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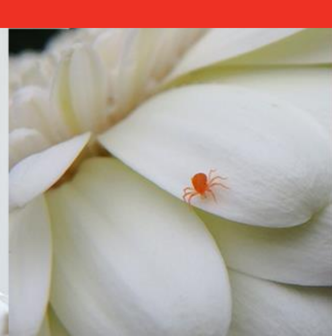
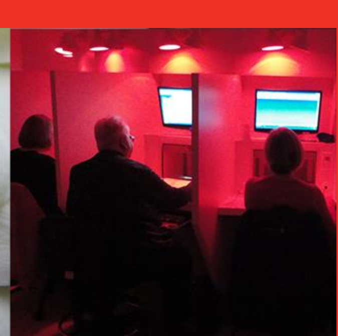

Report on Innovative Technologies

A Roadmap for Reducing Labour Challenges in Berry Production

March 30, 2021

Acknowledgement

This project was produced in collaboration between members of Vineland Research and Innovation Centre (Vineland) and the Berry Growers of Ontario (BGO). We are grateful to the Vineland team for their contributions to this report. We would like to thank Will Stafford of Forest Fringe Orchards, Prince Albert, Saskatchewan, for valuable insights into berry harvester equipment on Canadian farms. We also thank the Berry Growers of Ontario and its stakeholders for their support throughout this project. In addition, this project benefitted immensely from discussions with Kevin Schooley, General Manager of the Berry Growers of Ontario, who shared his expertise and insights in domains related to blueberry, raspberry, and strawberry production and operations.

Disclaimer

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Project Overview

In January 2021, the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) recognized the pressing need to make innovative changes that would both reduce the impact of the COVID-19 pandemic and have co-benefits helping address labour challenges within the sector.

The Berry Growers of Ontario (BGO), with financial support from OMAFRA, reached out to Vineland Research and Innovation Centre (Vineland) for assistance in developing a technological road map to address these concerns.

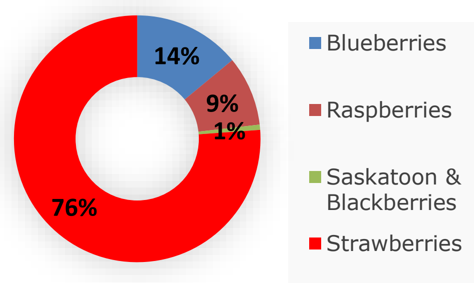
Beginning in February 2021, Vineland conducted a series of interviews with berry producers across Ontario, gathering information on the impact of the pandemic as well as growers' needs and priorities. After analyzing the results of the interviews, potential technological solutions were identified and evaluated on a series of criteria outlined in this proposal.

Main findings of the interviews, as well as select technological innovations addressing grower concerns have been summarized below for BGO's use and distribution.

Background

Labour challenges in the Canadian agriculture sector have been a continuous and long-standing problem. In the ten years between 2007 and 2017, the labour gap in Canadian agriculture is estimated to have doubled, increasing from 31,500 to 63,000[1]. Unfortunately, even with growth in the temporary foreign worker program this gap is expected to double again by 2029, reaching an estimated 123,000 people[2].

Figure 1. Ontario Berry Production by Tonnage in 2020



The ongoing shortage has led growers to increasingly rely on the temporary foreign worker program with over 57,000 temporary workers employed in the sector in 2018[3]. In an ominous foreshadowing of the 2020 COVID-19 pandemic, the Canadian Agricultural Human Resources Council noted the program, "is only a partial solution and one that could easily disappear due to policy changes or global events"[4]. While it is unlikely such a program would disappear, travel restrictions, quarantine requirements and ongoing uncertainty around future public health requirements have exposed the vulnerabilities of overly relying on a single program.

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[1] Canadian Agricultural Human Resources Council (2019). How Labour Challenges Will Shape the Future of Agriculture: Agriculture Forecast to 2029. 15

[2] Canadian Agricultural Human Resources Council (2019). How Labour Challenges Will Shape the Future of Agriculture: Agriculture Forecast to 2029. 1

[3] Statistics Canada. Fruit and Vegetable Production, 2020. https://www150.statcan.gc.ca/n1/daily-quotidien/210210/dq210210c-eng.htm (accessed March 1, 2021)

[4] Canadian Agricultural Human Resources Council (2019). How Labour Challenges Will Shape the Future of Agriculture: Agriculture Forecast to 2029. 1

Figure 1. Statistics Canada. Table 32-10-0364-01 Area, production and farm gate value of marketed fruits

Strawberry production outweighed all other berry crops in Ontario, representing three quarters of the overall berry production by tonnage in 2020 as seen in Figure 1. Preliminary data from Statistics Canada (Table 1), indicates Ontario berry growers were not equally impacted by COVID-19 when compared across crop type and against the rest of the country.

With Ontario strawberry growers making up 75 per cent of BGO's membership, and having seen the greatest decline in farm gate value in 2020, emphasis has been placed on examining potential technical solutions for strawberry crops. Blueberry and raspberry growers were also interviewed for this report and potential solutions are included.

Key Findings

A snapshot of key findings is presented below:

In a review of Statistics Canada information from 2020, strawberry production in Ontario was especially hit hard. After seeing gains in six of the last eight years, fresh strawberry production in 2020 saw a disproportional drop in farm gate value from 2019 for Ontario (-10%) compared to the figures for Canada (-2%), as seen in Table 1.

Table 1. Change in Farm Gate Value from 2019 to 2020[5]

Crop	Canada	Ontario
Strawberry	-2%	-10%
Raspberry	-10%	-3%
Blueberry	-11%	-9%

Interviews with growers clearly indicated labour shortages were worsened by COVID-19 with delays in the arrival of temporary foreign workers at the root of most issues. Attempts to bridge or replace temporary foreign workers with local labour did not succeed with reliability issues being the most common reason given for the failure.

Grower interviews and subsequent technical reviews of automated transplanting and harvesting equipment confirmed that while technologies are emerging rapidly for berries, they are not currently viable for small- to medium-scale operations, which are predominant in Ontario.

Tabletop strawberry production and long-cane raspberry production are beginning to be adopted in Ontario. Having the potential to increase market yield, improve the quality of produce, reduce labour requirements and improve conditions, are easily adoptable technologies that growers can undertake right away.

[5] Statistics Canada. Table 32-10-0362-01 Area, production and farm gate value of marketed fruits

Interview Outcomes

The Operations

Over the course of February 2021, Vineland conducted eight interviews with a sample of berry producers from across Ontario with operations ranging from 10 to 90 acres. The majority of growers produced more than one type of crop, with some combination of strawberries, raspberries, blueberries, or blackberries.

Labour needs were high for all crop types. Requirements ranged between 1 to 5 labourers per acre and represented 50 to 66% of the overall cost of production. Growers suggested a target labour cost of 40% of overall production costs. Significant costs were also attributed to crop protection (cost of chemicals) and maintenance needs (removal of runners).

In considering how labour is distributed between various tasks in the operation, harvesting dominated required labour using up to 80% of the overall labour supply in some operations. Pick-your-own operations, on the other hand, required very little harvest labour due to the nature of their business model but represented a minority of growers interviewed.

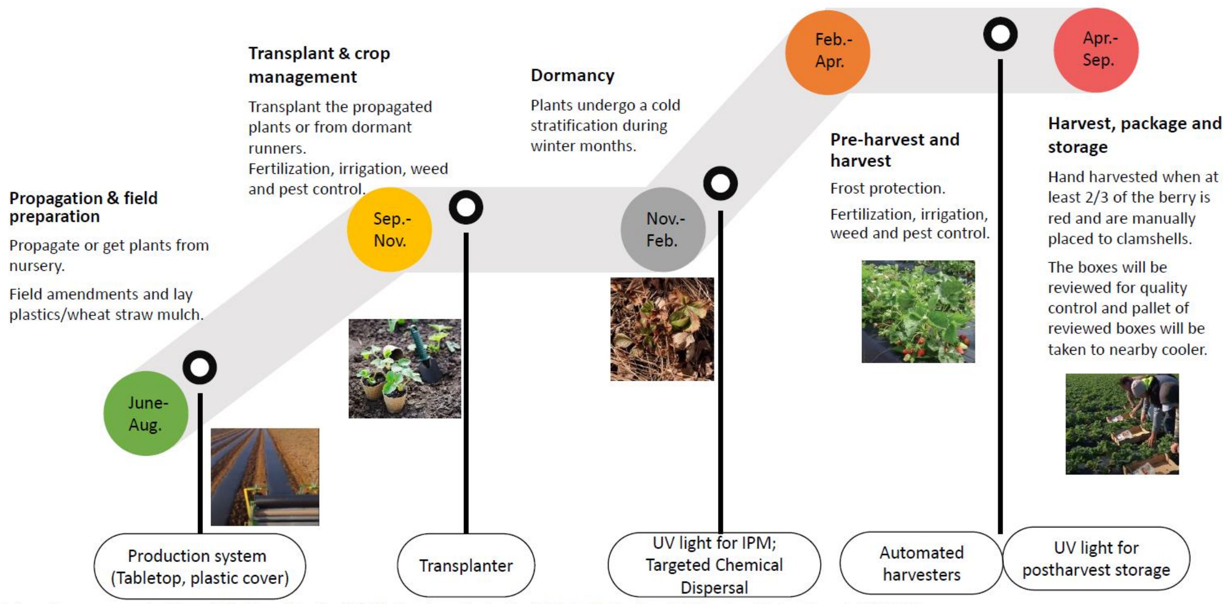
Production Insights

While the overall trend in the strawberry industry is a movement towards tabletop production, there remains skepticism within field producers in Ontario. In-ground field growers were concerned that the cost of production under a tabletop system would be much higher, making the production system uneconomical in Ontario.

However, the interview process indicated tabletop production has a strong possibility for labour savings during the entire production cycle. When asked to provide estimates on harvest rates, field producers estimated harvesters could achieve a rate of three flats an hour as opposed to the five flats an hour rate estimated by tabletop producers.

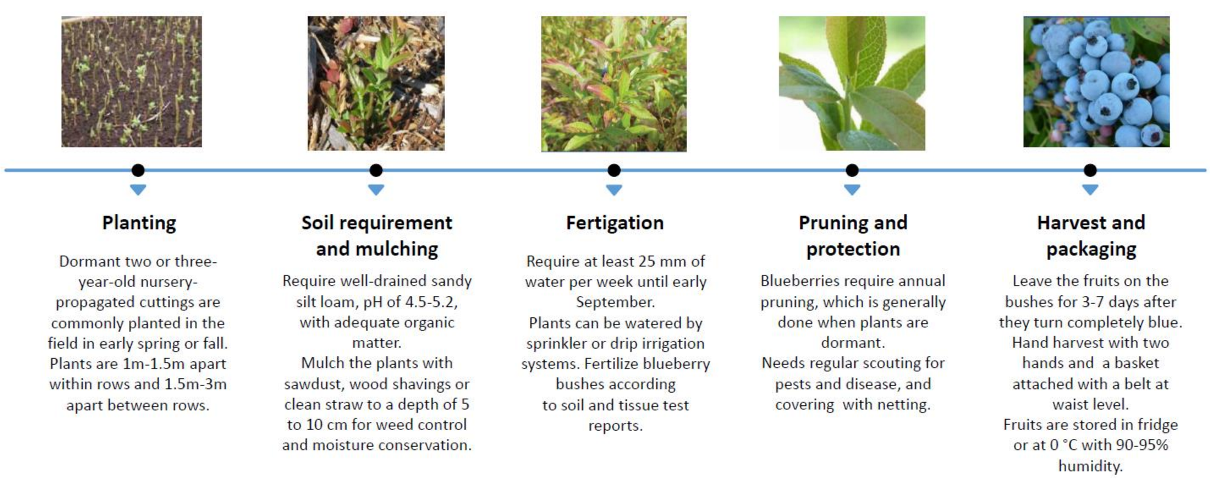
When growers were asked about the likelihood of adopting new technologies, a generational gap was seen with younger growers being more open to investing in new innovations that affected the production process.

Figure 2. Field strawberry production



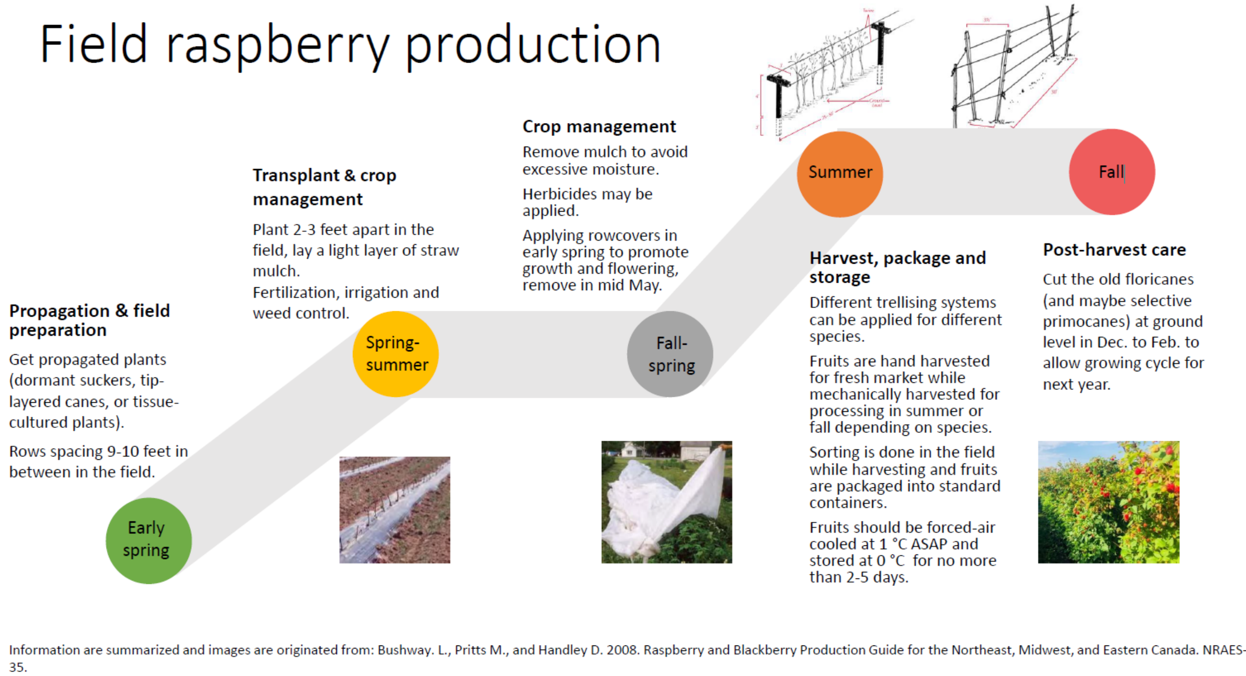
Information are summarized from: Pritts M. and Handley D. 2008. Strawberry Production Guide for the Northeast, Midwest, and Eastern Canada. NRAES-88.
Image sources: https://wishfarms.com/
https://www.garden.eco/when-to-transplant-strawberries
http://www.toshihiga.com/garden/2009/progress/vegetable.php
Kiki Fontenot, LSU AgCenter

Figure 3. Blueberry production



Information are summarized and images are originated from : University of Kentucky. 2013. Midwest Blueberry Production Guide. ID-210.

Figure 4. Field raspberry production



Challenges

Labour challenges were the most common concerns raised by producers of all crop types. Growers reinforced past research findings showing labour shortages have been an increasing challenge for the past five years or more. The temporary foreign worker program has been successful in bridging the gap but potential issues with overly relying on a single program appeared during the COVID-19 pandemic.

Producers across crop types identified pest management as an emerging challenge, facing both increasing pest pressures and limitations on fungicides, most notably Captan. Spotted wing drosophila (SWD) was the most commonly referenced pest, with thrips, anthracnose, tarnish bug and slugs also being mentioned.

Raspberry producers identified challenges with the compatibility between existing harvesting technologies and varieties suited for the Ontario climate. Pruning methods were attempted to improve the harvesters’ ability to successfully harvest berries but have not proved satisfactory.

Blueberry producers identified issues with current mechanical harvesting apparatus as being too damaging to products for sale in the fresh market.

COVID-19 Pandemic Impact

During the previous growing season, the impact of COVID-19 was most sharply felt in the disruption of labour arriving from the temporary foreign worker program. As global travel closed and restrictions were implemented at borders, foreign workers either arrived late or not at all, with an estimated labour shortage among interviewed growers ranging between 30 to 40 per cent.

The late arrival of temporary workers led to crop losses of up to 80 per cent from early weather events, as normal protective measures were too labour intensive to undertake without them. Higher costs of production also resulted as growers were forced to bear higher cost per unit harvested and some growers left between 60 to 70 per cent of their produce in the field as there simply weren't enough hands to harvest it all.

In response to the COVID-19 crisis, and concerns over a repeat of delays in the temporary foreign worker program occurring again in 2021, growers have been forced to suspend expansion plans or reduce acreage by up to one-third for this upcoming season.

Technology Awareness

The current development of robotic strawberry harvesters in the United States was well known by interviewed growers, however the majority expressed some form of concern when discussing the opportunities presented by current robotic harvesters. The most common of which was the expression of size and cost with most growers viewing the machines as too large and costly for the size of operations in Ontario.

Across growers of different berry types, pest management solutions were also discussed, most notably in the form of unmanned aerial vehicles, such as drone technology and the potential for them to both scout and apply pest management products. Some growers expressed concerns in regards to their likely adoption of such technology, pointing to the size of operations in Ontario and questioning its economic viability.

Other Considerations

While outside the scope of this project, the following points were captured during the interview process and have been included to maximize the value of this process for the Berry Growers of Ontario.

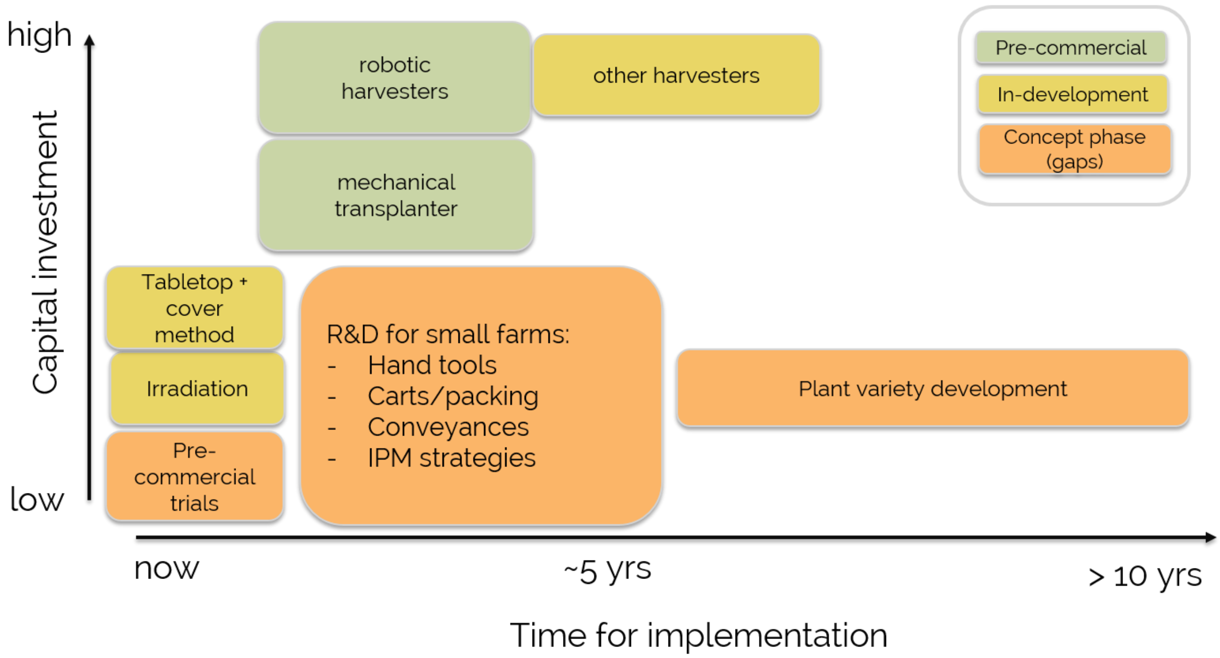
While speaking about the challenges of COVID-19, many growers focused on the regulatory roadblocks and investment costs of updating housing in order to follow public health guidelines. Delays in receiving permits from municipalities and limits on the types of housing growers were allowed to use (e.g., unable to use park-model trailers because they were on wheels) were specifically mentioned.

Growers were aware of COVID-19 government programs to assist with the costs of meeting new guidelines but expressed frustration with their limitations. The need for growers to pay upfront for renovation costs before they were able to apply for financial support was seen as a barrier to participating in the program. Additionally, concerns were raised about the program's focus on renovation of existing buildings, rather than supporting the teardown and rebuilding of new housing. Growers felt that in cases rebuilding could be a more effective option than renovating bunkhouses.

Technological Evaluations

After consolidating the findings of the interview process, potential technologies for investigation were summarized into Figure 5 and used by researchers at Vineland as a basis for technological evaluations.

Figure 5. Technology opportunities



Innovations in Production System

Innovative ideas and new technologies are shifting today's farm operation. More and more growers are seeking innovative approaches in the production system to maximize resource use efficiency, address labour challenge, improve sustainability, while at the same time improving crop productivity and quality. Strawberry tabletop production, protected system and long-cane raspberry production were frequently brought up during the interviews.

Tabletop Strawberry Production

With the increasing concerns of soil-borne disease and regulatory constraints on soil fumigants, tabletop production is becoming an emerging production method in Canada and the United States. Utilizing substrate filled bags or troughs on low trellis systems raised several feet off the ground, tabletop production has been established in Europe for the past decade.

Figure 6. Strawberry tabletop production in Ontario[6]

Tabletop cultivation also provides additional benefits such as eliminating concerns of weed control or the need for crop rotation and allowing early planting without worrying about soil drying out and/or warming up.

Tabletop production reduces the use of water and fertilizer by collecting runoff.

Most notably for labour concerns, strawberries grown on tabletops are well exposed and are at an ideal height for harvesters, substantially increasing picking speed.

Increasing harvest speed has the potential to reduce the overall required labour and allows for operations to more easily incorporate social distancing during harvest. The raised height of tabletop production also improves labour conditions as harvesters no longer have to bend over to harvest the fruit.

The initial investment and annual costs of tabletop production are higher than field production and the adaptability to tabletop production varies across cultivars[7], necessitating further evaluation.

Protected and Vertical Systems

As shown in Figure 6, strawberry production systems can also be covered with small tunnels (row by row), shelters or larger tunnels (multiple rows) to protect strawberries from precipitation and reduce pathogen infection risks. They have previously been tested by growers and researchers and are shown to increase the percent marketable yield, promote the flowering and fruit ripening of day-neutral strawberry cultivars[8].

A study conducted in Quebec highlighted the potential of using umbrella-type rain shelters for tabletop strawberry production, which increased the seasonal total and marketable yields by 15 to 24 per cent with lower incidence of strawberry mildew and similar quality compared to unprotected systems[9].

Due to their size and the architecture of strawberry plants, strawberries can be grown in many innovative cultural systems, like the vertical growing system. It promotes planting

[6] Courtesy of BGO.
[7] Daugaard H. (2008). Table-top production of strawberries: Performance of six strawberry cultivars. Acta Agriculturae Scandivavica Section B - Soil and Plant Science. 58(3), 261–6.
[8] Orde K.M., Sideman R.G. (2021). Winter Survival and Second-year Spring Yields of Day-neutral Strawberry Are Influenced by Cultivar and the Presence of Low Tunnels. Horttechnology. 4461(February), 1–12.
[9] Claire D., Watters N., Gendron L., Boily C., Pépin S., Caron J. (2018). High productivity of soilless strawberry cultivation under rain shelters. Scientia Horticulturae. 232 (2018), 127–38.

density and improves an individual's working environment. However, ensuring efficient water management and that plants are orientated so as not to block light from others are two major issues.

A European study compared the investment, annual cost and yield of different strawberry production systems in the Netherlands and Belgium[10] and is summarized in Table 2.

Table 2. Cost Comparison of Open Field, Plastic Tunnel Soil, Tabletop and Tabletop with Plastic Cover Strawberry Production in the Netherlands and Belgium in 2013

	Open field [a]	Plastic tunnel soil	Tabletop	Tabletop with plastic cover
Investment [b] (CA$10,000 /ha)	4.11	10.96	15.07	23.29
Annual cost [c] (CA$10,000/ha)	5.82	7.88	13.70	21.24
Yield (ton/ha)	25-30	35-40	45-50	65-70
Cost (CA$/kg)	1.9-2.4	1.9-2.2	3.0-3.3	3.0-3.2

[a] Calculated from one crop cycle/year (costs calculated based on average exchange rate of 1€=CA$1.37 in 2013)
[b] Initial costs for the system setup
[c] Annual production costs

Long-Cane Raspberry Production

The increased demand for out-of-season raspberry production has led European growers to develop a new long-cane production system in a protected environment which extends the marketing season, while reducing the risk of soil diseases and the need for crop rotation. Long-cane raspberry production is also an emerging production system in Ontario.

Long-cane raspberries are fruiting canes grown to 1.8 to 2 m tall at the nursery. Alternatively, growers can grow their own long canes from plug plants. After storing the canes in cold storage for the winter, two canes per pot are planted in 7 to 10 L pots and established at a density of three pots per linear metre in tunnels or under umbrella-type protected structures. The canes are supported by bamboo and often mesh is set up to support the laterals. The protected structures provide protection from wind, hail and rain, reducing disease pressure and the need for fungicides and improving fruit quality. The warmer conditions in tunnels also provide a season extension in the spring and fall. The cultivars being grown in Ontario include Tulameen and Glen Ample, with interest in other cultivars including primocane-fruiting cultivars.

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[10] Lieten P. (2013). Advances in Strawberry Substrate Culture during the Last Twenty Years in the Netherlands and Belgium. International Journal of Fruit Science. 13, 84–90.

Figure 7. Long-cane raspberry production[11]

Research in Europe is currently underway to optimize long-cane production systems. The temperature of cold storage, types of substrate, container sizes, the time moving plants out from cold storage and planting density are all critical and interactive factors affecting the yield of production. Further evaluation in the specific context of Ontario is needed for potential improvements. With appropriate practices, the yield of long-cane raspberry plants can achieve up to 3 kg per cane with excellent size and quality as demonstrated in Norway[12].

The long-cane production requires a high establishment cost and a lot of technical knowledge, as well as high labour costs to move and handle plants. However, the harvest season can be extended by varying cultivars, stagger the time moving dormant long-canes out of the cold storage, therefore spreading out the demand for labour, while providing out-of-season, consistent berries at higher profit margins.

Automated Transplanter

Transplanting is one of the most important but labour-intensive operations in strawberry production. Traditionally, it took 10 farmworkers eight hours to transplant one acre of strawberries in California. Automated transplanter could greatly address the labour challenge. For example, a collaboration between Driscoll's, Plantel and Solex in 2016[13] led to the development of a mechanical transplanter for field strawberries able to transplant into three beds at a time. It costs about US$120,000 for an entire unit, including the transplanter, tractor, racks, seating and other equipment.

[11] Kurt Koester and Marvin Pritts. (2013). Greenhouse raspberry production guide for winter or year-round production.
[12] Sønsteby A., Stavang J.A., Heide O.M. (2013). Production of high-yielding raspberry long canes: The way to 3 kg of fruit per cane. Journal of Horticultural Science and Biotechnology. 88(5), 591–9.
[13] https://ucanr.edu/blogs/strawberries-vegetables/index.cfm?start=39

Figure 8. Three-bed strawberry transplanter developed in California[13]

This three-bed transplanter is able to plant 10 acres a day with a 19-member crew, including a driver, a plant handler/loader, 12 planters and 5 people checking the transplanted plants on the bed. What used to take 100 people to manually transplant 10 acres can now be done with just 19. While it is understood that Californian field sizes are much larger than in Ontario, the concept clearly demonstrates significant labour savings in automating transplanting. However, in considering COVID-19 implications, social distancing measurers would be difficult if not impossible to implement on such a device.

The three-bed transplanter was developed from a single bed transplanter and could be implemented for smaller-scale production in Ontario. A single bed automatic transplanter prototype for vegetable seedlings has been developed in China. The transplanter handles the seedling tray, automatic seedling extraction and mechanical planting[14] and has a success rate of 92.59 per cent and can transplant seedlings at a rate of 60 plants per minute.

Additionally, an automatic strawberry plug seedling transplanter prototype for tabletop strawberry production was recently designed in China[15]. The main components include an autonomous vehicle, pneumatic rotary dual-gripper unit, a dual-hole punching unit, a grip-punch coupled transportation unit and an easy plug-feeding unit. This unit was able to achieve an overall success rate of 95.3 per cent with a transplanting speed of 17.5 plants per minute.

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[13] https://ucanr.edu/blogs/strawberries-vegetables/index.cfm?start=39

[14] Jin X., Li D., Ma H., Ji J., Zhao K., Pang J. (2018). Development of single row automatic transplanting device for potted vegetable seedlings. International Journal of Agricultural and Biological Engineering. 11(3), 67–75.

[15] Liu J., Zhao S., Li N., Faheem M., Zhou T., Cai W. (2019). Development and field test of an autonomous strawberry plug seeding transplanter for use in elevated cultivation. American Society of Agricultural and Biological Engineers Research. 35(6), 1067–78.

Transplanting technology generally improves the efficiency and uniformity of strawberry transplanting. Importantly, it significantly reduces the time, and depending on the level of autonomy, eliminates or greatly reduces the labour involved and therefore reduces the likelihood of COVID-19 transmission. However, most of the single bed transplanting technologies are still at the developmental stage and have not yet been commercialized. Some designs are only applicable to tabletop production systems.

Targeted Chemical Dispersal

Figure 9. Small-scale spray dispersal is now possible with Rantizo's quadcopter sprayer, with 10-litre capacity

***Image source**: https://rantizo.com/products*

Several berry farmers expressed an interest in automated dispersal technologies, such as drones. There are many emerging technologies for automated chemical dispersal, both aerial and ground-driven. Due to the highly technical nature of aerial surveying and delivery methods, commercially-available drone applications are sometimes offered under fee-for-service contracts. Growers interested in investing in drone surveying can stay current with online comparisons, such as Best Drone for the Job[16], a comprehensive summary of currently available drone technologies for growers.

Surveying, scouting and monitoring crop health using aerial multi-spectral or hyper-spectral imaging is proving to be a powerful tool for agriculture, particularly on large-scale operations. Using specialized cameras, images in the green, red and near-infrared range of the electromagnetic spectrum are used to assess crop health and target areas of pest damage and nutrient deficiency[17]. Headwall Photonics[18] was the first to offer aerial crop monitoring in Ontario, though the number of companies offering similar services is expanding.

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[16] Nixon, A. (2020). Best Drones for Agriculture 2020: The Ultimate Buyer’s Guide. https://bestdroneforthejob.com/drone-buying-guides/agriculture-drone-buyers-guide/
[17] Cotton-martin, J. (2020). Hyperspectral and Multispectral Imaging. *Photonics Spectra.* https://www.photonics.com/Articles/Hyperspectral_and_Multispectral_Imaging/a65595
[18] https://www.headwallphotonics.com/

Once areas requiring attention have been identified, targeted dispersal methods can be used to deliver interventions only where they are needed. Drone delivery systems for biocontrol agents are an emerging technology, such as Parabug in California[19], in which beneficial organisms can be spread widely across crop fields or targeted only to areas that need them. Small-scale (10 litres) solutions are currently on the market from companies such as Rantizo[20], which utilizes recreation-style drones. Large-scale aerial technologies for liquid spraying dispersal, such as Pyka or Volocopter[21], are currently awaiting licensing for use in the agricultural industry.

As an alternative to aerial drone technology, computer vision-based autonomous herbicide dispersal with ground-rolling robots, such as Ecorobotix' Autonomous Robot Weeder[22], are currently available for select crops and may be adapted to strawberries in the near future. Ground-based systems are better suited to targeted applications of herbicides than aerial dispersal, potentially reducing the overall use and costs of herbicides in operations. Future innovations may see similar ground-driven autonomous dispersal systems for other liquid or biocontrol agents.

UV Light Application in IPM and Postharvest Management

Research into ultraviolet (UV) radiation has proven an ability to combat molds and pests, boost a plant's or fruit's resistance to disease and even increase antioxidant levels in strawberries.

Ultraviolet C (UV-C) radiation is effective against grey mold, black spot and powdery mildew. Applying UV-C reduces the severity of infection by directly damaging fungi as well as increasing the plant's overall disease resistance. Application requires a two to four-hour period of exposure in complete darkness in order to disable microorganisms' ability to repair damaged DNA. The UV/dark treatment generally does not affect pollen germination, leaf development or yield and is more efficient in controlling infections than traditional methods.

Previous studies showed that applying UV-C light at limited doses twice weekly proved effective in controlling severe infections of powdery mildew[23,24]. Higher doses or rates may result in damage to plants so specialized training can be required. Other studies have also revealed significant biological impacts of UV-B radiation on plant-dwelling mites, raising an interest in the use of UV-B (as well as UV-C) for spider mite control.

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[19] For example: https://www.parabug.solutions/
[20] For example: https://rantizo.com
[21] For example: htttps://www.flypyka.com, https://www.volocopter.com/en/volodrone/
[22] For example: https://www.ecorobotix.com/en/autonomous-robot-weeder
[23] Janisiewicz W.J., Takeda F., Nichols B., Glenn D.M., Jurick W.M., Camp M.J. (2016). Use of low-dose UV-C irradiation to control powdery mildew caused by Podosphaera aphanis on strawberry plants. Canadian Journal of Plant Pathology. 38(4), 430–9.
[24] Pate J.S., Radetsky L.C., Nagare R., Rea M.S. (2019). Nighttime application of UV-C to control cucumber powdery mildew. Plant Health Progress. 21(1), 40–6.

Figure 10. Fully automated prototype USDA UV-C irradiation machine

***Source**: USDA*

Applying specific dosages of UV-C prior to postharvest storage effectively reduces anthracnose in blueberries[25]. Similarly, strawberry fruits accumulate higher phenolic contents when they are subjected to preharvest UV-C treatment[26]. Therefore, UV-B or UV-C irradiation could be applied during preharvest or postharvest stages to enhance antioxidant levels and increase disease resistance of berry fruits.

An automated prototype machine for night-time UV-C irradiation in high tunnel production system has been developed by the United States Department of Agriculture (USDA). Built onto a cart, the UV light applicator can be adapted to use the same transportation lines as sprayers and harvesting equipment in greenhouse and field growing systems. While the system is currently in the developmental phase, the automation of pest management solutions could reduce overall labour needs.

[25] Perkins-Veazie P., Collins J.K., Howard L. (2008). Blueberry fruit response to postharvest application of ultraviolet radiation. Postharvest Biol Technology. 47(3), 280–5.

[26] Xu Y., Charles M.T., Luo Z., Mimee B., Veronneau P.Y., Rolland D. (2017). Preharvest Ultraviolet C Irradiation Increased the Level of Polyphenol Accumulation and Flavonoid Pathway Gene Expression in Strawberry Fruit. Journal of Agricultural and Food Chemistry. 65(46), 9970–9979.

Autonomous UV-C robot for field production is close to commercialization. For example, the robot developed by TRIC Robotics[27], which combines UV-C light treatment, field tracking and weed control, is at pilot stage in one quarter to full acre strawberry fields.

Harvesting Technology

Strawberry Harvest

Automated and mechanical strawberry harvesting lags behind other crops in the berry industry, due to the challenges arising from the complex and delicate architecture of the strawberry plant.

Figure 11. Neupeak Pixaberry is currently in pre-commercial trials in British Columbia

Automated Harvesters

Automated strawberry harvesters are in pre-commercial trials from companies such as Agrobot and Harvest CROO Robotics[28] for both field-grown and tabletop operations, with robotic action guided by elegant computer vision technologies. Commercial availability in Canada will likely be a few years off and may be a viable option for large-scale strawberry growers. As a small-scale alternative, Pixaberry from Neupeak[29] is a small autonomous robot that picks 50 per cent of berries alongside human workers and is expected to be available to strawberry growers in Ontario in 2023. Neupeak offers their technology as a fee-for-service at $0.35/lb, eliminating the need for large up-front investments[30]. These robotic, fully-automated harvesters will drastically reduce the labour requirement for strawberry harvest, with minimal changes in infrastructure.

***Image source**: Neupeak*

Improved Efficiency of Hand Harvesting

Large, expensive automated strawberry harvesters may not be suitable for most small- or mid-size growers in Ontario. Increasing the efficiency of field labour may be an alternative strategy to reduce labour costs and help mitigate risks in transmitting COVID-19. There are many strawberry harvest aid techniques available to growers, including moveable benches. A systematic review of many harvest aids is currently under review by the USDA. There are some areas of research and development that remain under-explored, including the development of hand tools specific to strawberry harvesting and gantry conveyance systems[31] for field collection and packaging.

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[27] http://www.tricrobotics.com/
[28] For example: https://www.harvestcroo.com and https://www.agrobot.com/e-series
[29] https://www.neupeak.com
[30] Porwal, A (2021). Feeding the Future, presented at THRIVE Canada online conference. January 14, 2021. https://www.youtube.com/watch?v=EGiRUe0gq00
[31] For example: https://tumoba.nl/products/conveyors

Figure 12. Strawbot by AgPro Robotics - A self-guided follow-along cart

***Image source**: http://www.agprorobotics.com/products*

Field picking labourers spend approximately 30 per cent of their time transporting boxes to and from the field and walk approximately eight kilometres each day. Self-driving follow-along field carts, such as the Strawbot by AgPro Robotics[32], or gantry conveyance systems, can eliminate most of that labour, keeping pickers picking and reducing overall labour needs.

Raspberry and Blueberry Harvest

The automation of berry harvest in non-strawberry crops is a viable way to mitigate the risks of labour challenges and workplace safety surrounding COVID-19. Berry harvesters are commercially available at a broad range of scales, with a variety of designs suited to many of the types of berries and the individual demands of farm infrastructure. Berry harvesting machinery can be costly, usually requiring a six-figure investment, though investment can be reduced by searching the used market, such as MarketBook[33].

Many small berry operations in Ontario cannot support the investment required for large-scale harvesting equipment. There are however small-scale options available, such as the Joanna-4 Eco half-row harvester from Weremczuk Agromachines. Small-scale

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[32] For example: http://www.agprorobotics.com/

[33] https://www.marketbook.ca/listings/farm-equipment/for-sale/list/category/300103/specialty-crop-equipment-harvesters-grape-berry

harvesters such as the Joanna-4 can be purchased for less than $65,000 and have proven profitable on several small (under 10-acre) Ontario farms, even accommodating specialty berries and delicate cultivars[34].

Variety Development

June-bearing strawberry plants bud in late summer, flower in the following spring and produce berries during a three-week period in June. They are extremely popular because of their large and juicy fruits but they only produce fruits in the month of June.

Day-neutral strawberry plants are unique annual plants that can initiate flowering independently of day length. They produce fruits throughout the summer time from June to mid-fall.

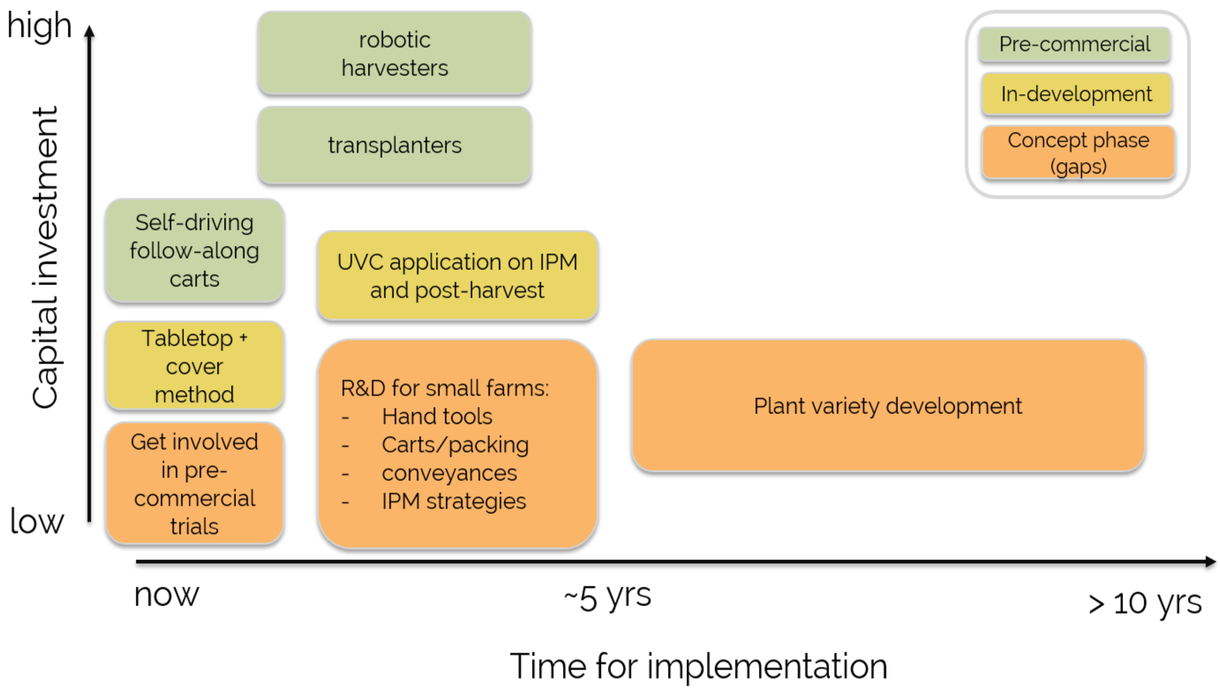
There are many breeding programs in Canada and globally with the ultimate goal to develop cultivars with high adaptability to different environments (i.e. soil, climate) and growing systems (e.g. field, tunnel, greenhouse) with less environmental impacts and increased productivity and quality (i.e. firmness, uniform shape, sensorial quality, micronutrients) for consumers. New varieties need to be tried and evaluated at various sites and growing conditions.

[34] Stafford, W. Forest Fringe Orchards. Personal communication, March 2021.

The Road Ahead

After reviewing potential technologies and incorporating feedback from members of BGO's executive, Vineland researchers have revised the potential technologies and organized them based on their ability to be implemented in the short to long terms, as well as the capital investment required.

Figure 13. The future of berry production automation



Note. *Pre-commercial technologies, technologies in development and gaps in innovation (see legend) are positioned to indicate estimates of the time required until they are commercially available (horizontal axis) and the capital investment required to implement them (vertical axis).*

In the following section, we lay out a roadmap aimed at helping growers reduce their dependence on manual labour in the short, medium and long term. We describe how the technologies outlined in the Technological Evaluations section can be implemented. Making strategic changes now, while making an informed plan for upcoming opportunities, can have a positive impact as we adapt to changing labour markets.

Short-Term Outlook

Tabletop strawberry production is an emerging technology relatively easy to adopt by Ontario growers with the potential to increase yield, improve fruit quality, reduce labour costs while improving labour conditions. Infrastructure changes for tabletop production require an initial investment and the annual costs are higher than field crops. However, tabletop growers report greater efficiency in crop maintenance and harvest labour. As the labour market shifts, tabletop production may be the way forward for many Ontario growers.

Self-driving follow-along carts are an emerging intermediate step in the path towards fully-automated strawberry harvest that can immediately mitigate the effects of the current labour shortages without a large capital investment.

Long-cane raspberry production is getting a growing interest in Ontario with the potential of increasing yield and also producing berries out-of-season. Although long-cane production requires additional labour due to plant handling, the timing of that labour does not necessarily coincide with the demanding seasons of traditional raspberry production. This new production method can help spread out the demand for labour throughout the year while providing consistent and high-quality berries all season long.

Pre-commercial trials are a valuable tool for companies developing high-tech agriculture solutions. Contacting R&D companies to inquire about setting up a pre-commercial trial can be a great way to get an inside look at emerging technologies.

Medium-Term Outlook

Robotic harvesters for field strawberries are currently in pre-commercial trials and will be a viable option for large operations in the years to come. The precise timing and required investment are difficult to predict, as companies navigate their commercial roll-out.

There are commercially-available **transplanters** for large-scale strawberry field, however, social distancing measures for COVID-19 could be difficult if not impossible to implement on such a device. Recently published prototypes are a promising step towards commercially-available strawberry transplanters, which will significantly reduce the labour involved and improve the uniformity of strawberry transplanting.

An autonomous UV-C light robot is at pilot stage and close to commercialization. The robot is suitable for small- to medium-sized farms, which Ontario growers could benefit from.

Research and development for small farms may be a key strategy for Ontario berry growers. Since most of the automation technologies emerging on the market require high levels of investment, fully-autonomous solutions may not be accessible to small- or mid-size farms. As an intermediate step, semi-automation technology can reduce the dependence on temporary foreign workers by increasing the efficiency of manual labour. Research programs focused on semi-automation might develop hand tools, carts, conveyances or other methods with a strong impact on the demand for labour on Ontario-sized farms.

Long-Term Outlook

Plant variety development strategies focused on reducing labour may be an effective long-term solution to the labour crisis. Varieties with fewer runners or optimized plant structure for automatic or semi-automated transplant and harvest would be a valuable asset to the industry.

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