Technology & Innovation Roadmap for Ontario Tree Fruit

Ontario Tender Fruit Growers

ONTARIO APPLE GROWERS

March 2021

Ontario's Tree Fruit Industry

- The Ontario apple and tender fruit sectors are becoming increasingly efficient with:
  - ongoing investments in advanced technologies,
  - improved storage techniques,
  - irrigation,
  - frost protection,
  - mechanization, and
  - conversion of older orchards to newer varieties and high-density

Opportunities

- Acreage may be decreasing but production volume per acre has steadily increased as growers adopt new technologies.
- Number of tree fruit growers has seen a sharp decline.
- Remaining growers are managing more acres to maintain economic efficiencies.
- Ontario is a net importer of tree fruit both in fresh and processed form.
- Substantial opportunity to increase production, recapture import market share while increasing greater food autonomy for Canadians.
- Ontario's tree fruit sector, both apple and tender fruit, have worked on developing new varieties suited for our climate to introduce to our strong consumer base.

With these new initiatives taking hold, there is a clear vision to bridge the gap and revitalize tree fruit orchards from current conventional orchards to newer state-of-the-art orchards.

Challenges

- Adverse Weather
- Crop Protection
- The COVID-19 pandemic (food security and local supply chains as a priority)
- Human resources and the critical role of temporary and seasonal foreign workers
- Solutions needed to reduce risk of COVID-19 transmission for a safe work environment

The drive is on, now more than ever, to develop and adopt new technologies and new innovative processes that address agriculture's labour challenges.

Objectives of the Report

- Key Focus:
  - To provide resources to encourage adoption of technologies and innovations that bring about a positive change to reduce risk of COVID-19 transmission and help address labour challenges faced by the sector.

Survey

- 87 tree fruit growers responded
- Represents about 25% of all growers, they reported growing
  - 5,838 acres of apples (45% of Ontario's 13,000 acres)
  - 4,945 acres of tender fruit (56% of Ontario's 8,756 acres)

District	Response %	# of Growers
Western	15	13
Central West	13	11
Northern	7	6
Central	58	50
Eastern	8	7
		87

Survey cont'd

- Median farm size was 60 acres.
- Many operations reported growing both apples and tender fruit however;
  - 16 of the 81 (20%) were identified as solely apple growers with more than 50 acres
  - 16 (20%) were identified as solely tender fruit growers with more than 50 acres.
- Of these apple grower responses:
  - Collectively they operate 3,581 acres
  - Plan to employ 7% more workers in 2021 vs. 2019, optimism during Covid-19
  - operating at about 4.8 acres/worker
- Of these tender fruit grower responses:
  - Collectively operate 2,421 acres
  - Plan to employ 5% more workers in 2021 vs. 2019, optimism during Covid-19
  - operating at about 3.5 acres/worker
- Suggests apple growers may have an advantage over tender fruit growers in labour efficiency, there are many reasons for this:
  - farm size
  - one crop (apples) versus many (peaches, nectarines, plums etc.)
  - High-density apple orchard systems and trellised fruiting walls allowing for more efficient pruning, thinning, and harvesting.

Fundamental Technologies

With heightened attention being given to labour-saving robotics and other innovative tools for tree fruit growers, strategic concentration must be given to the development of 2 main fundamental technologies:

1. Data management systems to track, understand and guide technological decisions (and sufficient high-speed connectivity to operate them)
2. Orchard planting systems that will be able to accommodate such breakthroughs

These 2 fundamental technologies are essential to implementing other new technologies.

Data Management System

- An essential tool for collecting and monitoring data to manage all aspects of fruit growing operations.
- A necessary piece of the puzzle when planning to incorporate new technologies and future innovations.
- In many cases, new technologies feed into existing data management systems making them even more robust for growers.
- Future innovative solutions are looking at bringing together real-world sensor and non-sensor data such as labour, crop protection, water and soil data, harvest data and imagery data to bring growers insights that are of value to their operations.

HIGH-SPEED INTERNET CONNECTIVITY

Reliable high-speed internet is no longer a luxury it is necessary for everyday life, and it is necessary for implementing new technologies on farms across Ontario.

Apple Orchard Infrastructure

- High-density, trellised production is shown to be more profitable compared to non-trellised orchard
  - In the OAG 2018 COP, high-density orchards have a greater initial investment, but the returns exceed expenses in the 5th year after planting for high-density compared to the 9th year for medium-density.
- The most common systems are tall and super spindle structures, but there are many types in other areas, including vertical low and high trellis, V and T trellis, and bi-axis.
- The planar cordon concept features multiple stems to control and distribute the canopy growth. Future systems likely will continue to utilize highly branched trees for high early yields.

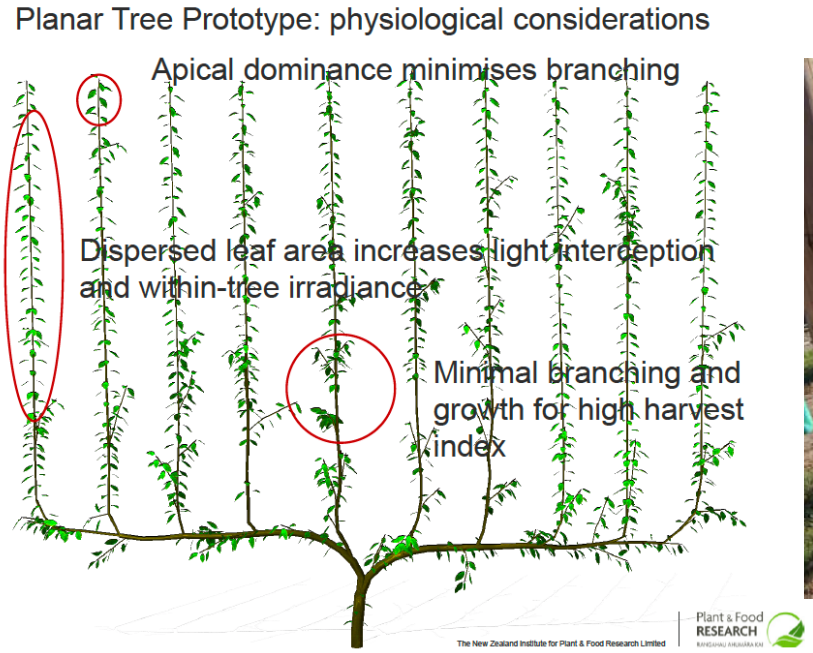
“Planar canopy for automation is really the future.”

Dr. Stefano Musacchi (IFTA Conference 2021).

Canopy shape Bi-axis vs Spindle and V-system

WSU TREE FRUIT ENDOWMENT

Orchard Infrastructure – Apple



Planar cordon concept that features multiple stems to control and distribute the canopy growth with the ultimate goal to increase light into the canopy

Innovative Technologies for Ontario Tree Fruit

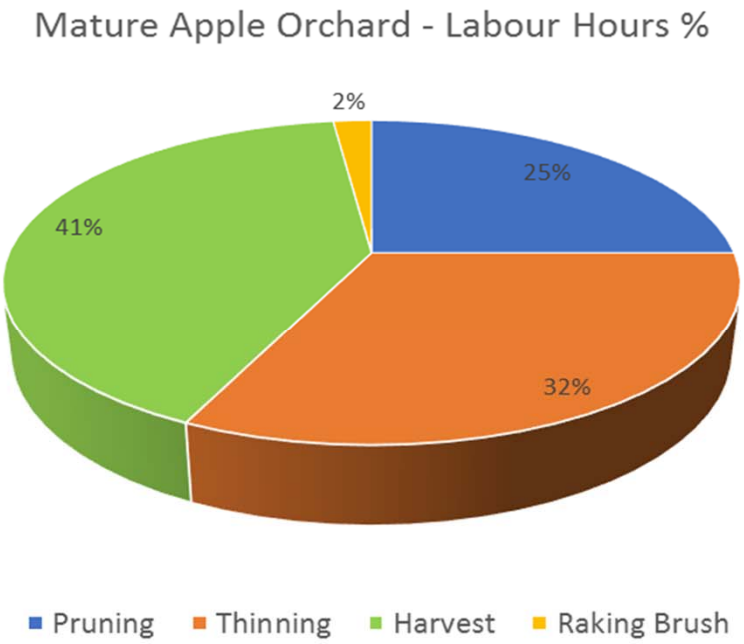
A catalogue of innovative technologies was created for each aspect of the industry including:

- Crop Production: Pruning and Training; Thinning; Harvesting; Tractor Operations
- Crop Protection
- Post-Harvest
- Adverse Weather
- COVID-19 Transmission Mitigation

Crop Production – Pruning, Thinning, Harvesting

- Tree fruit growers overwhelmingly agree that new technologies can help reduce the main hand labour activities; harvest and thinning are the two most intensive practices

Graph 1: Fresh Market Apple - Mature Orchard (per acre)



Source: 2018 Ontario Apples Establishment and Production Costs

Crop Production – Pruning, Thinning, Harvesting

- Innovative prediction models being used to target more precise crop loads include:
  - Pollen Tube Growth Model
  - Fruitlet Growth Model
  - Carbohydrate Thinning Model
- Current research for precision crop load management focuses on automated counting and sizing of blooms, fruitlets and fruit using camera images, sensors and algorithms.

Crop Production – Pruning, Thinning, Harvesting

Survey: *Technologies for pruning and training used recently to reduce labour*

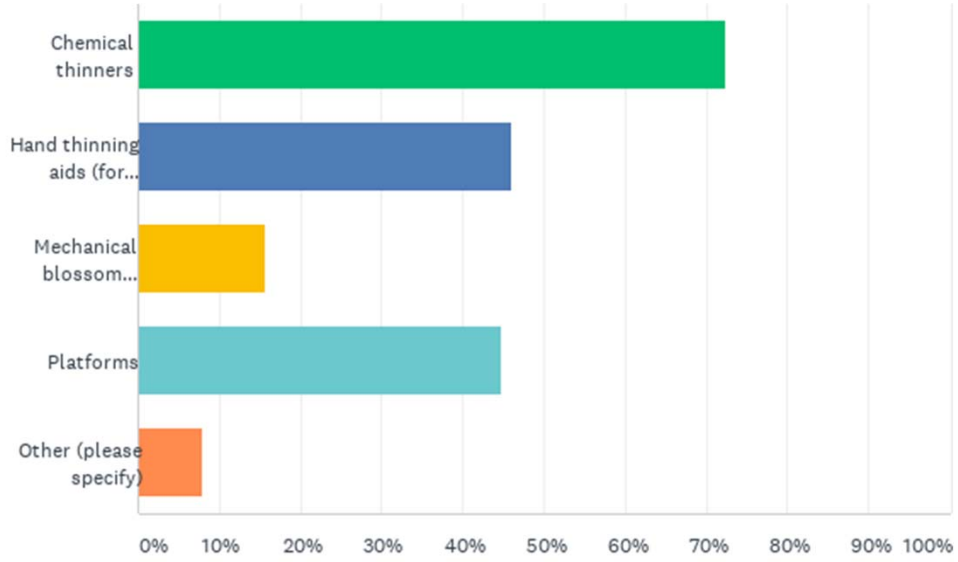
Answer Choices	Responses (%)
Battery operated pruners	54
Hand pruners & loppers	54
Mechanical pruning (Saw blades)	39
Platforms	46
Pneumatic pruners	32
Summer pruning (hedger)	30
Other	13

Survey: *Technologies growers are aware of or would like to see to reduce labour in pruning and training your trees:*

- Technology for making larger cuts in trees, cuts that are too big for shears
- Tighter plantings with shorter trees; 8-foot row spacing possibly
- On-line training modules for workers
- AI (smart) controls for pruning; take the decisions away from workers

Crop Production – Pruning, Thinning, Harvesting

Survey: *Technologies for thinning used recently to reduce labour*



Survey: *Technologies growers are aware of or would like to see to reduce labour in thinning your trees*

- More chemical options, especially for tender fruit; more research on different fruit growth stages; more availability from other growing areas; shorter re-entry intervals
- Robots that would 'learn' where fruit will be located, thin some, then know how and where to harvest later

Crop Production – Pruning, Thinning, Harvesting

Survey: Technologies for harvesting recently used

Answer Choices	Responses (%)
Harvest machines with/without bin carriers	32
Harvest machines with vacuum technology	4
Platforms	46
Other	45

Survey: *Technologies growers are aware of or would like to see to reduce labour in harvesting your crop*

- Platforms (13 growers) with various options (conveyors, bin fillers, robotic harvesting, GPS-guided, autonomous, multi-levels)
- Robotic harvesting (15 growers) 24/7 with minimal supervision (working prototypes are in other jurisdictions)
- Autonomous bin carriers
- Drone pickers
- Simpler RFID systems with better data collection on yields/block and inventory control
- Trellises for tender fruit would be a game changer
- Wearables that track worker productivity

Crop Production – Pruning, Thinning, Harvesting

Platforms	Pruning
Battery-operated Pruners	
3-wheeled bucket	
Hedgers (summer pruning)	
Mechanical leaf removal	
Battery-operated tying machine (for training)	
Plant Growth Regulators (PGR)	
Precision pruning (using computer vision and robotics)	
Platforms	Thinning
Chemical thinning	
Mechanical blossom thinner	
Hand operated blossom thinners	
Precision thinning (using computer vision and robotics)	
Platforms and harvesting machines	Harvesting
Harvest containers – bins and plastic totes	
Bin carriers, trailers	
Vacuum harvesting	
Robotic harvesting (using computer vision and AI)	

Platforms for Pruning, Thinning, Harvesting

EVALUATING NEW TECHNOLOGIES

	Feasibility and cost	Implement	Labour Reduced	Changes in production	Training for staff	Impact on risk of COVID-19 Transmission
Crop Production Activity	low, medium, high	easy, medium, challenging	% estimate	easy, medium, hard	none, medium, high	none, low, medium, high
Platforms - Pruning, Thinning, Harvesting	medium-high	easy	30-50	easy	medium	high

Current Status

- High-density trellised orchards can be easily mechanized using labour positioning platforms to reduce labour requirements.
- Platforms are multi-use and very suitable for partial mechanization of several **orchard** tasks including dormant pruning, hand thinning, building trellis, leader selection, tree training, summer pruning and harvest.
- It is estimated by manufacturers that one platform is needed for 50 acres.

Platforms for Pruning, Thinning, Harvesting

Feasibility of Implementation

- Platforms are costly, but because platforms are multi-purpose and used for several in-orchard tasks the return on investment is greater for growing operations
- Payback in 2-3 years depending on the number of acres
- More apple growers are using platforms and harvesting machines for harvest which can be made easier to implement with bin carriers.

Impact on Labour

- Sidewall shearing using platforms to produce narrow fruiting walls can reduce summer pruning costs and further facilitate partial mechanization of harvest
- Labour efficiencies gained from using platforms from OMAFRA Study in 2011:
  - Pruning on platforms is approximately 25% faster than workers using ladders
  - Training and tying tree leaders to stakes was 77% faster
  - Thinning was 46% faster from a platform compared to using a ladder
  - Harvest was 18% faster from a platform compared to using a ladder
- Most apple growers report - using platforms is one of the best labour savings devices for harvesting
- Workers reported - they liked working on the platforms, only one task to do and had less fatigue.

Platforms for Pruning, Thinning, Harvesting

Impact on Risk of COVID-19 Transmission

- Increases labour productivity and reduces labour requirements, therefore lowers the risk of COVID-19 exposure and transmission for growing operations
- Workers on platforms can wear PPE, be be spread far enough apart and barriers can be installed for increased protection to reduce the risk of transmission.

Need for Operational Change, Research and Training

- Implementation would require some training and a specialized set of skills for the operator of this equipment.
- It would also require the need for various operational process changes for the farm.
- However, very little additional training is needed for workers when working from the platforms.
- Safety equipment and training would be required.

Vacuum Harvesting

EVALUATING TECHNOLOGIES

	Feasibility and cost	Implement	Labour Reduced	Changes in production	Training for staff	Impact on risk of COVID-19 Transmission
Identified Technology	low, medium, high	easy, medium, challenging	% estimate	easy, medium, hard	none, medium, high	none, low, medium, high
Vacuum harvesting	unknown	challenging	30-50+	medium	medium	high

Current Status

- Current research trials and pilots of vacuum harvesting technologies in apple producing areas including Washington, U.S., and New Zealand.
- One type of vacuum harvest technology uses a self-propelled platform which has two individually operated hydraulic workstations with controls giving pickers on the platform maximum tree access and allowing the entire tops of trees to be picked from one side in plantings from 8’ to 14’ high.
- With the vacuum system, apples are placed into a small, lightweight bucket-style inlet with no apple-to-apple contact all the way into the bin.
- This technology is more like a harvest-assist machine and allows for the elimination of ladders and bags for harvest.
- Some vacuum systems can bolt on to an existing harvester and can go anywhere growers are using platforms currently.

Vacuum Harvesting

Feasibility of Implementing

- Thinner, more uniform, fruiting walls lend themselves more easily to vacuum harvesting technologies.
- Some providers are offering this technology as a custom harvest solution model with a cost-per-bin type fee. This solution would provide the machine, support, operator, and maintenance services.
- Quality standards would be a significant consideration when considering the feasibility of implementing this technology.

Impact on Labour

- This harvest-assist technology means that pickers only need to pick.
- It would increase labour productivity and efficiencies by saving time during the actual harvest process by reducing the need for pickers to climb ladders, walk back and forth, and eliminates the time it takes for pickers to turn around to empty harvest bags into bins.
- The goal of this technology is to make fruit harvesting faster while achieving the same or better-quality metrics as those achieved through hand harvest.

COVID-19 Mitigation Risk

- increases labour productivity and reduces labour requirements for harvest, therefore lowers the risk of COVID-19 exposure and transmission for growing operations

Need for Change, Research and Training

- The need for operational/process changes, research and training for growing operations would likely be substantial to implement vacuum harvesting technologies.
- Capacity for speed of harvest and monitoring the quality of fruit harvested may be challenging.
- With some vacuum harvesting solutions being developed as “pick and play” technology to be attached to pre-existing platforms this technology would not be as challenging to implement in comparison to full robotic harvesting.

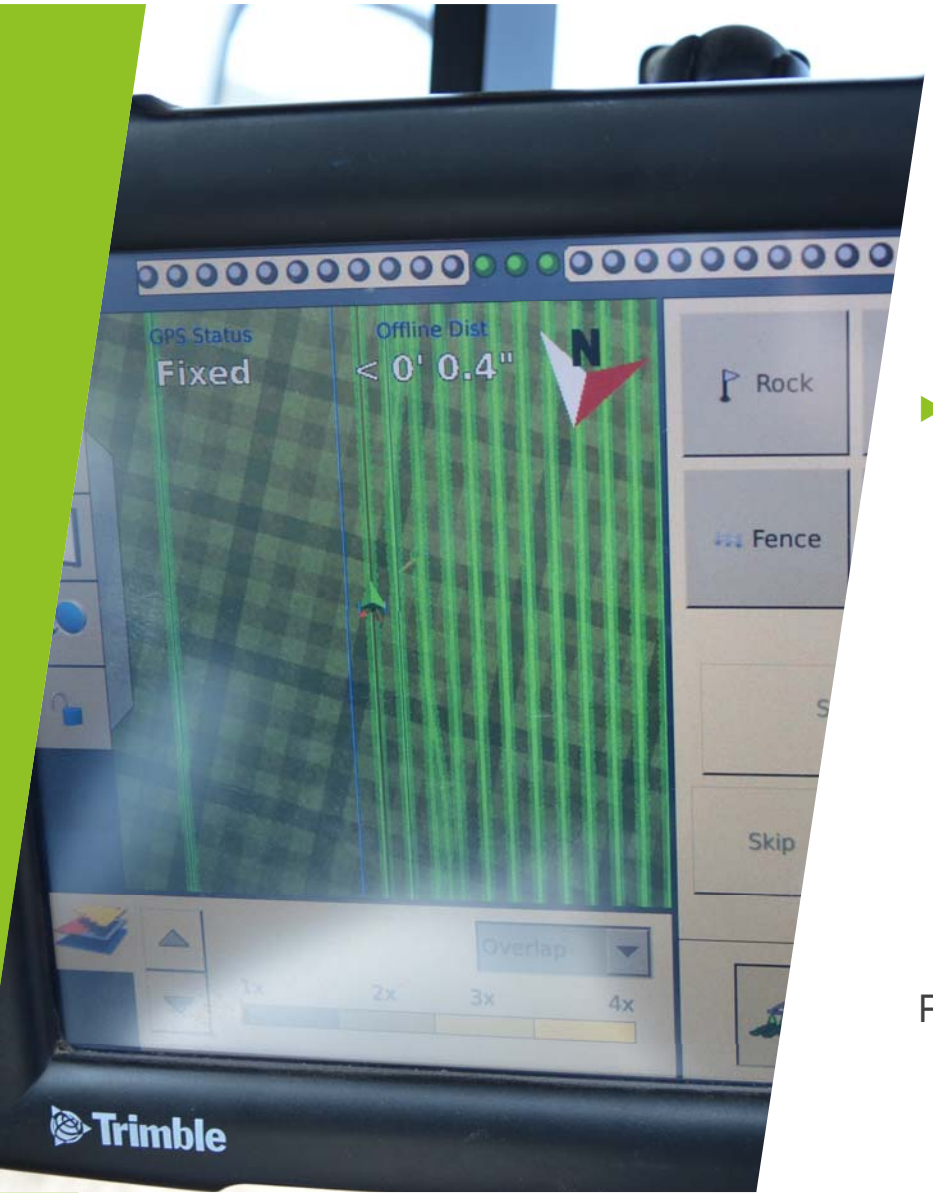
Vacuum Harvesting

- VACUUM HARVESTER: The DBR Bandit Cyclone, manufactured by Automated Ag, takes harvest-assist technology to the next level with a self-propelled machine that goes through rows.

Precision Pruning/Thinning - Computer Vision/Robotics

EVALUATING NEW TECHNOLOGIES

	Feasibility and cost	Implement	Labour Reduced	Changes in production	Training for staff	Impact on risk of COVID-19 Transmission
Crop Production Activity	low, medium, high	easy, medium, challenging	% estimate	easy, medium, hard	none, medium, high	none, low, medium, high
Precision pruning (using computer vision and robotics)	unknown	challenging	50+	easy	low	high



Crop Production – Tractor Operations

- Tractor operation technologies identified and evaluated:
  - Autonomous tractors
  - Dual PTO tractors
  - GPS guided tree planters
  - Mechanical brush sweeper
  - Mechanical weed control

Fact sheets available for each

Crop Protection

- Crop protection technologies identified and evaluated
  - Autonomous sprayers
  - Detection systems to apply sprays
  - Multi-row spraying equipment
  - Data management software / spray tracking module
  - Weather stations

Fact sheets available for each

Crop Protection – Detection Systems for Sprays

EVALUATING NEW TECHNOLOGIES

	Feasibility and cost	Implement	Labour Reduced	Changes in production	Training for staff	Impact on risk of COVID-19 Transmission
Identified Technology	low, medium, high	easy, medium, challenging	% estimate	easy, medium, hard	none, medium, high	none, low, medium, high
Detection systems to apply sprays	medium - high	medium	20-30	low	medium	high

Current Status

- New and innovative detection systems can detect green foliage and adjust the volume sprayed. They can also adjust to the density of the foliage and control the output.

Feasibility of Implementing

- The capital cost to purchase this equipment is high, but once installed it would be easy to use since it is fully automatic.

Impact on Labour

- Manufacturers suggest there is a 25% increase in spray application efficiency so each tank of spray can go further. This would translate to a savings of equal proportion for labour operations.

COVID-19 Mitigation Risk

- These systems help to reduce overall labour requirements for orchard operations therefore implementation can lower the overall risk of COVID-19 exposure and transmission for orchard operations

Need for Change, Research and Training

- This equipment would require some initial time allocation for setup, minimal required changes to orchard operations and processes. Limited training would be needed.

Post Harvest

- Post harvest technologies identified and evaluated
  - Automatic bin dumpers
  - Integrated packing system with optical sorer & sizer
  - Automatic / Robotic palletizer
  - Robotic packers
  - Cold storages and monitoring equipment
  - Data management system for packing, inventory, storage and shipping
  - Specialized processing equipment for cider and juice

Fact sheets available for each

Adverse Weather Technologies

- Adverse weather technologies identified and evaluated:
  - Drainage
  - Trickle irrigation equipment
  - Frost protection
  - Frost protection remote controls
  - Hail protection

Fact sheets available for each

Covid-19 Transmission Mitigating Technologies

Survey: *Please tell us what technologies you are aware of or would like to see that could help protect workers either while on the job or in their housing.*

- Better designed houses with more space for workers
- Mandatory vaccination when vaccines are available
- Better exhaust fan systems and filtering in enclosed work areas
- Good, filtered face masks with universal fit that allow workers who wear glasses to not get fogged up
- Plexiglass in living quarters
- HVAC purifiers
- On-farm test kits
- Cost-friendly barriers for between beds
- Wearables that check temperatures while working

Covid-19 Risk Mitigating Technologies

- Covid-19 transmission mitigating technologies identified and evaluated
  - PPE
  - Air Filtering & Monitoring
  - Sanitization
  - Wearable Contact Tracing Technology

- Fact sheets available for each

New Technology Wishlist

Survey: If money was no object, technologies (machinery and equipment) growers would purchase to reduce labour

Top 10 List

1. GPS-autonomous platforms, tractors, vehicles, cyclone vacuum, mowing, spraying, mowing/spraying, planting, bin filling/stacking/carrying, box making
2. Platforms for pruning, thinning, harvesting
3. Sprayers of all kinds; canopy; over-the-row; smart filling tech; targeted; GUSS; LIDAR; 2-sided herbicide application
4. Robots for hand labour, pruning, thinning, harvesting
5. Drip irrigation and monitoring; autonomous sprinklers; moisture sensors
6. Post-harvest internal/external defect sorting; sizing; weight; auto packing
7. Weather protection for frost/cold; hail nets; retractable covers; weather stations
8. Remote sensing for pests; wind machines; RFID on bins; crop load; disease; irrigation
9. Hedgers
10. Battery operated pruners

Operational Assessments – OMAFRA's *Fruits of Your Efficient Labour: Getting Better Bang for Your Buck*

	How to Benchmark Labour Productivity
Step 1	**Create a process map that identifies activities and responsibilities of everyone involved in key orchard processes** (pruning, harvest, packing)
Step 2	**Plan the best way to collect accurate data**
Step 3	**Measure and document each process activity using labour productivity and time/motion study methods**
Step 4	**Observe each process activity in turn**
Step 5	**Identify and prioritize opportunities to improve**

We would like to thank our OMAFRA specialists for all of their hard work bringing this resource together and for sharing it to our Roadmap resources:

- Kathryn Carter, Fruit Specialist (Tender Fruit and Grape)
- Erika DeBrouwer, Fruit Specialist (Apple)
- John Van De Vegte, Engineering Specialist

Educational Resources

- Educational resources available on websites include:
  - Listing of suppliers offering equipment-specific operational assessments
  - OMAFRA's Optimizing Labour Efficiencies in the Orchard

- *Best ways for you to learn about new and innovative technologies:*
  - Tours of existing farms in Ontario that are already trying new training systems and equipment
  - Consult 2-3 farm dealers and/or suppliers for specialized equipment or software
  - Consult with OMAFRA specialists and researchers, Vineland Research and Innovation Centre, University of Guelph, AAFC, suppliers and consultants to investigate new technologies of interest
  - Research newsletter articles and publications (University Extension Newsletters, Orchard Network Newsletter, ONFruit Blog, Good Fruit Grower)
  - Attend industry meetings and conferences

Conclusion

- A roadmap provides a pathway to increased adoption of mechanization to increase labour productivity, reduce labour supply challenges and remain competitive.
- As the sector examines and adopts new ideas and equipment to be more efficient, the goal of reducing the risk of COVID-19 in our workplace will also be realized.
- two fundamental innovations essential to implementing other new technologies:
  - high-density orchard systems with greater uniformity allows for increased mechanization
  - data management systems provide insight and guide technological decisions
- The innovations and technologies identified will have benefits for growers as they assess their operations for efficiency and risk mitigation plans for both short and long-term goals.

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