AEM
Association of Equipment Manufacturers

Modern Benefits of Specialty Crop Equipment

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Executive Summary

The realm of agriculture is no stranger to technological advancement. While the industry itself is typically thought of in terms of metal and iron, it is arguably undergoing the biggest shift it has seen since the advent of the tractor. Agriculture is, in many ways, at the forefront of technological innovation among all industries, not just equipment. Within agriculture, no segment is seeing a larger pace of innovation and change in terms of the "everyday" way of doing things than specialty crops.

The USDA highlights the vital impact of specialty crops on food nutrition and food security. Poor nutrition is the leading cause of illness in the United States, and focus remains around the nutritional benefits of specialty crops. From dietary guidelines to food safety certification programs, the USDA continues to put an emphasis on this industry. Innovations have taken this important segment of agriculture (which has long been reliant on manual labor and the use of rudimentary equipment) and placed it in a position to lead technological innovation within the agricultural industry.

Advancements in technology have revolutionized the cultivation of specialty crops, enhancing efficiency, sustainability, and productivity. Modern equipment has played a pivotal role in shaping these transformations, with innovations spanning autonomy and automation, precision spray application and weed management techniques, irrigation systems, and harvesting technologies. These developments not only address traditional challenges but also pave the way for a more resilient and environmentally conscious agriculture sector.

By achieving enhanced resiliency, efficiency, and timeliness within the specialty crop space, producers are able to provide a consistent source of one of the most important foods as outlined by USDA. This then directly impacts the industry's ability to not only meet the domestic goals set by USDA, but also global goals set by the United Nations (UN) through Sustainable Development Goals (SDGs) such as:

Goal 2: Zero Hunger

Goal 3: Global Health and Well Being

Goal 6: Clean Water and Sanitation

Goal 13: Climate Action

Goal 15: Life on Land

This paper explores the numerous benefits of these technological trends, emphasizing their implications on the future of specialty crop production.

Introduction to Specialty Crops

Before jumping into the innovations that are starting to shape the specialty crop industry, it is important to understand what the term "specialty crops" means. It is an all-encompassing one, and it was defined in the Specialty Crop Competitiveness Act of 2004 as, "Fruits and vegetables, tree nuts, dried fruits, horticulture, and nursery crops (including floriculture)." For this paper's purpose, the focus will remain on the consumable components of that definition and not as much on the horticulture or nursery crops components. In other words, whenever someone enjoys a fresh quart of strawberries, takes a bite from a crisp apple, or enjoys a bag of trail mix, the advancements highlighted in this paper will be shaping the ways that farmers and producers continue to provide people access to this vital part of their diets.

Specialty crops are not just an important part of everyone's diet, but they also play a vital role in the United States economy. In 2020, U.S. Specialty Crop production accounted for 25% of all U.S. crop production (or equivalent to $60 billion).

The Role of Autonomy and Automation

The challenges of finding and retaining skilled labor have become increasingly pronounced across all industry sectors, but especially in agriculture. This issue has only been magnified within the specialty crop sector, where growers have had a higher reliance on manual labor as a result of the lack of mechanized options for growing, maintaining, and harvesting their crops. During the COVID-19 pandemic, this problem was only exacerbated when farmers didn't have access to H2A labor and there were stories of crops lying in the field with nobody to harvest them (and as grocery store shelves sat empty).

This has prompted growers to turn to autonomy and automation as viable solutions. For example, as a study done by McKinsey & Company titled *Trends Driving Automation on the Farm* states, "For U.S. specialty crops, for which labor is a larger cost driver, the value potential for growers is even greater. For example, in the same scenario in which one worker manages four machines, automated weeding and mowing alone could generate $30 per acre in labor savings on U.S. vineyards."

The goal of these solutions is not to replace labor, but rather to supplement the jobs that farmers already are struggling to fill right now. The shortage of agricultural labor is a critical issue affecting growers, not just in California, but nationwide. This scarcity not only threatens the quality and efficiency of agricultural work but also underscores the need for innovative technologies that can perform tasks traditionally done by human hands.

The adoption of precision agriculture technologies allows growers to maintain full production capacity with fewer workers, alleviating the impact of labor shortages. This shift towards automation isn't about displacing jobs, but rather about empowering on-farm personnel with advanced tools and skills. The emphasis is on upskilling existing staff to operate and manage automated equipment effectively, thereby enhancing their roles within the organization. Workers who are exposed to new equipment and techniques gain the knowledge and skill to not only be efficient but share their experience as well. Putting specific training programs in place is a proactive approach to ensuring the growth of workers. Learning the functions of an automated sprayer, picking cart, or drone can develop a keen eye (which translates to effective and preventative management decisions). Workers can increase their knowledge base by studying how equipment operates.

Promotions and transfers within the farm workforce illustrate how individuals can advance through mastering new technologies and taking on higher responsibilities. This approach not only retains skilled employees but also fosters a culture of career development within the agricultural sector, countering the allure of other industries competing for labor. Embracing technology can allow producers to put their workers in safer, more comfortable working conditions. By integrating autonomous technologies like night harvesting in grape vineyards, as noted by Sonoma County Winegrowers, growers can optimize labor efficiency by working during cooler nighttime hours, thereby enhancing both worker comfort and productivity. This same example also applies to being able to autonomously air blast spray orchards and vineyards, taking the operator out of what was a hazardous working environment and instead allowing them to monitor the equipment remotely from a safe space.

"Technological advancements are not merely about doing more with less. They are about doing it smarter, ensuring both productivity gains and environmental responsibility in the process."

Economically, autonomous technologies offer substantial benefits to specialty crop producers. These technologies enable precise data collection on soil conditions and crop health, leading to optimized planting and harvesting schedules that maximize yield and quality. Moreover, by reducing reliance on manual labor, automation mitigates economic risks associated with labor shortages that may result in higher in-field waste due to the producer not being able to harvest their product on time.

From an environmental perspective, the adoption of autonomous farming practices supports sustainability goals by minimizing resource consumption and reducing environmental impact. Through examples like those shared above, along with the efficient use of resources and precise application of inputs, autonomous technologies contribute to higher crop yields while promoting environmental stewardship.

Autonomy and automation are pivotal in addressing the dual challenges of labor scarcity and agricultural sustainability in specialty crop production. By investing in technological advancements and upskilling their workforce, growers not only enhance operational efficiency and economic stability but also cultivate a more resilient and competitive agricultural sector for the future. These advancements are not merely about doing more with less. They are also about doing it smarter, ensuring both productivity gains and environmental responsibility in the process.

Advancements in Weed Management and Spray Application

Weed management is a critical aspect of specialty crop farming, where precise and efficient techniques are essential to ensure crop health and yield. Farmers continue to work toward finding more ways to improve their on-farm efficiencies, which in turn helps their bottom line and goes toward ensuring that their operation continues to be sustainable. Spray application is an area where great strides have been made to improve these on-farm efficiencies and sustainability. This starts with the utilization of data management technologies to make better, more informed decisions about crops. It also enables the more efficient use of time and resources, which in turn positively affects both the farmer's bottom line and the environment. However, in order to actually collect this data in a reliable and accurate manner, farmers often times utilize technology such as:

- Yield monitors
- Weather stations
- GPS location
- Rate controlers
- Application controls/input

Even then, every farm utilizes varying amounts of these technologies. There are still farmers who collect information by hand and record that information in a Microsoft Excel spreadsheet. Then there are farmers who utilize all the listed technologies, and there are a number who fall in between the two groups. The key to implementation comes down to knowing what to do with the data once it is captured. Fortunately, there are resources like ag service providers to assist with the process.

A key technology that helps to ensure the application is landing on target is section control. Not only does it help to ensure increased placement accuracy, but it also helps to reduce sprayer overlap within the field. Through the utiliization of the machine's location in relation to the various mapping details, the machine is able to determine when to shut off portions of the boom or even individual nozzles to help create buffer zones and ensure no spray zones are being followed. By pairing this with the monitoring of what has already been sprayed trough the machine controls, overlap is also reduced. All of these benefits are maximized in a system that is also utilizing some sort of guidance control to ensure the machine is in the proper place.

Rate control starts all the way back at data management, as that data is used to help create a specific prescription for a field. No longer do farmers look at a field as one single application. They are now able to make adjustments to their rate of application based off the needs of a specific section of a field. Changes can even be made in real time based on condition data that can be collected through things like weather sensors to make sure the applied chemical reaches the target.

One of the latest developments in application technologies is targeted spray application. This is a combination of all the other technologies to implement action that helps achieve the goals of right place, right rate, and right time. It is a utilization of imagery identification, such as cameras, and other sensors to identify weeds and target them specifically. This leads to an even more granular placement of the application.

Fungicide and insecticide application has seen its own transition to targeted techniques. Important factors to ensure efficient application are crop height, crop volume, and leaf area. Advancements in applying insecticides have allowed spraying to reach the underside of leaves, where certain types of insects live, as on leafy greens for example. Air blast spraying, often seen in orchards, has improved efficiency through changes in areas such as air velocity, which now allows spray to enter the canopy of trees and reduces drift.

However, spray application isn't the only way that farmers are working to address weeds and insects within their fields. There are also new innovations that leverage technology to tackle weed pressure-related issues from a different perspective. There are now robotic weeders equipped with advanced computer vision and machine-learning algorithms. These robots can navigate fields, identify weeds with high accuracy, and precisely target them for removal. By distinguishing between crops and unwanted plants, these systems minimize herbicide use and reduce labor-intensive manual weeding.

Additionally, unmanned aerial vehicles (UAVs) are equipped with GPS and multispectral imaging to allow for efficient spraying techniques. Innovation within this space continues to evolve, encompassing higher degrees of autonomy and payload capacity. Drone usage aids in the same theme of right place, right rate, and right time. Large areas can be covered in a short amount of time, reducing manual labor along with exposure to chemicals.

Similarly, other companies are offering a different approach by utilizing lasers to detect and eradicate weeds, operating with remarkable speed and precision. By autonomously scanning fields and targeting weeds without damaging crops. This approach is particularly beneficial for specialty crops that require delicate handling (and where traditional herbicide applications may not be suitable).

No matter how a farmer manages their fields, technology is undoubtedly revolutionizing weed management in specialty crop farming. By integrating robotics, artificial intelligence (AI), and advanced sensing technologies, these innovations not only enhance efficiency and productivity but also support sustainable agriculture practices. Furthermore, these technologies narrow critical windows for spray application, which translates to traceability and compliance. Farmers are enabled to maintain cleaner fields and optimize crop yields, ultimately contributing to a more resilient and environmentally conscious agricultural sector. As these technologies continue to evolve, they hold the promise of further transforming how weeds are managed, offering new solutions to age-old challenges in farming.

Water Management Technologies in Specialty Crops

Advancements in irrigation technologies and water management practices have significantly transformed specialty crop agriculture, enhancing water use efficiency and overall productivity. Historically, water-intensive crops like fruits, vegetables, and nuts have posed challenges due to their high-water requirements. However, modern irrigation techniques such as drip irrigation, micro-sprinklers, and precision irrigation systems have revolutionized water application methods.

Drip irrigation, for instance, delivers water directly to the plant roots in controlled amounts through a network of tubes and emitters placed near the plants. This method minimizes water loss due to evaporation or runoff, ensuring that plants receive the precise amount of water they need. Micro-sprinkler systems operate similarly but distribute water through fine sprays, covering larger areas while still maintaining high efficiency.

Furthermore, the integration of sensors and advanced data analytics has enabled precision irrigation management. Soil moisture sensors, weather forecasts, and even satellite data are utilized to monitor and optimize water application in real time. Farmers can adjust irrigation schedules based on specific crop needs and environmental conditions, thereby minimizing water waste and maximizing crop yield.

In addition to technological innovations, improved water management practices such as mulching, cover cropping, and regulated deficit irrigation (RDI) have contributed to enhanced water efficiency in specialty crop agriculture. Mulching reduces evaporation from the soil surface, retains soil moisture, and moderates soil temperature, benefiting plant growth and water conservation. Cover cropping not only prevents soil erosion but also enhances soil water retention and nutrient availability. Regulated deficit irrigation involves deliberately applying less water during certain growth stages to optimize water use without compromising crop quality or yield.

Collectively, these advancements have not only reduced water consumption per unit of produce but also improved crop quality and yield consistency. They have empowered farmers to sustainably manage water resources, adapt to changing climatic conditions, and meet the growing demand for specialty crops worldwide. As technology continues to evolve, the potential for further improvements in water efficiency and agricultural productivity remains promising, offering a pathway towards sustainable and resilient farming practices.

Advancements in Harvesting Technology

Advancements in harvesting solutions have revolutionized the way specialty crop farmers manage their harvests, offering a range of benefits that enhance efficiency, reduce waste, and improve overall farm management practices. These innovations enable farmers to optimize their harvest timeframe by significantly speeding up the harvesting process compared to traditional manual methods. For instance, automated harvesting machinery for fruits such as berries or vegetables like lettuce can swiftly and accurately gather produce, allowing farmers to harvest larger quantities within a shorter window of time. This capability is crucial in specialty crop farming, where crops are often highly perishable and must be harvested at peak ripeness to maintain quality and market value.

In addition to speed, these innovations are helping farmers minimize in-field waste by carefully handling crops and reducing damage during harvesting. Sophisticated technologies integrated into these machines, such as gentle handling mechanisms and precise cutting or picking tools, ensure that crops are harvested with minimal bruising or spoilage. This not only preserves the quality of the produce but also reduces losses that would otherwise occur due to manual harvesting errors or inefficiencies.

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Moreover, these new technologies are helping to gather data that provide farmers with valuable data insights that empower better decision-making. Many modern harvesters are equipped with sensors and data collection capabilities that monitor crop yield, quality parameters, and even environmental conditions during harvesting. This data can be analyzed to optimize planting schedules, adjust irrigation and fertilization practices, and improve overall crop management strategies. By leveraging these insights, farmers can make more informed decisions to maximize their yields, reduce costs, and enhance sustainability.

Furthermore, going toward mechanized forms of harvesting contributes to improved food safety standards. By automating the harvesting process, these solutions minimize human contact with produce, reducing the risk of contamination from handling. Automated systems can also include features such as sanitation protocols and traceability measures that ensure harvested crops meet rigorous food safety regulations and maintain high hygiene standards from field to table.

Overall, these solutions are helping specialty crop farmers streamline operations, reduce waste, provide data-driven insights, and enhance food safety. As technology continues to advance, these innovations will likely become even more sophisticated, further benefiting farmers and consumers alike by ensuring efficient, sustainable, and safe agricultural practices.

Industry Challenges and Future Needs

The complexity of growing specialty crops has proven to be a challenge for both equipment production and expenses. Equipment is pushed into a niche environment because of crop diversity. Canopies, seeding, bed and row dimensions, as well as care, are all aspects unique to each crop. The unavailability of holistic equipment and precision solutions had caused the transition to mechanization to initially lag behind the broadacre crop industry. Customer pain points combined with complexity have positively led to start-up companies noticing this trend and taking the initiative to fill the gap. Areas that once were a weakness have become areas of pride and growth, but more work needs to be accomplished.

Fundamental architecture changes to smaller equipment can address the issue of precision capabilities. Oftentimes smaller products, such as tractors, lack the electrical architecture needed to utilize implements aiding in precision. Higher quality products provide consistency, reduced maintenance, and even reduced accidents. Each area pinpoints the challenge for engineers to bring forth innovations to optimize equipment with new abilities.

From open APIs to analytic providers, partnerships and collaboration are essential to solve challenges and prevent a "here today, gone tomorrow" system. New relationships have proven to be key in fostering positive outcomes for industry challenges. A collective effort strengthens farmer success, which leads to the betterment of the overall industry.

Promoting sustainability and resilience in the face of numerous pressures is vital to combatting the future needs of specialty crop growers. Overall, the challenges facing specialty crop production are multifaceted, ranging from small equipment improvements to the continued need for precision ag solutions. Addressing these issues requires a concerted effort in innovation and collaboration. The collective effort will ensure the growth of the specialty crop sector, securing its indispensable role in the global food system.

Conclusion

The evolution of specialty crop farming, driven by technological innovations, underscores a pivotal shift toward sustainability, efficiency, and resilience in agricultural practices. Specialty crops, encompassing fruits, vegetables, tree nuts, and dried fruits, play a dual role in both dietary health and economic vitality, contributing significantly to the U.S. economy with a production value of $60 billion in 2020.

Autonomy and automation have emerged as indispensable tools in addressing the challenges posed by labor shortages and operational inefficiencies in specialty crop production. These technologies, ranging from autonomous harvesting to precision irrigation systems, not only enhance productivity but also optimize resource management. By empowering farmers with real-time data and advanced tools, autonomous systems enable precise decision-making, mitigate risks associated with labor fluctuations, and promote environmental stewardship through reduced resource consumption and waste.

Advancements in weed management and spray application further exemplify how technology is revolutionizing agricultural practices. Robotics equipped with AI and machine-learning algorithms can now identify and selectively target weeds, minimizing herbicide use and promoting sustainable farming methods. Similarly, innovations in water management technologies such as drip irrigation and soil moisture sensors, enable farmers to optimize water use efficiency, enhance crop quality, and adapt to changing environmental conditions, ensuring long-term sustainability.

Harvesting technologies have also undergone significant transformation, enabling farmers to streamline operations, reduce in-field waste, and uphold stringent food safety standards. Automated harvesting machinery equipped with precision sensors and data analytics not only accelerates the harvesting process but also ensures minimal crop damage and contamination risks, thereby enhancing overall farm efficiency and consumer confidence.

As we look ahead, the continued integration of advanced technologies promises to further enhance the productivity, sustainability, and profitability of specialty crop farming. By embracing these innovations, farmers can navigate future challenges effectively while meeting the growing demand for high-quality specialty crops worldwide. Additionally, the need for partnerships and collaboration remains crucial for providing avenues for continued innovation and adoption. Ultimately, the convergence of technology and agriculture not only shapes the future of farming, but also ensures a resilient and environmentally conscious agricultural sector for generations to come.

About the Association of Equipment Manufacturers (AEM)

AEM is the North America-based international trade group representing off-road equipment manufacturers and suppliers with more than 1,000 companies and more than 200 product lines in the agriculture and construction-related industry sectors worldwide. The equipment manufacturing industry in the United States supports 2.2 million jobs and contributes roughly $415 billion to the economy every year.

AEM's robust history began 130-plus years ago from a unique vantage point – its industry segments came together to create a fundamentally more powerful voice and advocate for the non-road equipment manufacturing industry.

AEM built on the successes and continued the legacy of its founding groups – the Construction Industry Manufacturers Association (CIMA) and the Equipment Manufacturers Institute (EMI). Both groups had a common goal – advocating for better roads that brought products to market faster, safer, and more efficiently.

For more than a century, AEM has provided a manufacturer forum for industry-wide action that transcends individual member company size, product line, or individual business concerns. Companies participating in AEM work together for the betterment of the industry and public needs, at the state, national, provincial, and international levels. In enabling growth together, AEM and its members build momentum for equipment manufacturers and the ag and construction markets they serve.

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