IUNU

STATE OF CEA

2023

Controlled Environment Agriculture

Industry Report

A deep dive into the emerging trends, challenges, and benefits of CEA.

Contents

Introduction 3

Industry Landscape 4

- Expansion 4
- Economic Outlook 6
- Acquisitions 9

Labor Spotlight 10

- Scouting 10
- Inventory Management 12

Technology 14

- Data Ownership 14

Automating Comprehensive Data Collection 16

- Autonomous Growing 18

The Future 19

About the Authors

Founded in 2013 and headquartered in Seattle, IUNU is closing the loop in greenhouse autonomy. We believe quality data and software leveraged by great growers enables businesses to grow profitably.

For questions or comments, please reach out to:
Marketing@IUNU.com | www.IUNU.com

Partners

UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources

Introduction

The purpose of this report is to look at the emerging trends, challenges, and benefits of controlled environment agriculture (CEA). IUNU has been producing the State of Industry reports since 2016 (formerly the Artemis State of Indoor Farming reports).

To conduct this report, we surveyed leading greenhouse growers in North America. This year, growers who operate more than 50 million square feet of greenhouse area participated. The resulting report is both quantitative - based on data provided by survey participants - and qualitative, as it's based on growers' opinions and perceptions. Data from the survey was supplemented by additional research conducted by our team.

This year, we segmented responses by the major reporting crop categories: leafy greens, tomatoes, and ornamentals.

Industry Landscape

2023 is proving to be a better year than 2022 for most operations. The majority of producers are seeing increases in sales this year. For leafy greens producers, 80% expect a better year this year based on current performance. For tomato and ornamental producers, it's been a stable year, with 57% of tomato producers and 50% of ornamental producers performing better than 2022 so far. For ornamental producers, 2023 has been a bit more of a mixed bag. While half of producers are seeing better years, half are seeing worse.

Expansion

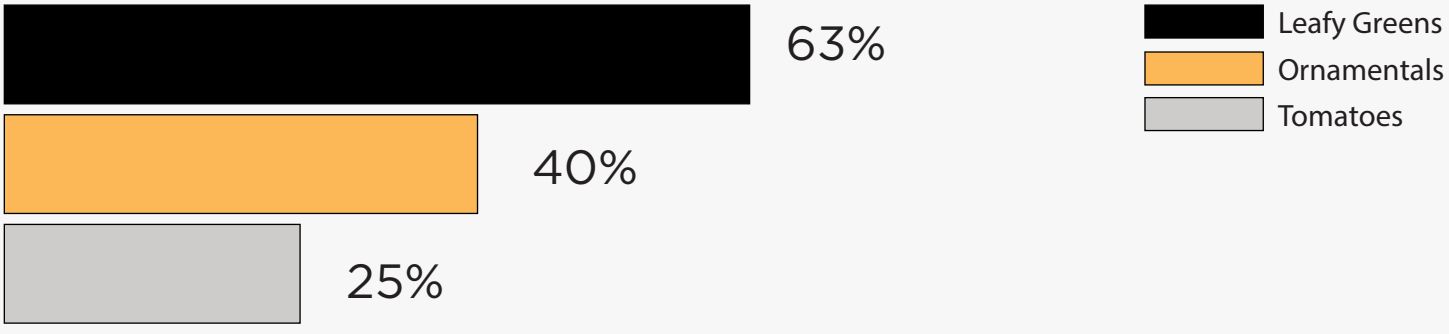
As the greenhouse industry continues to see profitable growth this year, plans for expansion also grow. While the ornamental and tomato markets are established, the leafy greens greenhouse market is still relatively young. Over the past two decades, we've seen more affordable sources of capital, such as project finance, become available to profitable operators. As the cost of capital comes down and the need for consistent, stable supply chains for products rises, we see more and more opportunities for the CEA industry to expand.

While this report doesn't focus on soft fruits, expansion is rapidly occurring in this area as well. Top producers across North America are building more than 100 acres currently for greenhouse strawberry production.

Retailer demand for greenhouse grown products is at an all-time high due to the need of certainty of supply. As a result, for products like lettuce, contracts with buyers are becoming more common. While 40% of lettuce producers reported having offtake agreements with buyers, 100% of new build facilities reported having offtake agreements. This makes new facilities more financeable, which is leading to more expansion.

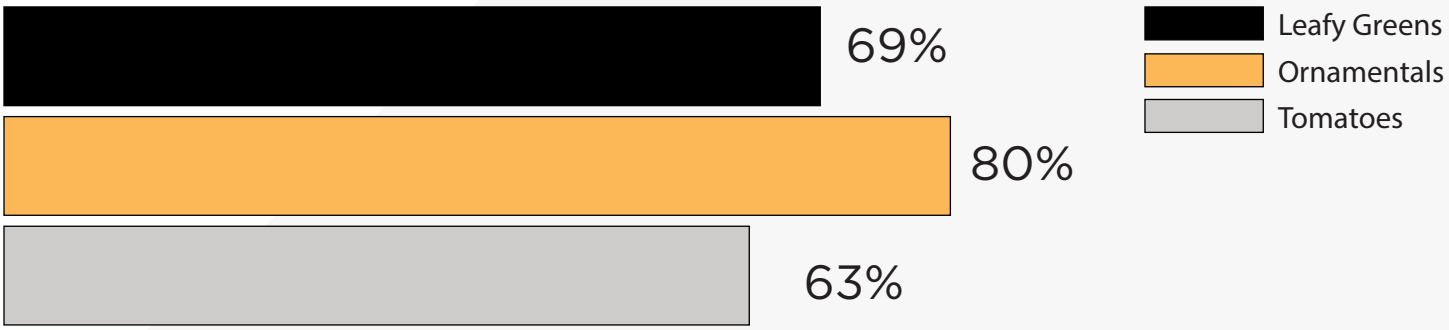
In the next 12 months, growers are planning on adding a moderate amount of square footage. While the majority of leafy greens operations surveyed have plans to expand, this means adding 23% to their existing acreage and for ornamental operations, plans only include adding 5% to their acreage.

Percentage of operators expanding acreage over the next 12 months



As we look to the next five years, expansion numbers grow. The majority of those surveyed have plans to expand acreage, with ambitious increases to existing acreage.

Percentage of operators expanding acreage over the next 5 years



The cost to expand varies greatly based on crop type, with leafy greens costing the most at $5.8m per acre, tomatoes costing $2.9m per acre, and ornamentals costing $1.5m per acre to build according to the survey results.

While the 12 month plans are more measured than in previous reports we've written, this aligns with the high cost to install and the current economic climate. In an unfavorable economic climate, expansion tightens and we're seeing delays in construction across the market. However, that doesn't mean plans are halted. As we see in the longer term forecasts, CEA operators still plan on opening new acreage and we've already seen a number of these expansion and new build projects start getting underway.

Amount of acreage expansion (increase to current production acreage)

67%
Leafy Greens

130%
Tomatoes

16%
Ornamentals

Economic Outlook

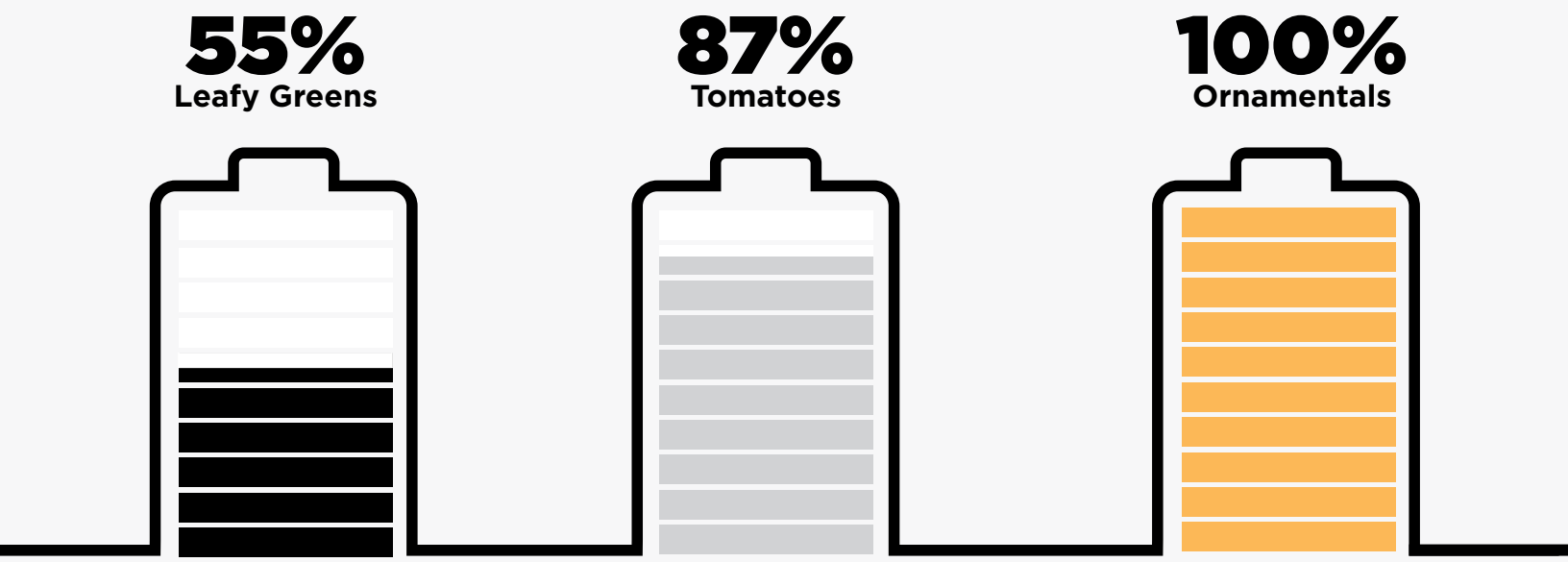
2023 has been a tumultuous year for the horticulture industry globally. Rising costs, less favorable capital markets, and poor operational performance has led to a number of bankruptcies and closures in our industry.

While this report does not focus on the vertical farming market, this segment of the industry has been hit hard by closures recently. Aerofarms recently filed for Chapter 11 bankruptcy citing fundraising challenges as the major driver. While Aerofarms was perhaps the highest profile bankruptcy, it's not alone. Kalera filed for Chapter 11 bankruptcy in April, Fifth Season shut its doors in late 2022, Upward Farms shut down its vertical farming business, and many companies like InFarm and IronOx have faced major layoffs.

The rising cost of energy hasn't helped the vertical farming market. Many of these businesses struggled with the economics of building a commercial vertical farm at scale. When the input costs rise dramatically and the financial market isn't as lucrative, it's difficult to continue funding this model.

The greenhouse market isn't immune to these challenges either. The majority of greenhouse producers have been affected by the recent rise in energy costs. Leafy greens and ornamental producers are both considering increasing the price of their products to combat this rise in costs, while the majority of tomato producers are going to absorb the cost of higher prices. Many producers also see this as an opportunity to invest into automation to help reduce costs.

Producers impacted by the current rise in energy prices



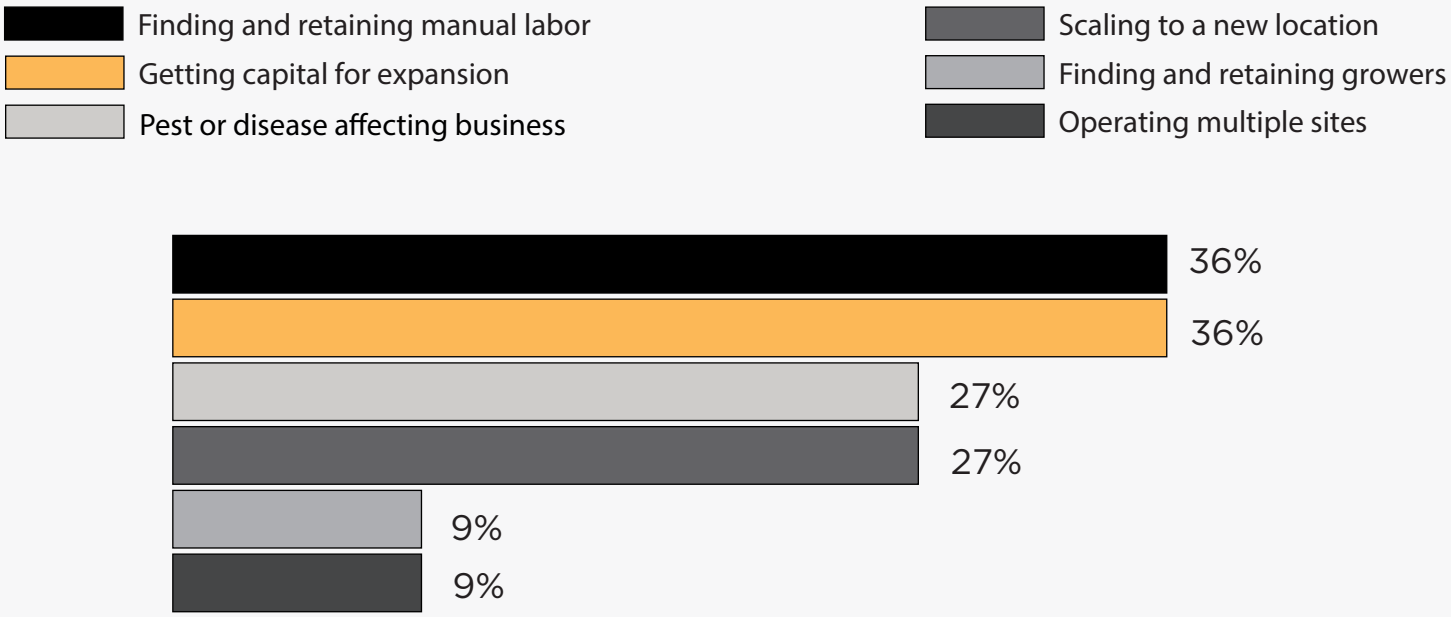
Leafy Greens

We're at an inflection point in the leafy greens market in North America. For decades, the majority of greenhouses in North America have produced vegetables like tomatoes, cucumbers, and peppers or ornamental plants. Over the past two decades, we've seen the rise of leafy greens as a greenhouse staple. With that growth brings a number of challenges and opportunities.

The market is in scale mode. Growers are seeking new forms of capital (debt, project finance, etc.) to scale operations as more and more facilities begin operating profitably. Leafy greens producers are focused on two top goals according to the survey: expand and operate profitably with higher margins.

To do that, growers face a number of challenges (in addition to rising energy costs). A quarter of respondents struggle to get capital for expansion. At the reported $5.8m per acre needed to expand, this is no easy task. With the downturn in the economy and higher interest rates, only the best producers have been able to secure expansion capital this year. This is why many producers are creating 5 year plans for expansion that look beyond the next 12 months.

Biggest operational challenges for leafy greens operators in 2023



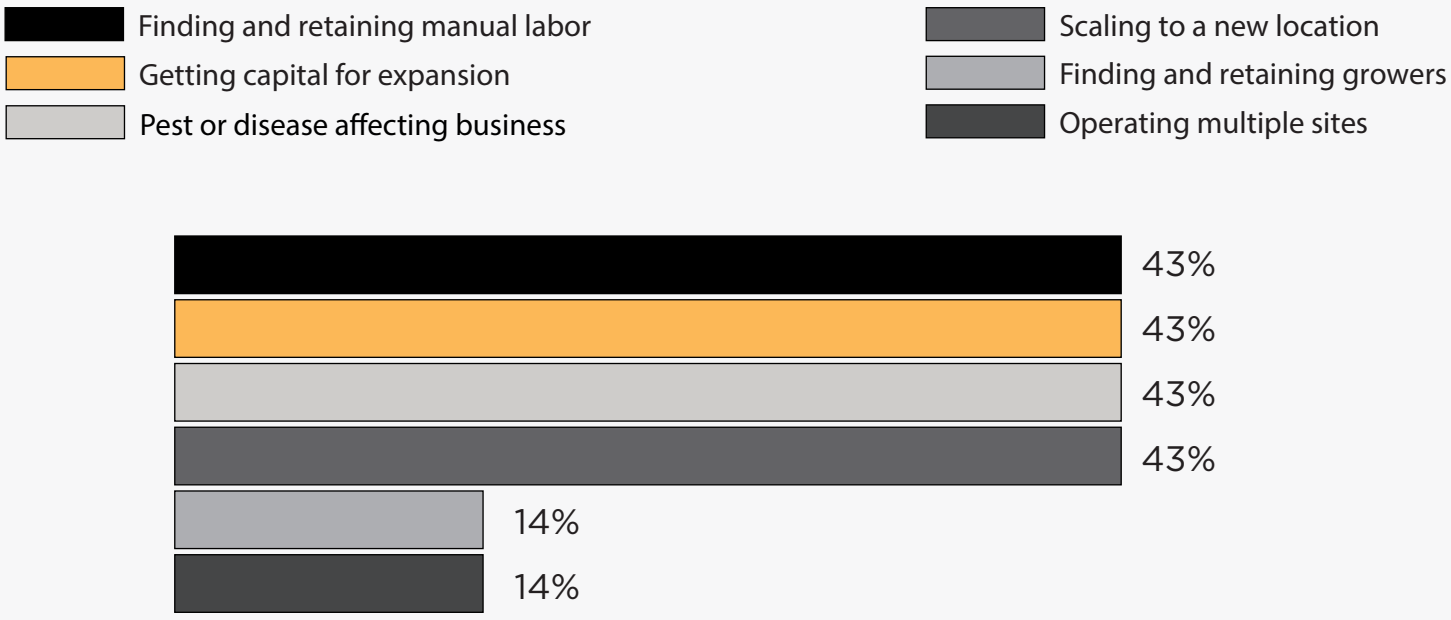
Tomatoes

Like leafy greens producers, most of the tomato operations who responded to the survey are focused on expansion and increasing profitability this year. And like leafy greens, access to capital for expansion continues to be a challenge for growers.

In addition, 43% of growers are experiencing challenges with pests or diseases affecting production. This isn't a surprise. Many producers are struggling to manage the effects of the Tomato Brown Rugose Fruit Virus (ToBRFV). For more than 5 years, the industry has focused on developing strategies to combat this disease in every step of production.

In our recent report, Learning to Live with ToBRFV just over 45% of growers experienced a catastrophic revenue loss at the level of $17 million in a given year due to ToBRFV. This is something our industry continues to face as a top issue this year.

Biggest operational challenges for tomato operators in 2023



Acquisitions

One of the paths growers are exploring as they face a difficult financial climate coupled with a desire to expand is growth through acquisitions. For leafy greens growers, 40% of companies reported that they are considering buying another company and 30% are considering selling their business to another. We've already seen consolidation start in the leafy greens market, like Local Bounti acquiring Pete's for $122.5 million last year and Cox Enterprises acquiring BrightFarms in 2021.

While most tomato respondents reported not considering acquiring other businesses, 17% did indicate an interest in selling their business. The industry is certainly experiencing consolidation with deals like Pure Flavor acquiring the Cervini Farms C5 location this year.

Labor Spotlight

Overwhelmingly the top challenge for all growers this year has been finding and retaining manual labor. More than 80% of growers across all crop segments struggled with recruitment, retention, and/or training employees.

Labor continues to be one of the most difficult things to manage as an operator. Greenhouses are not typically located near major hiring centers. The work is often seasonal. Changes in federal and local policy affect hiring for agriculture businesses. Getting great talent to come back day after day is no easy task for operators.

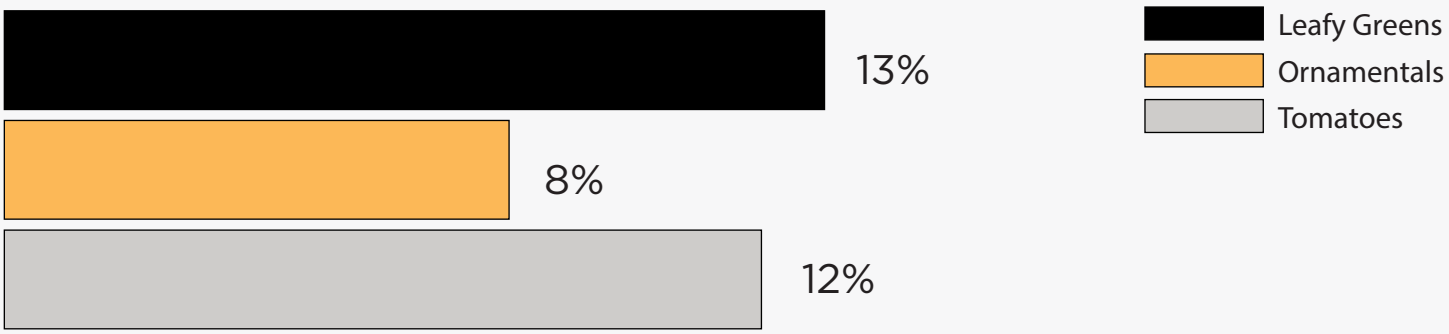
Automation for manual tasks is one way growers can reduce the risk of this massive challenge. Technology can replace labor for manual, repetitive tasks like scouting, counting inventory, seeding, transplanting, and harvesting. Many operations have already adopted machinery to help with these aspects of the business, but there are countless other areas where technology can add value to an organization by reducing labor costs.

Across the board, the majority of operations surveyed believe the two functions that can be most helped with technology are: Growing/IPM and Manual Labor.

Scouting

Scouting is a critical function of a greenhouse operation. Pest and disease can lead to massive crop loss for an organization.

Annual reported crop loss



Technology used by some growers to help with scouting.

On average leafy greens growers spend $25,000 per year on labor for scouting. In addition, leafy greens operations spend an average of $0.34 per square foot on pest and disease control.

Ornamental growers spend more than $40,000 per year scouting manually. Growers reported spending $0.10 per square foot on pest and disease control.

For tomato growers, scouting is an even more time consuming and expensive process, taking more than 4,500 hours per year equating to over $90,000 spent annually on manual scouting. Tomato growers reported spending an average of $0.17 per square foot per year on pest and disease control.

Consultants play a heavier role in pest and disease management for tomato growers, with 67% of them using consultants (compared to 40% of leafy greens operations and 50% of ornamental growers). This is another added cost to the scouting process, though often necessary.

Scouting isn't just a time intensive, manual process. It's also a skill set that is difficult to train. Many talented growers can walk the greenhouse and spot issues visually, but training the team to identify the small changes in a plant's visual queues is difficult to do. In addition, the larger the greenhouse, the more difficult comprehensive scouting becomes.

Growers utilize tools such as sticky cards to help catch pest issues, but there are many areas of the greenhouse we simply can't reach (example: the middle of a moving gully system for lettuce). Because scouting is a manual process, is difficult to train employees on, and is not possible to do comprehensively, it makes a great target for technology.

While scouting is still a manual process for tomato operations, 67% of growers are starting to use software or more advanced technology like computer vision to scout the greenhouse. This adoption is happening faster than in other markets. In comparison, only 20% of ornamental growers are using technology to aid with scouting.

Inventory Management

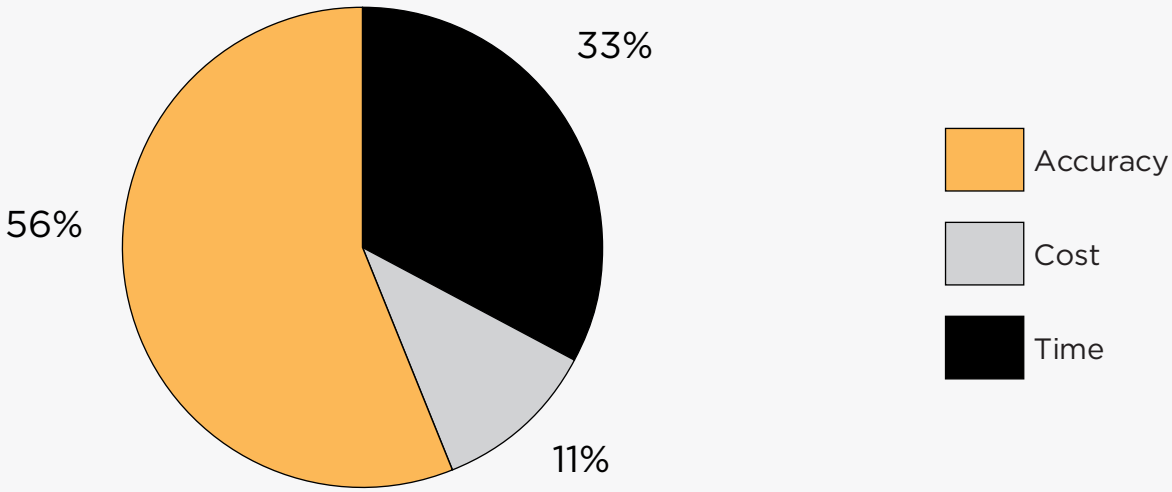
Counting inventory is another manual process for most growers. All ornamental operations surveyed have people manually counting inventory. This is often a weekly process (at a minimum) for operations, costing an average of $30,000 per year to complete.

For leafy greens growers, 82% of operations have people manually counting inventory, costing operations $10,000 - $15,000 per year. Similarly, 71% of tomato operations use people to count inventory and conduct crop registration. Even bigger than the expense of counting inventory manually is the challenge of accuracy with those counts. More than 80% of tomato operations said that inventory counts are not accurate.

Accuracy of counts is important. It feeds forecasts and is critical for the sales team to manage customer relationships. Operations are increasingly adopting more complex Enterprise Resource Planning (ERP) software to help manage inventory and some growers are adopting advanced technology to help automate the counting process. More than 9% of leafy greens operators surveyed reported using computer vision to automate inventory counting.

It's important for technology companies to understand the connection between inventory counting and how counts are used for forecasting and sales. Greenhouse operators want solutions that optimize each individual process, but that also have the potential to integrate, enabling optimization across the entire inventory management process (more in the technology section below).

Challenges with manually counting inventory (according to leafy greens producers)



**Images provided by participating growers.*

Technology

Every operation we surveyed is looking to use technology to drive operational efficiencies, with a big focus on reducing the cost of production.

Before implementing technology in your greenhouse operation, it's critical to evaluate your organization's readiness to adopt this technology. We asked survey respondents to evaluate how capable of adopting new technology their employees are. Leafy greens and ornamental operators both indicated that their organizations are somewhat capable of adopting new technology. The majority of tomato operators indicated that their teams are extremely capable of adopting new technologies.

This is an optimistic picture for both operators and technologists. Adopting new technology isn't easy. In fact, according to Gartner 75% of enterprise resource planning (ERP) implementations fail. Change management is difficult for organizations and it's critical to have a team that is capable of implementing new technology in place before purchasing.

Is your organization ready for AI?

Is your data accurate?	Data is the fuel for AI. Poor data quality leads to poor outputs. So it's critical to start with good data collection (automated and digital is preferred over manually collected data).
Do you have the right infrastructure?	AI requires processing large amounts of data, so having a healthy infrastructure in place is important. Start by checking your wifi strength and documenting what types of devices you're already using to run your operation.
Evaluate your data ownership and accessibility needs	Does your AI partner make it easy for you to securely access your data? Is this important to your organization? Check with your technology partner to see what their policy is around data ownership and ensure it aligns with your needs.
Do you have enough data?	AI requires vast amounts of data. If you're starting from scratch, make sure you budget time in for collecting data and training models.
Is your team ready?	Do you have a team in place to lead implementation? When there is no dedicated project manager for implementation, projects often fail. The team should be bought-in and ready to adopt.

Data Ownership

As we experience the rise of Artificial Intelligence and other data focused technologies, it's important to consider your organization's strategy around data ownership. For some greenhouse operators, data is their intellectual property. The more they understand what drives higher yield or quality differentiates them in the market. This needs to be accounted for when evaluating technology.

This is somewhat new territory in the world of Artificial Intelligence. For Artificial Intelligence platforms to work, they require source data to be inputted, then they train models to provide new outputs to the customer. It's not always clear who owns the source data or the new outputs provided.

Some companies are clear that the customer owns their data (both source and generated), some will have split policies around source and generated data, and others own the data outright. At IUNU, we've always been clear that the customer owns their data. We believe that Artificial Intelligence is a tool to generate more intellectual property for the customer and we've always designed our systems to account for this.

This doesn't just impact data ownership, it impacts how companies charge for various services. If you don't own your data, you might expect to pay for exporting your data or for the ability to sync your data with other systems. If you own your data, you should be able to access your data at any time and use it however you would like. These are all things you should evaluate with your technology providers and review in your contracts.

Percentage of growers who view production performance data as their IP and do not want to share

Leafy Greens

45%

Tomatoes

33%

Ornamentals

25%

When we asked growers how they viewed their data, leafy greens operators were more hesitant to share data with anyone, whereas tomato operators and ornamental operators were more open. Across all operators, there was a desire to have control over sharing data with third-party systems.

Integrating systems is an important component of any digital strategy. Overwhelmingly, the majority of all operations want to have software solutions that solve a core problem well as opposed to software that attempts to solve every problem. Operators don't mind having multiple solutions, but they are also looking for those systems to integrate. This helps eliminate duplicate data entry or functionality and creates a single source of truth for all operational data. It also enables additional functionality from all systems.

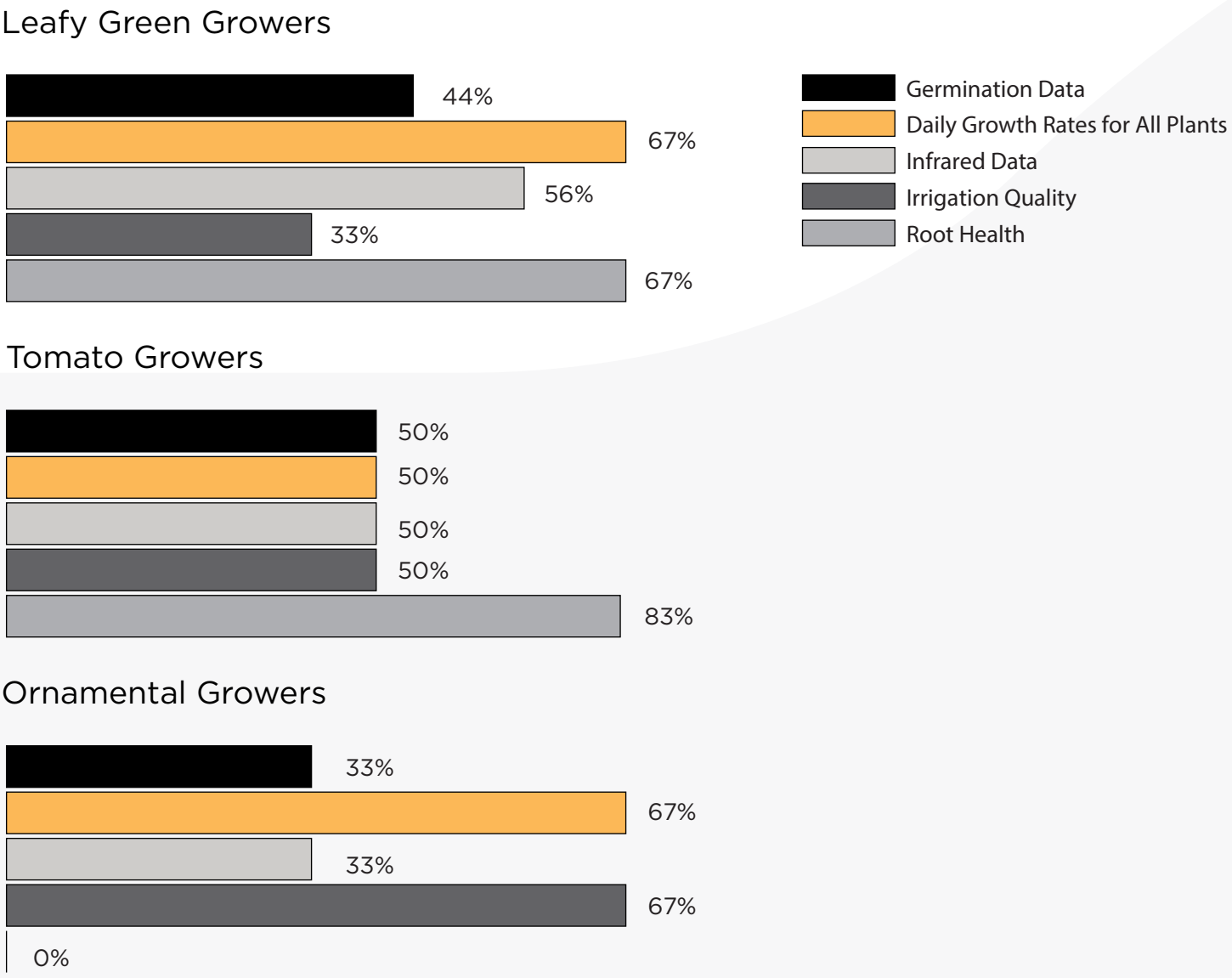
Operations don't expect technology companies to come with out of the box integrations either. Across all operations surveyed, 72% said they don't mind paying a third-party vendor to build an integration solution. Some leafy greens operations commented that they have the in-house capability to build technical integrations as well.

Automating Comprehensive Data Collection

A greenhouse operation is a data goldmine. There are so many areas of opportunity to collect data that it can be overwhelming. To collect all operational data would require entire teams of people full-time focused on data collection. That's just not feasible.

As a result, a lot of data is missed. All growers surveyed want to collect more data, but are limited by either labor or technical ability to collect the data. Growers want more insight into how crops are performing on a daily basis and they want to use that information to steer crops toward higher quality and yield.

Crop data growers wish they could collect that they do not collect today



Because we're limited by labor in collecting data, standard practice is to collect sample data. Based on current sampling practices, we know that the margin of error at a 99% confidence interval is over 100%. Growers would need to increase current data collection by 1,000x to be accurate enough to properly steer decisions based on crop data [1].

For example, according to greenhouse operators surveyed, yield forecasts are one of the most critical functions for the business and also one of the most inaccurate. The majority of tomato operations said they need to have accurate forecasts 3-12 weeks before harvest. At 3 weeks out, 40% of growers said their forecasts were between 80% and 89% accurate and 40% said their forecasts were below 80% accurate. Past this, forecasts dropped even further in accuracy and that's when growers need the accuracy most.

Lettuce has a fast growth cycle and growers need to forecast accurately a week out from harvest. For survey respondents, this is a challenge - 82% of growers said their forecasts are between 70% and 89% accurate for that time horizon.

Leafy greens respondents reported wanting to have more accurate long-term forecasts, with 50% indicating wanting accurate forecasts one month out and 20% looking to do quarterly forecasting. Three weeks out, forecasts are even harder to get accurate - the majority of respondents are under 69% accuracy three weeks out.

For those that said they see higher accuracy in forecasting, they also reported capturing all plant weights. They do not sample weights. The most accurate forecasts are created by those who collect comprehensive data.

Technology can provide a lot of value to growers in this area. With the labor limitation for collecting comprehensive data, technology can automate this function with no labor needed. Growers should consider both the cost of not having this data (or having inaccurate data) and the cost of collecting this data accurately and comprehensively when evaluating the return on investment technology can provide.

At IUNU, we focus on using computer vision to automate accurate, comprehensive data collection. Cameras allow us to see how each and every plant is growing on a daily basis. We then use Artificial Intelligence to analyze this information and provide growers with critical information for steering crop strategies.

1 - According to analysis of sampling data vs comprehensive data conducted by IUNU in 2023.

Autonomous Growing

One of the most talked about technologies coming onto the market recently is Autonomous Growing. Growers have to make decisions around controlling systems continuously in order to ensure optimized production. This means controlling climate, lighting, irrigation, and other mechanical systems. Technology companies claim they can automate these systems (either one or all) based on an operation's production data. Done well, this provides a huge value to growers.

Proper optimization would require 24/7 attention to all growing systems and the reality is growers don't have the time to sit behind a control panel tweaking settings all day long.

If you could completely automate your crop steering strategy, which would you prioritize first?

Climate Control

88%

Leafy Greens

Climate Control

60%

Tomatoes

Irrigation Control

100%

Ornamentals

For both leafy greens and tomato operators, the majority of growers want fully automated climate control. It's interesting to note that no respondents want autonomous lighting control and few outside of ornamental producers want irrigation control. There is already smart irrigation control and good lighting control provided through the climate computers. The majority of producers see an opportunity to focus on using Artificial Intelligence to automate climate control.

This is something we're focused on at IUNU. Recently we launched Intelligent Setpoint Control for LUNA AI, our Autonomous Growing solution to automate climate control for producers. By pairing climate data with comprehensive plant performance data using computer vision, LUNA AI provides growers with ideal crop strategies and executes the selected strategy autonomously.

Autonomous growing companies

IUNU

PRIVA Plantonomy

blue radix

Koidra

The Future

Greenhouse operators are excited about new technologies making their way into horticulture. Advanced technologies such as Artificial Intelligence, robotics, computer vision, and closed-loop autonomous growing topped the charts of technologies growers are most interested in exploring. In fact, 100% of ornamental growers indicated an interest in implementing Artificial Intelligence and/or computer vision this year.

Growers added that companies need to do what they say they're going to do when it comes to advanced technologies. With how much hype there is surrounding Artificial Intelligence and autonomous growing, it's critical for technology companies to be more specific in their marketing and share with growers what value the technology they're building has for their operation. Some growers also commented that many robotics companies haven't delivered that value to date.

The future is bright for CEA. As we continue to need more resilient supply chains, the market for greenhouse grown products only rises. New technology will enable growers to drive toward operational excellence and higher profits, and growers are prepared and adapting.

**Image provided by participating grower.*

Follow us on LinkedIn

IUNU

558 1st Ave S #100,
Seattle, WA 98104

WWW.IUNU.COM
Marketing@IUNU.COM