Sweet Potato Slip Production in Canadian Greenhouses

vineland
RESEARCH & INNOVATION CENTRE

Business Opportunity: Sweet Potato Slip Production in Canadian Greenhouses

February, 2020
Revised December, 2024

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Introduction

Overview of the Canadian sweet potato industry

In the past ten years, sweet potato consumption in Canada has doubled which presents a great opportunity for the industry. The majority of this consumption comes from 66,000 tonnes imported each year from North Carolina, U.S. and is valued at $60 million (Agriculture and Agri-Food Canada, 2019; Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), 2018). In 2018, approximately 2,344 acres of sweet potatoes were planted in Canada generating $21 million in farm gate sales and a significant potential for growth to offset imports.

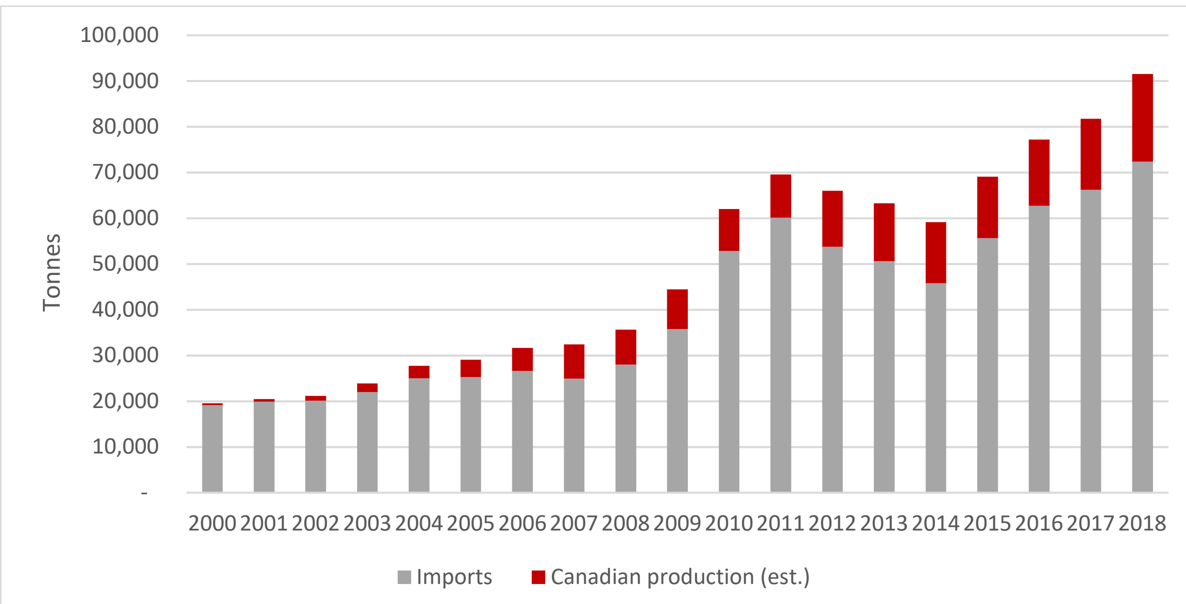

Figure 1: Canadian sweet potato market

- Canadian consumption of sweet potatoes is steadily increasing: in the past ten years, sweet potato imports have increased by 100% (2009 to 2018)
- 90% of Canada's sweet potato imports come from the United States
- Canadian producers see the opportunity – the Canadian production is steadily increasing (approximately 2,344 acres in 2018 from 600 acres in 2000)[1], producing about 19,138 tonnes in 2018
- Ontario is the main producer of sweet potatoes

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[1] Statistics Canada does not track domestic sweet potato production. The estimations above are based on the sweet potato acreage estimate from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the assumptions that a producer plants 13,000 plants per acre, 2 lbs are harvested by plant, 20% of production are culls (20,800 lbs per acre), 18,000 lbs yield/acre are assumed for 2012-2018 to account for differences in production practices among growers. Sources: CANSIM, Canadian International Merchandise Trade Database: Table 990-0007; Melanie Filotas, Specialty Crops IPM Specialist, OMAFRA; Valerio Primomo, Research Scientist Vegetable Breeding, Vineland Research and Innovation Centre.

Sweet potato production in Canada is affected by lower temperatures and a shorter growing season and a limited access to propagative material. In addition, the variety selection available to Canadian growers is not ideal as these varieties have been bred for the southern United States regions with warmer temperatures and longer growing seasons. For these reasons, almost all sweet potato production in Canada occurs in southern Ontario. An opportunity exists to expand production within Ontario and other Canadian provinces as well as to export sweet potatoes to Europe where imports and consumption have doubled in the past five years (CBI, 2019). Canadian exports of sweet potato to Europe have increased significantly in the past five years with a farm gate value of $22 million in 2017 (Agriculture and Agri-Food Canada, 2019; see Figure 2). Approximately 90% of exports are destined for the Netherlands, followed by France and Israel (Agriculture and Agri-Food Canada, 2019).

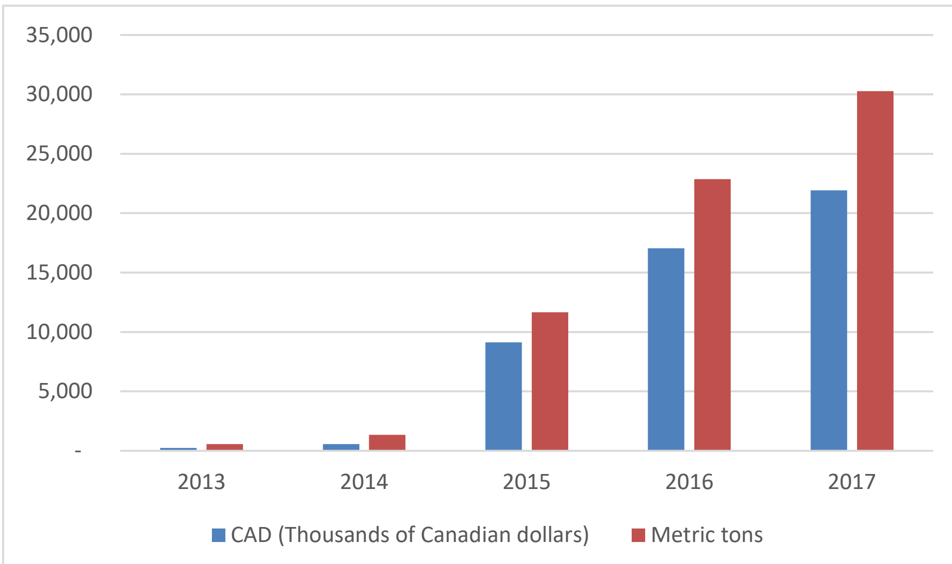


Figure 2. Canadian export of sweet potato from 2013 to 2017 (dollar value and metric tons).

To address this opportunity, the Canadian and the Ontario governments have invested in a sweet potato breeding program at Vineland Research and Innovation Centre (Vineland) to develop novel higher yielding germplasm adapted to the Canadian climate. Vineland has already identified a new high yielding variety with superior agronomic and consumer traits called Radiance and has filed Plant Breeders' Rights in October 2015. However, the success of this new sweet potato variety is contingent on growers' ability to access propagative material since sweet potatoes are vegetatively propagated through unrooted vine cuttings known as 'slips'. Currently, they are available only through North Carolina suppliers and the supplied slips are specific varieties developed by the Louisiana State University and North Carolina State University breeding programs tailored to their U.S. markets and growing seasons. This effectively affects Canadian growers in three ways:

1. Transportation-related costs and logistics: Ontario growers must arrange to ship slips by air or ground transportation resulting in high costs and delays which impact slip quality

2. Slip quality: Slips are often of inconsistent quality and size and increasingly they bear disease which lead to lower yields. Growers often order 20% to 30% more slips than they need to offset the inferior quality
3. Delivery time: The timing at which U.S. slips are grown coincide with the U.S. planting season. This, coupled with lengthy transportation times and border delays mean that Ontario growers do not have access to slips at optimal early planting dates. This impacts the production cycle and increases the risk of frost and chilling injury at the end of the season prior to harvest.

Building a Canadian value chain with locally-sourced propagative material

Establishing a Canadian slip propagation industry will allow growers to have access to slips when they need them and eliminate expensive transportation costs. Addressing this critical step of the sweet potato value chain will remove a major bottleneck in the expansion of Canadian production. Growers will have access to locally-sourced, high quality sweet potato slips at the right time and also support Canada's prior investment in the creation of new sweet potato varieties adapted to Canadian climates.

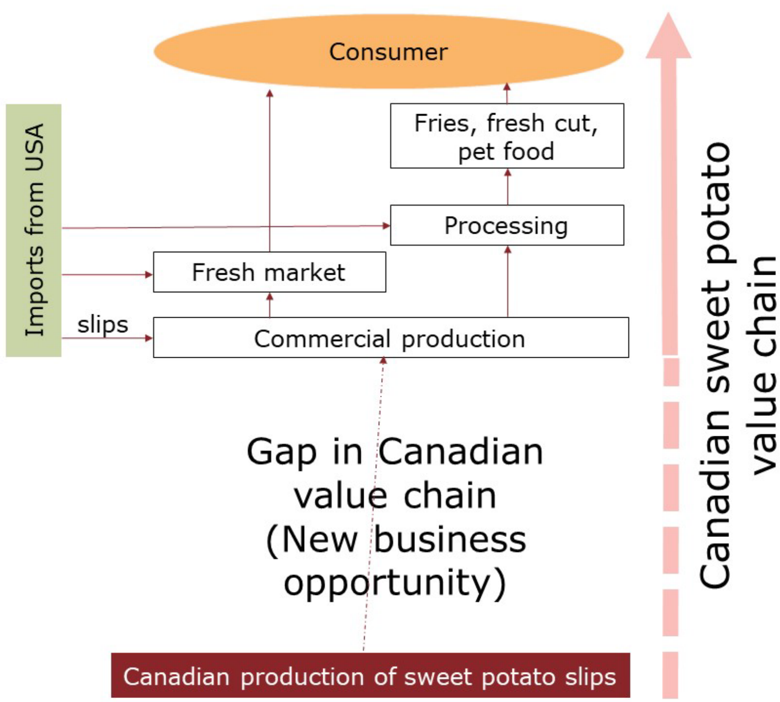


Figure 3. Canadian sweet potato value chain

In southern U.S. states sweet potato slips are produced in an open field environment. This is not an option in Canada since there are different weather conditions in the March to May timeframe during which slips are produced.

A technical and economic feasibility study on producing sweet potato slips in Canada was undertaken and a business case was developed for the opportunity to be taken up by a grower or propagator. The project focused on finding new slip propagation methods utilizing greenhouse space and rapid multiplication techniques to ensure high production slip volume at a competitive price. In addition, the project assisted with on-farm large scale testing of commercial slip propagation methods at two Ontario greenhouses and one in Nova Scotia using the Canadian developed variety known as Radiance throughout the research trials.

A number of Canadian growers and propagators are interested in seizing this opportunity by producing slips to supply local sweet potato growers. Sweet potato growers in turn will have access to a new source of sweet potato slips providing the following advantages:

- Avoid deterioration due to transportation and border control delays
- Available in time for the Canadian planting season
- Acclimatized for planting in cool Canadian conditions
- Sufficient quantities of slips will be available for growers to plant as many acres as needed
- Available new Canadian-adapted, high yielding, high quality sweet potato varieties' slips

Sweet potato slip production in Canada

Sweet potatoes are not propagated through seed like most traditional vegetables. Instead, sweet potatoes are propagated through slips which are vegetative stem cuttings about 20 cm to 30 cm in length. Slips are produced by planting a mature sweet potato referred to as sweet potato seed. Canadian sweet potato growers typically get their planting material from the U.S. in late May to early June, once soil temperatures are high enough to promote growth of slips. It is important for growers to have access to this material early, in order to maximize the growth of sweet potatoes during the short Canadian growing season.

The majority of sweet potato slips in North America are produced in the southern U.S., as the climatic conditions are conducive to outdoor production in early spring. This method is not appropriate for Canadian production since outdoor temperatures are too low to support the growth of slips. Sweet potato seed readily produce slips in the greenhouse, however, the cost of greenhouse production is considerably higher than in the field. To keep the price of Canadian-grown slips competitive with those of the U.S., improved production techniques were developed.

Producing high yielding sweet potatoes is not confined to only growers' cultural practices and is important at every stage of production. One of the primary factors influencing yield is the quality of slips and therefore producers must hold their production to strict standards. These include greenhouse cleanliness, sourcing of disease-free certified seed, suitable production practices and harvest techniques.

This document will address how Canadian growers may attain these standards, which will help develop a high quality, high yielding sweet potato slip propagation industry.

Picture 1: Sweet potato slips on heating mats (May 2017).

Chapter 1

Production of sweet potato cuttings in a Canadian greenhouse

Understanding the three generations of sweet potato seed stock

Understanding the production schedule when selecting sweet potato seed will help identify the benefits and limitations at each stage of production. The three stages of sweet potato seed production include G0 root seed (breeder seed), G1 root seed (foundation seed) and G2 root seed. Further generations of seed potato may be produced, however, they may not be suitable for commercial production of slips as they are dependent on the environment in which the slips were produced. The nomenclature system used to describe each generation of plantlet and seed potato described in this guide was slightly modified from the systems developed by North Carolina State University (Schultheis et al., 1994) and Louisiana State University (Don Labonte, personal communication).

Breeder seed (G0)

Breeder seed (G0) are produced each year from tissue cultured plantlets to maintain the variety's productivity and uniformity while being free of disease. This stock is propagated through a series of single-node cuttings (see Production of breeder seed) and transplanted in the field to generate storage roots used to produce G1 root seed.

G1 root seed (foundation seed)

G1 root seed (foundation seed) are storage roots produced from breeder seed (G0). They are carefully screened to maintain the variety's productivity and uniformity and ensure they are free of disease. The purpose of G1 root seed is to bulk up enough stock of G2 root seed for the following season for G2 slip production. Bedding G1 root seed in the greenhouse will produce G1 slips which are planted in the field to produce G2 root seed. G1 slips can also be multiplied for sale to commercial growers.

G2 root seed

G2 root seed are storage roots produced in the field from G1 slips. Bedding G2 root seed in the greenhouse will produce G2 slips which can be sold to the production market.

Greenhouse requirements

Sweet potatoes are native to tropical and sub-tropical environments of the Americas and greenhouse conditions need to mimic those environments. Greenhouse temperatures should be maintained between 24°C and 26°C throughout the growing season. The growing media should also be kept damp, starting from the time of planting until final harvest.

The production season for sweet potato slips begins early March and ends late June. During the early months of production, light may be limited depending on the geographic location of the greenhouse. To maximize natural light, growers should avoid whitewashing the area of the greenhouse where slips are produced. Additionally, seven to 10 hours of supplemental lighting may be required in the early months of slip production. High pressure sodium lights equipped with a 400-watt bulb providing 100 to 124 micromoles of light should be sufficient.

Picture 2: Sweet potato slip production at Roelands Plant Farms Inc. (May 2018).

Step-by-step process of producing slips

Step 1: Production of G0 (breeder seed)

Breeder seed, also referred to as G0, is clonally propagated through tissue culture to ensure the purity and disease-free quality of the variety. For this study, all virus-free tissue cultured plantlets of the variety known as Radiance were produced at the New Liskeard Agricultural Research Station SPUD Unit (contact: Candy Keith, Manager). Once the plantlets are ready to be removed from tissue culture (see Picture 3 on page 8), they are transferred onto a bed of growing media approximately 4 cm to 6 cm deep. Atypical of plantlets coming from tissue culture, sweet potato plantlets do not require a special treatment to “harden-off” prior to planting in the greenhouse.

Picture 3: Virus-indexed sweet potato plantlets from tissue culture (August 2017).

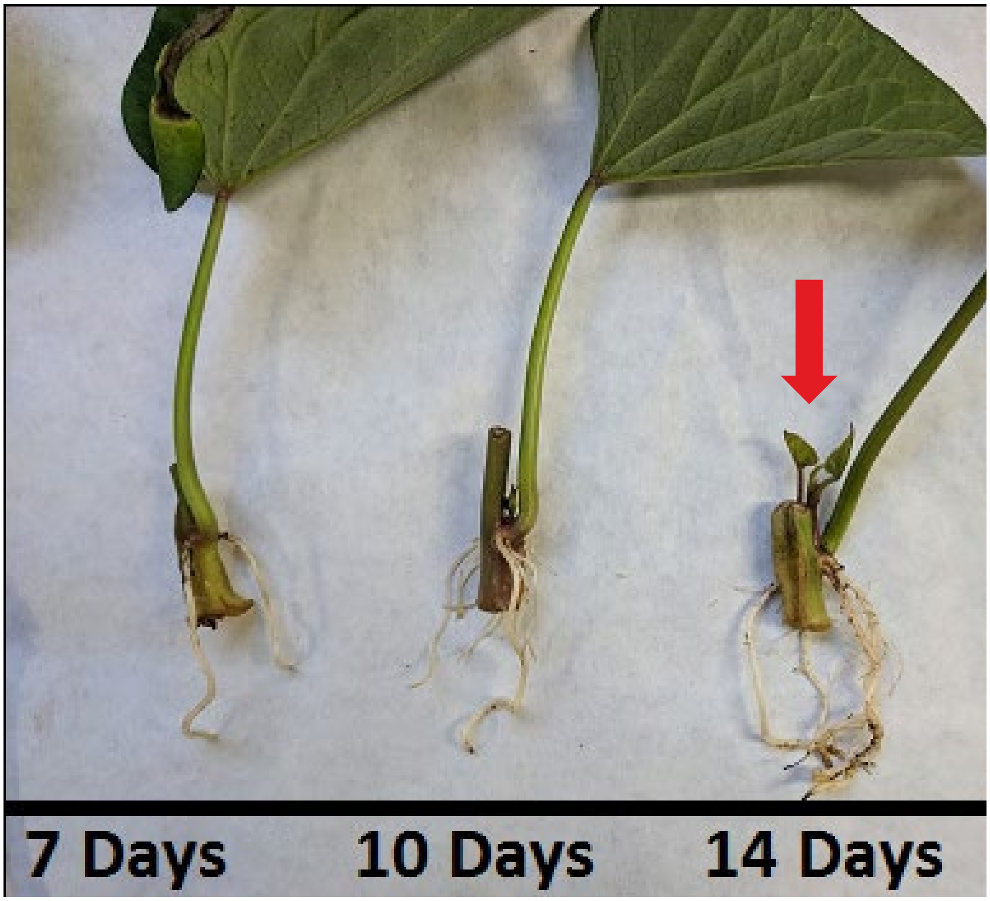
Following four to six weeks of growth, the plantlets are ready to be propagated using single-node cuttings (see Step 2: Single-node propagation). Single-node propagation rapidly increases the volume of planting material to support the demand for G1 root seed (see foundation seed).

Step 2: Single-node propagation

The single-node propagation method allows rapid multiplication of sweet potato material. Slips are harvested from bedded tissue cultured plants using clean sheers and are harvested 3 cm above the base of the plant. Clean sheers limit disease contamination of plant cuttings through mechanical damage.

Slips are cut slightly above and below each node. They can be transplanted directly into prepared beds with 4 cm to 6 cm of growing media at a density of 100 to 200 plants/m^2 or transplanted into 72-cell propagation trays. Each single-node cutting should contain one leaf and can be expected to begin rooting within seven days of transplanting (see Picture 4 on page 9). Cuttings started on 72-cell propagation trays should be planted into prepared beds after seven days. Within 14 days, a new slip should begin to sprout from the axil (see Picture 4).

One slip per node can be expected when using the single-node propagation method. This process can be repeated until the desired amount of material has been obtained.



Picture 4: Single-node cuttings seven, 10 and 14 days post-transplanting (January 2018).

Step 3: Field production of G1 root seed

After sufficient material has been propagated using the single-node cutting method, slips should be allowed to grow until the shoots reach a length of 35 cm to 40 cm. Slips can then be harvested and transplanted directly into the field using raised beds with an in-row spacing of 20 cm and a between row spacing of 30 cm. A high density of plants (approximately 24,000 slips per acre) is required to maximize the production of U.S. grade No. 2 storage roots. Fertility and irrigation recommendations for sweet potato root seed are the same as field production for the fresh market (see Chapter 2).

If a sufficient amount of material is not available in time for field transplanting, single-node cuttings can be transplanted directly into the field at the same density as slips. Single-nodes should be pre-rooted before being transplanted into the field. This can be achieved by harvesting slips that have been produced from tissue cultured plants seven days prior to the intended harvest date and single-nodes can be cut and transplanted into 72- or 144-cell propagation trays. Pre-rooted plugs may then be transplanted directly into the field.

Slip production from G1 and G2 root seed

The production of slips from sweet potato seed is similar across generations. It is necessary to keep generations separate from each other to avoid disease transfer and the addition of mutations.

All grades of sweet potatoes can produce slips. To reduce input costs associated with purchasing seed, it is preferable to use U.S. grade No. 2 sweet potatoes (United States Department of Agriculture, 2005; 5.1 to 17.8 cm in length and 2.5 to 5.1 cm in width; see Picture 5), as the slip yield is similar to the slip yield of U.S. grade No. 1 (see Figure 4) but with lower associated costs.

Picture 5: Sweet potato U.S. grade No.1 and U.S. grade No. 2 (January 2019).

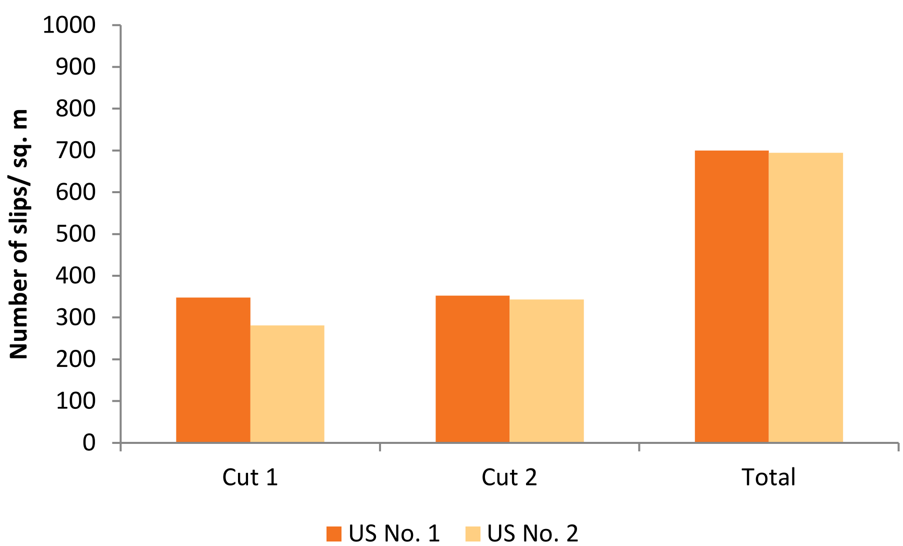


Figure 4: Average number of slips from two harvests of U.S. grade No. 1 and U.S. grade No. 2 sweet potato root seed.

Step 4: Pre-sprouting

Sweet potato seed should be pre-sprouted prior to bedding them to increase germination and yield of total slips. The process involves placing the roots in a dark room between 26°C and 29°C and a relative humidity of 85% to 95% for two to four weeks prior to the planting date (see Picture 6). Adequate ventilation is required as sweet potato seed are using oxygen and producing carbon dioxide during the process. They are ready for planting once most of the sweet potatoes have grown sprouts with a length of 0.3 cm to 0.6 cm. Pre-sprouting can be delayed by lowering the temperature in the facility no lower than 18°C.

Picture 6: Sweet potato seed in a pre-sprouting room (January 2019).

Step 5: Washing of sweet potato seed

Sweet potato seed may be washed or remain unwashed prior to planting depending on the grower's practices. If sweet potatoes are required to be soilless before entering the greenhouse they can be washed by hand or through a washing line with water. Care must be taken to avoid damaging the skin and sprouts of the sweet potato seed. It is recommended that sweet potato seeds not be washed prior to planting since it could lead to rotting of the seed potato. If washing is necessary, please contact authors for further options to prevent rotting.

Step 6: Bedding of sweet potato seed in greenhouse

Bed preparation

Slips from sweet potato seed are propagated in raised beds with 3 cm to 4 cm of growing media (see Picture 7). It is ideal to use a heating source under each bed to maintain a soil temperature no lower than 22^{o}C.

Beds can be built to any desired length, however considerations should be given to the width of each bed as access will be required throughout the growing season to scout for pests and diseases, monitor for nutrient deficiencies and ensure proper irrigation. Bed width and aisle space are also important considerations since workers will need access to each sides of the beds to harvest slips. A rule of thumb is to use a bed width of 60 cm to 110 cm with an aisle space of 45 cm to 60 cm, however adjustments can be made depending on the grower's practices.

Picture 7: Bed preparation with sweet potato root seed (February 2018).

Bedding of root seed stock

Root seed are placed 1 cm to 2 cm apart on each bed ensuring that none are touching. The planting density is a crucial component of the overall slip quality. If sweet potato root seed are too dense, slips will grow to be thin and weak and if they are too far apart they will not grow straight. Once the seed are placed in the beds they are covered with an additional 2 cm to 3 cm of growing media (see Picture 8). Sufficient water should be applied to moisten soil beds after planting. Sprouts will emerge from the soil within two weeks of planting.

Picture 8: Sweet potato root seed being covered with growing media (March 2017).

Growing and cutting back phase

Soil moisture should be monitored during the growing season using a tensiometer inserted to the depth of the sweet potato root seed (see Picture 9 on page 14). The resistance to the flow of electricity (expressed in Ohms) and the soil temperature are used to calculate the tension of the soil water in centibars (cb). Soil water tension (SWT) is the force necessary for plant roots to extract water from the soil. Soil water tension reflects the soil moisture status. The ideal soil tension will vary depending on the media mix, however, as a general recommendation a soil tension of 10 cb to 20 cb should be maintained to maximize water availability and decrease the incidence of rot.

Picture 9: Tensiometer inserted in the soil to the depth of a sweet potato root seed.

Three weeks after planting, slips should be cut back 2 cm to 3 cm above the soil line. Slips should be cut back a second time three weeks later (see Picture 10). Cutting back slips will help develop a uniform canopy as well as promote the growth of more sturdy slips.

Picture 10: Sweet potato slip beds after the second cut-back (January 2019).

Fertility requirements
Fertilizer should be applied during planting using a controlled-release fertilizer (see Picture 11 on page 15) or managed through fertigation. Both methods have benefits and limitations. The use of a slow-release fertilizer can be less time consuming and easier to

apply, although, nutrient levels throughout the growing season can be difficult to adjust. In the case of fertigation, modifications to the fertilizer solution can be adjusted throughout the growing season with relative ease, however, it can be more time consuming.

Controlled-release fertilizer should be incorporated into the growing media at a rate of 1 lbs/m^2 of 10-10-10 (with micronutrients – two- to three-months release). If a fertigation approach is selected, an alternating schedule of 20-8-20 (with micronutrients – electrical conductivity (EC) of 2.0) and 14-0-14 (balance - EC of 2.0) has demonstrated to produce high volumes of slips.

Growers should regularly monitor soil pH and EC to ensure nutrient levels are correct. Sweet potatoes grow best in soils with a pH of 5.8 to 6.0. Tissue sampling should be conducted on a bi-weekly basis and sent to a reputable laboratory for nutrient analysis to maintain appropriate fertility levels (see Table 1).

Picture 11: Spreading of controlled-release fertilizer (March 2017).

Table 1: Sweet potato nutrient and micronutrient ranges

Nutrient	Range (%)
Nitrogen	3.30 to 4.50
Phosphorus	0.23 to 0.50
Potassium	3.10 to 4.50
Calcium	0.70 to 1.20
Magnesium	0.35 to 1.00

Micronutrients	Range (ppm)
Zinc	20 to 50
Manganese	40 to 250
Copper	5 to 10
Iron	40 to 100
Boron	25 to 75

Source: Sweet Potato Fertility Guide. Agri-Food Laboratories, ON
http://www.agtest.com/articles/SweetPotatoFertilityGuide.pdf

Pest control
Growers should regularly scout for pests such as thrips, whiteflies and aphids (see Picture 12) since many diseases can be transmitted through them. There are no registered sprays for greenhouse slip production in Canada except for insecticidal soaps and *Beauveria bassiana* (Bioceres G WP; Anatis Bioprotection Inc.). Due to constraints on registered pesticides, a strict biological control program must be implemented to suppress pest populations that may arise.

Biological predators such as *Amblyseius cucumeris* and *Amblyseius swirskii* have a high efficacy against western flower thrips, Echinothrips and onion thrips. The Eretmix system is a combination of parasitoids *Encarsia formosa* and *Eretmocerus eremicus* which are effective against both tobacco and greenhouse whiteflies. Aphids can be suppressed by using predators such as *Adalia bipunctata* and/or parasitoids including *Aphidius colemani* and *A. matricariae*. However, certain parasitoids for aphid control can be species specific. It is always recommended to contact a biological control consultant to discuss integrated pest management (IPM) before starting to grow a new crop.

Picture 12: Potato aphids on sweet potato leaf (January 2019).

Harvest

When plant canopy reaches 35 cm to 40 cm in length, slips are ready for harvest (see Picture 13). They are harvested by hand 3 cm to 5 cm above the soil line to minimize the transmission of soil-borne pests and diseases. Only the highest quality slips measuring between 25 cm and 30 cm in length should be shipped to growers. Most of them are ready to accept slips by the third weekend in May. A second harvest can also occur as early as two weeks after the initial harvest for planting by the second week of June.

Picture 13: Slips at the appropriate length for harvest (May 2017).

Packaging and transporting

Sweet potato slips are packaged with the cut ends facing downward into corrugated boxes (see Picture 14 on page 18), large enough for 1,000 tightly packed slips and shipped between 14°C and 16°C. For highest slip survival and plant yield, they should be transplanted within seven days after harvest.

Picture 14: Packaged slips from the U.S. after shipping (July 2016).

Table 2: General outline of approximate dates and duties required for greenhouse slip production.

Week	Date	Task
1	1st week of March	Pre-sprouting
2	2nd week of March	Bed preparation, planting of root seed
3	3rd week of March	Growing: fertigation of root seed 20-8-20, EC: 2.0
4	4th week of March	First cut-back, transplanting slips from cut material
5	1st week of April	Growing: fertigation of root seed 20-8-20, EC: 2.0
6	2nd week of April	Second cut-back: transplanting slips from cut material
7	3rd week of April	Growing: fertigation of root seed 20-8-20, EC: 2.0
8	4th week of April	Third cut-back: transplanting slips from cut material
9	1st week of May	Growing: water only, no fertilizer
10	2nd week of May	Growing: water only, no fertilizer
11	3rd week of May	Growing: water only, no fertilizer
12	4th week of May	First harvest
13	1st week of June	Growing: water only, no fertilizer
14	2nd week of June	Growing: water only, no fertilizer
15	3rd week of June	Second harvest

Chapter 2

Production of root seed

The highest input cost associated with greenhouse slip propagation is the initial production of seed potato (see Chapter 3). The efficiency of root seed production is critical in reducing costs and allowing for a viable greenhouse slip production industry in Canada.

As with all crops, starting with high quality and disease-free root seed stock is of the utmost importance to ensure reliable slip yield production in the greenhouse, as well as maintaining a high final quality product. The first step begins with rigorous IPM practices in the greenhouse and strict procedures to maintain the integrity of each generation of root seed.

In the production of sweet potato root seed it is important to maximize the yield of U.S. grade No. 2 potatoes to use as seed stock for producing slips the following seasons. For more information on the differences between the three generations of sweet potato root seed stock see Chapter 1.

From tissue culture to root seed

Virus-indexed plantlets for each variety should be maintained in tissue culture and a fresh culture should be planted annually to create a stock of virus and disease-free material (see Chapter 1, Step 1: Production of breeder seed). As vines grow from the newly created stock, single-nodes can be used to rapidly increase the production of slips (see Chapter 1, Step 2: Single-node propagation). Subsequent slips created from this process can be harvested to create G1 root seed.

Production of G1 root seed from tissue culture plantlets

Slips harvested from tissue cultured material can be transplanted into the field using single-nodes or full slips. For more details on agronomic practices not covered here, see Chapter 1, Step 3: Field production of G1 root seed.

Production of G1 root seed from single-nodes

If tissue cultured material is limited, G1 root seed can be produced through single-node slip cuttings. To create material to be planted directly into the field, follow the methods outlined in Chapter 1, Step 2. Instead of transplanting this material directly into beds in the greenhouse, rooted plugs can be transplanted directly into the field after seven days post-planting. If weather does not permit to plant within seven days, the remaining leaf from each node may be removed to delay the growth for up to 14 days post-transplanting.

Agronomic practices (bed preparation, spacing, fertility, irrigation, IPM, harvest and storage) for single-node propagation are the same as sweet potato seed production from slips.

G1 root seed production from slips

If sufficient material has been produced using the single-node propagation method in the greenhouse, slips can be transplanted directly into the field in a similar fashion to the production of G2 and G3 root seed.

G2 and G3 root seed production from slips

G2 root seed are produced through the transplanting of G1 slips sprouting from G1 root seed bedded in the greenhouse that was produced from the prior field season. G3 root seed are produced and sold by commercial growers to the fresh market for human consumption. They are produced through the transplanting of G2 slips sprouting from G2 root seed bedded in the greenhouse that was produced from the prior field season.

Field production of root seed

Crop rotation

It is important to follow a three-year crop rotation schedule to reduce the accumulation of pests and pathogens. A well-planned crop rotation schedule will not only increase the yield of root seed but also increase the quality of material for slip production the next season. At Vineland, the second year of the rotation was planted with winter wheat and rye in the spring and left fallow for the growing season. In the third year, a blend of black oats, oriental mustard, groundbreaker radish, crimson clover and Austrian winter peas was used. Avoid grass species including corn and sorghum the year before planting to minimize the population of wireworms.

Soil analysis and preparation

Soil samples should be collected every year prior to preparing beds and sent to a reputable soil laboratory for a complete nutrient analysis (see Picture 15). For this study, soil samples were sent to the University of Guelph, Laboratory Services. Fertilizer recommendations were adjusted based on soil test results. Please note that land intended for use prior to the year of planting may be fumigated if soil fumigation is permitted in your jurisdiction.

SGS AGRIFOOD LABORATORIES

AgTest Farm Soil Report

1-503 Imperial Road North Guelph, ON, N1H 6T9 t: 519-837-1600 1-800-265-7175 f: 519-837-1242 ca.agri.guelph.lab@sgs.com

Report # 544969 VINELAND RESEARCH & INNOVATION CENTRE- - VIC910-VIC19F40 Page 1 of 3

Sample ID	Lab #	pH	BpH	Total Salts (mmhos/cm)	Organic Matter (%)	Nitrogen NO3-N (ppm)	Phosphorus - P (ppm) Sodium Bicarb.	Potassium K (ppm)	Magnesium Mg (ppm)	Calcium Ca (ppm)
VIC19-10 - 0-15cm	31463606	7.1			2.3		57	142	117 HR	1054
VIC10-10	31463607	6.8			2.5		46	180	102 HR	1509
VIC19-F10	31463608	6.0	6.9		2.7		49	177	95 HR	679

Sample ID	Zinc Zn (ppm)	Zn Index	Manganese Mn (ppm)	Mn Index	Copper Cu (ppm)	Iron Fe (ppm)	Boron B (ppm)	Texture	Cation Exchange MEQ/100g	Base Saturation K%	Mg%	Ca%	H%
VIC19-10	1.4 M	17.2	16.9 H	15.4	2.5 H	36.2 H	0.58 L	C	7.8	4.7	12.5	67.5	15.4
VIC10-10	1.2 LM	17.6	22.2 H	17.7	3.6 H	50.9 H	0.47 L	C	10.1	4.6	8.4	75.0	11.9
VIC19-F10	1.2 LM	24.1	11.7 MH	25.9	5.0 H	102.2 E	0.42 L	C	5.8	7.8	13.5	58.1	20.6

Sample ID	Sodium Na (ppm)	Sulphate Sulphur SO4-S (ppm)	Chloride Cl (ppm)	Aluminum Al (ppm)	K/Mg Ratio	Exchangeable Acidity
VIC19-10					1.2	
VIC10-10					1.8	
VIC19-F10					1.9	

Agri-Food Nutrient Management Guidelines (lb/ac)

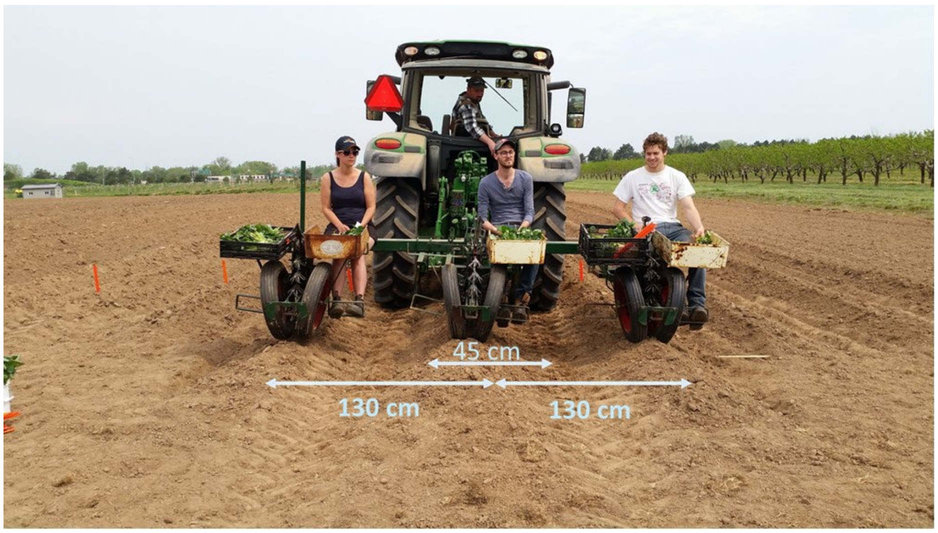
Sample ID	Crop to be Grown	Yield Goal	N	P2O5 Rec	P2O5 Removal	K2O Rec	K2O Removal	Magnesium	Calcium	Sulphur	Zinc	Manganese	Copper	Iron	Boron	Lime (te/ha)
VIC19-	Sweet Potato, Before Root		45					15			2.0					
VIC10-	Sweet Potato, Before Root		45					20			3.0					
VIC19-	Sweet Potato, Before Root		45					20			2.0	1.0				

Authorized By: *Jack Legg - CCA-ON, 4R NMS*

Picture 15: Sample soil report of Vineland field from the University of Guelph, Laboratory Services.

Bed preparation

An application of 60 kg/Ha of P_2O_5 and 100 kg/Ha of K_2O should be applied and incorporated into the soil through cultivation seven days prior to the intended planting date. If planting on bare ground, raised beds with widths of 45 cm and distances of 130 cm from the centre of one bed to the other should be prepared prior to transplanting (see Picture 16). If sweet potato root seed will be produced in an environment with lower growing degree days than Southern Ontario, raised beds with black plastic mulch (see Picture 17) will be necessary to extend the growing season. When planting on black plastic mulch, beds should be prepared with widths of 60 to 75 cm and distances of 150 to 180 cm from the centre of one bed to the other.



Picture 16: Prepared single row raised beds just prior to transplanting.

Picture 17: Prepared black plastic mulch raised beds just prior to transplanting.

Planting

Sweet potato slips should be transplanted when there is no risk of frost. In Ontario, this is typically between the final week of May and mid-June. Slips should be transplanted in single rows when using bare ground using an in-row spacing of 30 cm (see Pictures 16 and 17). If using the black plastic mulch system, two rows of sweet potato slips should be planted in each bed. The double-row system should be staggered with 30 cm between rows and an in-row plant to plant spacing of 30 cm (see Picture 18).

Picture 18: Double-row planting on black plastic mulch raised beds.

Growing

Irrigation is critical within the first six weeks post-transplanting for root formation. Irrigation should be supplemented at a minimum for the first six weeks to total 2.5 cm of water per week (see picture 19). After 15 days post-transplanting, 120 kg/Ha of K_2O should be applied with 5 kg/Ha of Borax. After 28 days post-transplanting, a total of 75 to 100 kg/Ha of nitrogen should be applied.

Picture 19: Overhead irrigation of sweet potato field.

Pest scouting should also occur on a weekly basis and appropriate controls can be employed to limit pest pressure and subsequent spread of disease. For a comprehensive list of chemicals registered for use on sweet potatoes in Canada click here.

Harvesting

Harvest should occur during the month of September, depending on the cumulative number of growing degree days. It is ideal to check the size of sweet potatoes at the end of August to determine the appropriate harvest date by digging representative samples throughout the field. Vines should be removed from plants by mowing and side-cutting vines five to seven days prior to the intended harvest (see Picture 20 on page 24). The removal of vines triggers the sweet potato skin to thicken which should minimize skin damage during harvest (see Picture 21 on page 24).

Picture 20: Vine removal in sweet potato field.

Picture 21: Sweet potato skin damage during harvest.

Harvest can be completed either mechanically with a sweet potato harvester or manually. Manual harvesting offers the benefit of reducing sweet potato skin damage, however, it is time consuming. Sweet potatoes can be collected into macrobins upon harvesting and should be stored immediately in the proper curing conditions.

Curing and storage

Curing is essential to help thicken sweet potato skin, heal harvesting wounds and prepare sweet potatoes for long-term storage. The macrobins full of sweet potatoes should be placed into a sealed room at a steady temperature of 28^{o}C and relative humidity of 85% to 95%. Adequate ventilation is important during the process. Sweet potatoes should remain under curing conditions for seven to 10 days to ensure that the skin is not easily rubbed away from the flesh and sprouts have not begun to form yet.

After curing, sweet potatoes may be stored for up to 12 months in a sealed compartment with adequate ventilation at a temperature of 14^{o}C to 16^{o}C and a relative humidity of 80% to 90% (see Picture 22). Sweet potatoes in storage should be regularly inspected to remove the rotting ones and to prevent the spread of rot to uninfected root seed stock.

Picture 22: Long-term storage of sweet potato in macrobins at Vineland facility.

Cost of production

The following sweet potato cost of production was derived from a similar template provided by OMAFRA (2005). The variable and fixed production costs represent the most commonly used strategies in the production of sweet potatoes in Ontario. Costs associated with conducting these activities were estimated using data collected from Vineland and several Ontario growers. The cost of producing sweet potatoes in Ontario was similar to Louisiana estimates (Guidry et al., 2019).

Table 3: Root seed cost of production and storage

Expense item	Unit	Quantity	Cost/ unit	$/acre	G1 root seed 0.125 acres	G2 root seed 3.33 acres
Variable costs						
Fertilizer						
Nitrogen (N)	kg	58	$1.38	$80.04	$10.01	$266.53
Phosphate (P_2O_5)	kg	58	$1.12	$59.12	$7.39	$196.86
Potash (K_2O)	kg	139	$0.93	$139.93	$17.49	$465.98
Micronutrients	kg			$20.00	$2.50	$66.60
Herbicide						
Round up	litres	1	$8.00	$8.00	$1.00	$26.64
Poast Ultra	litres	0.13	$126.51	$16.45	$2.06	$54.77
Merge	litres	0.4	$10.66	$11.06	$1.38	$36.83
Command	litres	1.15	$34.80	$35.95	$4.49	$119.71
Custom work						
Herb. application	acre	1	$13.34	$13.34	$1.66	$44.09
Fert. application	acre	1	$13.24	$13.24	$1.66	$44.09
Storage						
Bin rental	acre	37	$60.00	$2,220.00	$277.50	$7,392.60
Curing (10 days)	m^2	100	$2.00	$200.00	$25.00	$666.00
Long-term storage (6 mo.)	m^2	100	$7.70	$770.00	$96.25	$2,564.10
Labour						
Planting	hrs.	20	$15.00	$300.00	$37.50	$999.00
Weeding	hrs.	4	$15.00	$60.00	$7.50	$199.80
Top cutting	hrs.	2	$50.00	$100.00	$12.50	$333.00
Harvesting	hrs.	92	$15.00	$1,380.00	$172.50	$4,595.40
Sorting	hrs.		$15.00		$0.00	$0.00
Machine operation	hrs.	12	$50.00	$600.00	$75.00	$1,998.00
Other						
Irrigation	acre	2	$148.00	$296.00	$37.00	$985.68
Digger rental	acre	1	$110.00	$110.00	$13.75	$366.30
Fuel	acre	1	$177.00	$177.00	$22.13	$589.41

Machine repair	acre	1	$143.00	$143.00	$17.88	$476.19
Bldg. repair	acre	1	$22.00	$22.00	$2.75	$73.26
Land rent	acre	1	$400.00	$400.00	$50.00	$1,332.00
Gen. var. costs	acre	1	$199.00	$199.00	$24.88	$662.67
Interest on operation capital	acre	1	$72.00	$72.00	$9.00	$239.76
Total variable costs	**acre**	**1**		**$7,446.03**	**$930.75**	**$24,795.27**
Fixed costs						
Depreciation	acre	1		$206.00	$25.75	$685.98
Interest on loan terms	acre	1		$113.00	$14.13	$376.29
Long-term lease	acre	1		$0.00	$0.00	$0.00
General fixed costs	acre	1		$30.00	$3.75	$99.90
Total fixed costs	**acre**	**1**		**$349.00**	**$43.63**	**$1,162.17**
Total costs (var. + fixed)	**acre**	**1**		**$7,795.03**	**$974.38**	**$25,957.44**

Chapter 3

Introduction to slip cost of production and revenue potential

The total production area of sweet potatoes in Canada has increased 10-fold over the last 10 years with reported acreage of 162 acres in 2001 and 2,344 acres in 2018 (OMAFRA, 2014; Statistics Canada 2018; personal communication with multiple growers). Approximately 98.8% of the Canadian production area for sweet potatoes is in Ontario (Statistics Canada, 2018). Vineland has been working closely with growers across Canada and gathered data illustrating a greater acreage than reported by Statistics Canada in 2016 (see Table 4).

The vast majority of sweet potato slips are purchased from the southern United States and Canadian growers are facing a number of logistical, timing and disease issues. Growers have identified the need for a Canadian supplier of slips to resolve these issues. As the acreage of sweet potatoes in Canada continues to grow, there is a lucrative opportunity for greenhouse growers to provide quality greenhouse slips to meet this growing demand.

The most pressing issue for Canadian slip growers is the elevated cost of production. Since slips can be produced outdoors in the southern United States, in the spring, U.S.-sourced slips have lower input costs and therefore can be sold for $0.05 to $0.08 per slip (Jones Family Farms, 2019). While Canadian springs are too cold for outdoor production, slips must be produced in heated greenhouses, significantly raising the cost of production in comparison to the United States. Market research performed at Vineland has shown some growers will tolerate a higher price for better quality and higher yielding varieties in the range of $0.12 to $0.17 per slip. To produce slips at this price point, several cost saving measures must be investigated to minimize inputs while maximizing production efforts.

This chapter will identify and analyze costs associated with greenhouse production of different generations of slips (G0, G1 and G2), as well as identify important areas of continuing research to create a viable and profitable slip production industry in Canada.

Table 4: Estimated acreage and slip requirements for sweet potatoes produced per province.

	Acres										
Source	Canada	NF	PEI	NS	NB	QC	ON	MN	SK	AB	BC
Statistics Canada	1776	0	4	x	x	3	1755	2	x	0	5
Vineland estimates	2344	x	4	80	x	200	2000	10	x	x	50
	Number of slips required (million)										
Source	Canada	NF	PEI	NS	NB	QC	ON	MN	SK	AB	BC
Vineland estimates	29.6	x	0.72	1.44	x	2.40	24.0	0.12	x	x	0.90

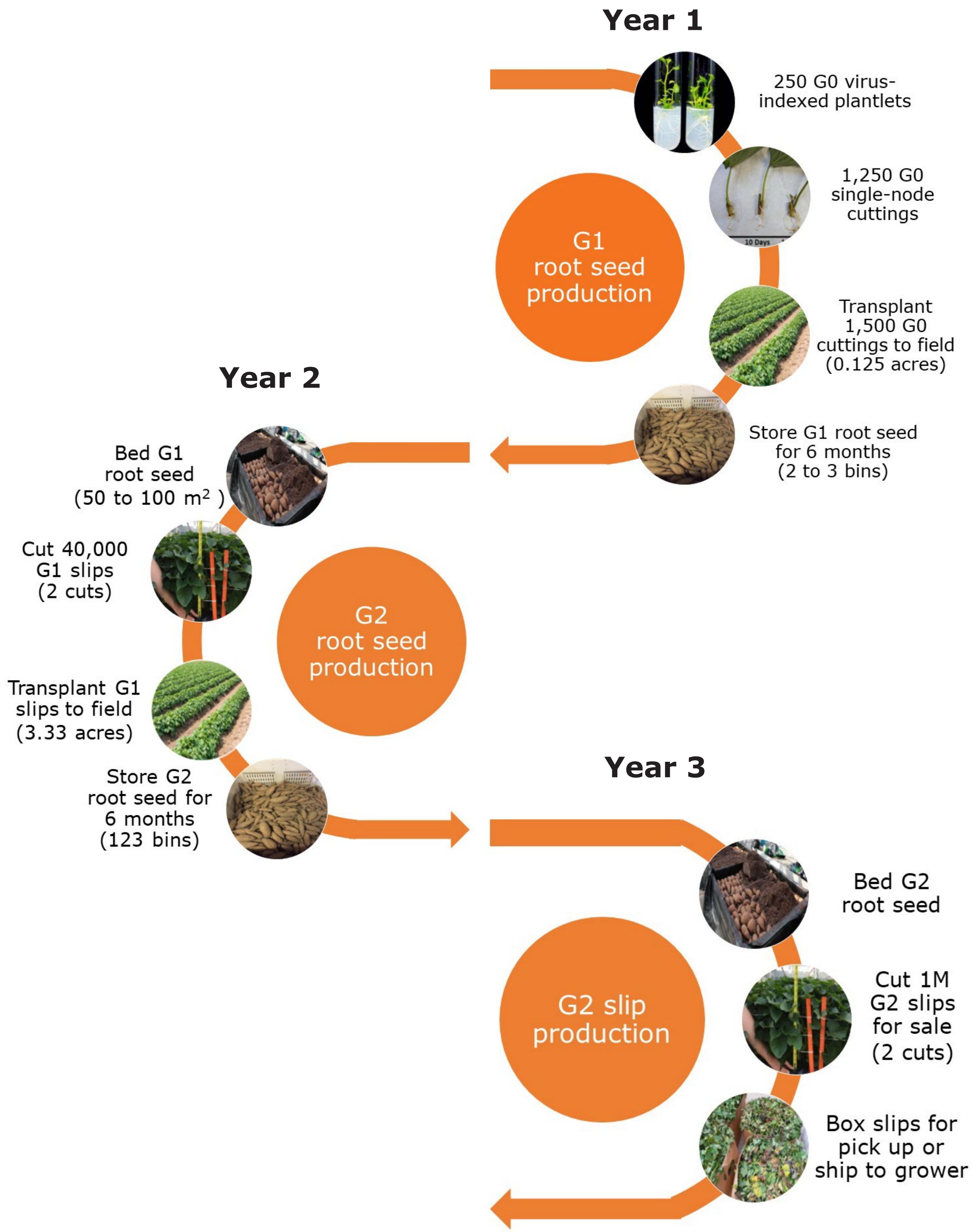


Figure 5: Summary of greenhouse slip production cycle. The three main phases for commercially producing virus-indexed sweet potato slips in a Canadian greenhouse: G1 root seed production, G2 root seed production and G2 slip production.

Breakdown of slip cost of production

Calculations and assumptions

The cost of production was calculated through research trials performed at three locations in Ontario and one in Nova Scotia. The direct costs were calculated based on 8 m^2 to 602 m^2 research trial areas. The following assumptions were taken into account:

- Low technology greenhouse is available
- End goal to produce G2 slips in a one acre (approximately 4,000 m^2) size facility by year 3
- Greenhouse operating overhead or fixed costs were calculated using the national average of 22% of total costs
- Greenhouse energy costs were derived from an economic report published by the University of Guelph
- Biological controls were used throughout the entire production season
- 1 m^2 requires 15 kg of seed potato
- 1 m^2 produces 600 slips (over two cuts)
- Each plantlet or slip produces 1.5 kg of root seed
- Capital investment such as the construction of a greenhouse or hoop house and installation of a storage facility for root seed, was not included
- Royalty rate for licensing Radiance was not included

Year 1: G1 root seed production

Tissue culture

Tissue cultured plantlets must be maintained to renew virus and disease-free material each year. A laboratory located at the New Liskeard Agricultural Research Station (NLARS) currently produces virus-free plantlets for a fee of $3.00 per plantlet. The first step for producing virus-indexed sweet potato slips is to order approximately 100 to 250 plantlets (see Figure 5 on page 29). This material is used to produce an additional 1,250 plantlets using single node propagation as discussed in Chapter 1. The goal is to transplant at least 1,500 plantlets into the field to produce G1 root seed. It is possible to order less plantlets to produce a total of 1,250 plantlets or more, if desired, which should reduce cost of production. The space requirements, consumables, labour and overhead costs associated with producing plantlets is shown in Table 5.

Table 5: Production cost of 1,250 single-node cuttings (SNC) from 250 pre-ordered virus-indexed plantlets.

Expense item	Unit	Qty	Cost/ unit	Experimental data total (8 m²)	Cost/m²	Cost to prepare 1,250 SNC
Direct expense						
Labour						
Plant 250 plantlets in bed	hrs.	4	$15.00	$60.00	$7.50	$60.00
First top cutting planting	hrs.	7	$15.00	$105.00	$13.13	$105.00

Cut/prepare cuttings for field planting	hrs.	2	$15.00	$30.00	$3.75	$30.00
Bed preparation						
Labour to set up bed	hrs.	3	$15.00	$45.00	$5.63	$45.00
Soil	3.6 ft³ bail	8	$16.00	$128.00	$16.00	$128.00
Fabric	12'x300' roll	1	$283.70	$28.37	$3.55	$28.37
Fertilizer						
20-8-20	15 kg bag	4	$63.40	$253.60	$0.42	$3.37
14-0-14	15 kg bag	4	$63.40	$253.60	$0.42	$3.37
8-20-30	15 kg bag	2	$63.40	$126.80	$0.21	$1.69
Pest management						
Swirskii	sachet	2	$0.40	$0.80	$0.10	$0.80
Eretmix	100/card	2	$1.00	$2.00	$0.25	$2.00
Athena	1,000/bottle	1	$92.40	$23.10	$2.89	$23.10
Botanigard 22WP (if necessary)	500 g bag	1	$140.00	$140.00	$0.23	$1.86
Fixed expenses						
Heating/lighting					$1.15	$9.20
Overhead (22% of total direct expenses)					$12.15	$97.19
Total expenses					**$55.22**	**$538.94**

Production costs for G1 root seed

Unlike most vegetables, sweet potato slips are not propagated through seeds but rather through whole sweet potatoes. Ideally, slip producers should have the capacity to produce their own sweet potato root seed to A) minimize input costs of sweet potato root seed and B) maximize quality by keeping sweet potato generations separate; maintaining a strict IPM schedule and limiting transmission of disease. The cost associated with producing G1 root seed from 1,500 plantlets was estimated using an OMAFRA sweet potato cost of production template (see Table 3 on page 26), where the fixed costs are adjusted for the acreage to be planted. Transplanting 1,500 plantlets to the field required approximately 0.125 acres assuming a planting density of 12,000 plants per acre. A grower could expect to harvest at least 1,500 kg of G1 root seed (1 kg per plant) in a typical southern Ontario growing season. The cost of producing G1 root seed in the field was estimated at $974.38 (see Table 3).

Year 2: G2 root seed production

Production costs of G1 slips

In year 2 of the slip production cycle (see Figure 5 on page 29), G1 root seed were bedded and sprouted in the greenhouse (see Chapter 1) to produce G1 slips which were transplanted in the field to produce G2 root seed (see Chapter 2). The cost to produce 40,000 G1 slips were estimated at $3,936.09 (see Table 6).

Table 6: Production cost for G1 slips to produce G2 root seed.

Expense item	Unit	Qty	Cost/ unit	Experimental data total (602 m²)	Cost/m²	Cost to prepare 40,000 G1 slips (100 m²)
Direct expense						
Bed preparation						
Labour to set up bed	hrs.	3	$15.00	$45.00	$5.63	$562.50
Soil	3.6 ft³ bail	360	$16.00	$5,760.00	$9.57	$956.81
Fabric	12'x300' roll	2	$283.70	$567.40	$0.94	$94.25
Fertilizer						
20-8-20	15 kg bag	4	$63.40	$253.60	$0.42	$42.13
14-0-14	15 kg bag	4	$63.40	$253.60	$0.42	$42.13
8-20-30	15 kg bag	2	$63.40	$126.80	$0.21	$21.06
Pest management						
Swirskii	sachet	9	$0.40	$3.60	$0.01	$0.60
Eretmix	100/card	24	$1.00	$24.00	$0.04	$3.99
Athena	1,000/bottle	2	$92.40	$184.80	$0.31	$30.70
Botanigard 22WP (if necessary)	500 g bag	1	$140.00	$140.00	$0.23	$23.26
Labour						
Head grower (management)	hrs.	64	$50.00	$3,200.00	$5.32	$531.56
Plant G0 seed in beds	hrs.	61	$15.00	$915.00	$1.52	$151.99
First top cutting	hrs.	25	$15.00	$375.00	$0.62	$62.29
Second top cutting	hrs.	25	$15.00	$375.00	$0.62	$62.29
Harvest for planting in field	hrs.	150	$15.00	$2,250.00	$3.74	$373.75
Clean-up	hrs.	61	$15.00	$915.00	$1.52	$151.99
Fixed expenses						
Heating/lighting					$1.15	$115.00
Overhead (22% of total direct expenses)					$7.10	$709.79
Total expenses					**$39.36**	**$3,936.09**

Production costs of G2 root seed

The cost associated with producing G2 root seed from 40,000 G1 slips was estimated using an OMAFRA sweet potato COP template (see Table 3 on page 26), where the fixed costs are adjusted for the acreage to be planted. Transplanting 40,000 G1 slips to the field required approximately 3.33 acres assuming a planting density of 12,000 plants per acre. A grower could expect to harvest at least 60,000 kg of G2 root seed (1.5 kg per plant) in a typical southern Ontario growing season. The cost of producing G2 root seed in the field was estimated at $25,957.44 (see Table 3 on page 26).

G1 slip production for commercial sale

The purpose of Year 2 was to scale up production of G2 root seed, which was used in Year 3 to produce G2 slips for commercial sale. During Year 2, additional slips may be rapidly multiplied for commercial sale by replanting single node cuttings from cut backs (see Chapter 1). A grower can expect to cut back 30,000 G1 slips from 100 m^2 of bedded G1 root seed. Each cut back should contain two to three nodes which can be replanted in approximately 300 m^2 of additional greenhouse space at a density of 200 nodes per square metre (see Chapter 1, step 2, page 8). Repeating this process according to the timelines in Figure 6 should produce 420,000 G1 slips for sale. Production of an additional 210,000 G1 slips is possible if growers are willing to receive them by the last week of June. The cost to produce 420,000 G1 slips through single node cuttings was estimated at $36,148.88 (see Table 7 on page 34).

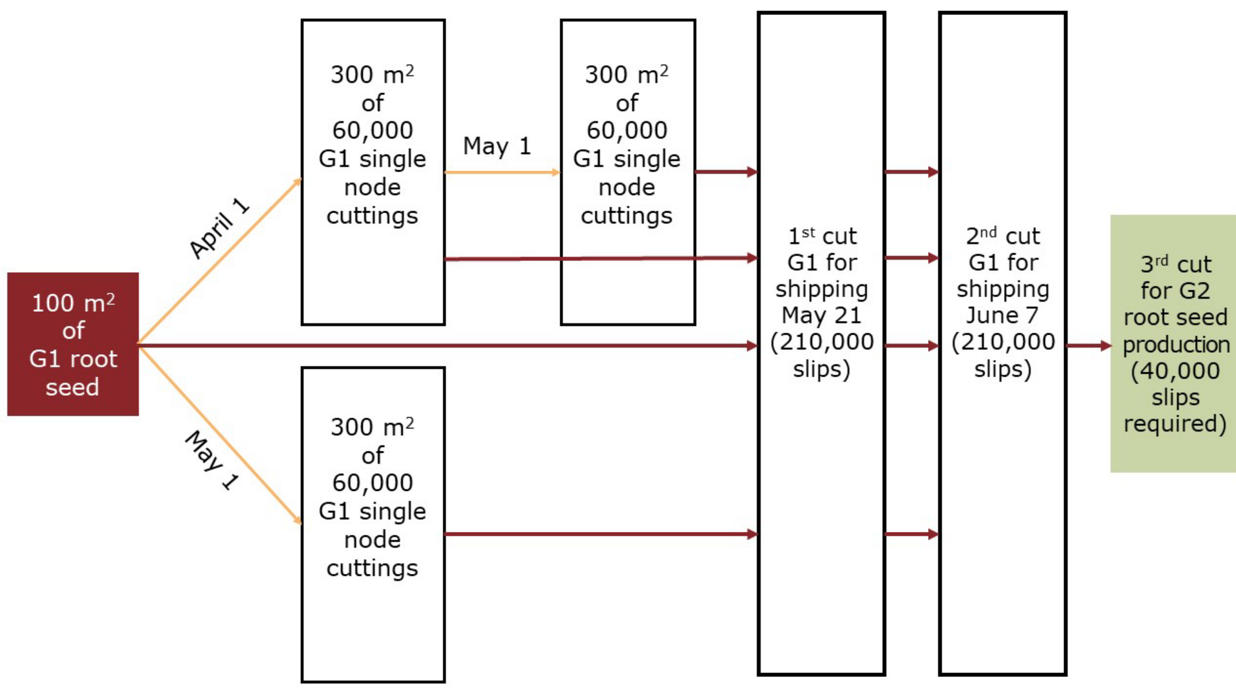


Figure 6: Timelines and greenhouse space requirements for producing additional G1 slips using single node cuttings.

Table 7: Cost to produce G1 slips for sale in Year 2 using single node cuttings.

Expense item	Unit	Qty	Cost/ unit	Experimental data total (602 m²)	Cost/m²	Cost to produce 420,000 G1 slips (1,000 m²)
Direct expense						
Labour to set up bed	hrs.	3	$15.00	$45.00	$5.63	$5,062.50
Soil	3.6 ft³ bail	180	$16.00	$2,880.00	$4.78	$4,305.65
Fabric	12'x300' roll	2	$283.70	$567.40	$0.94	$848.27
Boxes for shipping	each	361	$3.00	$1,083.00	$1.80	$1,799.00
Fertilizer						
20-8-20	15 kg bag	4	$63.40	$253.60	$0.42	$379.14
14-0-14	15 kg bag	4	$63.40	$253.60	$0.42	$379.14
8-20-30	15 kg bag	2	$63.40	$126.80	$0.21	$189.57
Pest management						
Swirskii	sachet	9	$0.40	$3.60	$0.01	$5.38
Eretmix	100/card	24	$1.00	$24.00	$0.04	$35.88
Athena	1,000/bottle	2	$92.40	$184.80	$0.31	$276.28
Botanigard 22WP (if necessary)	500 g bag	1	$140.00	$140.00	$0.23	$209.30
Labour						
Head grower (management)	hrs.	64	$50.00	-	$5.32	$4,788.00
First top cutting planting (100 m²)	hrs.	100	$15.00	-	$5.00	$1,500.00
Second top cutting planting (400 m²)	hrs.	200	$15.00	-	$5.00	$3,000.00
Harvest for sale (2 harvests/ 1,000 m²)	hrs.	150	$15.00	$2,250.00	$3.74	$3,737.54
Clean-up	hrs.	61	$15.00	$915.00	$1.52	$1,367.94
Fixed expenses						
Heating/lighting				$694.60	$1.15	$1,035.00
Overhead (22% of total direct expenses)					$8.03	$7,230.29
Total expenses					**$44.55**	**$36,148.88**

Year 3: G2 slip production

During this phase, the G2 root seed were taken out of storage and bedded in the greenhouse on March 1. Approximately 4,000 m^2 of greenhouse space (1 m^2 requires 15 kg of root seed) is required to bed 60,000 kg of root seed. The cost of producing G2 slips was estimated at $138,529.58 (see Table 8).

Table 8: Cost to produce G2 slips in Year 3 from 60,000 kg of G2 root seed.

Expense item	Unit	Qty	Cost/ unit	Experimental data total (602 m²)	Cost/m²	Cost to produce G2 slips (4,000 m²)
Direct expense						
Genetic material						
G2 root seed (produced in Year 2)	kg	9,030	$0.52	$4,695.60	$7.80	$31,190.86
Bed preparation						
Soil	3.6 ft³ bail	360	$16.00	$5,760.00	$9.57	$38,272.43
Fabric	12'x300' roll	2	$283.70	$567.40	$0.94	$3,770.10
Boxes for shipping	each	361	$3.00	$1,083.00	$1.80	$7,196.01
Fertilizer						
20-8-20	15 kg bag	4	$63.40	$253.60	$0.42	$1,685.05
14-0-14	15 kg bag	4	$63.40	$253.60	$0.42	$1,685.05
8-20-30	15 kg bag	2	$63.40	$126.80	$0.21	$842.52
Pest management						
Swirskii	sachet	9	$0.40	$3.60	$0.01	$23.92
Eretmix	100/card	24	$1.00	$24.00	$0.04	$159.47
Athena	1,000/bottle	2	$92.40	$184.80	$0.31	$1,227.91
Botanigard 22WP (if necessary)	500 g bag	1	$140.00	$140.00	$0.23	$930.23
Labour						
Head grower (management)	hrs.	64	$50.00	$3,200.00	$5.32	$21,262.46
Plant G1 seed in beds	hrs.	61	$15.00	$915.00	$1.52	$6,079.73
First top cutting (April 1)	hrs.	24	$15.00	$360.00	$0.60	$2,392.03
Second top cutting (May 1)	hrs.	24	$15.00	$360.00	$0.60	$2,392.03
Cut/harvest slips for shipping	hrs.	150	$15.00	$2,160.00	$3.74	$14,950.17
Clean-up	hrs.	61	$15.00	$960.00	$1.52	$6,079.30

Fixed expenses						
Heating/lighting					$1.15	$4,600.00
Overhead (22% of total direct expenses)					$6.25	$24,980.74
Total expenses (without root seed)					**$34.63**	**$138,529.58**
Total expenses (with root seed)					**$42.36**	**$169,429.58**

Direct expenses

Consumables

Soil

Berger BM6 HP is the recommended planting media as it is the least expensive media with high drainage that we could source. However, other soil media with high drainage may also be used. A small area should be tested if an alternative growing media is utilized. A 3.6 ft^3 bail can cover 1.6 m^2 of greenhouse space.

Landscape fabric

A fabric lining helps keep growing media from entering and clogging drainage systems. One 12’ x 300’ roll of landscape fabric can cover 334 m^2 of greenhouse space.

Fertilizer

An alternating schedule of 20-8-20 and 14-0-14 is recommended to encourage the growth of slips up to the second cut-back. Following the second cut-back, the remaining soil nutrients may be used by the growing plants by supplementing with only water. A finisher fertilizer with low nitrogen may be used directly after the second cut-back to help harden-off slips for field transplanting. One 15 kg bag of fertilizer covers a minimum of 200 m^2 of bedded sweet potato root seed.

Pest management

Major sweet potato slips pests include aphids, whiteflies, thrips and occasionally spider-mites. As these pests have been shown to transmit disease, a strict IPM strategy must be adopted. Very few chemicals are registered for use on sweet potato slips in the greenhouse, as this is a new industry in Canada. The following costs for biological control agents were calculated by using the manufacturer’s recommended rates for curative (light) infestations.

- Atheta (for control of fungus gnat and shore fly): $92.40 for 1,000/bottle; covers 300 m^2
- Botanigard (control spray for a wide variety of insects): $136.10 for 500 g bag; covers 600 m^2
- Eretmix (for control of both greenhouse and sweet potato whiteflies): $50.30 for 50 cards with 100 eggs/card; covers 1,000 m^2
- Swirskii (for control of thrips; some control of spider-mites): $238.60 for 500 sachet; covers 55.5 m^2

Packaging
Corrugated cardboard boxes (16"L x 14"W x 12"H) can be used to package slips for shipping to growers. Approximately 1,000 slips can fit in one cardboard box.

Labour
Labour costs can be broken down as follows:

- A head grower who is responsible for the daily management of the crop contributes 30 minutes per day for 90 days with an additional 19 hours to oversee cut-backs and harvesting
- Each worker beds root seed at a rate of 10 m^2 per hour
- Two cut-backs are needed during the growing period, where one worker can cut-back 25 m^2 per hour
- Labour costs for harvesting will be higher than for cut-backs since it takes longer to remove unmarketable material and to place the slips neatly into packaging. A reasonable estimate is that one worker can harvest and package 8 m^2 per hour.
- Each worker can plant single node cuttings at a rate of 3 m^2 per hour

Curing and storage of root seed
As mentioned in Chapter 2, curing is essential to help thicken sweet potato skin, heal harvesting wounds and prepare sweet potato root seed for long-term storage. The cost associated with curing and storage of G1 and G2 root seed is presented in Table 3 on page 26 which were based on facilities at Vineland. A grower would require three bins to store 1,500 kg of G1 root seed and 120 bins to store 60,000 kg of G2 root seed. A grower could also invest in purchasing used bins instead of renting them.

Fixed expenses

Electricity/gas
Findings by the Manitoba Ministry of Agriculture on different energy sources for heating a greenhouse can be found at
https://www.gov.mb.ca/agriculture/crops/production/print,energy-calculations.html

Operating expenses
Operating expenses include overhead expenses such as repairs, taxes, machinery, equipment, interest, insurance and contract work. According to Statistics Canada (Greenhouse, sod and nursery industries, 2017) the Canadian average cost for overhead expenses accounts for 22% of total expenses https://www150.statcan.gc.ca/n1/daily-quotidien/180425/dq180425b-eng.htm

Summary of cost of production

A summary of the total cost of production over the three-year cycle is presented in Table 9. To produce 2.4 million slips using 60,000 kg of G1 root seed would require 4,000 m^2 of greenhouse space and an estimated total expense of $170,686.43. Therefore, the cost to produce one slip works out to $0.07. A breakdown of the cost is shown in Figure 7. The cost of labour and consumables each account for one third of the cost.

Table 9: Summary of total cost of production by year.

Year	Production step	Total expense
1	250 tissue culture plantlets	$750.00
1	G0 slip production cost for planting	$538.94
1	G1 root seed production cost	$974.38
2	G1 slip production cost for planting	$3,936.09
2	G2 root seed production cost	$25,957.44
3	G2 slip production cost	$138,529.58
	Total expenses	**$170,686.43**
	Total slips produced for sale	**2,400,000**
	Cost of production per slip	**$0.07**

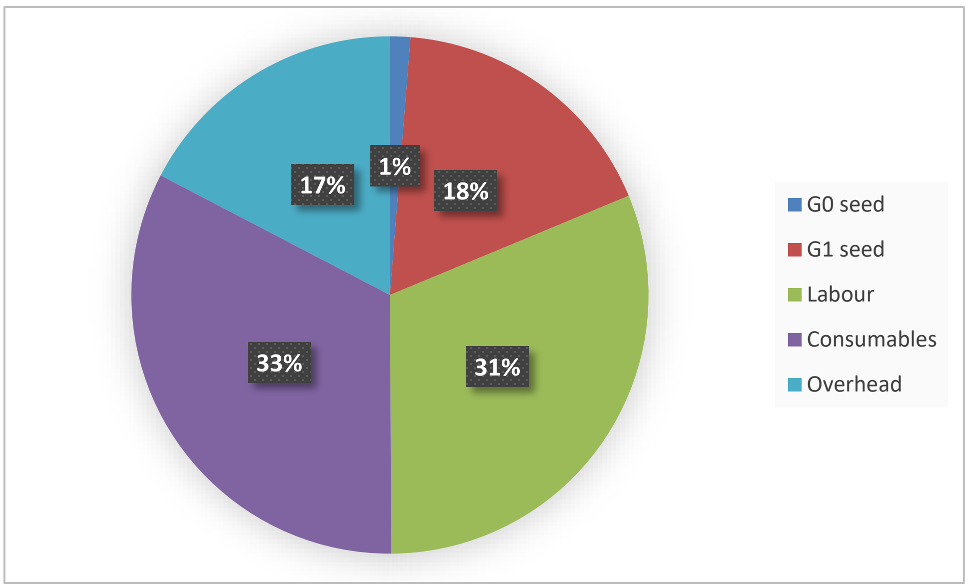


Figure 7: Breakdown of total cost for producing slips in a greenhouse.

Revenue potential

Year 2: Commercial sale of G1 slips

Although the purpose of year 2 is to bulk up production of G2 root seed for use in year 3, there is an additional opportunity to scale up production of G1 slips for sale using the single-node cutting approach described in Figure 6 on page 33. The revenue potential generated by taking advantage of this approach is summarized in Table 10 on page 39.

Table 10: Projected gross revenue, net revenue and net revenue per m² models based on number of G1 slips produced and sale price per slip.

Sale price/ G1 slip	Gross revenue	Net revenue (less cost of production)	Net revenue/m²
Pessimistic (280,000 G1 slips)*			
$0.12	$33,600	-$4,812	-$4.81
$0.13	$36,400	-$2,012	-$2.01
$0.14	$39,200	$788	$0.79
$0.15	$42,000	$3,588	$3.59
$0.16	$44,800	$6,388	$6.39
$0.17	$47,600	$9,188	$9.19
$0.18	$50,400	$11,988	$11.99
$0.19	$53,200	$14,788	$14.79
$0.20	$56,000	$17,588	$17.59
Expected (420,000 G1 slips)**			
$0.12	$50,400	$11,988	$11.99
$0.13	$54,600	$16,188	$16.19
$0.14	$58,800	$20,388	$20.39
$0.15	$63,000	$24,588	$24.59
$0.16	$67,200	$28,788	$28.79
$0.17	$71,400	$32,988	$32.99
$0.18	$75,600	$37,188	$37.19
$0.19	$79,800	$41,388	$41.39
$0.20	$84,000	$45,588	$45.59
Optimistic (630,000 G1 slips)***			
$0.12	$75,600	$37,188	$37.19
$0.13	$81,900	$43,488	$43.49
$0.14	$88,200	$49,788	$49.79
$0.15	$94,500	$56,088	$56.09
$0.16	$100,800	$62,388	$62.39
$0.17	$107,100	$68,688	$68.69
$0.18	$113,400	$74,988	$74.99
$0.19	$119,700	$81,288	$81.29
$0.20	$126,000	$87,588	$87.59

* Pessimistic – 200 slips/m²/cut from G1 root seed and 40,000 single nodes/cut back
** Expected – 300 slips/m²/cut from G1 root seed and 60,000 single nodes/cut back
*** Optimistic – 400 slips/m²/cut from G1 root seed, 60,000 single nodes/cut back and third cut for shipping (if required)

Year 3: Commercial sale of G2 slips

The revenue potential depends on the sale price per slip Canadian sweet potato growers are willing to accept and how many slips are produced per square metre. During the 2018 and 2019 production seasons, the cost ranged between $0.12 and $0.17 per G2 slip. Various revenue potential models are presented in Table 11 on page 40.

Table 11: Projected gross revenue, net revenue and net revenue per m^2 models based on number of G2 slips produced and sale price per slip.

Sale price/ G2 slip	Gross revenue	Net revenue (less cost of production)	Net revenue/m^2
Pessimistic (1.6 million G2 slips)*			
$0.12	$192,000	$21,314	$5.33
$0.13	$208,000	$37,314	$9.33
$0.14	$224,000	$53,314	$13.33
$0.15	$240,000	$69,314	$17.33
$0.16	$256,000	$85,314	$21.33
$0.17	$272,000	$101,314	$25.33
$0.18	$288,000	$117,314	$29.33
$0.19	$304,000	$133,314	$33.33
$0.20	$320,000	$149,314	$37.33
Expected (2.4 million G2 slips)**			
$0.12	$288,000	$117,314	$29.33
$0.13	$312,000	$141,314	$35.33
$0.14	$336,000	$165,314	$41.33
$0.15	$360,000	$189,314	$47.33
$0.16	$384,000	$213,314	$53.33
$0.17	$408,000	$237,314	$59.33
$0.18	$432,000	$261,314	$65.33
$0.19	$456,000	$285,314	$71.33
$0.20	$480,000	$309,314	$77.33
Optimistic (3.2 million G2 slips)***			
$0.12	$384,000	$213,314	$53.33
$0.13	$416,000	$245,314	$61.33
$0.14	$448,000	$277,314	$69.33
$0.15	$480,000	$309,314	$77.33
$0.16	$512,000	$341,314	$85.33
$0.17	$544,000	$373,314	$93.33
$0.18	$576,000	$405,314	$101.33
$0.19	$608,000	$437,314	$109.33
$0.20	$640,000	$469,314	$117.33

* Pessimistic – 400 slips/m^2 (over two cuts)

** Expected – 600 slips/m^2 (over two cuts)

*** Optimistic – 800 slips/m^2 (over two cuts)

Future research

Further research on lower input costs and higher slip yield is needed to increase profit margins for greenhouse slip producers targeting commercial growers. Examples of research projects include:

- Sourcing and evaluating cheaper alternative growing media such as Gro-Bark®
- Determining the optimal fertility regime to boost yield and increase slip quality
- Evaluating the effect of beneficial microorganisms such as Mycorrhizae inoculum
- Evaluating and registering the use of plant growth regulators, such as Ethephon which has been proven to increase total slip yield by up to 30%
- Evaluating and registering the use of chemical sprays to control pests in the greenhouse
- Reducing labour during peak times using automation
- Determining market size, cost of production and revenue potential for home garden and ornamental markets

Disclaimer

Results based on Vineland Research and Innovation Centre trials. Individual results may vary depending on season, location and cultural practices.

Suppliers

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Plant Products Head Office
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Landscape fabric

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Acknowledgments

The technical assistance of Mingshu Sun, Irina Perez-Valdez, Neran Manoharan, Michael Josiak, James Toivonen, Cathy Gray, Kevin Meester, Louise Van Pagee and Joanne Comeau is greatly appreciated.

The authors wish to thank Nathalie Dreifelds and Cheryl Lennox for assistance in the technical preparation of this manual.

Viliam Zvalo is acknowledged for submitting the initial research proposal, direction and securing greenhouse industry partners required for this project.

Michael Brownbridge, Melanie Filotas, Michael Pavone and Jim Chaput are acknowledged for acquiring plant protection product approval for greenhouse slip production.

The authors wish to thank Roelands Plant Farms Inc., Baker's Nursery, and C.O. Keddy Nursery Inc. for participating in this research project by providing greenhouse space for the slip production trials as well as the cost of production data.

Appreciation is extended to the Ontario Ministry of Agriculture, Food and Rural Affairs, the University of Guelph and Agriculture and Agri-Food Canada for their generous financial support.

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