plants was 46% automated in field production nurseries in 2020. In 2006, **moving containers from potting to vehicles** for transport within nurseries was 15% automated and **transporting containers** was 32% automated. **Automation for moving and spacing plants** increased to 39% in the 2020 survey. **Spacing plants** was just 4% automated in 2006 and was grouped with moving plants in the 2020 survey. Because plant handling and transport are repetitive, labor-intensive processes, this increase in automation is not surprising. Wagons filled with liners for transporting are pulled by tractors but are loaded and unloaded by hand. Articulating ball-handling equipment can increase the number of automated plant-handling tasks (Figure 4). The portable conveyor is one technology being used more frequently in container production than in field production. Used at 40% of container production nurseries but just 1% of field nurseries in 2020, these conveyors allow workers to load and unload plants with greater efficiency. It is possible that the use of portable conveyors in field production nurseries may soon increase as more success stories (like those described in the success stories) are shared. Automating these types of tasks can reduce labor costs and improve worker morale and retention as workers can be reassigned to more engaging, less monotonous tasks.

Weed management, including weed removal and herbicide applications, and applying weed barriers such as mulch, was the second-most automated task at field nurseries in 2020 (51%) but ranked fifth among automated tasks at container nurseries (35%). Plants and rows are more widely spaced in field production nurseries, which allows for the use of all-terrain vehicles (ATVs) and tractors and may account for the different levels of adoption between field and container production nurseries. Tractor and ATV access facilitates the use of cultivators, manure spreaders, weeding robots such as the Robocrop in-row weeder (Garford Farm Machinery LTD., Deeping St James, Peterborough, UK), and other devices like the Enviromist (Micron Group, Bromyard, Herefordshire, England) post-emergence herbicide applicator. In contrast, during container production, employees often walk between tight rows of plants and apply herbicides by hand.

Figure 4. *Mechanization can improve efficiency and reduce the opportunity for worker injury.*

Another difference in automation levels between field and container nurseries can be seen in **monitoring for pests and making pesticide applications**. These tasks were collectively 47% automated at field production nurseries in 2020 but only 27% at nurseries focusing on container production, representing an increase of just 2 percentage points from 25% in 2006. This level of automation in field production likely reflects the use of air-blast sprayers, other tractor PTO-operated sprayers, and sprayers attached to ATVs, with the labor required to mix chemicals, fill tanks and operate equipment accounting for much of the pesticide application-related manual activity. In Part I, we discussed sprayers equipped with the Smart Apply Intelligent Spray Control System (SmartApply Inc., Indianapolis, IN), as well as SmartSpray (Durand Wayland, LaGrange, GA), which are commercially available but have only been adopted by 3% of nurseries. A new sprayer, GUSS (Global Unmanned Spray System), and Herbicide GUSS offer a driverless sprayer that can be paired with the Smart Apply system to simultaneously reduce both the amount of pesticide and labor requirements when applying pesticides.

At the time of the 2020 survey, there were little to no automated pest scouting systems for nursery crops available on the commercial market. Growers are utilizing camera and drone-based systems to monitor pests and to apply pesticides to target plants. While currently for greenhouse production, 'hunting' drones, which are in development in Europe and are capable of eliminating pests by contacting them with their propellors, may also soon be commercially available in the US. Advances in technologies involving image recognition and machine learning are also being utilized in the development of pest-scouting systems. One such system, which automates the detection of fire blight, has already been developed.

Planting and fertilizer application were each 49% automated in field nurseries in 2020. Planting a crop in the field is an example of a task that is accomplished by laborers working in conjunction with automation, in this case, a large, mechanical planter. The planter creates a furrow for planting crops, but workers must cut bundles of bare-root liners and prune their roots or remove liners from their pots prior to planting. Additional workers are required to transport prepped liners to planting sites, hand the liners to workers on the setter, straighten liners, and then firm the soil around them. The setter is pulled behind a tractor, which requires an additional person to operate it. Planting can be accomplished faster, and the task is made less physically demanding using automation, but still requires many hands. This dependency on manual labor is not unique to planting. While the portion of fertilizer application that is automated at container nurseries has increased since 2006 from 16% to 47%, applicators that broadcast or deposit fertilizer to container crops are largely operated and refilled manually. It is still common to make fertilizer applications on a per-plant basis with a spoon or a cup, which is an entirely manual process. The 31 percentage point increase in the automation of fertilizer application between 2006 and 2020, may be partially linked to the adoption of potting machines that incorporate fertilizer. **Pruning** is automated at similar levels at both field (23%) and container (25%) nurseries. The portion of pruning that is automated in container nurseries has nearly doubled since 2006, increasing from just 13% to 25%. Crews of several workers prune blocks of shrubs at most nurseries, and for some species, this must be done multiple times per season. Automating this process could provide an opportunity to reduce the number of workers required for pruning and reallocate this labor to other tasks that are not as easily or affordably automated. In listening sessions, growers suggested that automating the pruning process would improve efficiency by increasing the speed at which they pruned, improve crop uniformity, and help create a more predictable crop schedule. Consequently, this would allow growers to stagger crops to promote growth or flowering during specific marketing windows. Automated pruning systems exist and have been implemented in some nurseries in the form of motorized, gantry-style mechanized pruners, but are relatively expensive at a base price of $40,000. These systems require both a driver to operate the machine and a worker who walks behind with shears, removing any branches that were missed by the pruner.

There are low levels of automation for **employee training, labelling, pulling orders, and inventory tracking** at both field production and container production nurseries. These tasks are each 21% or less automated at field nurseries and 27% or less automated at container nurseries. Online programs exist for training employees and include various pesticide certification training programs as well as programs such as The University of Tennessee original and Advanced Tennessee Master Nursery Producer programs (www.tnmasternursery.com). Automating the labelling process could allow workers assigned to this low-skill, highly repetitive task to focus on other tasks that increase the value of crops, potentially increasing worker retention. Inventory management is a time-consuming task and requires years of experience to correctly identify plants and assess them for overall health and potential for future growth. Inventory assessments require repeated counts as plants are sold or have changes in their health or size. Some container producers have recently been experimenting with systems to help automate their inventory process. The ScoreBoard System (Agronomix, Oberlin, OH) detects and accounts for individual plants as they are potted. This technology could be adapted for use in field production to include GPS location of crops (Figure 5). SmartApply (Indianapolis, IN) currently offers an inventory system that detects individual plants in the field using a laser detection system mounted on an ATV or tractor. Arbré Technologies (Wauwatosa, WI) developed a similar system using radio frequency identification (RFID) tags placed on individual plants or production blocks and handheld RFID readers. Some judgment-based tasks, however, may be more difficult to automate. Pulling orders, for example, requires the ability to identify a plant, assess its quality, determine its size, and tag and load the plant. As of 2020, this process is only 13% automated at field production nurseries and 16% automated at container production nurseries.

Laborers in nurseries ensure the health and quality of plants. They are needed to perform tasks that are too

difficult or expensive to automate or those that require significant amounts of subjective judgment. Each year, there are new advances in technology and new automated products available to increase production efficiency, product quality, and worker satisfaction and to reduce physical strain and injury risks for employees. In spite of these advancements, the overall percentage of automation for all production tasks is relatively low in both field (35%) and container (33%) nurseries. We know from analyses of these survey data that cost, both for purchase and installation, is the leading barrier to adoption of nursery-related automation. This possibly explains why relatively expensive automation, such as spray application technology, has not been more widely adopted in spite of independently determined efficacy and favorable payback periods. And yet there are many exceptions, which is expected based on adoption literature that explains adoption is highly behavior- and audience-specific. For example, potting machines and even conveyors are expensive, yet adoption rates are relatively high or are strongly trending upward, while very inexpensive forms of automation such as fertilizer dispensers have not been widely adopted. Additionally, factors other than cost influence adoption of nursery automation. Some of these factors include the perceived complexity and relative advantage compared to the current method or technology, as well as compatibility with the existing nursery infrastructure and values. Perhaps the relative advantage of some automation, such as fertilizer dispensers, is not evident. As an industry we often operate on an "if it isn't broke don't fix it mentality." However, nursery producers may want to examine the **opportunity cost** of labor associated with using traditional, labor-reliant practices and consider how adopting mechanization and automation may help better allocate scarce labor resources while improving production efficiency, increasing crop uniformity, optimizing windows of good weather, and reducing worker exposure to agrochemicals. As Cherrylake Tree Farm's motto goes, "If it isn't broke, break it and make it better!"

Success Stories

Conveyors...Not Just for Container Nurseries

An Ohio, US, nursery producing bare-root nursery crops is using telescoping conveyors (MaxxReach®, FMH Conveyors, Jonesboro, AR) to improve loading efficiency at their docks. Use of these conveyors **eliminates the repetitive task of walking armloads of liners to the front of shipping containers**. The use of portable racks has improved labor efficiency when moving groups of small container crops, and it is possible that the use of telescoping conveyors and similar technologies could dramatically improve loading efficiency of field-grown crops in much the same manner.

Figure 5. *Inventory systems that work in conjunction with potting machines can aid nurseries in not only counting plants but also giving workers a visual reference of their progress toward daily potting goals.*

Root and Shoot Pruning Advances Save Labor, Money, and Reduce Injury Hazards

An Oklahoma, US, nursery that replaced hand pruning with a custom root pruning machine was able to reduce the number of employees required for pruning bare root liners from roughly 27 to three. At Hale and Hines Nursery in McMinnville, TN, a single employee with a **gantry-style pruning machine is now able to prune as many plants as four workers**. After adopting this gantry-style pruner, pruning expense was reduced by approximately $0.10/plant. This pruner had a pay-back-period of only two years based on its use on just one of the two crops it is used to prune at this nursery. These pruning machines demonstrate the effectiveness of automation and mechanization in addressing the nursery labor shortage. In both cases, nurseries were able to **re-allocate workers to other, non-automated tasks**, and fill the current void left by labor shortages. At Cherrylake Tree Farm in Groveland, FL, nursery workers are using battery-operated pruners (Figure 6) with a protective glove to simultaneously eliminate hand and wrist strain while also protecting workers from cutting their hands. Workers reported that they **could prune faster and make cleaner, more controlled cuts** with the electric pruners. Similar pruners include Infaco Electrocoup Battery Pruner F3015, Bahco Electronic Pruner BCL22, and Zenport EP2. The Infaco wired model costs approximately $1,300 and requires charging the batteries and sharpening the blades approximately every three days.

Planting Mechanization Has Multiple Advantages… but Still Relies on Workers

Some growers are opting to buy larger planters to increase efficiency when planting liners. However, in order to prepare and plant 2, 3 or 4-fold more liners at one time using a multi-seat planter, additional workers are required. Therefore, increased efficiency, defined here as the ability to plant a given number of plants in less time, is still reliant on manual labor and importantly, more labor available at the same time. While not entirely decoupled from manual labor, a multi-person planter increases capacity and efficiency with an additional advantage besides just purely planting faster – the ability to plant a large number of liners quickly is particularly helpful when the window for working ground and planting a crop is short.

Figure 6. *Battery-powered pruners allow workers to prune faster and prevent hand fatigue.*

Opportunity Cost

Opportunity cost is the cost of making one choice over another. For example, a producer may continue to hand operate irrigation valves instead of adopting an automated irrigation system that would reduce a worker's time on this task by 5 hours per week. The opportunity cost is the loss of potential gain from using this worker in another way. In this example it is other tasks that worker could have accomplished in those 5 hours every week.

Acknowledgments
The authors thank Cherrylake Nursery, Cottage Gardens, Hale and Hines Nursery, and Turner and Sons Nursery for graciously sharing their experiences for the betterment of the nursery industry and gratefully acknowledge financial support from USDA SCRI Award 2024-51181-43291.

Additional Resources and References

Fulcher A, Rihn A, Warner L, LeBude AV, Schexnayder S, Altland J, Bumgarner N, Marble SC, Nackley L, Palma M, Velandia M, Zhu H, Gan H, Owen JS. 2023. Overcoming the nursery industry labor shortage: A survey of strategies to adapt to a reduced workforce and automation and mechanization technology adoption levels. HortScience. 58(12):1513-1525. https://doi.org/10.21273/hortsci17230-23.

Malewar A. 2023. Eradicating greenhouse pests with bat-inspired flying drones. https://www.inceptivemind.com/eradicating-greenhouse-pests-bat-inspired-flying-drones/

McClellan M. 2017. Improve inventory management with RFID. https://www.nurserymag.com/news/hibernia-nursery-rfid-arbre/

McClellan M. 2018. Ahead of the curve. https://www.nurserymag.com/article/willowbend-nurseries-automation/.

McClellan M. 2018. Don't wait, automate. https://www.nurserymag.com/article/five-tips-automation/

McClellan M. 2022. Race to the future. https://www.nurserymag.com/article/brian-decker-hila/.

Rihn A, Velandia M, Warner LA, Fulcher A, Schexnayder S, and LeBude A. 2022. Factors correlated with the propensity to use automation and mechanization by the US nursery industry. Agribusiness. 2022:1-21. https://doi.org/10.1002/agr.21763.

Warner LA, Rihn AL, Fulcher A, Schexnayder S, LeBude AV. 2022. Relating grower perceptions and adoption of automated nursery technologies to address labor needs. J Agric Educ. 63(2):150-168. https://doi.org/10.5032/jae.2022.02150.

UTIA.TENNESSEE.EDU

Real. Life. Solutions.™

W 1235 10/24 25-0301 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.