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United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1018055

Project Title

Improving production and profitability of nursery production using unmanned aircraft system

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** COMPLETE
Funding Source NIFA Non Formula	**Grant Year** 2019
Grant No. 2019-38821-29062	**Cumulative Award Amt.** $599,925.00
Proposal No. 2018-04961	**Multistate No.** (N/A)
Project Start Date Jan 01, 2019	**Project End Date** Dec 31, 2023
Program Code [EQ] Research Project	

Project Director

Baysal-Gurel, F.

Recipient Organization

TENNESSEE STATE UNIVERSITY
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Performing Department

College of Agriculture

Non Technical Summary

This is a standardintegrated (research and extension)project for the 1890 CBG Program. A major concern of nursery producers is timely and effective management ofdiseases and abiotic stresses. Another concern is the availability and escalating costs of labor.The goal of this project is todesign, optimize and implement an unmanned aircraft system (UAS) that can operate in nursery systems to improvethe production and profitability of nursery crops by 1) early detection of foliar diseases and abiotic stresses, and 2) reduce the cost of labor for determination of individual tree criteria for sale. The specific objectives of this proposal are: 1) design/build an UAS to operate within a nursery production environment, 2) evaluate the UASfor early detection and identification of foliar diseases, determination of abiotic stress factors, and plant growth measurements, 3)assess the economic impact of these technologies on nursery production costs and profitability,and 4)technology and information transfer to practitioners.This projectwill result in an UAS to improve nursery production,with the capability to move above the plant canopy, between rows of

plants, and hover directly beside a plant to collectfoliar disease, abiotic stressand plant measurement datawithin a nursery production environment. Practitioners and students will have access to hands-on experience as well as knowledge of UAS uses for nursery production. The utilization of the UAS and information delivery through Extension products will increase the likelihood of adoption by nursery producers and service providers by providing opportunities for small business.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	20%
Applied	50%
Developmental	30%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
205	2110	1020	20%
402	2110	2020	30%
216	2110	1160	40%
601	2110	3010	10%

Knowledge Area

[205] Plant Management Systems

[402] Engineering Systems and Equipment

[216] Integrated Pest Management Systems

[601] Economics of Agricultural Production and Farm Management

Subject Of Investigation

[2110] Ornamental trees and shrubs

Field Of Science

[1020] Physiology

[2020] Engineering

[1160] Pathology

[3010] Economics

Keywords

Extension, nursery production, plant disease, sustainable agriculture, unmanned aircraft system

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Goals / Objectives

Nursery crops are produced with an annual sale value of $5.1 billion in the United States.Nursery crops in Tennessee account for asignificant amount of agricultural production with annual sales of $132 million (USDA, 2014). Nursery producers are vulnerable to losses due to plant diseases and, in 2013;these losses were estimated to be approximately 15% of the farm gate value for field and container nursery production (Williams-Woodward, 2013). Although fungicides/bactericides are available for nursery production, they are most effective in reducing disease severity/incidence when applied during the early stage of disease development. Traditionally, nursery producers follow a calendar-based program for making fungicide/bactericide applications or conduct visual inspections for deciding when to start fungicide/bactericide applications. Nursery plants vary widely in size and leaf architecture, and different diseases cause different types of symptoms, therefore only specially trained personnel are able to perform accurate disease scouting.Plant growth measurements of nursery crops (such as height, width, stem diameter, etc.) dictate when a plant is at a marketable stage. These measurements must also be performed manually by nursery personnel. This dependence on physical labor is a critical weakness for the nursery industry for two primary reasons: 1) labor is costly, cutting into industry profits and increasing prices for customers; 2) the agricultural labor supply is diminishing due to potential immigration reforms and demographic changes in Mexico (Charlton and Taylor, 2016). Thus, developing unmanned aerial systems (UAS) applications for early detection and identification of diseases and abiotic stresses and quality measurements will help ensuresustainability for the nursery industry. Since fungicides /bactericides are expensive and there is high risk of fungicide/bactericide resistance development with calendar-based pesticide applications due to over-use, this new tool will help to reduce the risk of resistance development and the overall costs of pesticide applications. These tools will also help us to determine spatial distribution of foliar diseases and how this distribution affects crop growth and quality.Large- and medium-scale nursery producers have consulted with us on the need to develop and validate effective alternative tools such as UAS for early detection and identification of foliar diseases and abiotic stresses and for quality measurements strategies. Several nursery producers, theTennessee State University OtisL.Floyd Nursery Research Center(TSUNRC) advisory board, the Tennessee Department of Agriculture (TDA) plant pathologist, and TDA plant inspectors have participated in the development of this integrated (research and Extension) proposal by telephone, e-mail and group discussion at the TSUNRC. Stakeholder support for the proposed work is further indicated by the attached Letters of Support.The long-term goal of this proposed integrated project is todesign, optimize and implement an UAS that can operate in woody ornamental nursery systems to improvethe production and profitability of nursery crops by 1) early detection and identification of foliar diseases and abiotic stresses, and 2) reduce the cost of labor for determination of individual tree criteria for sale such as plant size and quality.The specific objectives of this proposal are: 1) design/build an UAS to operate within a nursery production environment, 2) evaluate the UASfor early detection and identification of foliar diseases, determination of abiotic stress factors (water, nutrients, etc.), and plant growth measurements (height, width, stem diameter, etc.), 3)assess the economic impact of these technologies on nursery production costs and profitability, and 4)technology and information transfer to practitioners[nursery producers, industry professionals and service providers (possible new small business opportunities)].?

Project Methods

Objective 1. Design/build an UAS to operate within a nursery production environmentNursery crops are produced with a high density of plants within a relatively small area.An UAS will be designed with the capability to move above the plant canopy, between rows of plants, around individual plants, and hover directly beside a plant to collectfoliar disease, abiotic stress and plant measurement data. The UAS will be equipped with combination of cameras, other sensors (thermal, multispectral, hyperspectral and/or time-of-flight) and a data mining station. ADJI Phantom 4 Professional+ Quadcopter will be used for the unmanned aerial vehicle (UAV) part of this UAS. The UAS will be composed of a UAV, which is equipped with GPRS signal receiver,Inertial Measurement Unit (IMU),a gripper, a robotic manipulator, a depth camera system, sensors and a laptop with a database for recording the data and data mining. The gripper will be customized and attached to a robotic arm manipulator on the UAV to collect leaf samples inside the branches. To determine the shape and sizes of the trees, a depth camera system-a stereo camera system

and time-of-flight sensors, will be used to generate a 3D mesh model of the trees separately as the UAV flies around these trees and uploads data to the station. The GPRS system will be used to localize the UAV and the trees. These components will be evaluated to minimize the weight of the UAV and to maximize data collection accuracy for the UAS.Objective 2.Evaluate the UASfor early detection and identification of foliar diseases, determination of abiotic stress factors, and plant growth measurements2.1. Early detection and identification of foliar diseasesIn Years 1 and 2, a UAS equipped with a depth camera, time-of-flight sensor, GPRS, IMU as well as other sensor such asthermal, multispectral or hyperspectralwill be evaluated for its effectiveness in detecting foliar diseases compared with visual scouting techniques.Model nursery crops will be flowering dogwood plants produced indifferent nursery production platforms (field, pot-in-pot, and containeron gravel and black fabric ground cover).The experimental design will be arandomized complete block designwith a minimum of 25 plants per setting.An UAS will be used daily to determine natural occurrence of dogwood powdery mildew and anthracnose symptoms during the early production season and sampling will be done using a gripper built on the UAS. Disease severity and progress (AUDPC)will be monitored to determine the sensitivity of the UAS camera and sensors. The visual scouting will be examined by a trained personnel /researcher using a0-100% scale for foliage area affected. Collected samples from plots will be examined for identification bya trained personnelin the plant pathology laboratory.Labor and time spent assessing disease severity and positive confirmation timing will be recorded for comparison.In Year 3, several other studies will be conducted withsame environment and experimental design as described before to determine the accuracy and consistency of the UAS for early detection of foliar diseases on other woody ornamental plants with various color and shape of leaves and making comparisons with visually evaluated plants.2.2. Determination of abiotic stressesNursery crops require adequate water and nutrients for healthy growth, yet symptoms for drought or nutrient stress may not be visible until after the stress has significantly progressed. Corrective actions can be taken, but it may take weeks or months for the crop to recover, if at all. Sensors are available that can detect drought stress and leaf greenness in plants prior to when more obvious visible symptoms of stress occur. An UAS equipped with these sensors would be a valuable tool for detecting signs of drought and nutrient stress in a timely manner so that producers could take corrective actions. Several studies will be conducted to evaluate UAS-mounted sensors for detecting drought stress at various stages using different irrigation regimes with two levels of water deficit compared with visual ratings collected by researchers in Years 1 and 2. Plants will be evaluated at different levels of water stress to compare the sensitivity of the UAS with the visual ratings. In a separate study, UAS sensors will be evaluated for ability to detect changes in leaf greenness based on different nutrient deficiencies and compared with visual ratings and readings from a handheld leaf greenness meter. Plants will be grown with three different levels of nitrogen, phosphorus and potassium to produce plants with varying levels of chlorosis for use to compare the accuracy of detection between the UAS and manual readings. The model nursery crop for these studies will be dogwood plant produced withsame environment. The experimental design will be asplit plotwith a minimum of 25 plants per setting on a randomized complete block design, control plants will be well-watered and fertilized. In Year 3, several other studies will be conducted to determine the accuracy and consistency of the UAS for determination of abiotic stresses on other plants with various color and shape of leaves and making comparisons with visually evaluated plants.2.3. Plant growth measurementNursery producers must manually measure each plant to grade the plant size and quality for sale. An UAS fitted with sensors to take plant measurements would allow producers to automate this process and allocate labor to other tasks. An UAS equipped with a camera and/ortime-of-flight sensor will be evaluated for measuring plant height, width, and stem diameter in Years 1, 2 and 3. The studies will be conducted on plants with different morphological characteristics to determine the accuracy and consistency of the measurements determined by the UAS and making comparisons with manually measured plants.Objective 3.Assess the economic impact of these technologies on nursery production costs and profitabilityThe use of an UAS in nursery production systems will allow nursery producers to automate certain tasks such as scouting for disease and abiotic stress issues and measuring/monitoring crop growth. Although a technically trained person will be required to operate the UAS and manage the data, producers may be able to operate with fewer employees overall. In Years 2 and 3, we will conduct several studies to compare the time required to conduct manual scouting/measuring with how much time is saved by utilizing the UAS.Objective 4.Technology and information transfer to practitionersOnce the UAS has been developed and optimized for use in nursery production systems, we will conduct workshops for practitioners detailing the advantages of using UAS, rules and regulations of

using UAS, and research updates in Years 2 and 3 at the TSUNRC. We will also conduct training sessions /demonstration field days for practitioners to teach how to operate the UAS, how to download and interpret the data and how to develop business plan in Years 2 and 3 at the TSUNRC auditorium and demonstration plots. Questionnaires will be presented to participants following each activity session to identify the impact of the activity and suggestions for changes which will be used to revise activity for the next session. Three months after each activity, a general assessment will be delivered to participants to determine their decision-making in adoption of an UAS on their farms or creating a small business.Our outreach efforts will also include dissemination of information to the nursery industry through local crop management and nursery conferences as well as national conferences, meetings, written materials, video clips, social media.