United States Department of Agriculture
Project Initiation

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Project Title

Exploring The Feasibility Of End Of Production Regimens To Improve Leafy Green Nutritional Content, Appearance, And Post-Harvest Longevity

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** ACTIVE
Funding Source NIFA Non Formula	**Grant Year** 2023
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Project Director

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Performing Department

Plant Science

Non Technical Summary

The major barrier to controlled environment agriculture (CEA) production is economic feasibility due to high capital and operating costs. While CEA technology provides producers the ability to precisely control the environment, the "optimal" production conditions to maximize yield, quality, and energy efficiency are largely unknown for most crops. Thus, there is a critical need to identify cost-effective strategies such as end-of-production (EOP) regimens to improve the yield, appearance, nutritional content, and post-harvest longevity of leafy greens species and cultivars; therefore, this critical need is the overall goal of our project.To achieve this goal, we propose improving the critical production stage, EOP, by investigating how multiple management components of CEA hydroponic production systems can be integrated to improve leafy green quality and productivity; an investigation of how cropping system intensification will affect plant health and system resilience, a goal of the "Foundational Knowledge of Agricultural Production Systems"

program.The objectives of this project are to identify EOP 1) lighting, 2) nutrient solution temperature, and 3) mineral nutrient limitation or elevation strategies that effectively improve yield, appearance, nutritional content, and post-harvest longevity, and 4) evaluate the economic feasibility of EOP regimes. Our fifth objective is to provide a comprehensive virtual training resource encompassing the basic, intermediate, and advanced knowledge of hydroponic CEA leafy green production.Upon completion of this project, we will have identified effective EOP strategies to effectively improve leafy green yield and quality while also creating resources for producers to effectively apply recommendations.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	0%
Applied	100%
Developmental	0%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
601	1430	3010	20%
205	1430	1060	25%
204	1430	1060	25%
701	1430	1060	30%

Knowledge Area

[601] Economics of Agricultural Production and Farm Management

[205] Plant Management Systems

[204] Plant Product Quality and Utility (Preharvest)

[701] Nutrient Composition of Food

Subject Of Investigation

[1430] Greens and leafy vegetables (includes endive, lettuce, spinach, turnip-greens, celery,rhubarb, parsley, asparagus)

Field Of Science

[3010] Economics

[1060] Biology (whole systems)

Keywords

Controlled Environment Agriculture, Economic Feasibility, Greenhouse, Phytonutrients, Dynamic Systems

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Goals / Objectives

The overall goal of this project is to identify and evaluate the economic feasibility of EOP regimens to improve the yield, nutritional content, appearance, and post-harvest longevity of leafy greens grown in controlled environments.To meet our overall goal, we propose investigating three main EOP strategies: (1) lighting, (2) nutrient solution temperature, and (3) nutrient solution composition. Our overall goal is to identify strategies to improve the yield, nutritional content, appearance, and post-harvest longevity of leafy greens grown in controlled environments by investigating different aspects of the production system and (4) to improve economic feasibility. To meet this goal and to (5) aid in producer implementation, we propose five Specific Aims:Specific Aim 1: Identify EOP lighting strategies to improve leafy greens yield, appearance, nutritional content, and post-harvest longevity. Our working hypothesis is that increasing the light intensity at the EOP will increase crop quality, but the effect will depend on the light intensity, duration, species, and cultivar.Specific Aim 2: Determine the extent EOP nutrient solution temperature changes can be leveraged to improve leafy greens yield, appearance, nutritional content, and post-harvest longevity. We postulate that leafy greens finished under reduced nutrient solution temperatures for a short duration will contain higher phytonutrient concentrations compared to crops subjected to warmer nutrient solutions.Specific Aim 3: Determine if nutrient changes at the EOP are effective in improving leafy greens yield, appearance, nutritional content, and post-harvest longevity. Our working hypothesis is that removing or increasing the concentration of nutrients that play specific roles in plant quality at the EOP will improve crop quality at harvest.Specific Aim 4: Evaluate the economic feasibility of the EOP regimes investigated in Aims 1 to 3. We hypothesize the economic feasibility of EOP regimes would vary depending on changes in costs, potential changes in revenue associated with changes in yield, crop quality, and the potential price premiums associated with changes in crop quality.Specific Aim 5: Provide a comprehensive training platform and resource center encompassing the basic, intermediate, and advanced knowledge of hydroponic CEA leafy greens production. Our hypothesis is that while some producers will be readily able to apply the effective strategies determined in Aims 1, 2, 3, and 4, others may need more basic and intermediate training.

Project Methods

Specific Aim 1:1.1: ProductionFive leafy greens species, arugula, kale, lettuce, mizuna, and spinach were selected based on growth, nutritional content, and CEA producer usage. Two cultivars of lettuce and kale and one cultivar of arugula, mizuna, and spinach will be selected. Seedlings will be grown using standard practices and finish-stage plants will be grown in DWC hydroponic systems in a glass-glazed greenhouse. At 1, 3, and 7 days before harvestable maturity, plants will be transferred to EOP lighting treatments consisting of background solar radiation providing 10 mol·m-2·d-1 with additional 0 (control), 100, 200, 400, or 600 µmol·m-2·s-1 of white light or 100 µmol·m-2·s-1 of red and blue light.At harvest, the growth (height, width, leaf number, fresh mass, and dry mass) of at least 10 plants of each taxa per treatment per replication will be measured to characterize economically important changes in plant morphology and yield. Images and/or colorimeter measurements will be taken to quantify plant coloration. Plant subsamples will be dried in a forced-air drying oven and stored at room temperature or frozen and stored at -80 °C. Post-harvestAdditional plants from each treatment for at least 5 taxa will be placed in a walk-in cooler and stored for up to 21 days. Overall visual quality will be assessed every two days and plants will be weighed to determine shelf-life. Storage will be terminated early if quality is below the consumer acceptance limit. Plant subsamples will be frozen and stored at -80 °C. The experiment will be completed three times over time.1.2: Nutritional analyses. Mineral NutrientsForced-air dried tissue will be prepared and analyzed by a commercial testing lab for macro- and micro-nutrient concentrations.PhytonutrientsFrozen tissue will be freeze-dried for analyses. Both air- and freeze-dried tissue will be weighed, and dry mass will be recorded. Phytonutrient analyses were prioritized based on crop popularity and stakeholder discussions. Carotenoids, glucosinolates, and water-soluble vitamins (C and Bs) will be quantified with high performance liquid chromatography (HPLC) with an evaporative light scattering, photodiode array, or refractive index detector and methods. Total anthocyanins and/or phenolics will be quantified using a spectrophotometer. Specific Aim 2:2.1: ProductionIn a glass-glazed greenhouse, the five leafy greens species will be grown as described in Task 1.1 in a DWC hydroponic system. Seven days before harvestable maturity, plants will be transferred to

separate DWC systems with nutrient solution temperatures of 0, 5, 10, 15, or 20 °C. At harvest, physical data will be quantified as described in Task 1.1. Plant subsamples will be dried in a forced-air drying oven and stored at room temperature. Additional tissue will be frozen and shipped to UT for phytonutrient analyses.Post-harvestEvaluations will be similar to Task 1.1.2.2: Nutritional AnalysesMineral NutrientsEvaluations will be similar to Task 1.2. PhytonutrientsPhytonutrients of 3 treatments will be quantified as described in Task 1.2.Specific Aim 3:3.1: ProductionIn a glass-glazed greenhouse, the five leafy green species will be grown in a DWC hydroponic system as described in Task 1.1. Seven days before harvestable maturity, plants will be transferred to separate DWC systems containing the nutrient solution treatments. Each system will be filled with a modified Hoagland's all-nitrate solution formulated with lab-grade elemental salts providing either 1) complete nutrition (control), 2) nitrogen, 3) phosphorus, or 4) potassium exclusion or limitation, or 5) sulfur elevation. Plants will be monitored daily to document and photograph sequential series of symptoms on young, recently matured, and maturing leaves. At harvest, physical characteristics (see Task 1.1) of at least 10 plants of each taxa per treatment per replication will be measured and observable nutrient deficiencies or toxicities will be documented to characterize economically important changes in plant morphology and yield. Images and/or colorimeter measurements will be taken to quantify plant coloration, an important characteristic contributing to plant appearance. Plant subsamples will be dried in a forced-air drying oven. Additional tissue will be frozen and shipped to UT for phytonutrient analyses as described in Task 1.1.Post-harvestEvaluations will be similar to Task 1.1.3.2: Nutritional AnalysesMineral NutrientsEvaluations will be similar to Task 1.2.PhytonutrientsEvaluations will be similar to Task 1.2.Specific Aim 4:4.1: Capital Budgeting Valuation and Scenario AnalysisPartial and total capital budgeting valuation and scenario analysis will be conducted for the five leafy greens evaluated to assess the profitability and economic risk of the EOP regimes identified as most effective in enhancing leafy greens' appearance, phytonutrients, and post-harvest longevity. A partial budget analysis will evaluate the changes in profitability across EOP regimes compared to baseline scenarios identified in Aims 1 to 3 as controls. This analysis evaluates marginal changes in costs and revenue associated with the adoption of a specific production practice. We will use sensitivity analysis to evaluate risk; that is, the volatility of profits associated with potential changes in the most sensitive input costs. We will conduct a total capital budgeting valuation and scenario analysis and build discounted cash flow models to evaluate the profitability and risk of EOP regimes. Net Present Value, Modified Internal Rate of Return, and payback period will be estimated, providing profitability measures in terms of dollars, rates of return, and years to recover the investment. Alternative scenarios to the baseline, constructed with specific parameters will be evaluated. The degree of sensitivity to the risk of each variable will be evaluated to determine how influential each variable is on profitability. We will use a focus group approach to validate the enterprise baseline budgets with CEA operations and experts.4.2: Consumer Preferences and Willingness-to-payA conjoint analysis based on a consumer online national survey will be used to identify consumers' responses to and willingness-to-pay (WTP) for leafy greens' attributes resulting from the implementation of EOP regimes evaluated in Aims 1 to 3. Participants will view images of the real products displaying predetermined attribute levels, logos, price information, and other relevant production related information. They will receive information treatments with content relative to the production practices in Aims 1 to 3 to identify if methods influence purchasing behavior. The WTP estimates will be incorporated in the economic analysis proposed in Task 4.1 to assess the economic feasibility of adopting various EOP regimes.Specific Aim 5:5.1: Basic Training ResourcesA website will be developed for this project to not only serve as an information center to host and disseminate resources generated in Aims 1 to 4, but to also access the hydroponic production training modules. The first training module will focus on basic hydroponic production and economics knowledge, targeting people interested in hydroponic production with no background.5.2: Intermediate Training ResourcesThe second training module will focus on intermediate training resources and will target stakeholders who have either completed the basic training module or have some hydroponic background or experience.5.3: Advanced Training ResourcesThe third training module will focus on advanced training resources and will target stakeholders who have either completed the intermediate training module or have extensive hydroponic production experience. The main goal of this module is to train producers in the latest research and guidelines, like those produced in Aims 1 to 4.