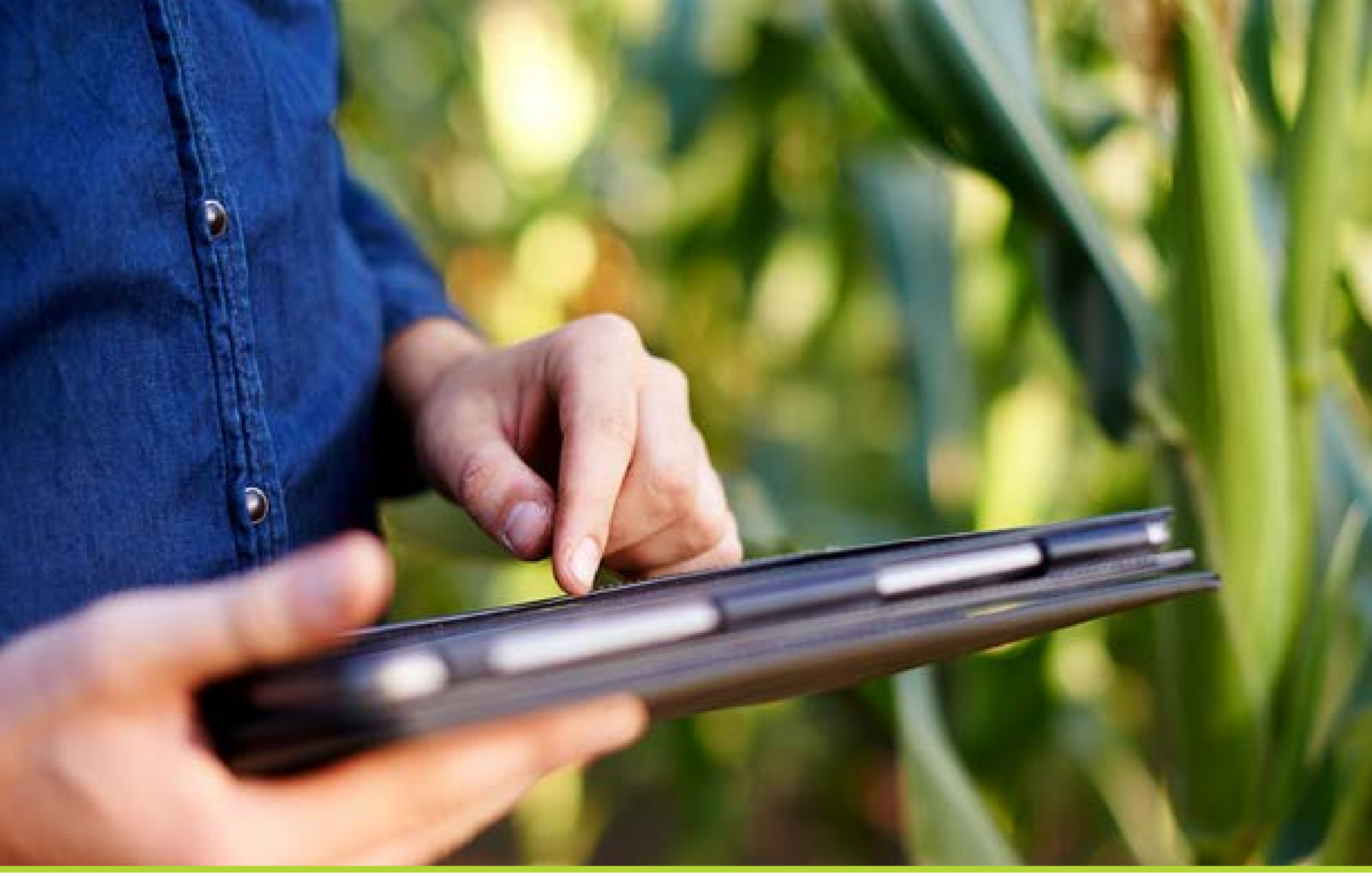

TECH TRENDS 2017: SOLVING FOR LABOR

PRODUCE MARKETING ASSOCIATION

Robert J. Whitaker, Ph.D. | Chief Science and Technology Officer | PMA

ABSTRACT

The shortage of labor has had significant impact on the produce and floral industries in recent years.

The crisis has grown to the extent that many commodity groups rate labor as the most concerning issue they face today, surpassing water availability and food safety. At the same time the industry is facing labor uncertainties, a number of new technologies are emerging that offer produce and floral growers and distributors across the global supply chain options for mechanizing or automating select operations or alternatives that permit them to work more effectively and efficiently, thereby reducing overall labor needs.

Tools to enable precision agriculture, automated field and processing operations, artificial intelligence (AI), an array of new sensors, and increased computational capacity are fueling serious efforts to reduce reliance on manual labor and evolve the produce and floral industries to their next growth phases. Believing that we learn best from our peers, we will examine current produce and floral innovations focused on automating various tasks within the industry and discuss the opportunities and challenges they represent.

We will also explore the potential impact of AI and the gains that are being made to harness this technology that will permit machines to take on tasks that heretofore have been the province of humans. We will also describe how to evaluate your operation to identify areas where automation might make sense and how to develop a technology road map to guide your efforts. However, the effort to reduce reliance on manual labor is more than just automating operations; it can also be about simply working smarter and more efficiently.

We will look at several areas where technology is driving the development of tools that can facilitate a more efficient and productive workplace and thereby reduce labor dependence. Lastly, we will focus on the impact the adoption of new labor-related technologies will have on the remaining labor force and the expertise that will be required to operate that technology.

The current labor issues we face are real and not likely to be solved by a wave of new immigrants willing to take on the challenges of agricultural work. Therefore, the decisions we make in the next 5 –10 years to evolve our industry via the adoption of new technologies and away from its dependence on heavy manual labor will be critical for its sustainability.

The issue:

Agriculture is and has always been a labor-intensive industry subject to constantly evolving labor force dynamics. Although not a new trend, agriculture today faces a labor shortage. The reliance of farmers on immigrant labor has been essential for centuries (see **Breakout Box #1**); however, the next wave of immigrant agricultural workers is not likely to come soon. Current obstacles such as complicated guest worker program requirements, increased deportations, reverse immigration, and Mexico's retention of its citizens due to the country's elevated economy have significantly, and maybe permanently, altered worker availability.

Breakout Box #1 - Historical Emphasis on Immigrant Labor

Since America's founding, the agricultural industry has been reliant on laborers to work in the fields. Whether from Africa or Asia or Latin America, generations have started in the fields and moved beyond them to owning their own land and companies or to jobs in other industries. Following each generation's start in the field – to the subsequent generation's assimilation to jobs beyond the field – the agricultural labor force has faced shortages. In the late 19th century, the U.S. began importing laborers from China, Japan, and the Philippines to work in the fields. During and after World War I, immigrant groups arrived from Central and Western Europe and helped establish land in the Midwest; however, this group quickly assimilated into higher social classes, leaving the fields behind. To fill the void left by European workers, laborers were imported from Mexico. During the Great Depression, U.S. Congress passed legislation to restrict Mexican workers' immigration in hopes of providing Americans with jobs. With the U.S. entry into World War II, domestic labor was once again in short supply for field work. To meet the demand for workers, Florida sugarcane farmers were given permission to hire temporary workers from the Caribbean and Mexico via the Bracero Program (1942 – 1964).

The currently operating H-2A guest worker program was instituted as part of the 1952 Immigration and Nationality Act. Although in recent years, the H-2A program has supplied less than 5% of hired farm labor, applications by farmers have surged 40% in the past five years. Today, immigrants, mostly from Latin American countries, continue to work in the fields, representing much of the labor force on which the agricultural industries rely. In addition to field workers' progression into other industries, industrial progress itself drastically changed farming. Invention of new technologies such as Andrew Meikle's thresher in 1786 and Cyrus McCormick's reaper in 1830s vastly decreased worker numbers for crop harvesting and processing. In subsequent years, these machines were improved with additional inventions such as grain separators, conveyors, and twine-tying mechanisms. The industrial revolution brought other inventions such as the steam engine that helped relieve the backbreaking manual labor of transporting and processing harvested crops. Throughout history, the trend of decreasing the need for laborers as technologies and economic mobility changed farming practices has been continuous.

A few agricultural labor statistics paint a stark picture for future labor availability:

- The average number of farmworkers has declined steadily over the last century from roughly 3.4 million to just over 1 million due to: reduced immigration from Mexico owing to a stronger Mexican economy, declining birth rates, difficulties in crossing the border, unwillingness of the domestically-born to live in rural areas and perform agricultural work, and an aging farm population. Read more.

- Between 2002 and 2014, the number of full-time equivalent field and crop workers decreased by more than 20% (146,000 workers), resulting in a loss of $3.1 billion in farm revenue each year. California alone lost 85,000 full-time equivalent field and crop workers.

- In 2002, Alabama, Georgia, and South Carolina lost more than 25% of their crop workers; Colorado, Nevada, and Utah lost 36.7%.

- During 1998-2002, 14.2% of farm workers were 45 years old or older; from 2008 to 2012, 27.1% were in that age group.

Recent stories on crop losses due to labor shortages are not encouraging either, as we have routinely seen reports like these:

- In 2013, one grower lost $140,000 worth of cantaloupe in two days; left in the field unharvested due to labor shortages.
- In September 2014, 88 Michigan vegetable farms reported the need for additional workers. Vegetable growers reported a loss of $6.6 million in sales due to worker shortages.
- For the past two years, as much as 20% of the California strawberry crop was left in the fields due to labor shortages.

The political and economic landscape does not provide any relief:

- Wages, salaries and contract labor expenses represent roughly 17% of total variable farm costs and as much as 40% of costs in labor-intensive crops such as fruit, vegetables and nursery products. Read more.
- Recent efforts to raise minimum wages and changing immigration policies are expected to result in labor shortages and increased costs for the labor that is available.

All of these factors have led the Grower Shipper Association of the Salinas Valley in California to select labor shortages as their number one concern in their yearly top ten survey of critical issues facing their membership. Indeed, labor-related issues ranked first (immigration reform, farmworker housing, labor costs), second (wages and hours compliance) and seventh (workers compensation) out-distancing critical issues like water and food safety. At the same time, the industry is facing labor uncertainties, a number of new technologies are emerging that offer produce and floral growers and distributors across the global supply chain options for mechanizing or automating select operations or alternatives that permit them to work more effectively and efficiently, thereby reducing overall labor needs. While many other industries have already either wholly or partially automated aspects of their workforce, specialty crop primary production operations have only sporadically explored automation and technological possibilities.

A recent study by PricewaterhouseCoopers (PwC), reported widely in the press, asserted that up to 38 percent of jobs in the US are at risk of being eliminated due to predicted advances in artificial intelligence (AI) and robotics. The percentage of jobs that are at risk differed by sector, but those in the transportation/storage (56%), manufacturing (46%), and wholesale/retail (44%) were the most vulnerable, matching up with sectors of the produce and floral supply chain.

Today, the produce industry still relies heavily on manual farm laborers. As we will explore in this paper, that is starting to change. For example, 46% of greenhouse growers are investing in production equipment and functional automation due to the decreased availability of labor. This investment permits expanded growing operations and provides flexibility for employees to focus on higher priority operational issues. To compensate for the diminishing supply of field labor, companies are developing and/or adopting specialized technologies for use at all crop stages: planting, growing, and harvesting. Precision agriculture, mechanized harvesting aids, various sensors and data collection tools, and pallet movers are just a few examples of technologies being implemented today to satisfy labor needs at the field level. **Similar efforts are already in place or being developed for packinghouses and processing plants with wash water sensors, carton formers, vertical and horizontal packing machines, and optical sorting equipment serving as prime examples.**

With this backdrop, let us look at the technology trends emerging now to provide solutions to the produce and floral industries' shortfall in labor:

> **"Business disruption and escalating labor costs will drive the continuation of the current trend to automate specific operational tasks in the produce and floral industries."**

Walk into any produce packing or processing operation and, chances are, you will see one or more automated systems performing tasks that once used only manual labor. Often, the packing or processing line starts when automated bin or tote dumpers feed raw product onto conveyor systems. **Many wash systems are now equipped with sensors that can detect water quality parameters and automated pumps that can adjust disinfectant levels and control key water quality indicators.** After washing, products are typically dried; sometimes via automated and/or mechanized drying systems. Products may then be graded and sized – once again by automated systems equipped with scales, optics, and lasers. In the past decade, equipment manufacturers have leveraged technological advances in optics, analytical capacity, and engineering to create sophisticated automated systems that analyze product properties and qualities in fractions of a second, then direct product through the rest of the packing or processing line accordingly. With a number of products, final placement in a package is frequently automated, especially when bagging machines are used. We are also beginning to see automated solutions for end-process operations where trams can deliver and collect pallets as needed; robotic arms stack boxes on the pallets while another robotic arm wraps palletized boxes in plastic wrap. These systems have greatly improved over the last decade and are saving companies labor-related costs.

Specifically:

- ### The robotic hand (1)

British-based Ocado has been working with several universities and Disney on SOMA, or soft manipulation, to develop a robotic "hand" that can be coupled with modern digital camera technologies to permit a machine to grip a delicate fruit to determine its state of ripeness and grasp it so as not to damage or bruise it. Potential applications might be in sorting on packing lines but also in place-packing products in shipping containers.

- ### The robotic hand (2)

Similarly, Taylor Farms has collaborated with Soft Robotics on the development of a robotic arm with "grippers" that can handle fresh fruits or vegetables with amazing dexterity. Striking a common theme, Soft Robotics, located in Cambridge, MA, had innovative robotic technology, but lacked input from produce companies to understand the industry's specific needs to customize their technology for produce. As a result of their collaboration with Taylor Farms, the performance characteristics of their robotic arm and gripper have been refined to handle and manipulate raw produce products of varying weight, size, and shape. This has been an obstacle to the produce industry in the past, due to structural inflexibility and expense of previous robotic grippers.

- ### Special grippers (3)

Lacquey, a Dutch company specializing in robotic food handling technology, collaborated with FTNON, an equipment manufacturer, to develop a robotic hand with a specialized gripper. The gripper mimics the human grasp to pick up cabbage and lettuce heads and orient them so that they fit into a machine that removes the core. Together, the two companies created a system with a consistent throughput of 1,800 heads per hour that, unlike humans, operates accurately and without fatigue. Lacquey has plans to develop similar technology for use with other produce such as tomatoes, peppers, and mangoes.

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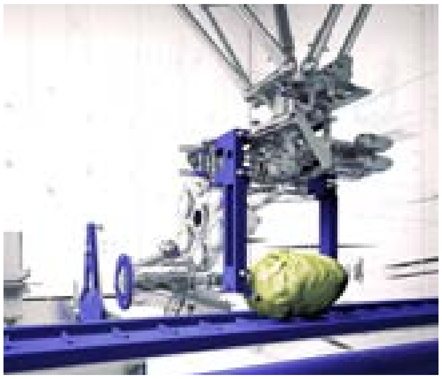

With some exceptions, the pace of automation in field operations has been historically different from what occurs in a packing or processing facility. While still largely reliant on manual labor, growing and harvesting operations across the agricultural labor landscape are rapidly changing. Acute labor shortages are resulting in crops left unharvested in the field, driving the development and adoption of technologies that reduce labor dependence. Specifically:

- According to a report from the New American Economy, the number of full-time equivalent field and crop workers declined approximately 20% between 2002 and 2014, while hired farm worker wages increased 51%.

- The US Department of Labor estimates an additional 6% decline in agricultural jobs between 2014 and 2024.

- California, the dominant domestic producer of fresh fruits and vegetables has an estimated 330,000 farmworkers (US Bureau of Labor Statistics) and the Fresno-based Nisei Farmers League believe that as many as 80 percent may be undocumented; not an encouraging statistic when one considers the current immigration policy and social climate.

In the face of these sobering statistics, it is understandable why the produce and floral industries are looking to extend the reach of automation in packing and processing operations and place renewed emphasis on reducing or eliminating labor on the farm. Indeed, we are entering an era where the long-term survival of farming, packing, processing and distribution operations is dependent on automating some or all of the traditionally manual labor functions.

Automation on the farm depends on the use of collections of technologies to create more efficient and effective farming operations. In many instances, automation activities have been focused on planting and crop harvest, as these activities are often the most labor intensive:

- **The automated transplanting system (1)**

Tanimura & Antle, a grower-packer-shipper based in Salinas, CA, purchased PlantTape; an automated transplanting system developed in Spain to improve planting efficiency by using a biodegradable continuous tape thread. After seeds germinate in the greenhouse, the tape is fed through a tractor-pulled device that cuts it into individual plants and sows them directly into the soil. Holding up to twice as many plants per tray as conventional plug-style trays, the PlantTape system conserves valuable nursery space and, since seedlings can be planted as early as a few days after germination or as late as a full-grown seedling plant, the system provides more flexibility in logistics and planting schedules. Additionally, unlike traditional planting methods, where up to 80% of seeds planted end up being eliminated (a process called thinning), seedlings planted with the PlantTape system do not require thinning. Every seed sown in the nursery grows into a seedling and gets transplanted in the field, so resources are not spent thinning the field. After years of testing and refinement by Tanimura & Antle, PlantTape is commercial for lettuce growing operations, and work to develop the system for other commodities such as celery and onions is underway. By using PlantTape, Tanimura & Antle has reportedly reduced their transplant team from 15-20 people to just three individuals, and cut their overall work hours 10-15%.

- **The see and spray machine (2)**

Blue River Technology's LettuceBot; recognized by the American Society of Agriculture and Biological Engineers (ASABE) as one of the most innovative designs in agricultural engineering in 2017, precisely applies herbicide to individual plants. Equipped with cameras, 20 processors, computer vision algorithms, and quarter-inch-precise sprayers, the LettuceBot scans every plant and calculates more than 5,000 decisions per minute as it passes over a field. The LettuceBot can differentiate a weed from a lettuce plant and directly spray at the ground level. Additionally, it can determine when seedlings are growing too close together and optimally thin out the row. Blue River Technology claims the LettuceBot can reduce chemical usage as much as 90% and lower the number of workers needed to weed and thin fields.

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- **The vacuum-based robot (1)**

There have been recent advancements in commodity-specific automated harvesting aid machinery for apples, citrus, strawberries and more. When developing commodity-specific harvesters, the critical success measures are speed, efficiency, ability to differentiate mature and immature fruit, and protecting quality. A vacuum-based apple-picking robot developed by Abundant Robotics Inc., recently underwent trials in Washington and is expected to be commercially available for the 2018 harvest. The harvester's sensory devices are able to differentiate ripe fruits from branches, leaves, and unripe fruit – overcoming one of the primary hurdles in robotic harvesting technology. The harvesting mechanism noninvasively harvests the apples by gently suctioning them off the tree, reducing bruising and prolonging shelf life.

- **The strawberry harvesters (2)**

Similarly, mechanical harvesters for strawberries can gently pluck ripe fruit using robotic arms based on the berry's total percent ripe-red color. Agrobot, a Spanish company with offices in Oxnard, California, already has a robotic strawberry picker on the market and continues to work on other models. More than 20% of the U.S. strawberry industry has invested in Harvest Croo Robotics, founded in 2013 to invent a robotic strawberry harvester. Harvest Croo's prototype is still undergoing field trials, where it is picking berries at rate of 8 seconds per plant and the expectation is to cut that time in half before completion. When finished, the fully-automated system will include robots to inspect and pack the harvested berries on a platform above the pickers.

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- **The fully-automated harvester (1)**

Researchers at the University of Lincoln in England are using 3D technology in a fully automated robotic harvesting system for broccoli fields. Based on a platform of 3D cameras, the harvesting system will use 3D algorithms and layers of temporal filtering to focus on a head of broccoli that is ready to harvest. However, it is not a 100% robotic system just yet. To obtain the in-field and in-soil images, the cameras are pulled along by humans on a tractor to collect field data information. The next step in development is pairing the camera system with an automated slicer that will cut the florets in the field. Researchers say that the cameras boast an accuracy rate of up to 95%, marking a significant step towards reducing the production costs associated with time-sensitive harvesting.

- **The water-based robot (2)**

  In the vegetable arena, Taylor Farms of Salinas, CA, continues to develop and refine the Ramsay Highlander harvester that utilizes water jet cutters to cut and harvest romaine lettuce and spinach.

- **The sonar robot**

A team at Israel's Institute of Agricultural Engineering and Tel Aviv University is looking to mount a robot onto a sonar system to make the next breakthrough in agriculture by helping growers figure out how much yield they can expect. They've developed what they're calling the "AGRYbot" – not ANGRY-bot – which is an automated robotic sonar for yield assessment and plant evaluation. The robot's sonar identifies acoustic signatures of objects on the farm by sending out waves and analyzing the data. It then uses smart algorithms that enable it to recognize, or "see," and differentiate between the leaves of a plant and the fruit itself. It can also provide a count of numbers of leaves on a tree and the weight of its fruit, within 100 grams.

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What are the implications of automation for the produce and floral industries?

- **The horse is out of the barn.**

Automation is a reality and positioned to make considerable contributions to reducing the risk that escalating labor shortages and costs pose to produce and floral businesses. As technological advancements continue and costs decline, more and more automated solutions will be refined and adopted for growing, harvesting, packing, processing, and warehousing operations. How and when to embrace technologies are challenges faced by industry members. Being smart, well-informed consumers of technology in a smart technology world is vital to making the best decisions for your company. Often, automation technologies or supply chain/production innovations that reduce labor inputs are not specifically designed for the often harsh or unique environments of fruit, vegetable or floral production.

This creates a gap where further development and refinement is required to adapt to industry requirements. Filling this gap can be expensive, but ultimately requires collaboration between innovators and industry operations. It is important for business owners to evaluate their operations for opportunities to adopt new technologies and understand their potential return on investment . (See section on "whole systems approach" below.)

- **Produce and floral companies will continue to be more than just spectators to innovations which solve labor issues.**

Over the last five years, a number of growers, shippers, and processors have recognized the potential for technology to address critical issues for the industry. This is especially apparent in the Salinas Valley of California, with its close proximity to Silicon Valley, and the targeted efforts of business leaders in both sectors there to join forces to help producers work more effectively and simultaneously reduce labor pressures. Many fruit and vegetable producers are not waiting for solutions to come to them; they are getting involved at the ground level. Produce and floral companies are acquiring or collaborating with technology companies and equipment manufacturers to develop automation and robotic solutions for their specific operations. As depicted above, several produce companies have directly financed the development of labor-reducing solutions to address labor-intensive activities such as harvesting and packing. Some of the resulting technologies are proprietary, but others are or will be commercially available.

- **You have to do your homework.**

We will discuss the importance of developing strategy or technology roadmaps for how to identify and deploy new technologies in an operation later (see below). While Pandora's Box may well be open and technologies to reduce labor needs or improve operational efficiencies are available and in use, it is important for each operation to understand what does and does not make sense for their business.

"No two packinghouses are the same" is one of Compac's mantras, driving the company's mission to be the world's leading producer of the most accurate, high-speed packinghouse technology for the produce industry. While the "one size fits all" theme is not appropriate for operations in the produce and floral supply chains and each company needs to understand technology opportunities in the context of their own business, operational similarities between different operations can provide opportunities to test common platforms and modify them to specific needs.

Therefore, each operator needs to shoulder the responsibility of determining how to proceed. While the current technology environment is changing quickly and generating global excitement, it is important to remember that automation is not simple. As discussed in a recent article from WG and Shipper, January/February 2017, an automated harvest machine needs to move in the field, see the product, select the product that is mature for harvest, grasp or harvest it without damage, then move on to the next plant. Those tasks are routine for a human, but represent a level of technical sophistication that remains an engineering and technology challenge for many crops and production systems. In the end, it seems that the global produce and floral industries have moved to the threshold where the specter of continued labor issues and the ongoing pressure to control costs and work smarter have accelerated to the point where the natural human hesitancy to change and invest in or adopt new technologies has been surpassed. Indeed, in a recent article in Politico, Salinas-based Church Brothers Farms' CEO, Steve Church, stated that "growers and shippers are going to have to find ways to mechanize or we are not going to be able to harvest our crops".

- **Change still comes hard and cost considerations are important.**

For established machine-based systems that have been available to the industry for some time and are available from multiple suppliers, the upfront costs are well known and the return on investment (ROI) analysis is straightforward. The benefits of using a proven machine-based system include long-term cost efficiencies, fewer defects, and increased sustainability. Unlike humans, machine output is consistent and reliable. Except for maintenance and occasional mechanical failure, they show up for work every day and tirelessly work nonstop.

For innovations and emerging technologies in automation or operational solutions to help operators "work smarter", the unknowns can be more pronounced and add uncertainty to the ROI equation. This will undoubtedly continue to be the case for many produce and floral producers as upfront capital costs often weigh heavily on the decision-making process. It is important to create the proper context for addressing financial considerations and removing some of the uncertainties.

Some questions to consider when making technology investments are:

- What are the purchase or investment costs associated with introducing an experimental system?
- The initial capital cost is usually the primary consideration. How long will it take to recover the costs in terms of reduced labor costs and defects and/or increased throughput?
- When making an investment or purchase decision, it is important to review the documented system capabilities and understand the test parameters used to validate the technology. Under what conditions can you expect to achieve those capabilities? How robust has testing been with the new system and has it been tested in a similar operation with the same commodity?
- How reliable is the technology/system?
- What is the required down time? Are engineers required for maintenance?
- During implementation when usual start-up issues might arise, what alternative production capacity is available to you? Can you maintain a human crew to perform task in lieu of the new equipment or use older equipment? What impact might interrupted production have on the operation?
- Does your company have the personnel to fix the equipment? Will you need a maintenance contract? What is the warranty on the parts?
- Is this a scalable system that can expand as your operations grow?
- What if you change your operations and need to reconfigure the system?
- Consider the company you buy from. Do they have the personnel to work on the equipment when needed as their operations grow? What is their history and reputation in the industry?

All of these questions and more go into the decision and ultimately impact the success of automation in your operations.

- **One plus one can sometimes equal three.**

In our 2016 Tech Trends article, we discussed the exponential effects of combining technologies to develop game changing innovations. Look for the same concept to emerge with automation and work-smarter innovations. In other words, adoption of a technology to reduce labor inputs may result in collateral savings or improvements that were not the primary target. Engineers and architects looking to improve labor efficiencies when designing facilities may incorporate more effective ways for workers to move from work areas to non-production areas to reduce transit times and guard worker safety. These design features may be simple – as in, incorporation of elevated walkways as in Paramount Citrus' state-of-the-art automated packing facility to keep workers off the floor and out of harm's way of forklifts. However, many facility designers and engineers are improving labor efficiency today by integrating highly technical robotic and automated systems and features such as finger- or handprint identification systems and sustainable antimicrobial surfaces to reduce the risk of pathogen contamination.

In the future, integration of technologies used in facilities will permit combining data collection and analysis streams that are currently separate into a single platform to create greater efficiencies. We are also likely to see construction of automated equipment performed to facilitate food safety objectives. Sanitation is a prime example; today, it is labor-intensive and requires use of toxic chemicals and repetitive motions with the potential for injury and adverse health effects. Various cleaning and sanitation technologies have reduced the need for backbreaking human manipulation such as scrubbing, but scrubbing is still required for biofilm removal. Equipment designers are exploring materials that interfere with biofilm formation to reduce the ability for pathogens to contaminate surfaces and hence the need for harsh, labor-intensive removal processes.

Nano-sized materials and other biocidal materials hold great potential as antimicrobial and anti-biofilm products. Researchers at Cornell University have demonstrated that nanoscale alumina and silica surfaces and cationic chlorinated coatings can reduce bacterial attachment and biofilm formation of E. coli and/or Listeria spp. Ultrasound, sensing, and imaging technologies are also being used to monitor equipment cleanliness in enclosed systems.

> **"Emerging artificial intelligence technologies will combine with automation advances to extend applications to replace rote, manual labor into tasks that require decision making and problem solving skills."**

More often than not, when we think of automated and/or robotic systems, we think of a mechanical arm or color sorter performing individual tasks that previously required rote, manual labor. This has been largely true for many of the automated or mechanized solutions we have seen implemented in the produce and floral industries thus far, but improvements in artificial intelligence (AI) technologies are increasingly enabling automation of tasks that require decision-making and problem-solving skills. In their 2013 report on the future of employment in the age of computerization, authors Frey and Osborne point to an account illustrating how rapidly the pace of technology is progressing. They relate an ironic tale of how, in a book about computers creating jobs published in 2004, the book's authors declared that driving in traffic is too difficult for automation.

Six years later, Google amazed the world with modified autonomous, self-driving Toyota Priuses. What did the authors of this book miss? They assumed that cars, in order to negotiate complex traffic patterns, would need to be programmed with a complex set of rules and did not consider the potential for cars to "learn" how to drive using machine learning abilities.

- **So, what exactly is AI?** (see Breakout Box #2)

The term is broad and dynamic – what was considered AI five years ago may not be considered AI today. Five years ago, an app telling you how close you were to your favorite coffee shop location, no matter where in the country you were, would have been considered "smart" beyond any one human's ability. Today, this is so commonplace we would hardly label it as an AI application. As a description, AI is generally reserved for novel innovations that elicit our awe and amazement. When you read that Watson, IBM's supercomputer cognitive system, is better at diagnosing cancer than doctors, you feel the "wow" factor that generally goes along with the artificial intelligence label.

Breakout Box #2 – AI Today

Many of the AI systems we read about or see in the news today – Amazon's Alexa, Google's driverless car, IBM's Watson – are machine learning applications. But how do machines learn? Not surprisingly, there is more than one way to structure machine or computer learning, but most systems follow one of two basic methods, depending on which tasks need to be accomplished. One method of learning is the "top-down" method, where the computer is pre-programmed with rules used to make decisions and assessments. However, the significant disadvantage of the top-down method is that the computer is unable to adapt when it encounters an exception to the rule. The "bottom-up" technique, on the other hand, mimics the human brain's layers of neuronal connections or networks. Instead of processing information based on a fixed set of rules, a computer is trained to recognize certain patterns. "Learning" then occurs through a process of preservation and elimination as the computer looks for patterns in the data – very similar to the trial and error methods humans use to experiment. As tasks get more complex, it is increasingly crucial to create systems that can learn to figure out solutions from trial and error and not just rely on fixed parameters within which to problem-solve. AI today is moving beyond a pre-programmed, rule-based solution that repeats certain functions to perform a set number of tasks to a decision-based system that gathers information from its environment (i.e., via sensors, images, etc.) and then uses this information to act accordingly.

While there is no real consensus on the definition of AI, it is understood to be the outcome of computer or machine learning combined with data. Rather than programming a computer to calculate a set of results, AI involves computers recognizing patterns and acting on those patterns to complete tasks and solve problems. To do this requires both computational capacity and the availability of big data. As computers become faster and more sophisticated, the potential for AI and its capabilities evolves. In addition, the exponential growth of data collection in the past few decades, particularly from consumer products and systems such as the Internet, has resulted in an accumulation of massive amounts of data. This combination of computational power and "big data" to determine patterns is the basis for intelligent systems.

We have already witnessed novel AI developments. For example:

- **AI can diagnose equipment performance.**

With the multitude of equipment that is used in growing, harvesting, and processing produce, we know that one of the most expensive business costs is when that equipment breaks down and operations grind to a halt. But what if there were a way to get ahead of a potential breakdown? A number of startups are working to train computers to detect changes in sounds, vibrations, heat emissions, and other signals that machines give off as they are working or failing. The goal is for the computers to catch mechanical failures before they happen, saving on repair costs and reducing downtime. A human would still make the repairs, but once the problem is fixed, the mechanic's diagnosis is added to a database, where it will be used to fine-tune algorithms to not only detect unusual sounds, but also interpret them to understand what kind of repair is needed.

- **AI can manage nutrient inputs on vertical farms.**

AI is also finding its way into vertical farming. At the Bowery, a vertical farm in northern New Jersey, a proprietary technology system called FarmOS uses machine learning and vision to understand and respond to all the variables that go into how its vegetables are grown. Sensors installed around the farm track the optimal levels of light and nutrients for each variety of produce, which are adjusted to effect things like taste and flavor. The system also detects when plants are ready for harvest by monitoring growth 24 hours a day and sending this data back into the operating system to determine the optimal harvest point. Every time a plant reaches the "peak harvest moment," the system records what it has learned about optimal light and nutrients for the next round of growing.

- **Improved worker training and management**

Speech recognition advances resulting from AI can have an impact on the fresh produce and floral industries. Speech recognition enables hands-free controls and the ability to get tasks done faster, as humans generally speak faster than they type. Many have already witnessed the in-home commercial applications of voice recognition with the introduction of systems like Amazon's Alexa. Physical hardware for speech recognition components (e.g., microphones, telephones, etc.) are fairly inexpensive, so upgrades to existing systems could be relatively cost-effective. Use of speech recognition to operate equipment also eliminates touch points on machines where contaminants could spread person-to-person and throughout a working environment. Voice recognition applications have been used in warehouse operations directing forklift operators to picking locations.

- **Document translation for worker training and verification of operational parameters**

  In addition to advances in speech recognition, computers have been improved in their ability to accurately translate written information from one language to another; think Google Translate. In a global industry with English, Spanish, and a few other languages dominating, translation software can be used to improve communication and increase worker efficiency and productivity. Watson, IBM's supercomputer, now has a "tone analyzer" service. It uses linguistic analysis "to detect and interpret emotional, social, and language cues found in text." The many linguistic-related AI applications will be powerful tools, useful for training a diverse work force in an efficient and effective manner. In the food safety arena, the era of the Food Safety Modernization Act (FSMA) brings with it the need to have written documentation daily from field to consumer to verify program compliance. These AI-driven tools will benefit operations who need to translate verification records from Spanish to English.

- **Yield improvements and process efficiencies**

  In food processing and manufacturing, most systems are automated (i.e., programmed to run to prescribed parameters to achieve a desired outcome). However, as data amasses, operating systems equipped with machine learning capabilities can use data to identify process areas and conditions that could be improved or optimized. For example, PreciBake®, a smart baking technology supplier, has developed computerized control systems for bakery ovens that determine optimal baking conditions. Instead of baking under a preprogrammed set of conditions (e.g., time, temperature, humidity, etc.), the computer uses data gathered from various scanners, probes, and other sensors to set the precise temperature and baking time to deliver a perfectly baked product. In another example, an equipment manufacturer, Tomra, wanted to address the food waste issue by increasing grading efficiency. Produce suppliers have long supplied high quality produce to retail and food service enterprises based on consumer demand for visually appealing fruit and vegetables. However, as consumers become increasingly aware of the amount of edible food wasted simply because it is not visually appealing, many have acknowledged the role their food choices play in this issue and are changing their ways. To help companies get the most out of their produce and reduce waste, Tomra has designed a sorting machine that uses a variety of sensors to analyze a product's molecular and surface structures as well as its elemental composition to "view food in the same way that consumers do." This capability is especially significant at the raw product level, where packers and processors can channel product to processed, fresh market, juice, animal food, etc. depending on product quality.

Engineering and technology experts believe that in 2017 we will see an increase in attempts to apply machine learning to automated and robotic industrial applications. They predict these applications will significantly improve system efficiencies such as determining optimal running speeds and operational conditions, thus reducing down time. In the coming year, experts foresee significant inroads being made in the ability to predict system failure; allowing maintenance strategies to evolve beyond addressing or preventing equipment breakdowns to getting maximum equipment life before scheduling maintenance.

- **Equipment cleaning efficiencies based on AI**

  Equipment engineers have developed AI applications focused on improving cleaning and sanitizing efficiencies. Current industry practice is to routinely clean and sanitize equipment according to standard sanitation protocols and schedules. Cleaning is labor-intensive and requires significant production downtime, in addition to a sizeable amount of energy and water. Martec, a Derbyshire-based U.K. company, specializing in cleaning technology, collaborated with university researchers to develop an artificial intelligence system using ultrasonic sensing and fluorescent imaging technologies that measure dirt levels inside equipment. Moving forward, the software is capable of "learning" from the data collected during each cleaning event to improve its performance. The inventors estimate that users will realize a 20-50 percent cost savings in cleaning using this technology. With this technology in place, food processors can have confidence that their equipment is clean and schedule cleaning when needed, which will save time and resources.

- **AI optimization of crop inputs**

  We have already described the LettuceBot in the previous section on automation. In the field, weed control is an important issue for produce and floral growers. LettuceBot identifies weeds using machine vision to gather data, then uses algorithms to decide if it's "seeing" a weed, a sick plant, or a healthy plant. If it sees a weed or a sick plant, LettuceBot applies a small amount of herbicide at the base of the plant, essentially providing a lethal dose that kills weeds and ultimately reduces competition for other nutrients that go to the crop plant. For managing plant disease, scientists are developing machine-learning software. After "educating" the computer by entering photos labeled by disease, the software uses an algorithm to identify plant diseases in newly-submitted, unlabeled photos. However, more work is needed to accurately diagnose disease in lower quality photos. The scientists developing the software see plant disease diagnosis expanding into identification of nutrient deficiencies and physiological stresses, since these conditions are often mistaken for disease and money and chemicals are wasted in addressing the wrong problem. Although pesticides have become nearly pest-specific and less toxic to humans and the environment, other measures for pest control are urgently needed as production increases and pests grow tolerant to biocidal mechanisms currently being employed. In order to move away from broad-based pesticide application, technology companies are using AI applications to capitalize on the vast amounts of data banked from sensors and satellite/drone images to allow for pinpointed pesticide applications. To add to this precision application capability, computers are also learning to recognize pests based on images of the parts of a pest's body. Analysis at this granular level helps pave the way for more targeted pest management strategies.

- **AI can manage growing operations**

We have described a number of different data collection tools to manage pest programs, irrigation and fertilizer applications, plant disease monitoring and production schedules, but what is going to manage all of these software programs for a grower? As various technologies for managing field operations are developed and implemented, growers could feel overwhelmed and look for ways to integrate their applications. This is another place AI platforms come into play. An AI platform brings all these different data streams together and integrates them to produce meaningful, actionable information. Although farmers are still the ultimate decision-makers, these AI platforms not only gather and assess data, but can also recommend or even autonomously take action based on its assessment. For example, Arizona vineyard owners are using such a platform to manage their high-end grape variety vines.

The owners:

- Enter sensory information (i.e., how the grapes look, smell, taste) via a tablet in the field, Sensors communicate information related to environmental conditions (i.e., temperature, soil moisture, and humidity) in the vineyard.
- The AI platform then uses an algorithm to process all this information to recommend or take appropriate action, such as activating/deactivating irrigation systems or frost fans and alerting the owner via text message or email that it has done so.

By integrating systems in this manner, growers no longer need to keep track of all their individual data streams, reducing lag time between data access and decision-making.

What are the implications of AI for the produce and floral industries?

AI may still seem like science fiction, but though you may not have thought about it, AI solutions are already integrated into many existing applications used today throughout the industry. As a business owner and produce professional, it may no longer be a decision about whether or not to use them, but rather understanding how these systems can be employed to improve and enhance your business. With a shrinking labor pool and rising labor costs, the floral and produce industries need to find ways to continue delivering a high quality product that consumers want, and AI applications offer tools enabling industry to meet those needs.

- **AI is already a part of many of our automated systems, and its use will only expand**

Many produce or floral operations already employ versions of AI as part of their automated systems. Wash water management systems used in packinghouses and processing plants employ disinfectant and pH sensors that generate digital data, which feeds to an operational software that analyzes the data to create decisions on whether more disinfectant is needed, enabling pumps to deliver the correct dose to maintain water quality. Scales that weigh washed leafy greens and dump their contents into bags formed on a vertical packing machine are calculating weights and selecting which units to open to deliver the exact weight desired. Indeed, many of the examples discussed in the preceding section on automation, from field harvest to final product, employ some form of AI. However, these applications are essentially capable of performing a single task. The same machine that controls a wash water system is incapable of also sorting produce by size. Ian Sample refers to these current applications as "one trick ponies". However, that may be about to change. DeepMind by Google is a system designed to work more like a human mind. Most AI systems perform single tasks because, to learn a second, they essentially overwrite the first. DeepMind overcomes this by preserving previous lessons like a human mind does and going on to learn a new task.

- **Here come the robots...**

Robots can come in all forms – not just the walking, talking versions we see in movies or on television. With the major engineering and materials advances being made in robotics coupled with the data collection and analytics of computers that enable artificial intelligence, it is fair to ask what the floral and produce industries will look like in the next decade. Robots conjure up the notion of an autonomous system that can move and perform either repetitive or complex tasks and perhaps even use data to make "decisions". Will robots become more adept at the human-like movements needed to carry out specific tasks on existing production lines? Equipped with machine learning abilities, a two-arm robot has already figured out how to prepare and assemble a simple salad of lettuce, tomatoes, and cheddar cheese after a self-training period of exploring the foods and tools needed to do the task. We see examples of Abundant Robotics' apple-picking robots that can locate ripe fruit and move a picking arm to the fruit, pick the apple, and place it in a tote.

The key with robotics is the time required to "teach" them how to do a specific task that humans might have learned to do with the benefit of years of learning. University and industry researchers are looking for ways to help robots learn faster. One of those projects is called the Million Object Challenge, and aims to create a cloud-based repository for research robots to upload their data when they learn how to spot and handle simple objects. By accessing this shared information, other robots can "learn" by downloading and analyzing data about a new object without needing to explore it themselves.

The use of robotics is not only a production opportunity but may also find its way into retail. U.K.-based retailer Ocado, in partnership with the SoMa project, has been developing a humanoid robot called SecondHands.

In addition to having the AI ability to understand human speech, the robotic worker will be capable of handling delicate, irregularly-shaped items like fruits and vegetables. The retailer has already built new warehouses using a proprietary Smart Platform that will enable robotic picking as part of their automated journey.

Ocado representatives note that the biggest challenge, especially with produce, will be properly calibrating the grip of the robotic worker so that fruits and vegetables are not bruised or damaged. We are currently on the forefront of automation/AI/robotics in the produce and floral industries, and we can only expect accelerated growth of their development and refinement going forward.

- **Robotics can take on non-human tasks**

While robotics certainly have the potential to affect jobs traditionally held by humans, they might also spread into the non-human arena. Last summer, researchers at Harvard created RoboBees - autonomous flying microrobots to address pollination and other issues. The interesting thing about these robots is their ability to hover, which gives them the ability to pollinate crops. Scientists also believe that these robots could be used for high-resolution weather and climate mapping as well as environmental monitoring. Most recently, scientists at Japan's National Institute of Advanced Industrial Science and Technology have developed a tiny flying drone to address the critical pollination need in plants; especially as bee populations continue to decline worldwide. The bottom of the drone is covered in horsehair coated in a special sticky gel. When the robot flies into a flower, the pollen grains stick lightly to the gel and transfer to the next flower visited. In tests, the drones successfully cross-pollinated Japanese lilies without damaging the plants. In both examples, scientists acknowledge that these drones could be used together with bees until a long-term natural solution to pollinator population declines is found.

- ## Predictive analysis and operational management

In the near future, experts predict that AI applications will move beyond the present to "see" the future. In addition to collecting and analyzing data to perform tasks in real-time, AI systems will learn to identify risk factors in order to predict future events. For example, AI-enabled systems might be able to predict pest infestations. With this ability, pest problems can be forecasted and preventive measures can be proactively used to diminish the effects or prevent occurrence. Another application is predicting product contamination. As more data characterizing risk factors for pathogen or chemical contamination becomes available, AI systems can be used to forecast the probability that contamination will occur. Indeed, we reported on the development of mobile apps to characterize risks associated with using various sources of open water sources for irrigation of crops in the 2016 tech trends article. One can certainly envision the value of this tool to help growers understand risks associated with using irrigation water that might be at risk for carrying contamination onto a crop. But, might we see in the future this same functionality combined with a controlling system that can choose a different water source or direct "at risk" water to a "treatment" that reduces the risk to a more acceptable level?

- ## Will AI eliminate the need for workers in the future?

Reaching a bit further into the future, might it be possible that AI, combined with other technologies, could result in a future packing or processing operation where humans are not needed? This is termed a "lights out" operation, and some forms of manufacturing in other industries are getting closer to that vision today.

For example, automobile manufacturing is no longer what it was fifty years ago, when assembly lines were full of workers performing specific tasks to produce a car. Those same workers have now been replaced by rows of robotic arms performing the same tasks (and doing it with more consistency, precision, and quality). People are still involved in car production, but far fewer than before and those that are involved do very different jobs. It is hard to say whether the produce industry will truly ever see a "smart" farm or a "lights-out" manufacturing plant where human involvement is eliminated, but it is inevitable that we will see a diminished need for workers to conduct specific tasks. In reality, this trend started over 30 years ago and has been continuing in produce and floral production ever since. We have decreased worker needs with the introduction of seeding and transplanting machines, mechanized harvest equipment for specific commodities, modern cooling equipment, vertical and horizontal packing machines and other innovations. So, that we will continue to replace workers with AI-driven, automated processes manned by robots of various shapes and sizes is without question. The only question to be answered is: with what pace will it be done?

> "A whole systems approach is required to successfully automate production and create efficiencies."

When contemplating the issue of overcoming labor shortages and exploring how an operation might solve for this issue using technology, it is important to develop a technology roadmap for your company and consider how implementation of any single technology or automated system will affect the whole production system.

In order to create a smarter workplace, systems need to work together. The goal is not to create stand-alone, autonomously operating units, but to have an integrated, comprehensive, more labor-efficient system. Consider:

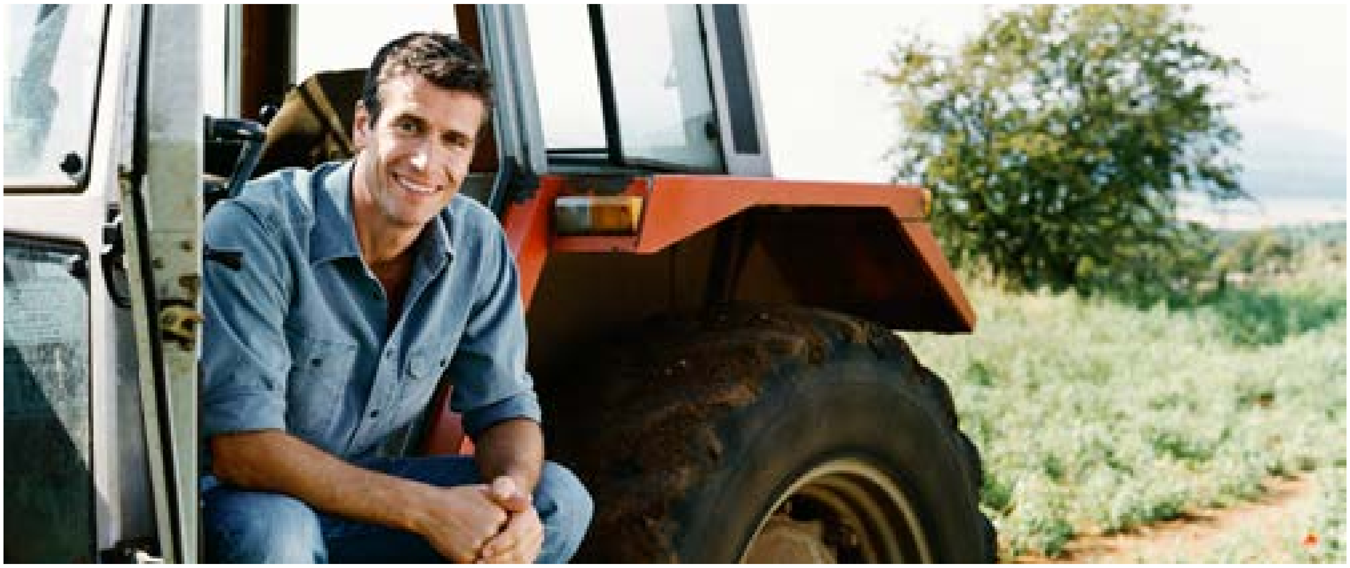
- **System integration is critical**

For companies to truly "work smarter" by reducing labor dependence or becoming more efficient in labor uses, technical solutions cannot create redundancies or disconnections from existing processes or work flows. Too often, companies implement new technologies and buy or develop new equipment and software as stand-alone systems when the real value lies in the ability of these systems to cross-reference and share data. Integrating your company's data collection and analytic systems allows operators to extract substantially more value from collected data. For example, more than likely a grower-shipper adds a lot number multiple times during planting, harvesting, and packing/processing. With an integrated system, redundant data entry can be eliminated (i.e., data is entered into the system once); thereafter, it is available to the user by a click of the mouse and labor resources are conserved. Expanding integration beyond your company's internal systems to external data adds even more value (this will be discussed further in the section addressing supply chain efficiencies). A good example of the benefits of integrating with external systems is the advances experienced in field monitoring capabilities. Expanding geographic information systems, coupled with progress in sensor technology, are providing new opportunities for noninvasive plant disease detection and other field monitoring activities.

- **Watch for problem displacement**

Many technologies offer solutions for improving efficiencies. By focusing on solving a problem with one part of your system without consideration of its consequences, you may inadvertently create problems in other areas. Many in the leafy greens processing segment of the produce industry learned the lesson of product displacement and system integration when automating their production lines. It was quickly learned that bin dumpers, wash lines, drying systems, elevator speeds, and bagging machine rates had to be fully integrated or efficiencies went down and lines needed to be adjusted to prevent idle equipment time. **Today, we see that we not only need to match equipment to work together and communicate with each other, but that equipment construction and food safety properties are also important.** For example, some companies are transforming production lines and installing automated systems to reduce labor inputs, but also understanding that while automation can reduce human contact, proper equipment construction is also needed to enable proper sanitation and both will improve product safety. This means robotic systems have to be built to withstand the harsh chemicals and processes involved with daily cleaning and sanitizing activities. The ability to withstand these harsh, wet conditions creates a challenge for how robotic and automated equipment are designed and constructed. As an example, when Soft Robotics first created a robotic arm for handling produce, the arm failed to withstand the constant washing necessary to meet cleaning protocols. Including members of your sanitation team in your technology roadmap discussion could help foresee these types of problems.

Another real produce world problem encountered with the adoption and integration of new technologies is a change in maintenance and repair mind-set. Farmers have a well-earned reputation of fixing things themselves (think baler twine) to get the job done. Many packing facilities also have maintenance professionals that can "fix anything". Many newer computerized technologies, however, are cyber-locked so that repairs and maintenance are controlled at the manufacture and dealer level. You may own the machine or equipment, but you do not own the "keys" to the computer code that makes it work. This can be very frustrating for those who are of the do-it-yourself ilk and can cause considerable downtime waiting for a technician to come and do repairs.



- **Be prepared to examine the whole production system for modifications when introducing new systems**

It is commonplace to focus on the design of an automated harvester or wash line and perhaps overlook the downstream and upstream ramifications that piece of equipment might have on the overall operation.

For example, we have already described the Ramsey Highlander harvester that utilizes water jet cutters to harvest Taylor Farms romaine lettuce. What may get lost in the design and technical elegance of the harvester are the modifications Taylor Farms had to make to their overall romaine production agronomy and handling to fully take advantage of the automated harvester. Ground preparation to enable the jet cutter harvester is critical. The production beds are 80 inches wide and perfectly flat to ultimately help the cutting head smoothly roll down the plant bed and limit the vertical "travel" of the water jet to insure the cutting water hits the plant in the right place to keep the head intact. Otherwise, leaves might become detached and yield would be lost. Consideration also had to be given to the romaine plant architecture as well. Again, to maximize yield and provide a "target" region for the water jet cutter to strike the plant, romaine varieties had to be selected that exhibited a more upright posture and a tighter leaf wrapping so as not to interfere with the water jet. Of course, the harvest platform itself had to be developed to not only facilitate the movement of the cutting head down a row, but also to transport romaine to a small work crew to load bins or totes. The harvest equipment had to be constructed of stainless steel and be made to be easily washed down and sanitized daily. Drives and speed adjustments had to be made so that harvest rates could be synchronized with packing rates. Finally, adjustments were needed downstream in the processing plant itself to permit proper handling of these new varieties of romaine and the products made from the romaine had to be adjusted to assure customers continued to receive high quality products. This systems approach has been critical to the overall success of the automated harvest machine. **One can certainly envision the importance of these same considerations for other automated or mechanized harvest solutions or processing lines.**

What are the implications of a whole systems approach for the produce and floral industries?

You have to have a plan. Lisa Montanaro from Montanaro Global Enterprises emphasizes the importance of developing a production "audit" before embarking on technology investment.
This production or operational audit includes three specific components:

- **People**

How can the operation be designed or laid out to make the people more efficient or work smarter? What tasks are they doing and what would be the impact to your business if they were done more effectively and efficiently? Where are they deployed in the process or field operation, and would they be more effective elsewhere? Do they have the information they need to be efficient at their disposal and can it be delivered to them more effectively?

- **Places**

What is the physical environment, and what impact does that have on production and the characteristics required of equipment? How much physical space do you have? What kinds of legacy equipment do you have, and what changes might be necessary in order to maximize the impact of new technologies? How do your workers interact with that equipment, and what might be more efficient?

- **Process**

Evaluate your operation. Look back to what you already have in place and determine what is working well and what is not. Where possible, replicate what has worked well in your operation or learn from others. Importantly, engage your workforce in the process. Ask for input on what changes might be effective. Getting employee buy-in early and often will ultimately reduce the barriers to change later down the line when you begin to change your operation. Identify bottlenecks or pinch points in the process flow; how might they be eliminated? If you could make a change and improve efficiencies or increase speed, what impact might that have before or after that point?

This measured approach becomes more critical when one considers the wave of emerging technologies coming to the marketplace today: the demand on growers, packers and processors, and the distribution time and resources it takes to meet with vendors and then try to wade through the options presented.

It's analogous to going grocery shopping hungry and without a list of what is needed at home – there's no telling what you will buy! Having a plan in place and understanding your needs in a comprehensive way will help you avoid ending up with systems that cannot talk to each other and exchange data. It can provide a roadmap so that a technical solution applied in one part of the system doesn't create an even bigger problem somewhere else in the process. The roadmap can also help the operator envision changes that need to be made to permit new technologies to be maximized (e.g.: new varieties with characteristics that make them amenable to the new process, sensors that permit data collection and synchronization of process components and re-engineered workflows that are more efficient).

The idea of developing a plan or a roadmap is not too different from what has been proposed for developing food safety plans. In food safety, the best operators step back and observe the operation: what works, what does not, what impact does the environment have, where are the hazards for cross contamination, involve employees in solutions, determine what changes are needed, implement the changes, measure success and then fine tune the change. At least, early on in the discussion about food safety, the question was always asked: **how do we create a food safety plan? We do not have the expertise on staff, so what can we do? In developing a technology plan, industry operators may have an advantage in that they know their operations inside and out.** Traditionally, we have sustained our businesses by being able to cut out wasted activities and deploy resources effectively. Our traditionally high-volume, low-margin businesses demand that behavior. That internal expertise by itself may still not be enough, especially for medium to smaller producers who may not be as comfortable with emerging technologies as their larger counterparts that might employ specifically-trained engineers and experts. Minos Athanassiadis of Fresh Link Group points to the importance of using an outside consultant to help develop your roadmap.

Consultants or outside experts can provide three essential elements: (1) knowledge of the technology and contacts to help make connections for you, (2) an understanding of who the reliable purveyors of new technologies are and their performance records, and (3) a fresh set of eyes to help evaluate what you have in place and the ability to make decisions without the bias that the operator might have for the current operation. Knowledgeable consultants can integrate into your team, work with your internal experts, and likely save operators from missing opportunities to capture the full value of the technologies adopted.

Lastly, it is important to note that once you make a technology investment and you are in operation, the work is not done. A technology roadmap is a dynamic, fluid, continuous process of evaluating your systems to ensure the company is meeting its objectives. Part of the roadmap process is to routinely assess the operating systems to make sure they are accomplishing what they were intended to and to look for new opportunities to improve. Assessment includes asking whether you are gleaning all you can from the available data and whether there are any remaining data gaps. It is asking whether your systems could be providing more value to your operations and whether your resources might be put to better use than they currently are.

"Technology can help us "work smarter" and thereby reduce labor inputs in our operations."

Technology can decrease labor needs and costs by providing greater access to information and enabling more timely and informed decision-making. We have seen the explosion of computers and hand-held devices in the last decade owing to technologies that increase computational and analytical capacities at decreasing costs. This creates the opportunities for acquiring, storing, and analyzing digital data that are playing out across every facet of our lives; including along the global produce and floral supply chain. While it might have taken three of four people to collect wash water quality data in a packinghouse or processing plant, it can now be done with a single computer and properly arrayed sensors. The daily passes through an orchard by a grower in advance of harvest to discern fruit maturity can be accomplished with an aerial drone equipped with digital cameras. Certainly, technology can offer operators alternatives for performing certain operational tasks or replacing conventional practices that require less direct labor input. Among these are:

- **Supplier selection and management**

Increasingly, operators in our industry are moving away from a vertical integration business model and becoming more reliant on service providers and suppliers to perform key functions. A grower might employ a fertilizer company to spread fertilizers in fields, a seedling company to provide transplants, a pesticide application company to spray crops when needed, work crews to weed or thin crops, a harvest company to harvest the crop, and finally a shipper to cool and sell the crop. Virtually every permutation of this scenario occurs across our industry, spanning the extremes from growers owning or operating every aspect of production to only focusing on the growing of the crop. No matter what tasks are executed internally versus externally through suppliers and vendors, doing them well requires communications and data sharing.

Using software to manage vendors and communicate needs, track operations, or analyze data to determine next steps is becoming more commonplace every day. A number of these tools were previously outlined in the 2016 Tech Trends article.

- **Real time data collection and analysis**

Sensors, tablets, smart phones, cameras, etc. are just a few of the devices produce and floral companies are using to collect data in their operations. Improved wireless sensor and reader technologies are now capable of tracking a product from field-to-kitchen, so inventory and storage conditions are manageable in real-time to bring the highest quality product to consumers. Sensors are one of the primary technologies used in precision agriculture. The primary function of sensors is to gather and transmit data, often remotely, using instruments that detect electrical, chemical, electrochemical, magnetic, optical, or vibrational signals. Sensor technology is rapidly expanding as the cost continues to decline while reliability and accuracy improve. Sensors can also be used on multiple platforms.

Typically, sensors can be used on the ground, by hand, or on trucks or tractors. Ground sensors are generally tasked with measuring nutrients in soil, gathering weather information, or determining soil moisture content. Sensors are also deployed aerially on drones. These types of sensors often are engaged in performing plant population counts or in detecting weeds, chlorophyll, or estimating yield. Lastly, sensors might be found on satellites, where they can be used to measure crop status and yield.

Warehouse operators and transportation providers have used sensors for some time to monitor temperature and other product quality measurements. With innovative ideas such as imbedding sensors on pallets, real-time monitoring capabilities are getting closer and closer to the actual product. Sensors and sensor networks provide valuable data along the entire supply chain. Farmers use sensor data to schedule irrigation and to irrigate more efficiently, to evaluate plant health and nutrient requirements, to assess pest burden and apply pesticides, to detect plant diseases, to identify weeds, to schedule harvest, etc. Before sensor technologies, these data were collected by humans and processed using labor-intensive analytical methods. With wireless capabilities, sensors can directly transmit data as it is collected, making it actionable in or near real-time, and in specific locations. AgriHouse developed sensors designed to attach to plants that send a text message to the farmer's phone if moisture levels drop below a designated level. Inexpensive sensors are delivering a steady stream of data to operators, and again system developers are looking for ways to streamline both data collecting and analysis. In Australia, researchers are using a fully-automated robot containing a variety of active sensors, which collects data as it wheels over a field. Guided by one person, the robot accomplishes data-gathering tasks on field and crop conditions in a fraction of the time that whole teams of technicians typically take using the traditional, manual method to gather the same data. The robot's adjustable, lightweight frame is designed to accommodate multiple sensors and digital cameras and to break down into smaller units for easy transport. With its high-resolution optics, researchers see this robot as a more economical alternative to use of drones in commercial fields.

- ## Genetics and working smarter

As the agricultural industry focuses on feeding the world's growing population, scientists are drilling down to the molecular level to improve crop yields. In doing so, researchers are hoping to create models and other tools to help farmers maximize the genetic potential of crops. In order to do this, scientists first need to understand how a plant's genetic makeup (genotype) affects how a plant looks and responds to its environment (phenotype). Using plant images and other physical data, researchers perform a comprehensive assessment of a plant's genetic traits compared to its growth pattern in the field under certain soil and climatic conditions. This practice, called phenotyping, strives to use this data to develop high-performance crops that are optimally suited for soil types and climate. Genetic information is also used to select optimal plant traits in marker assisted breeding. Using genetic material native to the plant of interest, marker assisted breeding allows breeders to more rapidly screen a much larger population of a plant's DNA for the desired traits, compared to conventional breeding. This method significantly reduces the time it takes to create a new variety. In looking to the future, massive amounts of plant phenotyping data will enable development of models to predict how plants will respond to variation in environmental conditions and their specific architectures (i.e., height, branching, fruit set, etc.). As discussed earlier, efficient breeding of new varieties more amenable to automated or robotic harvest permits growers to maximize the potential impacts of both technologies.

- ## Identify and fix problems quickly

One of the ways companies can become more efficient and productive is to increase the pace of problem solving. Investing in technology that identifies and solves problems quickly can provide a company an edge over its competitors. Computers commonly detect problems by monitoring continuous data streams and looking for deviations from standard, predicted, or expected results.

For instance, if a company's products have not sold well in one location in comparison to all other locations, a computer, given access to the right information, will figure out why this is true much faster than a human could. Walmart's centralized analytics system tracks store inventory and sales, among other data, at each of its 20,000 locations. If there is a significant difference in sales of a particular item among stores, the system alerts analysts who review the data to identify the reason. The computers are able to drill down through the huge quantity of data and pick up small problems that often go undetected when dealing with vast amounts of data. As an example, floral and produce companies primarily use truck transportation for shipping their products. Traffic congestion added nearly $50 billion in operational costs to the trucking industry in 2014 (i.e., there is room for improving transportation efficiencies). Artificial intelligence systems are able to assess transportation routes and determine which routes are more efficient and suitable for getting a product from point A to point B. With wireless capabilities expanding, every aspect of the floral and produce supply chain needs to re-imagined with the goal of improving efficiencies and decreasing labor inputs.

- **Might a "smarter" supply chain be on the horizon?**

The produce industry has pursued traceability and product coding systems for a number of years, with the Produce Traceability Initiative (PTI) being the most recent. The ultimate goal of many of these programs is to enable a smarter supply chain; one where products can be tracked and traced for more efficient recalls in the case of a food safety crisis or inventories can be better managed to ensure best quality to customers. In the last year or so, the potential of the blockchain has emerged as the next evolution of traceability and, ultimately, supply chain transparency. Nathaniel Popper and Steve Lohr have characterized the blockchain as a "bookkeeping method that chains together entries so that they are very difficult to modify later. It provides a way for large groups of unrelated companies to jointly keep a secure and reliable record of their transactions". Walmart is one of 400 companies to join up with IBM to develop blockchain for tracking products. Similarly, Microsoft is working with JPMorgan Chase and a consortium of thirty companies on a competitive approach for blockchain. Their system has been characterized as similar to Wikipedia in that it is maintained by a group of writers as opposed to a single author. As the momentum to explore blockchain technology inevitably comes to the produce and floral industries, it will be critically important to focus on the advantages the technology might offer. Greater transparency on product movements can permit analyses to uncover inefficiencies in product distribution and pinpoint choke points.

What are the implications of "working smarter" for the produce and floral industries?

Futurists are predicting that within the next 15 years, supply chains will be completely autonomous and self-orchestrated, with manual labor replaced by drones, robots, and unmanned trucks with AI computers running the operations. Amazon, typically presented as one of the leaders in developing innovative technologies for improving their supply chain, has a fleet of 45,000 robots in its warehouses, is experimenting with delivery using drones and self-driving trucks, and even filed a patent for a flying warehouse held aloft by blimps. Although floating warehouses seem a bit like science fiction, driverless trucks are not science fiction, they are already here: the first delivery by Uber-owned Otto took place this past October in Colorado. Current technology only allows autonomous driving on highways, however, infrastructure development is underway to accommodate self-driving vehicles in more populated areas with more complex traffic patterns. In an effort to draw driverless technology developers to its state, Ohio announced it will develop a 35-mile stretch of "smart road" outfitted with a fiber-optic cable network and sensor systems so technologies can be safely tested in real-life traffic situations. Many of Amazon's relentless efforts to get orders to customers as quickly as possible hold promise for those that sell perishable products. The floral and produce industries need to pay attention to these pioneers and early adopters to glean what we can from their innovative supply chain ideas and experimental technologies.

Clearly, new technology opportunities are arising every day that can help the entire supply chain work smarter and reduce labor inputs. We have outlined the importance of having a technology roadmap and focusing efforts to be sure the systems an operation employs are integrated and able to communicate and share data. Another point for consideration is to be realistic. Too often, companies can become over-ambitious when implementing technologies. Many times, companies are looking to hit that "home run" when there are a lot of important "singles" to be collected and improvements in operations made. As Minos Athanassiadis of Fresh Link Group asserted in a recent interview, the process of adopting technologies to permit more effective deployment of human resources and, ultimately, automated or robotic replacements for human resources is likely an evolutionary process, not a revolutionary one.

"Labor force of the future: changing job descriptions."

As in many, if not all, other U.S. industries, future workers in the agricultural industry will need to be workers who not only know how to work with currently available technologies, but are also able to learn and adapt to new and evolving technologies as they are introduced. Although the experts do not agree on how technology will ultimately affect job growth, it is not a new phenomenon for machines to replace human tasks. In 1900, 41% of the U.S. workforce was working in agriculture, but by 2000, the agricultural labor force, largely due to mechanization, had dropped to 2%. What is new is that machines are often computer-based and are becoming more sophisticated and able to not only perform preprogrammed tasks, but also capable of problem-solving and decision-making; uniquely human abilities. Many human tasks will eventually be replaced by computerized technologies; the controversy surrounds how much of the workforce will be displaced. According to one report, published in 2013 by Oxford University's Oxford Martin Program on Technology and Employment, 47% of U.S. jobs are at risk from automation. As already discussed, a PricewaterhouseCoopers March 2017 report suggests 38% of US jobs are in jeopardy from automation.

- **What is the current status of agricultural jobs in the U.S.?**

  According to a 2015 USDA report, there is a need for college graduates with a degree in agricultural programs to fill an estimated 57,900 jobs annually in food, agriculture, renewable natural resources, and environment fields. Currently, the U.S. is averaging 35,400 graduates with bachelor's degrees or higher in ag-related fields annually; enough to fill only 64% of the available positions. Nearly half of the jobs available are projected to be in management and business, while 27% will be in science, technology, engineering, and mathematics (STEM) fields.; another 15% will be in food and biomaterials production, with the remaining 12% in the fields of education, communication, and governmental services. In the next five years, the report predicts strong employment markets for e-commerce managers and marketing agents, agricultural science educators, crop advisors and pest control specialists. In STEM fields, job opportunities will be strongest for food and plant scientists, specialists in sustainable biomaterials and precision agriculture and water resources scientists and engineers. The top 50 U.S. ag schools and colleges offer anywhere from four to 22 agricultural majors. Many universities with strong agricultural programs offer courses in agricultural technology, although the number and type of courses differ significantly. U.S. land grant universities offer undergraduate and graduate programs in sustainable agriculture, as well as graduate programs in agricultural engineering. However, quite often, what students learn in the classroom does not fully equip them for the marketplace.

In looking to the future, what skill sets should employers look for in employees? How will emerging technologies affect the skill sets needed to run successful floral and produce companies? A report by the World Economic Forum predicts that five years from now, over a third of the skills considered important in today's workforce will have changed. If this is the case, what are the new skills replacing the unneeded ones? According to the report, when asked what skill sets are critically important for their industry by 2020, survey respondents consistently named the ability to analyze data and to market innovative products and services to clients and consumers. In general, there will be a higher demand for strong interpersonal and collaborative skills such as persuasion, emotional intelligence, and the ability to teach others.

What are the implications of a changing workforce for the produce and floral industries?

In the coming decades, the technologies we have explored here (e.g., artificial intelligence, robots, automated machines, quantum computing, nanotechnology, and many others) will undoubtedly replace and reshape much of our daily work. However, at the same time, new jobs we cannot even imagine today will be created. The optimist may see all the new job opportunities and argue that they far outweigh the job losses. Of course, it is easy to support this view with countless examples of jobs that exist today that no one even imagined 100 years ago (think the long forgotten jobs of stage coach builders, blacksmiths, switchboard operators, and typesetters). Many believe that the world is facing another major industrial revolution that will bring unprecedented change to the global labor force's job descriptions. **Recognizing and understanding not only the industry's workforce needs and challenges but also those of your own company will be crucial in successfully navigating the rapidly evolving marketplace.**

The floral and produce industries face a major challenge in creating awareness (i.e. getting the word out about industry careers to young people). Programs such as those sponsored by the Center for Growing Talent by PMA aim at attracting university students and developing leadership for the industry. These types of programs augment classroom studies and equip students with specific skill sets to assist them in establishing successful careers in the produce and floral industries. In addition, student internships offer valuable industry experience while providing an industry introduction for students and a chance for employers to evaluate future employees prior to employment. However, it is more than just a matter of creating awareness; we also need to create work environments that are appealing to the next generation of potential employees. The produce and floral industries have long been fast-paced, 24/7 operations, often in less than comfortable working environments and comparatively lower paying. To attract the best talent equipped to adopt new and emerging technologies and move us to the next level of innovation, we are going to have to create more inviting work conditions and adjust our business cultures to value technically-trained employees.

FINAL THOUGHTS

As we look to the next decade and beyond, the produce and floral industries are faced with numerous challenges and opportunities. Labor is clearly one of these challenges and technology may hold the answers.

We are in the midst of a technology development explosion, fueled by incredible advances in computational capacity converging with developments in sensor technologies, genomics, vision systems, robotics, AI and other disciplines, that may provide us with answers to business and production challenges and open the doors to new opportunities. We are already seeing the outputs of this technology explosion in automated weeding and thinning machines, mechanized harvesters, vision-enabled sorting machines, automated packing machines, GPS-guided forklifts and other innovations designed to improve efficiencies, reduce costs, and decrease dependence on human labor. Our recent history suggests that while the underlying technologies that fuel the innovations we see today to address labor shortages are exploding upon the scene, changeover to automating production or incorporation of AI-enabled robots will be evolutionary rather than revolutionary. It is not reasonable to expect "smart farms" to spring up overnight, nor is it likely that a single computer, controlling all aspects of the operation, will run our packinghouses and processing plants. But, we will move in that direction in the next few decades. As labor availability, cost pressures, demand for improved product quality and better consistency, natural resource limitations and a growing population whose existence depends on having enough food pushes the industry to maximize production, we will increasingly turn to AI, automation, mechanization, and other innovations that permit a more efficient deployment of human resources. That is why we need to plan now.

It is important to understand our operations (where we perform well and where we are inefficient), to develop technology roadmaps that address those inefficiencies and challenges, and to consider the employees of the future and how we can engage them to help us transition our businesses to be sustainable in the future.

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The technologies and companies described in this paper are not meant to be endorsements, but simply examples of emerging companies and/or technologies that may impact the produce and floral industries moving forward. The reader should not infer any special significance to the technologies discussed here or the emerging technologies that were not covered. The content of this paper was developed as a result of technology themed conferences and meetings, literature review and correspondence with technology entrepreneurs throughout the course of late 2016 and early 2017.

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