

THE ROLE OF AUTOMATION IN ADDRESSING THE NURSERY INDUSTRY LABOR SHORTAGE

PART I: CURRENT AUTOMATION ADOPTION

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In the US, specialty crops firms' labor represents 39 percent of total cash expenses, more than 2.5 times greater than dairy, the next most labor-intensive farming venture. Among specialty crops, nursery crops production is one of the most labor-intensive. Some of the labor-intensive nursery tasks include planting, pruning, fertilizing, staking and moving plants (**Fig. 1**). This reliance on manual labor makes the nursery industry vulnerable to labor scarcity.



Fig. 1. Staking young liners is very labor intensive.

The domestic and foreign labor supply is increasingly insufficient for today's nursery labor demands, and there is no indication it will improve. In recent years, more than 75 percent of surveyed nurseries indicated that their greatest challenge was labor (McClellan, 2018b). Jobs in other industries including food service, construction and retail offer alternative employment options frequently with higher hourly wages; benefits; more stable, year-round employment; or more comfortable working conditions. Across the US, nursery producers are exploring automation and related technologies to address labor concerns. This interest, coupled with record levels of pandemic-fueled sales that generated significant capital at nurseries (McClellan,

2021), suggests automation of production tasks may be a critical strategy for the nursery industry's future in a labor-scarce environment.

A three-part Extension publication series was developed to aid members of the Tennessee nursery industry and the automation manufacturers who serve the green industry as they navigate automation options, and automation trends, perceived benefits and outcomes of automation, with the goal of helping to prepare nurseries for an increasingly labor-scarce future. In "Part I: Current Automation Adoption," use of a range of container- and field-production automation is described. In "Part II: Advances in Automation within Task," we evaluate the portion of a given task that is automated and compare that to automation levels in previous years. In "Part III: Outcomes from Adopting Automation and Perceived Helpfulness Analysis," we examine nursery producer perceptions of helpfulness associated with specific pieces of automation and outcomes from using automation.

The data presented in this Extension publication series are from the Labor, Efficiency, Automation, Production (LEAP) Nursery Labor and Automation Survey, which was administered to US nurseries in 2021 and asked about practices used in 2020. The survey was sent to 1,225 individuals at a manager or higher position. In the survey, certain technologies were only available to respondents representing specific nursery production systems. For example, questions related to drip irrigation were only an option for field and mixed (field and container) nurseries. The number of total nurseries responding to the survey was 189. The average annual sales reported was \$10.7 million, and the median reported annual sales was \$1.4 million. The sample was biased toward the South, with 42 percent of respondents representing the southeastern US. The sample was also weighted toward container production with slightly more than half indicating they were solely container producers (51 percent). Respondents averaged nearly 25

years in a decision-making role. We compare these national survey results with results from a survey conducted in the southeastern US over a period of several years (Posadas, 2018). For simplicity, however, we refer to that survey as occurring in 2006.

Descriptive statistics were used to achieve the objectives of this study and included means and standard deviations. Mean separation was conducted at a significance level of $\alpha = 0.05$.

Nurseries are adopting automation to help with a range of container and field production tasks (**Table 1, page 3**). Current automation was highest for using trucks or tractors with wagons (73.0 percent), permanent rigid irrigation such as metal or PVC (60.3 percent), and timer-based irrigation controllers (56.6 percent). Granular fertilizer applicators, potting machines, liquid fertilizer applicators, forklifts and tree spades were used by roughly 40-50 percent of survey respondents. Mechanical liner setter/planter, polyethylene irrigation tubing, tying machines, substrate mixers, conveyor belts, B&B tree handler, foliage trimmer/pruner, root pruner and drip irrigation are in use at approximately 28-35 percent of responding nurseries. Less than 20 percent of nurseries responding to the survey are using hose and gun or center pivot irrigation; irrigation scheduling technology other than a timer, for example leaching fraction or moisture probes; mechanical bundler (post-harvest); lifter or shaker; pneumatic c-ring fastener; Horticultural Trike; mechanical stake installer; robotic plant spacers; or laser-guided spray technology.

The type of production system impacted whether or not certain automated nursery technologies were currently adopted, sometimes as a function of the production method itself (Table 1). Certain technologies were not available to respondents in accordance with the type of production system (i.e., container grown, field grown, mixed system container and field), and therefore, all possible comparisons were not made. For example, hose and gun irrigation was not a response option for container only nurseries. More mixed nurseries adopted rigid irrigation (57.7 percent) and timer-based irrigation controllers (57.7 percent) than field nurseries (34.0 percent and 31.9 percent, respectively). More container nurseries (56.7 percent) and mixed nurseries (48.1 percent) adopted liquid fertilizer injectors than field nurseries (23.4 percent). Flexible polyethylene tubing (54.4 percent) is used by more container nurseries than mixed operations (3.8 percent). Survey results suggest responding field nurseries (10.6 percent) currently use fewer conveyors than either container (40.0 percent) or mixed nurseries (42.3 percent). Predominately field nurseries (25.5 percent) use lifter/shakers more than mixed operations (1.9 percent).

Overcoming the Hassle Factor

Decker's Nursery recently adopted Horticultural Trikes (pot forks) and encourages their fellow producers to have an open mind about making changes that allow for adopting new automation. It is not always simple or easy, but it can be worth the extra effort. Decker's first experimented with pot forks and found they would need to start using a new type of container with a stronger lip to support the weight of the container when it was suspended by the forks. Next, they developed an insert for their wagons to hold plants in rows that maintained space for the forks to slide through and pick them up. They replaced all solid set irrigation on the nursery floor with a flexible tubing that can be driven over without causing damage. Finally, they found that to obtain the maximum utility of Trike automation, they needed to widen doors to production houses. After adopting Horticultural Trikes, **Decker's Nursery went from four employees to unload plants from wagons and place them in production beds to less than one full-time person.** How did they do it? One way that Decker's Nursery creates the capacity to make big changes is by allocating some profit to support a project manager who oversees new initiatives. In doing so, they have made investing in the nursery's future a priority. You can hear firsthand from growers who are reaping the benefits of adopting Horticultural Trikes and other automation at the LEAP Virtual Nursery Automation Tour: <https://youtu.be/zzgYq9vNBsk>.

Between the 2006 nursery survey (Posadas, 2018) and the current survey, some types of automation have been adopted more quickly than others. The current survey found that conveyors (**Fig. 2**), although a newer technology for the green industry, were as widely adopted (33.3 percent) as other pieces of automation that have been available for



Fig. 2. Portable conveyors have been rapidly adopted by US nurseries.

Table 1. Nursery use of automation and mechanization as determined in a survey of decision-makers representing the US nursery industry conducted in 2021 asking about practices used in 2020.

Technology	Total sample	Container-grown (\approx 76% in container)	Field-grown (\approx 76% in field)	Mixed Operations (mix of production methods)	Container-field	Container-Mixed	Field-Mixed
	Mean (%)				Significance ²		
Tractor/truck/wagon	73.0	76.7	66.0	73.1	NS	NS	NS
Permanent, rigid irrigation	60.3	75.6	34.0	57.7	*	NS	*
Time-based irrigation controller	56.6	68.9	31.9	57.7	*	NS	*
Granular fertilizer applicator	51.3	51.1	44.7	57.7	NS	NS	NS
Potting machine	47.2	47.8	---	46.2	---	NS	---
Liquid fertilizer injector	46.0	56.7	23.4	48.1	*	NS	*
Forklift	43.9	38.9	48.9	48.1	NS	NS	NS
Tree spade	41.4	---	51.1	32.7	---	---	NS
Mechanical liner setter/planter	36.4	---	38.3	34.6	---	---	NS
Flexible, polyethylene tubing-based irrigation	35.9	54.4	---	3.8	---	*	---
Tying machine (during production)	35.4	44.4	27.7	26.9	NS	NS	NS
Substrate mixer	35.2	34.4	---	36.5	---	NS	---
Conveyor belts	33.3	40.0	10.6	42.3	*	NS	*
B&B tree handler	33.3	---	42.6	25.0	---	---	NS
Foliage trimmer/pruner	29.6	37.8	19.1	25.0	NS	NS	NS
Root pruner	29.6	---	23.4	23.1	---	NS	---
Drip irrigation	28.3	---	36.2	21.2	---	---	NS
Hose & gun or center pivot irrigation	19.2	---	21.3	17.3	---	---	NS
Irrigation scheduling technology	15.9	16.7	10.6	19.2	NS	NS	NS
Mechanical bundler (post-harvest)	13.1	---	14.9	11.5	---	---	NS
Lifter or shaker	13.1	---	25.5	1.9	---	---	*
Pneumatic c-ring fastener	10.1	---	10.6	9.6	---	---	NS
Trike	9.0	14.4	---	7.7	---	NS	---
Mechanical stake installer	5.1	---	4.3	5.8	---	---	NS
Robotic plant spacers	4.2	04.4	---	3.8	---	NS	---
Laser guided pesticide sprayer	3.0	---	2.1	3.8	---	---	NS
No. of Obs.	189	90	47	52			

¹Significance was tested using ANOVA and Tukey's honest significance test at a significance level of 0.05. A production method combination with an * in the corresponding cell indicates the automation use was different for the two production types being compared; NS in the corresponding cell indicates there was not a significant difference between the two production methods; --- in the corresponding cell indicates the comparison was not made because the automation was not applicable to one or both production methods.

a long time for field and container production, such as B&B tree handlers (33.3 percent) and substrate mixers (35.2 percent). In the 2006 nursery survey, just 2-9 percent of nurseries used conveyors for moving plants, with the exact percentage varying by the specific plant handling task (Coker et al., 2010, 2015). Analysis of the 2020 survey data revealed that perceptions of relative advantage, complexity and compatibility were the strongest predictors of future adoption of automated nursery technologies (Warner et al., 2022). Relative advantage refers to how improved a new technology is compared to the current practice it may replace. Complexity refers to how difficult it is to use, and compatibility refers to how easily it can fit within the current nursery values, infrastructure or systems. Conveyors appear to rate highly on all of these measures. Conveyors are easy to use and to integrate within a nursery and they are a notable improvement over the traditional practice of an employee carrying a plant or two at a time or pushing a small cart of plants.

Several other factors may influence which automation is readily adopted. Some forms of automation, such as tractors, trucks and wagons, have multiple uses, whereas some of the lesser-adopted automation is very specialized. Robotic plant spacers, mechanical stake drivers and pneumatic C-ring fasteners, while all helpful in reducing manual labor, each accomplish only one specific nursery task. Other types of automation have a large capital expense that may be cost prohibitive for smaller nurseries and those with smaller profit margins. In the 2020 survey, nursery producers responded that purchase cost was the highest-ranking barrier to adopting automation (Rihn et al., 2022). In addition, some automation is not standalone but rather necessitates more involved planning, additional space allocation or other changes that increase the overall complication and cost to adopt. As an example, investing in a potting machine (Fig. 3) includes a capital expense of at least \$60,000, as well as a structure such as a barn,



Fig. 3. Adopting a potting machine includes related investments such as a structure to house it and one or more hoppers.

Automation Side Benefits

In 2020, the LEAP Team held national listening sessions with nursery leaders from across the US. Many growers on the calls had taken the plunge and invested in automation. Other than labor savings, what were some of the most common benefits they listed? Product consistency, predictability of task completion and timeliness of tasks leading to more uniform crops. By better controlling when crops are pruned, the production manager can better control when they will be in flower or achieve market size. By investing in potting technology, large crops, such as contract crops that need to finish at the same time, will be potted in a smaller window and finish together. One nursery was able to take an order due in eight weeks because it could pot 19,000 plants in three days, whereas by hand, it would have taken them three weeks. One of the take-home messages from the listening sessions was that nursery producers who invested in automation did not just achieve labor savings, they gained better control of their production schedules and gained new sales opportunities.

three-phase electricity, and/or a generator. It may also require additional hoppers; a dedicated front-end loader; lines feeding inputs to the machine; and more conveyors, tractors, tracking trailers and drivers to achieve maximum efficiency. On the other hand, affordable automation that seems to have an obvious relative advantage, low complexity and reasonable compatibility within nursery systems does not always saturate the industry in terms of adoption. Irrigation was applied using automated timers by 25.8 percent of nurseries in 2006 and by 56.6 percent in 2020 (Coker et al., 2010) (Fig. 4). While approximately doubling in this timeframe, overall adoption remains modest, considering the low-cost and seeming alignment with other predictors.



Fig. 4. Irrigation controllers are affordable, low-tech options for reducing manual labor.

While cost is a known barrier to adoption, there are programs that make automation and other capital improvements more affordable. Tennessee nursery producers have a unique opportunity to invest in automation through a partnership between the Tennessee Department of Agriculture's (TDA) Tennessee Agriculture Enhancement Program www.tn.gov/agriculture/farms/taep.html and the University of Tennessee's Tennessee Master Nursery Producer (TMNP) Program tnmasternursery.com. Following TDA acceptance of their application, growers can fulfill their eligibility for enhanced levels of cost share, currently at 50 percent with a current TMNP certification, versus just 35 percent cost share without the TMNP certification. Some of the technology that growers can apply for include automated irrigation controllers, sprayers and potting line equipment.

Nursery production has traditionally been heavily dependent on domestic and foreign workers for the many manual tasks that must take place during production. As the labor supply continues to dwindle, nurseries must operate with an increasingly insufficient workforce. Nursery operators may need to consider labor-saving options, such as automation, to sustain their businesses in the future. Here, we present current use of automation and explain some of the factors that impact nurseries' adoption of automation. This information can help those in decision-making roles at nurseries understand where their operation fits in the adoption curve and where there are opportunities to adopt, and how to recognize known barriers, so that they can begin to address those barriers and position their business for the future. Automation manufacturers can also utilize this information as they develop new technology so that it is more readily adopted by the nursery industry.

How One Tennessee Nursery's Investment Paid Off

At Turner and Sons Nursery, a bareroot and container operation, labor is at a premium and recently, labor costs nearly doubled. That caused John, Terri, and sons Lee-Allen and John Adam, to start thinking about more efficient ways to complete tasks. They recently acquired four tying machines at a cost of \$7,300 each that bundle trees approximately four times as fast as their workers could by hand. The tying machines allowed them to reallocate two to three workers from their limited workforce to grading or harvesting trees. While expensive, the tying machines have helped Turner and Sons Nursery extend their limited workforce and complete tasks on time.

Automation Success Story

A field nursery used a Robocrop in-row weeder to reduce their number of employees by 63 percent, and consequently reduced their annual labor expenses by approximately \$350,000 (McClellan, 2018a). As a result, as their labor becomes even less available, they will be able to allocate their limited workforce to other tasks without compromising weed control.

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