Title: Labor, Efficiency, Automation, and Production: LEAP Nursery Crops Toward Sustainability

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Collaborating/Partnering States

TN

Collaborating/Partnering Countries

{NO DATA ENTERED}

Collaborating/Partnering Organizations

The University of Tennessee

Non-Technical Summary

LEAP received USDA-SCRI planning grant 2020-51181-32137 and found that labor availability is the most critical sustainability challenge facing nursery crops producers, a labor-intensive industry that includes potting, pruning, staking, scouting, weeding, taking inventory, harvesting, and loading orders. Nursery crop production relies heavily on full-time workers augmented by seasonal employees. Scarce availability among both is limiting producers from facilitating rural prosperity and economic development. Despite the acknowledged advantages of automating repetitive tasks, overall adoption of innovations in nurseries is low due to few mechanisms designed specifically for nursery crops, and no reliable, consistent decision-making aids to determine economic feasibility. LEAP's long-term economic benefit is a sustainable US nursery industry that is more resilient to labor shortages and that drives economic growth of rural communities. LEAP's trans-disciplinary team will 1) Develop new automation and evaluate existing automated nursery technologies that improve labor efficiency; 2) Evaluate socioeconomic impacts of automation and develop decision-making tools to inform adoption strategies that optimize the limited available labor; 3) Develop a route to accelerate automation adoption for growers by mapping diffusion of current innovations through their information-sharing networks; 4) Assess consumer preference and willingness to pay for impacts to economic, environmental, or worker health benefits by augmenting tasks with automation; and 5) Educate stakeholders with LEAP resources to increase awareness and accelerate adoption of automated nursery technologies. LEAP's outcomes will strengthen private land stewardship and rural economies by accelerating automation adoption, improving worker experiences, attracting available labor, and creating higher skilled positions thereby maximizing sustainbaility of US nurseries.

Goals / Objectives

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Our goal is to develop new automation and through better understanding of diffusion of innovation stimulate adoption of existing technologies to study their effects on the remaining system components, including consumer preference at the retail level and the effect of labor retention and re-allocation as a buffer against ongoing labor scarcity. The teams created for this project will work collaboratively with the advisory board, stakeholders, producers, county and regional Extension staff, and allied industries to accelerate the diffusion and impact of automation adoption through nurseries and their workers to illustrate technology's inherent effect on output, labor efficiency and productivity, revenue, rural economics, and nursery sustainability.

Methods

Obj 1.1a ANDREW Autonomous Nursery Driving Robot for Eliminating Weeds. Evaluation: Build three prototypes in Y 1-3. Prototypes will be tested by LEAP and collaborators and at ETREC for payload. Tests will evaluate autonomy accuracy of navigation on multiple surfaces and precision spraying functions. After testing and AB feedback, we will pursue commercialization through technology transfer to Moss Robotics, Inc.
Obj 1.1b PIPER a Pot-in-Pot (PNP) Extraction Robot. During Y 1-3, we will test PIPER's hardware in field conditions at ETREC and optimize the mobile platform using Farm-ng's Amiga. In Y 3-5, PIPER will incorporate the vision system for object I.D. and localization. Evaluation: PIPER will be tested in nurseries by randomly selecting rows and trees. The Phase-II design output is a prototype robotic platform that can navigate within row, I.D. and localize a target plant pot nested within a socket pot for harvest.
Obj 1.1c TALI a terrestrial automatic laser-based inventory system. Evaluation: Accuracy of TALI will be validated with artificial objects and live trees at various travel speeds under both laboratory and field conditions. Field experiments every 2 weeks beginning in dormancy on 3 one-acre blocks, with or without bamboo and fiberglass stakes on 8 nurseries will test the standard nursery practice of manually counting and measuring height, canopy dimensions, and caliper.
Obj 1.1d A-IPM Artificial Intelligence Pest Monitoring system for early detection of Japanese maple scale. Evaluation: The presence/absence success rate of the scouts and A-IPM will be compared using a generalized linear model fitted to a binomial distribution. Over on-farm tests with producers and commercialization collaborators (e.g., Moss.ai, Farm.ng, Clearpath Robotics™) we will identify a threshold for successful diagnosis of JMS infestation at different distances and densities of infestation.
Obj 1.2.1&2&3 Evaluate existing herbicide, fertilizer, and irrigation ANTs. Application technologies will be tested at 6-8 nurseries across FL, NC, TN and OR.
Obj 2.1&2 Socioeconomics (SE) Increase the adoption of automation and technology (ANT) through the development of SE information and tools to help firms make informed decisions. Partial budget and scenario analysis valuation data will be collected from 21 nursery firms in key production areas using case studies, and evaluated and validated by a firm panel approach and personal interviews with stakeholders and Extension agents. Workers from 4 nursery operations with different levels of ANT will be surveyed to assess: 1) worker job satisfaction; 2) beliefs/experiences related to the replacement of tasks by ANTs' 3) beliefs/experiences related to changes in worker efficiency and productivity-related to ANT adoption; 4) beliefs/experience related to changes in worker health associated with ANT adoption; and 5) impacts of ANTs on family life and overall well-being. Changes in the number of workers employed on the farm over time, changes specifically related to the adoption of ANT systems and changes in worker availability will be collected. Eight semi-structured interviews (2 interviews x 4 operations, with workers at different managerial levels). Using qualitative analysis, we will assess the trade-off between changes in the number of workers employed and changes in workers' perceptions related to job satisfaction, wellness, and productivity. Interviews and discussions will be analyzed with NVivo qualitative analysis software.
Obj 3A&B Behavioral Adoption (BA) Develop routes to ANT adoption for firms and map growers' information-sharing networks that accelerate adoption. Use qualitative focus groups and quantitative survey methods, purposive sampling to recruit innovative individuals and use individual interviews to quantitatively capture perceptions associated with adoption of ANTs including relative advantage, compatibility, complexity, trialability, and observability, motivators and outcomes, barriers, and other social factors, including normative influences drawn from specific referent groups. Use social network analysis (SNA) to visually map a social system using UCINET to generate a matrix representing the flow of information about ANTs. Qualitative data will be analyzed using the constant comparative method to identify themes pertaining to adoption, multivariate analyses to identify which variables predict respondents' adoption or nonadoption of specific ANTs.
Obj 4.1&2&3 Consumer Preference (CP) Assess consumer knowledge and preference for potential impacts of ANTs in nurseries. An online discrete choice experiment (DCE) will elicit preference and willingness to pay (WTP) estimates from 4800 people. DCE results will be analyzed using mixed logit models to determine how the attributes influence consumers' probability of choice and how perceptions impact their plant selections. Eye-tracking experiments will assess how ANT and employee well-being related information at the point-of-sale influences consumer purchasing behavior and WTP for nursery plants. Two national surveys will be guided by Grunig's Situational Theory of Publics to identify audience segmentations based off issue involvement and ANT knowledge. The Elaboration Likelihood Model of Persuasion will framework the second survey to identify how messaging influences consumers' attitudes and purchasing intent of plants produced with ANTs.
Obj 5 Extension, Outreach and Science Communication (EX) Analysis of Results: Outreach activities and products are

coordinated and evaluated by LEAP's Extension Management team and collaborators every four months, then presented to the AB at annual meetings. Descriptive statistics, e.g., downloads, site visits, will be recorded for print resources, videos, project websites, decision-aid tools, and publications. Where thorough data is collected (i.e., seminars, webinars, LLC, tours) a standardized evaluation tool developed by CI Warner will evaluate adoption through the Transtheoretical Model of Change as a non-linear series of stages in contrast to an all-or-nothing approach.
5.1 Increase awareness and educate stakeholders about new ANTs to improve labor efficiency. LEAP will organize 10 field days and 6 to 8 tours over five years at multiple US locations and Europe to showcase ANTs in operation. CI Altland will organize an AI and Automation in Nursery Crops conference. Ivers will produce 60 minutes of video.
5.2 Develop digital and printed resource materials and case studies to inform grower decisions about ANT adoption. Resource materials, in-person illustrated presentations, hands-on trainings, and decision-aid tools will be developed in English and Spanish. The 21 case studies will use print and video to illustrate the adoption process and effect on management and employee engagement and wellbeing for nurseries of several sizes and segments.
5.3 Create the LEAP Learning Center (LLC). NC State CALS Online Academy will host the learning center and bestow a completion certificate credential to producers, extension agents, and students.
5.4 Design, develop, and curate LEAP websites. https://www.nurseryleap.com/ will host outputs and a second website will educate consumers about impacts of ANTs on production practices, environmental stewardship, labor efficiency, employee well-being, plant quality.
5.5 Create a social network for growers willing to share information and mentor other growers. Producers will mentor other growers considering ANT adoption and have completed the LLC.

Target Audience

The primary target audience for LEAP-developed automation and economic tools is nursery owners and employees. Secondary audiences include the allied businesses that provide automation and technology (ANT) and production inputs; Extension staff, scientists, educators, students; garden center staff and consumers including Master Gardeners. Producers are likely to first contact other well-respected producers, therefore, several innovative nationally known producers will serve on the Advisory Board (AB), host research, and collaborate on LEAP Research and Extension Management Teams. Our Behavioral Adoption Team will map this social network to highlight key brokers of information and accelerate future adoption. LEAP will organize national workshops for automation in horticulture, field days, and symposia. Our entire digital footprint containing all publications, inventions, photos, videos and other training resources, decision-aid tools, and case studies will be stored at nurseryleap.com. The LEAP Learning Center, hosted by NC State's Online Academy, will support a certificate program based on learning modules that pair production practices with ANTs and economic decision-aid tools to generate individualized strategies for adoption. Upon completion, producers can enter the LEAP-supported producer-to-producer ANT mentoring program. AB members, and other stakeholders serving on our management teams or hosting research are leaders and drive acceptance of new practices. They will meet frequently with us to guide our efforts and put our early findings into practice. Other LEAP collaborators are either nursery or ANT staff who will rely on our collective deliverables to educate their customers and overcome barriers to accelerate adoption, thus multiplying our impacts beyond the project timeline. LEAP is catalyzing efforts of stakeholders, allied firms, and influential producers to collaborate and collectively remain sustainable in the future.

LEAP will develop automation trialed at innovator and early adopter nurseries in TN, OH, FL, NC, and OR to highlight socioeconomic benefits and model compatibility, trialability, and use of the social network inherent within these production areas to accelerate adoption. Collaborating commercializing companies and automation distributors will help market LEAP outputs to other producers nationwide. LEAP will develop tailored science communication deployed through a nationwide social network of trade show education, automation field tours in Europe and the US, video content on NurseryLEAP.com, trade journal articles (e.g., Nursery Management), and both LEAP and Extension agent social media. LEAP will make 5000 US producers and 300 Extension agents aware of diverse ANTs available for integration into production. We will accomplish this by presentation, webinar, trade show education and use of a multiplier effect for each producer contacted and their number of employees. Our approach to science communication extends beyond the deficit-model approach of assuming knowledge alone will increase acceptance. Instead, we will take into consideration individuals' psychographic characteristics, like values, attitudes, and cognition, along with past experiences, cultural and social contexts, and media use, to develop tailored science communication that will resonate with target audiences. LEAP will use Institutional Review Board Approval (IRB) to maintain contact with producers over the lifetime of the project to track changes in adoption rates, attitudes, and sharing of information. Additionally, 10,000 consumers will engage resources on the National Initiative for Consumer Horticulture (https://consumerhort.org/) and the Extension Master Gardener National Committee (App. D) to become aware of ANTs and their socioeconomic benefits. Target audiences will engage LEAP developed, grower validated socioeconomic tools through nurseryleap.com and the LLC education modules to determine the impact of ANT adoption on current and future labor efficiency, revenue, and employee satisfaction. We are expecting perhaps 20 total growers over the course of 5 years to complete both the LLC and enter the mentoring

program. Adoption of ANT is a complicated timely process, so LEAP is proposing to accelerate this process by creation of an unbiased, dynamic decision-aid portfolio based on labor, technology, efficiency, economics, and marketing to determine its real effect on nursery production systems, labor efficiencies, and sustainability.

Products

1) ANDREW Autonomous Nursery Driving Robot to Eliminate Weeds applies herbicide in rows of pot-in-pot container plant systems
2) PIPER, a pot in pot extraction robot that can navigate within row, identify and localize a target plant nested within a socket pot and harvest that pot
3) TALI, a terrestrial autonomous laser-based inventory management system capable of counting and grading shade trees based on caliper and canopy metrics available for commercialization
4) A-IPM, an artificial intelligence pest monitoring image-based system that identifies armored scale pests on select nursery crops
5) Nine Interactive decision-aid tools for a suite of select automation and technologies
6) Survey instruments to determine effect of adoption on employee health and well-being
7) A route to adoption for different sized operations (acres and revenue) and segments (field vs. container) of the nursery industry
8) A social network analysis of innovation diffusion among producers
9) Improved consumer awareness of automation in nursery production
10) Consumer willingness to pay for employee benefits obtained from automation adoption
11) Two interactive websites
12) The LEAP Learning Center (LLC) and completion certificate hosted by the CALS Online Academy
13) New scientists and students interested in automation and nursery production
14) Webinars, illustrated presentations, in-service trainings for Extension Agents
15) A grower-to-grower mentoring program
16) Automation field days and nursery tours both in the US and Europe
17) Automation and AI in Nursery Production Conference
18) Twenty-one in-depth case studies of nurseries that have adopted automation
19) Sixty minutes of professionally edited video about automation
20) Curation of several social media platforms.
21) Publish five peer-reviewed Extension publications
22) Publish 10 refereed journal manuscripts
23) Publish 15 trade journal articles (national or state commodity),
24) Publish 25 extension publications,
25) Present 30+ presentations,
26) Produce 60 minutes of professionally produced video,
27) Design and develop 9 economic decision-aid tools.

Expected Outcomes

Increase the knowledge, abilities, skills, attitude, opportunity, and intent for socioeconomic benefits of automation and technology for
5000 producers
300 Extension agents
10,000 consumers

Train 100 stakeholders either online or in person to use decision-aid tools to create nursery specific adoption strategies

Producers will complete multi-module online grower education certification courses

Producer will create adoption strategies for LEAP invented and existing automation and technologies

Producers will learn about production optimization, collateral benefits, and labor efficiency practices to increase sustainability

Future and early career scientists are trained about economic viability of automation adoption

Six graduate students lead inventions, project direction, stakeholder interaction, survey development, data analysis, field day

organization, and publishing

Publish 20 trade journal articles

Producers will improve task reliability, use less labor, focus more on value added tasks and marketing, and increase efficiency and revenue by using ANDREW to keep pot-in-pot rows weed free, PIPER to identify the correct plant and extract it, TALI to collect and manage inventory, and A-IPM to detect scale insects on shade trees and reduce pest infestations.

Producers apply decision-aid tools to accelerate diffusion of existing innovations

Producers use a LEAP developed evaluation tool to measure employee health benefits from automation

Visually mapped social networks of information shared about innovations are used to target late adopters (the little guy) with LEAP outputs

Extension professionals and researchers use nursery-specific tools and education resources to train future agents, students, and producers
Nursery operations improve sustainability by adopting automation that improves existing labor efficiency and labor productivity, reduces reliance on scarce labor, and returns their investment as planned to tolerate market stress and extreme weather events

Worker safety, wellness, productivity, knowledge, and engagement increase at automated nurseries

Consumers will pay for employee health improvements from automaton in product price creation

Create more high-skilled positions to offer higher pay to more local labor sources

Producers who have adopted innovations mentor other producers, which accelerates adoption nationwide

Automation reaches critical mass of adoption among early and late majority adopters

Reduced use of water, pesticides, and herbicides with less production runoff

Commercial companies adapt LEAP developed automation for use in other crop commodities

Stakeholders can communicate both the production and employee health benefits of ANT more efficiently to consumers and generate added value, thus factoring in overall benefits of ANT and increased potential revenue when making decisions about ANT adoption.

Keywords
robotics feasibility laser invention nursery crops employee health wellness engagement producer

Estimated Project FTEs For The Project Duration

Role	Non-Students or Faculty	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	0.0	0.0	0.0	0.0	0.0
Professional	0.0	0.0	0.0	0.0	0.0
Technical	0.0	0.0	0.0	0.0	0.0
Administrative	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	0.0	0.0
Computed Total	0.0	0.0	0.0	0.0	0.0

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Animal Health Component 0 %

Activities		**Research Effort Categories**	
Research	50 %	**Basic**	50 %
Extension	45 %	**Applied**	30 %
Education	5 %	**Developmental**	20 %

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
111	2110	1060	10
402	2110	2020	40
601	2110	3010	20
211	2110	1060	10
204	2110	1060	10
803	2110	1060	10

Knowledge Area

111 - Conservation and Efficient Use of Water; 204 - Plant Product Quality and Utility (Preharvest); 211 - Insects, Mites, and Other Arthropods Affecting Plants; 402 - Engineering Systems and Equipment; 601 - Economics of Agricultural Production and Farm Management; 803 - Sociological and Technological Change Affecting Individuals, Families, and Communities

Subject Of Investigation

2110 - Ornamental trees and shrubs

Field Of Science

1060 - Biology (whole systems); 2020 - Engineering; 3010 - Economics