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RESEARCH & INNOVATION CENTRE

# An Automation Technology Strategy for the Canadian Horticulture Sector

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## A Symposium Report

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Prepared with the assistance of Synthesis Agri-Food Network

# Executive Summary

Availability and cost of labour are two of the biggest challenges facing the horticulture sector today. There are over 27,500 horticulture farms in Canada, with 120 major crops farmed on close to 1 million acres of land and producing over $5 billion in annual direct farm cash receipts. Across the diversity of crops and production systems, labour is a common challenge. In the majority of cases it is the single highest contributor to production costs and 60% of farms report lost sales due to a lack of available workers.

In November 2016, Vineland Research and Innovation Centre (Vineland) hosted a symposium to develop an automation technology strategy for the Canadian horticulture industry. The event brought together leading researchers from around the world along with a diverse set of stakeholders including growers, manufacturers and government representatives, to discuss research and development needs in the sector.

Researcher presentations and the ensuing discussion centred on current major trends in the field including: big data, decision support and system of systems, an overview of which is presented later. Participants saw many opportunities to implement these technologies in horticulture, particularly in the latter stages of the production cycle. Along with the technology opportunities, there are also barriers to adoption with the most significant being high capital costs and resistance to changing production systems.

Automation that increases the Canadian horticulture sector competitiveness can be achieved by targeting the following two high level goals:

## Targets

1. Increase labour efficiency with automation. Target: 50% reduction in overall labour cost per unit of production in 10 years
2. Increase the efficiency of crop inputs through improved decision support tools and process automation. Target: 50% reduction in overall use of crop inputs (energy, water, fertilizer, pesticide) per unit of production in 10 years

## Research and development priority areas

Three priority areas were identified for technology research and development which, in order to succeed, must be underpinned by a guiding principle of collaboration and co-development with growers, researchers and manufacturers.

1. Technology development and adaptation

- Develop or adapt labour support automation technologies
- Develop multi-use automation technologies
- Develop decision support systems

2. Technology validation

- Measure and communicate the return on investment (ROI) of adopting automation technology

3. Information Technology and data sharing

- Develop platforms and systems that enable easy collection and analysis of production data
- Enable data sharing among growers

# 1.0 Introduction

Two of the largest challenges for Canadian horticultural producers are the availability and the cost of labour. Automation can provide a solution to these issues.

On November 29, 2016, Vineland hosted a symposium to develop an automation technology strategy for the Canadian horticulture industry. The event brought together leading researchers in automation and big data from around the world, along with a diverse audience of growers, manufacturers, government representatives, academics, and industry stakeholders to discuss research and development needs in the sector.

Speakers provided an overview of current trends and driving forces, as well as specific examples from their field of expertise. Symposium participants had an opportunity to discuss the information presented and to provide their own insights into key opportunities and challenges with regards to automation in the Canadian horticulture sector. This report provides an overview of emerging trends in automation and opportunities for the Canadian horticulture industry, and a strategy for developing automation technologies in key areas.

## 1.1. Labour and automation in the Canadian horticulture sector

There are over 27,500 horticulture farms in Canada, covering close to 1 million acres of land and producing over $5 billion in annual direct farm cash receipts. Despite Canada's seasonal climate, there are over 120 different horticultural crops grown in Canada[1] including field and greenhouse fruits and vegetables, flowers and ornamental plants, maple and honey products, and more. In the past five years, Ontario has accounted for just under 60% sales of Canadian horticulture products each year. British Columbia accounts on average approximately 25% of sales, Quebec 10%, and the rest of the sales are divided among the remaining eight provinces. This breakdown remains relatively consistent when the horticulture sector is further broken down into fruits and vegetables, and flowers and plants.[2]

Current challenges for the Canadian horticulture industry include a shallow labour pool and increased competition from international imports. For example, in 2014 Canada imported $2.93 billion worth of vegetables with the majority (62.1%) arriving from the United States. Mexico was the second largest source of vegetables with 25% of total vegetable imports. Climate change and the growing costs of inputs are also additional challenges. Labour costs are a significant factor for Canada's horticulture sector as the labour portion of the cost of goods can be as high as 40-50%.[3]

In addition to labour costs, access to labour is a major challenge for the Canadian horticulture industry. In 2014, the horticulture industry (including fruit, vegetable, greenhouse, floriculture and nursery) employed 107,100 people, which was 29% of the agricultural workforce.[4] That year, the sector was unable to fill 5,800 jobs costing the industry $350 million, and 60% of field fruit and vegetable farms reported lost sales due to

[1] Canadian Horticulture Council, 2016
[2] Statistics Canada
[3] E. Laate, The Economics of Production and Marketing Greenhouse Crops in Alberta, 2013; Ontario apple farmers face many challenges, Sun Times, 2014
[4] Canadian Agriculture Human Resources Council, Labour Market Information, 2016

the lack of labour availability. This labour gap is expected to increase over the next 10 years and forecasts show that 32%-45% of the horticulture labour force demand will not be met by domestic workers by 2025. While foreign workers have helped the horticulture industry fill labour shortages, reliance on foreign workers for such a large portion of the workforce may leave the industry vulnerable to changes in policy or other external factors.

Automation provides an avenue for growers to help reduce costs, gain efficiencies and reduce risks. Automation also offers an opportunity to become more cost-effective with a significant return on investment for growers with the introduction of labour efficiencies, increased disease detection and resource management.

Despite the automation potential to improve efficiency, automation still faces some challenges in terms of adoption by the Canadian horticulture industry. Although the greenhouse sector is a leader in the adoption of horticultural automation in Canada, the current solutions (mostly planting and postharvest) do not always apply to the Canadian context; as well, there are opportunities for automation to provide solutions in disease detection, harvesting, and more. For unstructured field environments, there is a limited availability of automation solutions as the complexity of the growing environment presents challenges for automation. Furthermore, the engineering required to create an automation system that will operate as well or better than humans, may not result in a cost-effective solution.

Automation continues to grow in importance in the horticultural industry. It is estimated that labour trends and economic factors will continue to drive the value of the global agricultural robotics market to $16.3 billion by 2020 and $73 billion by 2024.[5] Driving forces in the horticulture sector that are influencing the adoption of robotics include:

- Increasing size of production facilities
- Labour costs
- Product prices
- Skilled labour availability
- Employee health and safety
- Specialization of crop production
- Individualization of plant treatment (precision agriculture)
- Growing consumer attention to food quality and food safety

Overall, Canada lags in the development and adoption of automated systems in horticultural production. The most developed sector is the greenhouse industry which has adopted automation technology, mostly imported from other countries, such as the Netherlands. Canada has made great progress in adapting Dutch technology to Canadian conditions and markets but as they seek to grow beyond their current size they will require new knowledge and discoveries. That technology needs to be discovered and developed here in order to best fit the needs and priorities of Canadian producers.

[5] Estimate by U.S. marketing firm, Tratica

## 1.2 Trends in automation technology development

Perspectives on the following four leading trends were provided by symposium speakers.

- System of systems – Prof. Eldert Van Henten, Head of the Farm Technology Group, Wageningen University
- Big data for horticulture – Krijn Poppe, Business Development, Wageningen University
- Decision support systems – Dr. George Kantor, Senior Systems Scientist, The Robotics Institute, Carnegie Mellon University
- Digital growing: the LetsGrow.com system – Peter Hendriks, Business Unit Manager, LetsGrow.com

### System of systems

Horticultural production can be viewed as a system of systems. Taking a system of systems view means that the steps in a particular process act not as individual steps but as a network, with one part of the system influencing other parts of the system. In order to optimize within a system of systems, solutions must incorporate and account for how the interactions between different parts of the system affect the network of the system. For example, a harvest automation solution may impact how the crop must be planted or pruned, so the automation solution must consider how changes in this network impacts efficiency and profitability. The most developed system, in terms of horticulture automation, is greenhouse production.

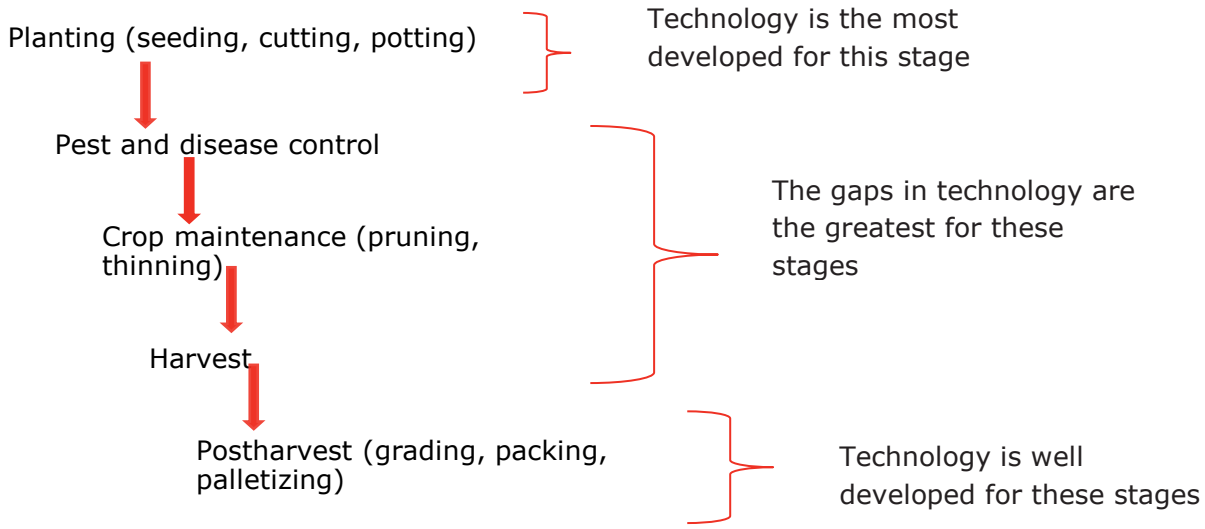



**Figure 1. State of the art in global greenhouse mechanization**

Automation technology is most developed for the initial and final steps of the greenhouse production process because these tasks deal with the position, size and shape of clearly defined objects. More gaps exist in crop maintenance and harvesting since these steps require the intelligent transformation of perception into mechanical action, which is a difficult task for robotics. Since people are better able to make smart decision-making in complex environments, technology can be used to support human labour in these tasks. For example, sensor technologies that can surpass human capability can be used to improve

product quality and consistency (e.g. hyperspectral imaging to detect ripeness). The detection of pests and disease is also an area where automation can support timely management decisions.

Opportunities to enhance horticultural automation include:

- Development of generic (multi-purpose) capabilities (detection, localization, actuation) for re-use in different applications. Collaboration with other industries to cross-apply technologies developed for other purposes.
- Engagement in a multi-disciplinary approach – including growers through to consumers, as well as plant scientists
- Recognition of company logistics and economic factors from the earliest stage of development
- Identification of pre-competitive issues that the industry can work on together

## Big data for horticulture

Information and communications technologies (ICT) continue to be disruptive technologies, including the Cloud, the Internet of Things (IoT), and social networks. These trends will influence prescriptive agriculture, predictive maintenance, and enhanced tracking of food from the grower right to the consumer's refrigerator. The uses of big data in horticulture will also be influenced by:

- Food security and food safety issues
- The impact of climate change
- An increased focus on the environment
- Consumer needs and perceptions about health and diet

The ability to collect and leverage big data may also have an impact on the marketing of food. It is possible that the global value chain governance will move towards alternate systems, based on the governance types identified by Gerrefi (below).[6]

[6] Gerrefi G. et al., The Governance of Global Value Chains, Review of International Political Economy, 12(1), 2005.

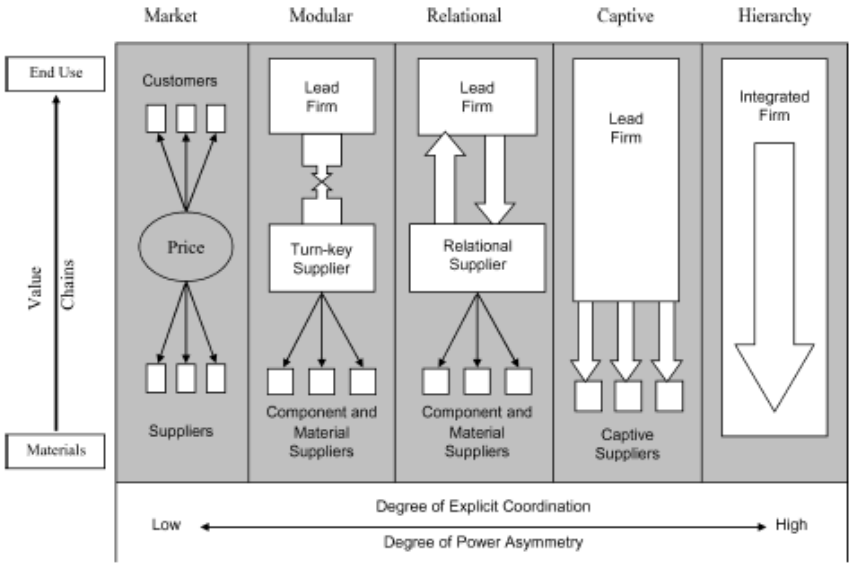



**Figure 2. Five global value chain governance types**[7]

Big data, globalization, sustainability and other factors may drive food chain governance toward two scenarios: (a) a captive product chain (franchisee with limited freedom) or (b) an open network collaboration (integrated and complex). Other countries are responding to the opportunities and challenges of big data in agriculture by defining ICT strategies.

In the European Union, the IoF2020 project (the Internet of Things for Farms) strives to combine, aggregate and benchmark data. The Agri-ICT Research Strategy:

- Promotes data exchange (via standardization, platforms, open data)
- Promotes innovation (that starts in ICT, IoT, big data)
- Offers advisory services in real-time

An example of big data application in horticulture is to use collected data to identify and prescribe changes within the system of systems by recognizing hidden interconnections among the systems. In order to take advantage of the opportunities provided by big data, there is a need for a coordinated ICT strategy and the connection pathways to facilitate the collection and exchange of data.

[7] Gerrefi G. et al., The Governance of Global Value Chains, Review of International Political Economy, 12(1), 2005.

### Decision support systems

Currently, there are several technologies available to support decision-making in horticultural production. These capabilities include:

- Autonomous vehicles
- Wireless In Situ Monitoring and Control
- Crop-modelling-based control
- Photosynthetic sensors to aid in decision-making
- Plant breeding rapid phenotyping of progeny

In order to increase the usefulness and maximize the return on investment for new technology development, there is increased effort in making automation tools multi-purpose/generic so that they can be used at several stages of plant growth or in multiple crop types.

The major gaps that exist in decision support systems are (a) the automatic conversion of data into actionable information and (b) intelligent cost-effective manipulation of plants or produce in both structured and unstructured environments (i.e. in the field).

### Digital growing

A new trend in horticulture production is digital growing – the ability to digitize the entire plant growth cycle. One example of this is Letsgrow.com based in the Netherlands. The availability of sensors has permitted the collection of data about multiple aspects of greenhouse production including climate, plant growth, and manual inputs through to sales. This data can add value to producers by using plant models that predict disease, energy demand, and provide decision support for the management of the crop.

When data is shared between producers and facilities, value can be added by allowing growers to benchmark their production system, and by assessing key performance indicators (KPIs) growers can manage multiple locations or multiple processes more effectively. Coupling this approach to big data collection and analysis should enhance its usability and impact.

## 2.0 Vision and Strategy Development

Following speaker presentations and the question and answer session, participants engaged in a facilitated group discussion that included a visioning exercise, survey results to ultimately identify key considerations and priority areas of focus for the automation strategy.

### 2.1 What does success look like in 10 years?

At the symposium, a visioning exercise asked participants what successful automation in the horticulture sector would look like in 10 years. The collected ideas of the group follow.

In 10 years, automation and big data would successfully be used to:

- Reduce labour costs
- Reduce input costs
- Manage resources, conserve water and energy
- Increase consistency of product
- Lead to proactive decision-making
- Increase yield
- Provide precision in packaging, sorting, quality control
- Control inventory and track products
- Help meet regulatory and quality standards
- Increase competitiveness of the Canadian horticulture sector

## 2.2 Applications most likely to benefit from automation

31 symposium participants completed a survey that included a question asking them to rank the horticulture production activities that would benefit most from automation, "1" being the area that would benefit the most and "5" being the area that would benefit the least.

### Priority ranking of automation benefits by production stage

| | Number of responses for each rank | | | | |
|---|---|---|---|---|---|
| **Rank of 1-5** | **Planting** | **Pruning, thinning** | **Pest and crop management** | **Harvesting** | **Postharvest** |
| **1** | 4 | 3 | 4 | 9 | 11 |
| **2** | 8 | 6 | 5 | 7 | 5 |
| **3** | 2 | 9 | 11 | 5 | 5 |
| **4** | 6 | 4 | 7 | 5 | 4 |
| **5** | 9 | 7 | 2 | 3 | 4 |
| **Summary** | **Low** | **Low** | **Medium** | **High** | **High** |

Respondents saw more benefit from automating the processes at the end of the growing cycle (harvest and postharvest) than automating those at the beginning (planting, pruning, etc.). 35% of respondents identified postharvest as the area of primary production that could benefit most from automation, followed closely by harvest at 29%. Postharvest tasks may be more generic and the equipment may be more easily transferred between commodities. Although the diversity of packaging requirements by retailers increases complexity, it may also provide a competitive advantage and/or premium pricing for growers. Harvest is often perceived as the largest labour cost, however, this cost differs between crops. Harvest is also viewed as the most difficult to fully automate, thus developing labour support or partial automation solutions are likely the best approach.

## 2.3 Barriers to adoption

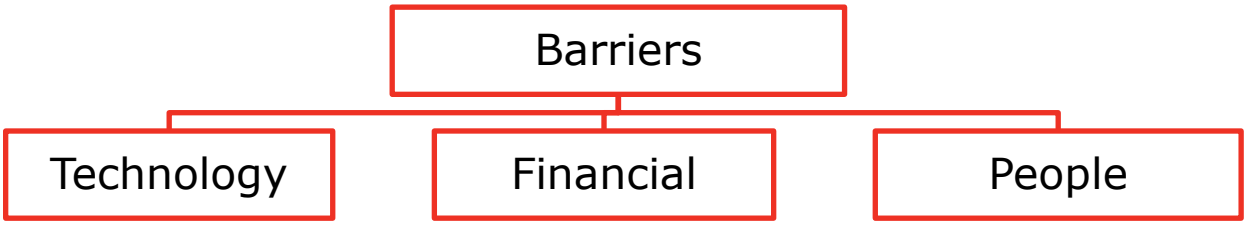
In the same survey, respondents were asked to rank a list of barriers to technology adoption in order of their impact on the Canadian horticulture, "1" being the biggest barrier to adoption and "5" being the least important barrier to adoption.

More than one third of respondents listed "Resistance to change production systems" as the top barrier to adopt automation technology in Canadian horticulture. High capital investment and difficulty securing financing was the second top barrier, followed by uncertainty in the return on investment. Lack of training or know-how in using the technology was not seen as a significant barrier.

**Priority ranking of barriers to adoption of automation technology**

| | **Number of responses for each rank** | | | | |
|---|---|---|---|---|---|
| **Rank of 1-5** | **High capital investment/ Difficult to get financing** | **Low/ uncertain ROI** | **No appropriate technology available/ Difficulty to source equipment** | **Lack of training/ know-how** | **Resistance to change current production systems** |
| **1** | 7 | 5 | 5 | 1 | 11 |
| **2** | 11 | 11 | 3 | 5 | 3 |
| **3** | 5 | 4 | 9 | 5 | 11 |
| **4** | 7 | 9 | 7 | 6 | 3 |
| **5** | 1 | 2 | 7 | 14 | 3 |
| **Summary** | **High** | **Medium** | **Medium** | **Low** | **High** |

The main barriers to automation adoption were resistance to changing production systems and the associated high capital costs to adopt automation. Further exploration of these barriers resulted in the following constraints that can be divided into three categories: technology, financial, and people.




- Diversity of horticulture crops grown in Canada
- Large number of varieties per farm operation
- Specialized packaging requirements are increasing
- Perishable and fragile product is difficult to handle with automated systems
- Growers need to meet regulatory changes (food safety, labour standards, etc.)

- Overhead and operating costs (energy - high percentage of cost of production)
- Risk in developing new technology for small markets
- Cost of automation technology (equipment as well as changes to operation)
- Cost of automation technology R&D

- Labour costs (high percentage of cost of production)
- Lack of skilled labour/talent available
- Collaboration and data sharing is not common practice
- Reluctance to change production practices by some growers
- Gap in leadership to promote the implementation of automation

**Figure 3. Barriers to adopt automation technologies**

Reducing these barriers and increasing the adoption of automation technologies could be accomplished using the following approaches:

- A gradual adoption of automation can start with the introduction of technology to support decision-making and existing human labour
- Increased ROI may be realized with generic solutions that can be used for multiple stages of production or multiple crops
- The development of locally-based automation solutions will permit collaboration between technology developers, equipment manufacturers and end-users from the earliest stage of development
- The industry needs to foster a culture of data sharing and collaboration to realize the benefits of big data and automation

## 2.4 Key considerations

Several common themes emerged from the discussion at the symposium which describe key considerations and areas for research and technology development.

### Collaboration and data sharing

- Collaboration will be integral for maximizing the usefulness of big data. Efforts should be directed at enhancing the capacity and willingness of the industry to collaborate. Developing a culture of collaboration could start by identifying pre-competitive

projects to foster collaboration in the sector. These should include both public and private partnerships.
- Technology and big data solutions are needed to help growers reduce input costs. Water, fertilizer and pesticides represent high input costs as well as areas of significant government oversight. Big data solutions are required to increase precision, reduce input costs and also help growers meet regulatory demands. This responds to the market need for efficient solutions in terms of time, labour and energy.

**Labour support systems**

- Focus on labour support systems that can help people work more effectively, rather than trying to replace labour completely for a particular task, was discussed as a viable strategy for the sector.
- Try to fully automate tasks that require complex decision-making such as pruning and harvesting fruit will be very difficult. However, making labour more efficient at these tasks will be more achievable and still provide a financial benefit to growers (reduce labour costs through partial automation).
- Develop technologies to help make people working in the horticulture sector more efficient at the tasks that require complex decision-making (pruning plants, picking fruit, etc.).
- Develop technologies that can reduce time spent/labour cost on repetitive actions/processes that are most easily automated (handling/moving product, monitoring crop conditions, planting, etc.).

**Decision support systems**

- Focus R&D on developing decision support systems. Automation technology can be used to assist workers in their ability to perform repetitive tasks, or enhance their ability to make management decisions faster, earlier, and/or more accurately.
- Increase precision at any stage of production should be a priority. Automation of data collection and analysis aimed at making smarter decisions earlier in the production cycle to increase yield, reduce inputs and/or reduce quality losses.
- A systems approach must be used to develop a holistic view of the production system and an understanding of how the technology affects the whole production system. For existing production systems, the impact of one technology on other parts of the system must be considered.

**Multi-use/generic capabilities**

- Research and development on multi-use or generic automation technologies is desirable. For example, technology that can be used at more than one stage of crop production or that can be used for more than one crop type.
- Multi-use technology will have a broader application in the marketplace (rather than just appealing to one crop type or type of operation). This will be a benefit to the technology developers/manufacturers but might also be more applicable to a wider range of Canadian growers such as orchard and ornamental growers.
- A research focus could be on tasks that are repeated more than once per year, or across different crop types.

## Return on investment (ROI)

- Growers need to be engaged in all stages of technology R & D and validation testing (demonstration) so that the return on investment is clear. This will reduce risks for domestic suppliers of automation technology and increase the likelihood of technology adoption by Canadian growers.
- Operations most ready for automation are mono-crop operations, growing large-scale crops. These technology-ready systems should be analyzed to determine which stages of production would benefit from technology but also determine whether the competitive technology already exists or is being developed. Looking for the gaps and unmet needs of these larger operations may provide opportunities that have a positive ROI for growers as well as technology providers.
- Adapting existing automation technology to meet the current production systems and needs of Canadian growers might provide the highest ROI for growers. This is an opportunity worth pursuing both in greenhouse and field (unstructured) production.

## Develop locally-based R&D solutions

- Locally-based R&D solutions can also lead to a higher level of trust in the technology and a more direct route for effective knowledge translation and transfer (KTT), in particular where co-development of the technologies occur.
- There is both a need and opportunity to accommodate current growing systems from the initial stage of equipment design. Therefore, growers need to be involved at the outset to ensure that the technology will be used and that the adaptations to current production systems are manageable and feasible.
- As mentioned previously, finding unmet needs and avoiding areas where competitors can provide automation technology at a lower cost will be a key for success.

## 3.0 Horticulture Automation Technology Strategy

The long term goal for this strategy is to: increase the competitiveness of the Canadian horticulture sector through innovation in automation and supporting technology. Specific targets were identified as follows. Further crop-specific targets should be defined in such a way to contribute to these overarching sector targets.

1. Increase labour efficiency with automation that supports people to work more efficiently. Target: 50% reduction in overall labour cost per unit of production in 10 years
2. Increase the efficiency of crop inputs through improved decision support tools and process automation. Target: 50% reduction in overall use of crop inputs (energy, water, fertilizer, pesticide) per unit of production in 10 years.

In order to achieve these long-term goals, three areas of priority were identified for technological development and adoption. In order to succeed, these must be underpinned by a guiding principle of collaboration and co-development that includes growers, researchers and manufacturers.

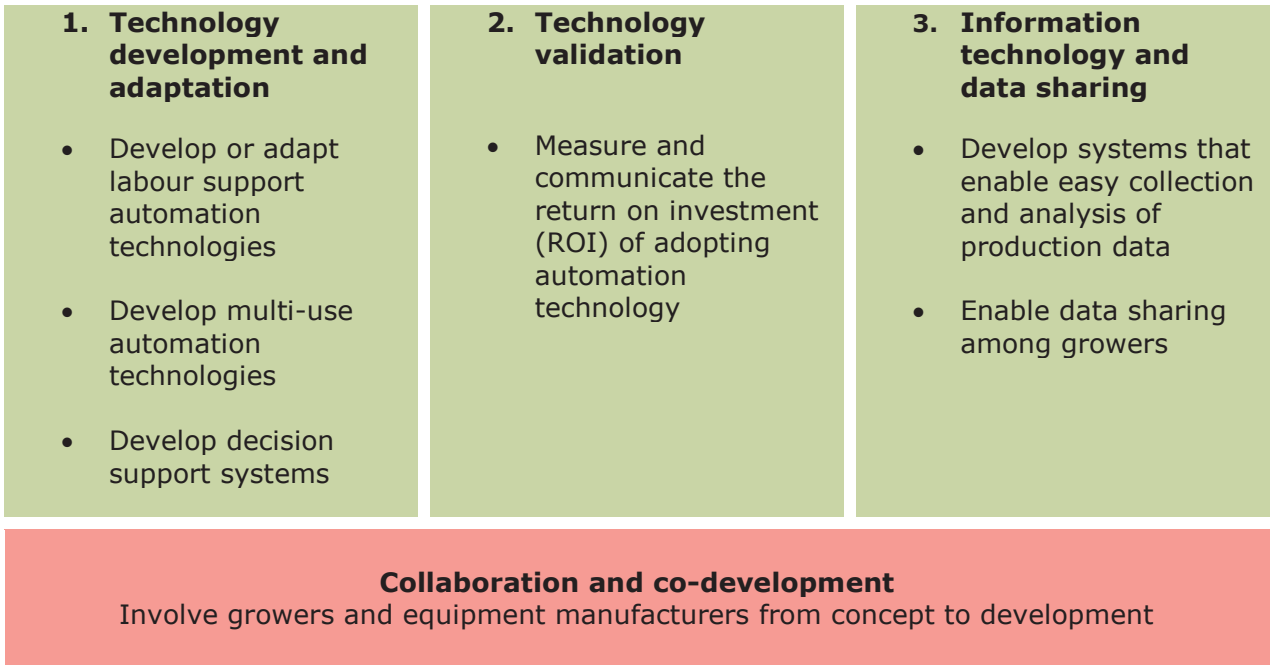



**Figure 4. Automation technology strategy: priority areas**

## 3.1 Technology development and adaptation

### Opportunity: Develop or adapt labour support automation technologies

- Focus research and development on labour support systems that help people work more efficiently and safely (rather than replacing labour)
    - Help to make people working in the horticulture sector more efficient at the tasks that require complex decision-making (pruning plants, picking fruit, etc.)
    - Reduce time spent/labour costs on repetitive actions/processes that are most easily automated (handling/moving product, monitoring crop conditions, planting, etc.)
    - Intelligent systems may support repeated decision through data mining (imitating the capabilities of growers)

- Focus technology development efforts on postharvest, harvest and planting stages of production for both greenhouse and field production systems
    - Postharvest handling and sorting of crops
    - Harvest operations
    - Planting operations

- Focus on adapting existing technology to meet the needs of Canadian growers whenever possible (rather than re-inventing technology that may already exist)
    - Some sub-sectors, for example planting and postharvest activities in the greenhouse environment, already have well-developed automation technology available from other countries such as the Netherlands
    - Look for opportunities to adapt these technologies to better meet the needs of the Canadian industry (possible unmet needs could be special climate/environment factors, expand uses of technologies to more/different crop types, develop technologies to fit into existing infrastructure, etc.)

### Opportunity: Develop multi-use automation technologies

- Develop multi-use automation technologies that can be applied to several tasks/functions as a way to increase return on investment for growers
    - Automation technology that can be used for more than just one operation or more than just one crop/variety will have a potentially larger market size which is a benefit for the equipment developers/manufacturers. It can also help increase ROI for growers who may be using the technology at several times during the production cycle or on several different crops.

**Opportunity: Develop decision support systems**

- Focus on technology development of improved data collection and decision support tools to improve crop management and quality control
    - Automated crop monitoring/scouting and notification systems in greenhouse as well as field production can be a benefit to growers and may be an easier entry point for adding automation into an existing operation
    - The expected outcome will be reduced input use/cost per unit of production through higher yields of product that meet the desired quality standard and/or reduced crop inputs required

## 3.2 Technology validation

**Opportunity: Determine return on investment**

- Measure and communicate the return on investment of automation technology in both greenhouse and field crop production systems
    - Resistance to change current production systems was mentioned as a major barrier to adopt automation technology
    - Proving and demonstrating the simplicity and value, and then communicating the benefits and ROI to growers will help to overcome the barriers to change such as:
        - Culture change that may be required when adopting new technology
        - Financial decision on the investment in new technology
        - Make it easier for financing these new investments (availability of financing)

## 3.3 Information technology and data sharing

**Opportunity: Develop systems that enable easy collection, analysis and sharing of data**

- Enable easy collection, analysis and sharing of production data for growers as a way to:
    - Measure the benefits/ROI of adopting new innovations
    - Track sustainability metrics such as fertilizer, energy and water use efficiency
    - Benchmark progress against peers and their own operation in terms of output, labour costs, input costs

## 3.4 Guiding principle: Collaboration and co-development

- Automation research initiatives should actively involve the collaboration between growers and equipment manufacturers from concept to application

- A co-development approach and philosophy will increase the probability of success and applicability of the research
    - Ensure that the technology being developed is practical
    - Ensure that the technology will meet the current and future needs

- Ensure that the technology can be realistically adopted into current horticulture production systems
- Enhance the development and sustainability of the domestic manufacturing sector

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