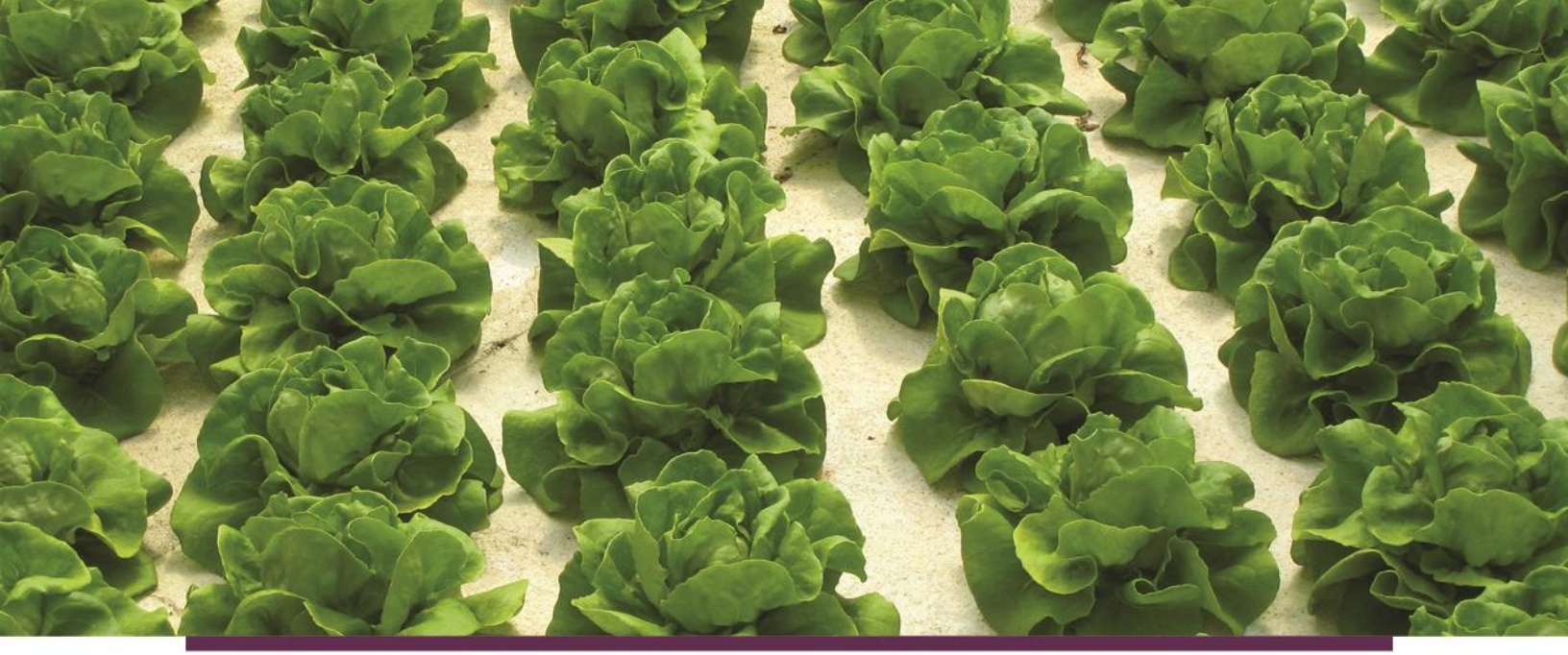

Crop Profile for Greenhouse Lettuce in Canada, 2017

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Preface

National crop profiles are developed by the Pest Management Program of Agriculture and Agri-Food Canada (AAFC). The national crop profiles provide baseline information on crop production and pest management practices and document the pest management needs and issues faced by growers. This information is developed through extensive consultation with stakeholders.

Information on pest management practices and pesticides is provided for information purposes only. No endorsement of any pesticide or pest control technique discussed is implied. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

For detailed information on growing greenhouse lettuce, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

Every effort has been made to ensure that the information in this publication is complete and accurate. Agriculture and Agri-Food Canada does not assume liability for errors, omissions, or representations, expressed or implied, contained in any written or oral communication associated with this publication. Errors brought to the attention of the authors will be corrected in subsequent updates.

Agriculture and Agri-Food Canada gratefully acknowledges the contributions of provincial crop specialists, industry specialists and growers in the gathering of information for this publication.

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Lettuce (*Lactuca sativa*), is a member of the Asteraceae family. Lettuce was cultivated as early as 4500 BC in the Mediterranean region for the oil extracted from the seeds. Since then, production of the annual plant has spread worldwide. Today, lettuce is grown almost exclusively for the fresh market. It is used in salads, sandwiches and as a garnish. Lettuce can be split into two main groups: head lettuce (*Lactuca sativa* var. *capitata*), which includes iceberg, crisphead and butterhead lettuce; and leaf lettuce (*L. sativa* var. *longifolia* and *L. sativa* var. *crispa*), which includes romaine, greenleaf, and redleaf lettuce. Only butterhead lettuce, also known as 'Boston' or 'Bibb' lettuce (*L. sativa* var. *capitata*) is grown in greenhouses; 'Prior' and 'Cortina' are the most common cultivars.

The primary product of greenhouse lettuce is the leaf which is produced in heads, which is used mainly for salads. A good source of Vitamin A, E and folacin, lettuce is considered a healthy food. Pre-washed and pre-cut packaged salad mixes have become popular with consumers.

Crop Production

Industry Overview

The total greenhouse lettuce farm gate value in 2017 was $32 million (Table 1). Fresh or chilled seasonal lettuce exports (field and greenhouse) amounted to $27 million, but were much lower than all year imports valued at $448 million.

Table 1. General greenhouse lettuce production information, 2017

Canadian production[1]	6,256 metric tonnes 209,183 m^2
Farm gate value[1]	$32 million
Food available in Canada[2]	8.48 kg / person
Exports[3]	$26.9 million 18,038 metric tonnes
Imports[3]	$447.9 million 191, 914 metric tonnes

[1] Source: Statistics Canada. Table 32-10-0456-01 (formerly CANSIM 001-0006) - Production and value of greenhouse vegetables (database accessed 2019-08-14).

[2] Source: Statistics Canada. Table 32-10-0054-01 (formerly CANSIM 002-0011) - Food available in Canada (database accessed: 2019-08-14).

[3] Source: Agriculture and Agri-Food Canada. Statistical Overview of the Canadian Vegetable Industry 2017; includes greenhouse and field lettuce; http://publications.gc.ca/site/eng/9.507808/publication.html. (Accessed 2019-08-14).

Production Regions

Quebec leads the greenhouse lettuce production with a farm gate value of $20 million, comprising 61% the total Canadian production value (Table 2).

Greenhouse lettuce is grown in areas where light and energy costs favour greenhouse crop production and also where production is close to major markets. In 2017, lettuce production in Canada comprised 209,183 m^2 of greenhouse area with Quebec accounting for 52% of that area. British Columbia and Ontario each having 21% of the national area under lettuce production.

Table 2. Distribution of greenhouse lettuce production in Canada, 2017[1]

Production Regions	Harvested area[1] (meters square and percentage national area)	Production[1] (metric tonnes)	Farm gate value[1] (millions of dollars)
British Columbia	42,837 m^2 (21%)	1,669 m. t.	x^2
Alberta	7,181 m^2 (3%)	126 m. t.	x^2
Ontario	44,774 m^2 (21%)	906 m. t.	$5.3 million
Quebec	107,794 m^2 (52%)	3,513 m. t.	$19.7 million

…continued

Table 2. Distribution of greenhouse lettuce production in Canada, 2017[1] (continued)

Production Regions	Harvested area[1] (meters square and percentage national area)	Production[1] (metric tonnes)	Farm gate value[1] (millions of dollars)
Nova Scotia	2,306 m^2 (1%)	x[2]	x[2]
Canada	209,183 m^2	6,256 m. t.	$32 million

[1] Source: Statistics Canada. Table 32-10-0456-01 (formerly CANSIM 001-0006) - Production and value of greenhouse vegetables (database accessed 2019-08-14).

[2]x: suppressed to meet the confidentiality requirements of the Statistics Act.

Cultural Practices

A two-stage production system is used for growing greenhouse lettuce: plant raising (production of seedlings) and crop production.

Greenhouse lettuce is grown primarily in soil-less media, using a hydroponic nutrient film technique (NFT). In this system, plants are grown in a re-circulated, continuously flowing film of nutrient solution. Seeds are sown in seed trays in a mixture of peat and perlite, or directly into Rockwool mini-blocks, foam medium or peat pellets, that are placed in plastic trays. Seedlings grown in peat-perlite are transplanted to Rockwool mini-blocks or foam media when the first true leaves appear (seven to ten days). Seedling plugs are then transplanted to temporary NFT troughs under supplemental lighting. At two to three weeks after germination (in the summer), or four to six weeks after germination (in the winter), the seedling plugs (three to four leaf stage) are placed in permanent NFT troughs. Depending on the variety, six to seven weeks or ten to twelve weeks are required from seeding to harvest for summer and winter crops, respectively. However, some lettuce varieties can be harvested as soon as 30 days after transplanting. Generally, there are eight to ten production cycles per year.

There are many different NFT trough systems. All consist of a support or cover which holds the transplant in place, with the plant roots suspended in the trough through which the nutrient solution flows. An alternative system is the 'Floating Culture' system, in which transplants are placed in holes in styrofoam sheets which are floated on a pool of nutrient solution. In both systems, the nutrient solution is re-circulated to mixing tanks where it is aerated and amended with nutrients.

During crop growth and production, cooling fans, high pressure foggers, ventilation, heating, and moveable shade cloths or whitewash are used to maintain a night temperature of 15 to 18^{o}C and a day temperature ranging from 18 to 19^{o}C on cloudy days and to 19 to 22^{o}C on sunny days.

To optimize plant growth rate, supplemental artificial lighting in the form of high-pressure sodium lights and more recently, LED lights, at a rate of 20 watts/m^2 on a variable photoperiod duration, is often used when seedlings are placed in NFT troughs, especially in cloudy weather. During crop production, supplemental lighting is used to maintain an 18-hour photoperiod under low light conditions, such as during cloudy periods and winter months.

Humidity is also closely monitored and controlled for greenhouse lettuce crops. During production, a relative humidity (RH) of 75 to 85% is generally sought whereas during storage, the RH is maintained between 80 to 90%. For optimal growth and development, the level of CO_2 is also monitored and adjusted to the desired concentration depending on various parameters of production.

The concentration of nutrient salts (electrical conductivity) and the pH of the nutrient solution are regularly monitored as these have a significant impact on the growth of greenhouse lettuce. A pH of 6.0 is optimal for plant growth. Fertilizer and acidic solutions are added to the reservoir tank to maintain pH and appropriate nutrient levels for each cultivar and stage of crop development. Good aeration of the re-circulating nutrient solution is essential to provide oxygen to roots and reduce the incidence and severity of root rot diseases.

Most greenhouse lettuce is harvested as a whole plant head with roots attached. Roots are tied off with a rubber band and the plant is placed in an open poly bag or a clam-shell container. Some lettuce may be harvested and bagged without roots. Proper storage temperature and humidity is essential to maintain crop quality.

Depending on the time of year, plant densities and pest management practices used during production may vary. Pesticides and fertilizers are also used at different stages of development. Water quality (salts and pH), tissue and solution nutrient levels are checked frequently. At transplanting, fungicides may be applied preventatively against root and stem rot diseases.

Table 3. Greenhouse lettuce production and pest management schedule in Canada

PRODUCTION STAGE	ACTIVITY	ACTION
Seeding and Transplant Production	Plant Care	Proper temperature, humidity and moisture for seed germination maintained
	Media Care	Implementation of good sanitation practices; cleaning of seedling medium and trays
	Disease Management	Fungicides applied to seedlings to prevent damping-off and root rot
	Insect Management	Maintenance of conditions that discourage fungus gnat and shore fly populations
Crop Production	Plant Care	Maintenance of appropriate temperature, light, relative humidity and CO_2 levels to prevent diseases and tip-burn
	Media Care	Monitoring and adjusting of media pH and nutrient content; maintenance of good aeration of nutrient solution
	Disease Management	Application of drenches of protectant fungicide for root and stem rot as needed, after transplanting; monitoring for botrytis, powdery mildew and downy mildew and application of fungicides if necessary; maintenance of good aeration of re-circulating water to minimize pythium root rot; maintenance of correct temperature and humidity to minimize disease pressure
	Insect Management	Monitoring for the presence of thrips, aphids, cabbage looper and whiteflies and applying insecticides if necessary; utilisation of biological control agents (predators or parasites) for pest control; maintenance of a weed-free zone around the greenhouse; preventing pests from entering the greenhouse by sealing cracks, keeping doors closed and screening vents
Harvest and Post-Harvest	Plant Care	Prompt harvest of plants and maintenance of proper storage conditions to ensure crop quality
	Media Care	Cleaning of tanks, water lines, etc. between crops to prevent algae build-up
	Disease Management	Cleaning, sanitizing and disinfecting of the greenhouse between crops; Prompt removal and destruction of infected plant debris
	Insect Management	Cleaning, sanitization and disinfection of the greenhouse between crops; prompt removal and destruction of plant debris

Abiotic Factors Limiting Production

Temperature

Temperature is an important factor at all stages of lettuce growth. Too high a temperature will prevent seed germination and, in the production stage, will reduce leaf and head quality. Too high storage temperatures promote further leaf development, resulting in a less appealing product. Sudden changes in temperature can favour disease development by causing condensation on leaves or increase the incidence of tip burn. Lettuce is highly sensitive to freezing, which damages the leaves.

Humidity

Too high humidity, especially under cool temperatures, will favour condensation on the leaves and the development of diseases, such as botrytis grey mold. Excessive humidity will reduce transpiration resulting in decreased nutrient transport.

Tip-burn and glassiness

Tip-burn of young, inner leaves of lettuce is caused by a calcium deficiency and is characterized by browning of the edges and tips of the leaves. To prevent this disorder, calcium levels in the nutrient solution must be high enough for sufficient calcium uptake by roots and transpiration rates must be high enough to enable sufficient translocation of calcium ions to the growing tips. Environmental conditions that reduce the transpiration rate, such as sudden temperature changes, too high relative humidity (RH), too low light or low temperature, can result in tip-burn. Increasing ventilation and air circulation with fans will increase transpiration and reduce the incidence of tip-burn of inner leaves. Limiting growth by reducing the application of nitrogen, harvesting the lettuce slightly before maturity and maintaining proper humidity will also reduce the incidence of tip-burn. Tip-burn of older, outer leaves can develop as a result of insufficient water, high salts, or excessive transpiration due to low humidity.

Glassiness results from excess water uptake by the roots, followed by inadequate water loss from the leaves. Good ventilation and the avoidance of high humidity will prevent glassiness.

Russet spot

Russet spot affects lettuce in storage and transport. It can be caused by too low storage temperature (chilling) or by exposure to ethylene gas in the storage facility. Symptoms include tan to brown spots along leaf veins; numerous or large spots will make the product unmarketable.

Premature leaf yellowing

Premature leaf yellowing is associated with warm temperatures, high humidity and low light levels in late fall and early spring. These conditions result in reduced CO_2 absorption, high respiration rates and leaf senescence. Lowering humidity and increasing ventilation and air circulation and using supplemental lighting will help to prevent this condition.

Diseases

Key issues

- Non-chemical control strategies, including the use of disease suppressing microorganisms, surfactants and pH adjustment, are required for damping-off control in hydroponic growing systems.
- There is a need for the registration of new fungicides and biofungicides, including those for which application methods differ from traditional sprays (e.g. sulfur burners), for the management of powdery mildew.

Table 4. Occurrence of diseases in greenhouse lettuce production in Canada[1,2]

Disease	Ontario	Quebec
Damping off and root rot		
Downy mildew		
Drop (white mould)		
Grey mould		
Powdery mildew		
Widespread yearly occurrence with high pest pressure.		
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.		
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.		
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.		
Pest is present and of concern, however little is known of its distribution, frequency and pressure.		
Pest not present.		
Data not reported.		

[1]Source: Greenhouse lettuce stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2017, 2016 and 2015 production years.

[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 5. Adoption of disease management practices in greenhouse lettuce production in Canada[1]

Practice / Pest		Damping-off and root rot	Downy mildew	Grey mould	Powdery mildew
Avoidance	Rotation with non-host crops				
	Optimizing fertilization for balanced growth and to minimize stress				
	Minimizing wounding and insect damage to limit infection sites				
	Control of disease vector				
	Varietal selection / use of resistant or tolerant varieties				
Prevention	Equipment sanitation				
	End of season disinfection of structure				
	Use of sterile growing medium				
	Optimize ventilation and air circulation in crop				
	Maintain optimum temperature and humidity conditions				
	Modification of plant density (row or plant spacing; seeding rate)				
	Water / irrigation management				
	Culling and proper disposal of infected plants and plant parts				
	Isolation of infected areas and working in these sections last				
	Restriction of movement of workers and visitors to greenhouse to minimize / prevent disease introduction and spread				
Monitoring	Regular monitoring throughout the crop cycle				
	Maintaining records to track diseases				
	Use of indicator plants				

… continued

Table 5. Adoption of disease management practices in greenhouse lettuce production in Canada[1] (continued)

Practice / Pest		Damping-off and root rot	Downy mildew	Grey mould	Powdery mildew
Decision making tools	Economic threshold				
	Weather conditions				
	Crop specialist recommendation or advisory bulletin				
	Decision to treat based on observed disease symptoms				
	Decision to treat based on stage of crop development				
Suppression	Use of biopesticides (microbial and non-conventional pesticides)				
	Use of diverse product modes of action for resistance management				
	Spot (targeted) application of biopesticides and pesticides				
	Use of biopesticides and pesticides that are compatible with beneficial organisms				
	Use of novel biopesticides and pesticide application techniques				
	Follow sanitation practices				

This practice is used to manage this pest by at least some growers.

This practice is not used by growers to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]Source: Greenhouse lettuce stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2017, 2016 and 2015 production years.

Pythium Damping-off and Root Rot (*Pythium aphanidermatum* and other *species*)

Pest Information

Damage: Pythium species are soil and water-borne fungal organisms that attack the roots of lettuce. Pythium infections can kill seedlings, either before or after emergence and cause root rot in mature plants. Infected plants develop brown, soft roots and may wilt, although in some cases obvious signs of disease may not be visible. Pythium outbreaks can lead to significant yield loss.

Life Cycle: The pathogen enters greenhouses in infected plug transplants, growing media and irrigation water. Poor root aeration, root injury, and improper greenhouse temperatures predispose plants to disease. The fungus produces reproduction bodies called sporangia (spore producing structures) that release swimming zoospores (motile spores), that colonize root tissues and wounds. *Pythium* spp. can also be spread by fungus gnats and shore flies.

Pest Management

Cultural Controls: Sowing seeds in sterile propagation media and taking care to minimize overcrowding of seedlings can reduce damping-off and root rot development. The maintenance of good aeration of the re-circulating solution helps to reduce the likelihood of infection. Cleaning and disinfecting greenhouse interior surfaces, water supply equipment, and tools are good safeguards against infection. Good water management practices such as avoiding water from wells or streams that may be carrying contaminated soil particles will help minimize the spread of the pathogen. Additional management practices for damping-off and root rot are listed in *Table 5. Adoption of disease management practices in greenhouse lettuce production in Canada.*

Resistant Cultivars: None available, however, vigorous varieties have better tolerance.

Issues for Pythium Damping-off and Root Rot

1. Non-chemical management strategies, including the use of disease suppressing microorganisms, surfactants and pH control, are required for the control of the pathogen complex causing damping-off and root rot in hydroponic growing systems.
2. The registration of new fungicides with a short pre-harvest interval (PHI) is required for the management of these diseases in greenhouse lettuce.

Downy Mildew (*Bremia lactucae*)

Pest Information

Damage: Symptoms of downy mildew on lettuce include yellow patches on leaves, which shrivel up and turn brown.

Life Cycle: Sporangia (reproductive structures) of downy mildew are produced on the underside of infected leaves. They are spread by air currents, in water and by handling plants. The optimum temperature for infection and disease development is 15 to 20ºC but they can occur at lower temperatures. The disease does not develop when the temperature is over 25ºC.

Pest Management

Cultural Controls: Maintaining low humidity and preventing dew formation on the leaves by controlling the night temperature and ensuring adequate greenhouse ventilation, will reduce the occurrence of this disease. Avoiding the planting of new lettuce crops near older ones and removing crop debris from the greenhouse will reduce the risk of infection. Additional management practices for downy mildew are listed in *Table 5. Adoption of disease management practices in greenhouse lettuce production in Canada.*

Resistant Cultivars: None available.

Issues for Downy Mildew

1. There is a need for the development of lettuce cultivars resistant to downy mildew, suitable for greenhouse production.

Lettuce Drop or White Mould (*Sclerotinia sclerotiorum, S. minor*)

Pest information

Damage: Lettuce drop is primarily caused by *S. sclerotiorum* and to a lesser extent by *S. minor*. The disease is more common in lettuce grown in soil. Infected plants appear wilted and their outer leaves drop to the ground, while remaining attached to the plant. Symptoms begin on the stem near the soil surface. The lettuce head becomes a wet, slimy mass due to the development of secondary bacterial rots and is not marketable.

Life Cycle: S. sclerotiorum and *S. minor* produce fluffy white mycelium on and inside infected plant parts. Cool and wet conditions favour the spread of the disease. *Sclerotinia* spp. produce sclerotia (dormant resting structures) in infected plant tissues which are the structures that allow these fungi to survive in the soil in the absence of a plant host. Sclerotia of *S. sclerotiorum* produce apothecia (fruiting bodies) that release ascospores over a period of several days, which are blown by wind to the aerial portions of plants and which can enter greenhouses through vents and doors. Ascospores survive for only a few days after release. Sclerotia of *S. minor* germinate to produce hyphae that infect roots and crowns in contact with the ground and progress upwards on the host plant. Sclerotia overwinter in the soil and on plant debris and are capable of surviving for many years.

Pest Management

Cultural Controls: To control lettuce drop caused by *S. minor*, hyphal germination of sclerotia can be reduced by allowing the soil surface to dry thoroughly between irrigation events. Each

irrigation event must therefore provide sufficient water to allow for a prolonged dry period. Sanitation practices including the removal of weeds and cull piles in the vicinity of the greenhouse and complete greenhouse sanitation between crops will reduce the likelihood of disease development.

Resistant Cultivars: None available.

Issues for Lettuce Drop (White Mould)

None identified.

Powdery Mildew (*Erysiphe cichoracearum*)

Pest information

Damage: Round, white powdery spots that develop on the upper surface of older leaves are the first symptoms of this disease. These spots enlarge and can eventually cover the entire surface of the leaf.

Life Cycle: Conidia are produced on the leaf surface of infected plants and are dispersed by air currents, landing on new plant tissues where they cause new infections. The fungus survives between crops as cleistothecia (spore producing structures) and thick-walled mycelium in dry crop residue.

Pest Management

Cultural Controls: Maintaining a uniform relative humidity of 70 to 80% and promptly removing infected leaves can help to prevent the spread of infection. Disinfecting the greenhouse between crops is also helpful in reducing the incidence of powdery mildew. Spraying the plants every two to three days with water may reduce spore buildup, but may also predispose plants to botrytis grey mold, downy mildew and other diseases. Additional management practices for powdery mildew are listed in *Table 5. Adoption of disease management practices in greenhouse lettuce production in Canada.*

Resistant Cultivars: None available.

Issues for Powdery Mildew

1. There is a need for the registration of new fungicides, with different modes of action, notably those for which application methods differ from traditional spraying (e.g. sulfur burners), for the management of powdery mildew.
2. There is a need for the registration of biofungicides for the control of powdery mildew.

Botrytis Grey Mold *(Botrytis cinerea)*

Pest Information

Damage: Botrytis grey mold of greenhouse lettuce is characterized by basal stem rot and grey-green, shrivelled leaves.

Life Cycle: Botrytis cinerea may infect the stems or the base of leaves of lettuce plants. Powdery, grey, spore masses produced by the pathogen under humid conditions can lead to new infections. The pathogen overwinters as black sclerotia (resting bodies) in soil, on perennial plants and on plant debris.

Pest Management

Cultural Controls: Avoiding injury of plants will help reduce infections, as wounds provide entry sites for the disease. Disease spread can be reduced by good sanitation practices when handling plants and by the frequent removal of crop residue from the greenhouse. Ensuring proper heat and ventilation and preventing condensation on the leaves at night will reduce disease development. Monitoring nitrogen levels to prevent lush growth, that is more susceptible to disease development is also helpful. Additional management practices for botrytis grey mold are listed in *Table 5. Adoption of disease management practices in greenhouse lettuce production in Canada.*

Resistant Cultivars: None available.

Issues for Botrytis Grey Mold

1. There is a concern that resistance to iprodione may be developing in the pathogen population, and that the effectiveness of this fungicide is decreasing. Therefore, registration of new fungicides with different modes of action is required for effective disease control and resistance management.

Rhizoctonia Bottom Rot (*Rhizoctonia solani*)

Pest Information

Damage: Symptoms of rhizoctonia bottom rot typically appear when head lettuce is reaching maturity. Rust-coloured, sunken lesions develop in the midrib of lower leaves and, if conditions are damp, these lesions expand to cover the entire midrib and cause the leaf blade to collapse. Under favorable conditions, this disease will cause the leaves to rot one by one as it moves inward and upward on the plant. The disease is more common in crops grown in soil.

Life Cycle: This disease can be spread by contaminated soil, tools and equipment. Peat and loam potting mixes as well as contaminated planting trays may provide a source of inoculum.

Pest Management

Cultural Controls: The raising of seedling flats on benches, out of the range of splashing water or soil, and other sanitation practices will help reduce disease development. Disinfecting greenhouse structures, tools and equipment between crops is also helpful in minimizing the spread of disease.

Resistant Cultivars: None available.

Issues for Rhizoctonia Bottom Rot

1. The registration of fungicides for the control of rhizoctonia bottom rot is needed.

Fungicides, bactericides and biofungicides registered for disease management in greenhouse lettuce production in Canada

Active ingredients registered for the management of diseases in greenhouse lettuce are listed below in Table 6 *Fungicides, bactericides and biofungicides registered for disease management in* greenhouse lettuce *production in Canada*. This table also provides registration numbers for products registered on greenhouse lettuce as of September 30, 2019 for each active ingredient, in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific diseases, the reader is referred to individual product labels available on the PMRA pesticide label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse lettuce production in Canada

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
ametoctradin + dimethomorph	30321	triazolo-pyrimidylamine + cinnamic acid amide	45 + 40	C8: respiration + H5: cell wall biosynthesis	complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site + cellulose synthase	R + RE
Aureobasidium pullulans DSM 14940 and DSM 14941	31248	biological	N/A	unknown	unknown	R
Bacillus amyloliquefaciens strain D747 (synonym to B.subtilis)	31887, 31888	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus subtilis,strain MBI600	28705, 28706, 28707, 28708	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus subtilis strain QST 713	28627, 30522	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus subtilis var. amyloliquefaciens, strain FZB24	30720	microbial: Bacillus spp. and the fungicidal lipopeptides they produce	N/A	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse lettuce production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
boscalid + pyraclostrobin	27985	pyridine-carboxamide + methoxy-carbamate	7 + 11	C2: respiration + C3: respiration	complex II: succinate-dehydrogenase + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R + R
copper (present as cupric ammonium formate and tannate complex)	33376	inorganic (electrophile)	M01	multi-site contact activity	multi-site contact activity	R
cyprodinil + fludioxonil	30185, 30763	anilino-pyrimidine + phenylpyrrole	9 + 12	D1: amino acids and protein synthesis + E2: signal transduction	methionine biosynthesis (proposed) (cgs gene) + MAP/histidine-kinase in osmotic signal transduction (os-2, HoG1)	R + R (RVD2018-04)
dazomet (soil fumigant)	15032	methyl isothiocyanate generator	8F[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	R (RVD2018-34)

… continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse lettuce production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
fenhexamid	26132	hydroxyanilide	17	G3: sterol biosynthesis in membranes	3-keto reductase, C4-demethylation (erg27)	RE
ferbam	20136, 20536	dithiocarbamate and relatives (electrophile)	M 03	multi-site contact activity	multi-site contact activity	PO (RVD2018-37)
fluopyram	32208	pyridinyl-ethyl-benzamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
fosetyl-Al	24458, 24564, 27688 only in B.C.	ethyl phosphonate	P 07	P7: host plant defence induction	phosphonates	R (RVD2019-08)
Gliocladium catenulatum, strain J1446	28820, 32404	biological	N/A	unknown	unknown	R
hydrogen peroxide + peroxyacetic acid	32907	inorganic	N/A	unknown	unknown	R (RVD2018-09, RVD 2018-10)
iprodione	15213, 24709	dicarboximide	2	E3: signal transduction	MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	RES* (RVD2018-16)
mandipropamid	29074, 30759, 32145	mandelic acid amide	40	H5: cell wall biosynthesis	cellulose synthase	R

… continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse lettuce production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
metalaxyl-M and S-isomer	27055	acylalanine	4	A1: nucleic acids synthesis	RNA polymerase I	R
phosphites (mono and dibasic sodium, potassium and ammonium phosphite)	30449, 30648	not classified	N/A	unknown	unknown	R
phosphorous acid (mono and di-potassium salts of phosphorous acid	30648, 30649, 30654	ethyl phosphonate	P 07	P7: host plant defence induction	phosphonates	R
polyoxin D zinc salt	32688, 32918	polyoxin	19	H4: cell wall biosynthesis	H4: chitin synthase	R
potassium bicarbonate	28095	diverse	N/A	not classified	unknown	R
Streptomyces lydicus, strain WYEC 108	28672	biological	N/A	unknown	unknown	R
Trichoderma harzanium Rifai strain KRL-AG2	27115, 29890, 31503	biological	N/A	unknown	unknown	R (RVD2018-19)
Trichoderma harzanium,strain T-22	31502, 31503	biological	N/A	unknown	unknown	R (RD 2018-14)

… continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse lettuce production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
Trichoderma harzanium Rifai strain KRL-AG2 + Trichoderma virens, strain G-41	30539, 31989	biological	N/A	unknown	unknown	R (RVD2018-19) + R (RD 2018-14)
Greenhouse Treatment						
potassium peroxymonosulfate (disinfectant)	24210	Potassium peroxymonosulfate Sulfate	N/A	unknown	unknown	R

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of September 30, 2019. While every effort has been made to ensure all fungicides, bactericides and biofungicides registered in Canada on greenhouse lettuce have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.
[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2019: Fungicides sorted by mode of action (including FRAC code numbering).*February 2019. (www.frac.info/) (accessed August 19, 2019).
[3]PMRA re-evaluation status as published in Re-evaluation Note REV2019-05 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2019-2024 and other re-evaluation documents: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.
[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.3; June 2019)* (excluding pheromones) (www.irac-online.org) (accessed August 19, 2019).

Insects and Mites

Key issues

- There is a need for the registration of reduced-risk control products for a number of insects in lettuce including aphids, thrips, greenhouse whitefly and fungus gnats.
- There is a need for the development of biological control options for pests including whitefly, fungus gnats, shore flies, thrips, and aphids.

Table 7. Occurrence of insect and mite pests in Canadian greenhouse lettuce production[1,2]

Insect and mite	Ontario	Quebec
Aphids		
Green peach aphid		
Lettuce aphid		
Caterpillars (various species)		
Fungus gnats and shore flies		
Whiteflies		
Greenhouse whitefly		
Sweet potato whitefly		
Thrips		
Western flower thrips		
Two-spotted spider mite		

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however little is known of its distribution, frequency and pressure.

Pest not present.

Data not reported.

[1]Source: Greenhouse lettuce stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2017, 2016 and 2015 production years.

[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 8. Adoption of insect and mite pest management practices in greenhouse lettuce production in Canada[1]

Practice / Pest		Aphids	Caterpillars (various species)	Fungus gnats and shore flies	Whiteflies
Avoidance	Rotation with non-host crops				
	Optimizing fertilization for balanced growth				
	Minimizing wounding to reduce attractiveness to pests				
	Use of trap crops				
	Use of physical barriers to prevent pest entry into greenhouses				
Prevention	Equipment sanitation				
	End of season crop residue removal and clean-up				
	Pruning out / removal of infested material throughout the cropping season				
Monitoring	Regular monitoring throughout crop cycle				
	Maintaining records to track pests				
	Use of indicator plants				
Decision making tools	Economic threshold				
	Weather conditions				
	Crop specialist recommendation or advisory bulletin				
	Decision to treat based on observed presence of pest at susceptible stage of life cycle				
	Decision to treat based on observed crop damage				
	Decision to treat based on crop stage				

… continued

Table 8. Adoption of insect and mite pest management practices in greenhouse lettuce production in Canada[1] (continued)

Practice / Pest		Aphids	Caterpillars (various species)	Fungus gnats and shore flies	Whiteflies
Suppression	Use of biopesticides (microbial and non-conventional pesticides)				
	Release of arthropod biological control agents				
	Use of banker plants as reservoirs or refuges for beneficial insects and mites				
	Trapping				
	Use of diverse pesticide modes of action for resistance management				
	Spot (targeted) application of pesticides				
	Use of pesticides that are compatible with beneficial organisms				
	Use of novel pesticide application techniques (e.g. use of pollinating insects to carry biopesticides)				
	Follow sanitation practices				
Crop specific Practices	Minimize use of artificial lighting				
	Use of cultivars resistant to the lettuce aphid (*Nasonovria ribisnigri*)				
New Practices (by province)	Control of algae in substrate (Quebec)				

This practice is used to manage this pest by at least some growers.

This practice is not used by growers to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]Source: Greenhouse lettuce stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2017, 2016 and 2015 production years.

Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1,2]

Pest	Biological Control Agent	Description
Aphids	*Aphelinus abdominalis* *Aphidius colemani* *Aphidius ervi* *Aphidius matricariae*	Parasitic wasp
	Aphidoletes aphidimyza	Predatory midge
	Adalia bipunctata *Hippodamia convergens* *Cryptolaemus montrouzieri*	Predatory lady beetle
	Chrysoperla (= Crysopa) carnea *Chrysoperla rufilabris*	Predatory lacewing
Caterpillars	*Trichogramma spp.* *Chrysoperla rufilabris*	Parasitic wasp Predatory lacewing
Fungus gnats	*Steinernema feltiae*	Predatory nematode
	Dalotia(=Atheta) coriaria	Predatory beetle
	Gaeolaelaps gillespiei *Stratiolaelaps scimitus (= Hypoaspis miles)*	Predatory mite
Leafminers	*Dacnusa siberica* *Diglyphus isaea*	Parasitic wasp
Mites (two-spotted spider mite)	*Amblyseius andersoni* *Neoseiulus (= Amblyseius) californicus* *Neoseiulus (= Amblyseius) fallacis* *Phytoseiulus persimilis*	Predatory mite
	Feltiella acarisuga	Predatory midge
	Stethorus punctillum	Predatory beetle
	Chrysoperla rufilabris	Predatory lacewing

… continued

Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1,2] (continued)

Pest	Biological Control Agent	Description
Mealybug	*Cryptolaemus montrouzieri*	Predatory lady beetle
	Chrysoperla (= Chrysopa) carnea *Chrysoperla rufilabris* *Micromus variegatus*	Predatory lacewing
Thrips (western flower thrips)	*Steinernema feltiae*	Predatory nematode
	Amblydromalus limonicus *Amblyseius swirskii* *Iphesius (= Amblyseius) degenerans* *Neoseiulus (= Amblyseius) cucumeris* *Gaeolaelaps gillespiei* *Stratiolaelaps scimitus (= Hypoaspis miles)*	Predatory mite
	Dalotia (= Atheta) coriaria	Predatory beetle
	Orius insidiosus	Predatory bug
Whiteflies: Greenhouse whitefly and/or silverleaf whitefly, sweet potato whitefly	*Chrysoperla (= Chrysopa) carnea* *Chrysoperla rufilabris* *Micromus variegatus*	Predatory lacewing
	Amblydromalus limonicus *Amblyseius swirskii*	Predatory mite
	Delphastus catalinae	Predatory beetle
	Dicyphus hesperus	Predatory bug
	Encarsia formosa *Eretmocerus eremicus*	Parasitic wasp

[1]Source: R. Buitenhuis, Research Scientist Biological Control. Vineland Research and Innovation Centre, Vineland Station, ON. Canada

[2] For information on biological agent sources, see Beneficial Insects and Mites Suppliers. OMAFRA. (www.omafra.gov.on.ca/english/crops/resource/beneficial.htm) (accessed online December 31, 2019)

Aphids: Lettuce Aphid (*Nasonovia ribisnigri*), Green Peach Aphid (*Myzus persicae*), and Potato Aphid (*Macrosiphum euphorbiae*)

Pest Information

Damage: Plants severely infested with aphids may become stunted and develop discoloured foliage or curled leaves. Plants may also become covered in aphid secretions (honeydew), cast aphid skins and black sooty mould, which often grows on the honeydew. Green peach aphid colonizes mostly external and basal lettuce leaves, whereas lettuce aphid prefers the lettuce heart and the potato aphid, the internal face of lettuce leaves near the heart. Even in small numbers, the presence of aphids may make the crop unmarketable. Since aphid populations can grow very quickly, failure to control populations at first appearance may result in severe damage to the crop or even total crop loss.

Life Cycle: Aphids overwinter as eggs on alternate hosts, usually outdoors on a variety of weed or garden plants. In the spring, winged aphids enter greenhouses where they start new colonies on lettuce. Several winged and wingless generations occur each summer. In the fall, winged aphids return to their alternate hosts outdoors to mate and lay eggs. It takes seven to twelve days for one generation. Aphids can also transmit lettuce mosaic virus (LMV).

Pest Management

Cultural Controls: Screening of greenhouse vents and maintaining a weed and garden-free area around the greenhouse can help control aphid populations. Close monitoring in the spring before lettuce heart closing, is important to detect the first aphids on the crop. Additional management practices for aphids are listed in *Table 8. Adoption of insect and mite pest management practices in greenhouse lettuce production in Canada.*

Biological controls: Refer to *Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada* for a list of organisms available for the management of aphids in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Aphids

1. There is a need to develop effective, non-chemical options for the management of aphids, including additional biological control agents.
2. There is a need for the registration of reduced risk products for the management of aphids.

Caterpillars (Order Lepidoptera)

Pest Information

Damage: Caterpillars chew holes in leaves of lettuce.

Life Cycle: Adult moths enter the greenhouse from outside and lay eggs on the leaves of lettuce. The eggs hatch and larvae feed and develop through a number of instars (stages) before pupating and eventually emerging as adults. Several generations may occur in the greenhouse compared with only one or two generations per year in the field.

Pest Management

Cultural Controls: Screening of vents and keeping doors and other openings to the greenhouse closed, especially at night, will minimize the risk of entry by egg-laying adult moths. Additional management practices for caterpillars are listed in *Table 8. Adoption of insect and mite pest management practices in greenhouse lettuce production in Canada.*

Biological controls: Refer to *Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada* for a list of organisms available for the management of caterpillars in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Caterpillars

None identified.

Cabbage looper (*Trichoplusia ni*)

Pest Information

Damage: An important pest of cruciferous crops in some regions, the cabbage looper can also be a problem on greenhouse lettuce. The larval stage can cause significant damage by feeding on leaf tissue during its development. Larval damage to leaves makes the crop unmarketable and may also provide entry sites for secondary disease organisms.

Life Cycle: The cabbage looper does not typically overwinter in Canada, usually moving north as an adult moth from the south in July and August. However, it has been known to overwinter in greenhouses. One generation per season is typical outdoors, but in greenhouses under warmer temperatures, as many as three generations are possible. Eggs are laid near the edge or underside of a leaf and larvae hatch in three to four days. Larvae develop through five instars (stages) over the next two to three weeks and then pupate. The pupal stage lasts about two weeks, after which a mature moth emerges.

Pest Management

Cultural Controls: The screening of vents and keeping doors and other openings to the greenhouse closed, especially at night, will minimize the chances of entry by adult moths.

Biological controls: Arthropod biological control agents available for the management of cabbage loopers in greenhouse lettuce are listed in *Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada*

Resistant Cultivars: None available.

Issues for cabbage looper

1. The registration of new, reduced-risk products is needed for the control of cabbage looper in greenhouse lettuce.
2. There is a need for the development of effective biological control agents for cabbage looper control (e.g. *Trichogramma* spp.), particularly in deep flow hydroponics where spraying is difficult.

Fungus Gnats (*Sciaridae: Bradysia* and *Corynoptera* spp.) and Shore Flies (*Ephydidae* spp.)

Pest Information

Damage: Adults of these insects are occasionally a nuisance through their sheer numbers. Larvae are found in growing media where they feed on decaying organic matter, fungi and algae. They may also feed on roots and root hairs of young seedlings, which can be damaged or become stunted. Feeding wounds provide entry points for fungal pathogens such as pythium, phytophthora, fusarium and rhizoctonia.

Life Cycle: Mature female fungus gnats lay eggs in moist soils, potting mixes and hydroponic media. The eggs hatch in two to four days. The larvae feed on decaying organic matter, on root hairs and tender lower stems, for about two weeks before pupating and maturing into adults. The life cycle of shore flies is similar. Fungus gnats can transmit pathogens by means of spores caught on their legs and bodies.

Pest Management

Cultural Controls: Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult insects. Cultural controls that will help reduce damage by these insects include removing waste plant material, practicing good sanitation, and providing good drainage to eliminate puddles and algae formation. Adult insects can be monitored with the use of yellow sticky traps. Additional management practices for fungus gnats and shore flies are listed in *Table 8. Adoption of insect and mite pest management practices in greenhouse lettuce production in Canada.*

Biological Controls: Several biological control agents are commercially available and can be used to manage fungus gnats and shore flies. Refer to *Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada* for a list of organisms available for the management of fungus gnats and shore flies in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Fungus Gnats and Shore Flies

1. The registration of reduced-risk products is required for the management of fungus gnats.
2. There is a need to develop effective, non-chemical control options, including biological controls, for fungus gnats and shore flies.

Whiteflies: Greenhouse Whitefly (*Trialeurodes vaporariorum*) and Sweet Potato Whitefly (*Bemisia tabaci*)

Pest Information

Damage: Whiteflies cause damage by sucking sap from the plant, reducing plant vigour. They also excrete a sugary waste product called honeydew that supports the growth of secondary fungi called sooty moulds, which reduce photosynthesis and detract from the appearance of the plants.

Life Cycle: The adult whitefly lays eggs on the underside of leaves. Eggs hatch within five to ten days. The first nymphal stage, the mobile crawlers, move around and find a suitable spot to feed where they remain during the development of the second and third nymphal stages. Then, they pupate and adults emerge. Their entire life cycle can take between 18 and 35 days depending on temperature. Whiteflies can also transmit viruses. Sweet potato whitefly is reported to be able to transmit over 60 viruses, whereas greenhouse whitefly is reported to spread beet pseudo-yellows virus in cucumber.

Pest Management

Cultural Controls: The entry of adult whiteflies can be minimized by screening vents and keeping doorways and other openings to the greenhouse closed. Yellow sticky traps, can be used to monitor for whiteflies and may also be used to reduce the adult population. To minimize damage from whiteflies, new seedlings and transplants can be quarantined until it is confirmed that they are virus-free. Additional management practices for whiteflies are listed in *Table 8. Adoption of insect and mite pest management practices in greenhouse lettuce production in Canada.*

Biological controls: Refer to *Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada* or organisms available for the management of whiteflies in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Whiteflies

1. The registration of new, reduced risk insecticides is needed, especially for the management of greenhouse whitefly, as resistance against currently registered pesticides is developing in this pest population.
2. There is a need for the development of additional biological controls for whitefly in lettuce.

Western Flower Thrips (*Frankliniella occidentalis)*

Pest Information

Damage: Thrips feeding causes white, bleached to brown flecks or streaks on leaves. Thrips may also feed on growing buds causing distorted leaves. Plant growth may be reduced by severe infestations. Western flower thrips are the most important vector of a group of viruses called tospoviruses which include tomato spotted wilt virus (TSWV).

Life Cycle: The life cycle of thrips consists of five stages: egg, larval, pre-pupal, pupal and adult stage. Thrips lay eggs inside soft plant tissues, including flowers, leaves, buds and stems. Pupation occurs in soil or growing medium. Female adults of western flower thrips live up to 30 days and can lay two to ten eggs per day. Adults are weak fliers but they can disperse rapidly throughout the greenhouse. Adult thrips can be transported by wind currents and enter the greenhouse through vents and doorways. They can also be dispersed on workers' clothing and on infested plants, growing media or greenhouse tools.

Pest Management

Cultural Controls: Screening vents, keeping doorways closed and maintaining a three-metre-wide, weed-free zone around the perimeter of the greenhouse will minimize the entry of thrips. Effective sanitation will help reduce or eliminate thrips in the greenhouse. Maintaining a healthy crop and an optimal greenhouse environment (80% relative humidity) will prevent the rapid increase in thrips populations.

Biological controls: As thrips have developed resistance to most registered insecticides, biological control is now the primary strategy for controlling thrips in greenhouse vegetable production. Refer to *Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada* for a list of organisms available for the management of thrips in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Thrips

1. The registration of new products compatible with biological control agents is needed for thrips control.
2. There is a need for the development of additional biological control agents for thrips control.

Two-Spotted Spider Mite *(Tetranychus urticae)*

Pest Information

Damage: Two-spotted spider mites feed on the underside of lettuce leaves, creating small, yellow or white lesions. Fine webbing may be present on the underside of the leaf and a silver sheen on damaged surfaces may be apparent. Toxins injected by the mites can also result in distorted, thickened and twisted growth at the top of the plant. Outbreaks of two-spotted spider mite can result in moderate to severe losses of production and severe feeding can result in total loss of a crop.

Life Cycle: Two-spotted spider mite has a broad host range. It can spread by hanging from the plant by silken strands which readily attach to people and equipment. Adult females lay approximately 100 eggs on the lower leaf surface (five to eight eggs per day). Following hatch, the immature mites develop through three nymphal stages to become adults. The life cycle may be completed in as little as three days at 32ºC, but typically takes two weeks to complete. Females overwinter in dark crevices in the greenhouse.

Pest Management

Cultural Controls: Infestations can be monitored by closely examining the leaves. Sanitation in the greenhouse is an important means to control spider mites. A three-metre-wide weed-free zone maintained around the perimeter of the greenhouse will reduce the risk of mite entry. Restricting movement of workers, equipment and plants between infested and non-infested areas will also help to minimize spread of the pest.

Biological controls: A number of biological control agents are available for the management of spider mites in greenhouse lettuce. Refer to *Table 10. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada* for a list of available organisms.

Resistant Cultivars: None available.

Issues for Two-Spotted Spider Mite

None identified.

Insecticides, miticides and bioinsecticides registered in Canada for the management of insect and mite pests in greenhouse lettuce production

Active ingredients registered for the management of insects and mites in greenhouse lettuce are listed below in Table 9 *Insecticides, miticides and bioinsecticides registered for the management of insect and mite pests in greenhouse lettuce production in Canada*. This table also provides registration numbers for products registered on greenhouse lettuce as of September 27, 2019 for each active ingredient in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific insects and mites, the reader is referred to individual product labels on the PMRA pesticide label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 10. Insecticides, miticides and bioinsecticides registered for insect management in greenhouse lettuce production in Canada

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
Autographa californica Nucleopolyhedrosis virus, FV11	31791	biological	N/A	unknown	R
Bacillus thuringiensis subsp. a*izawai*, strain ABTS-1857	31557	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis subsp. *kurstaki* strain ABTS-351	24978	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis subsp. *kurstaki* strain EVB113-19	27750, 32425	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis var. israelensis, strain AM 65-52	19455	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Beauvaria bassiana strain PPRI 5339	32993	biological	N/A	unknown	R
canola oil (insecticide)	32408	not classified	N/A	unknown	R
cyromazine	24465	cyromazine	17	molting disruptor Dipteran	RE
ferric phosphate	27085, 30025	not classified	N/A	unknown	R (RVD2018-23)
flupyradifurone	33175, 33176	butenolide	4D	nicotinic acetylcholine receptor (nAChR) competitive modulator	R

…continued

Table 10. Insecticides, miticides and bioinsecticides registered for insect management in greenhouse lettuce production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
imidacloprid	25636, 27357	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES* (RVD2019-06)
lambda-cyhalothrin	24984, 26837, 29052, 32427	pyrethroid, pyrethrin	3A	sodium channel modulator	RE (PRVD2017-03)
malathion	4590, 8372	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R
Metarhizium anisopliae, strain F52	30829	biological	N/A	unknown	R
mineral oil	33099	not classified	N/A	unknown	R
potassium salts of fatty acids	14669, 27886, 28146, 31433, 31848	not classified	N/A	unknown	R
potassium salts of fatty acids + pyrethrins	24363	not classified + pyrethroid, pyrethrin	N/A + 3A	unknown + sodium channel modulator	R + R
spinetoram	28778	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	R
spinosad	26835, 27825, 30382, 33306	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	RE (REV2018-07)

… continued

Table 10. Insecticides, miticides and bioinsecticides registered for insect management in greenhouse lettuce production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
spirotetramat	29567	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R
tebufenozide	24503	diacylhydrazine	18	ecdysone receptor agonist	RE (REV2017-07)
Greenhouse Treatment					
phosphine (greenhouse structure fumigant)	27684	phosphide	24A	mitochondrial complex IV electron transport inhibitor	R

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of September 27, 2019. While every effort has been made to ensure all insecticides, miticides and biopesticides registered in Canada on greenhouse lettuce have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.3; June 2019)* (excluding pheromones) (www.irac-online.org) (accessed August 19, 2019).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2019-05 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2019-2024 and other re-evaluation documents: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

Weeds

Weed management in and around greenhouses is important as weeds can be an alternate host for insects and diseases. Weeds within the greenhouse are eliminated by hand weeding and through the use of ground coverings. Weeds exterior to the greenhouse can be reduced by mowing and by maintaining a ten-metre-wide lawn area. These measures will reduce the risk of insect and disease problems entering the greenhouse from outside. Herbicides may be used in the vicinity of greenhouses for the control of weeds. When herbicides are used, it is important that measures are taken to reduce the potential of spray drift from entering the greenhouse.

Vertebrate Pests

Rodents: Field Mouse (Vole) (*Microtus pennsylvanicus*), House Mouse (*Mus musculus*) and Norway Rat (*Rattus norvegicus*)

Pest Information

Damage: Rodents can chew through plastic ground liners causing drainage problems and contaminating re-circulating water. House mice and Norway rats are also known to chew on young plants in greenhouses.

Life Cycle: These rodents are primarily outdoor pests, but house mice and Norway rats can invade indoor facilities. Field mice prefer weedy, covered areas. These rodents are attracted to sources of food, water and shelter for nesting, such as garbage containers, cull piles, old planting media, piles of sawdust, building debris, burlap or Styrofoam sheets which are left outdoors or where bags of seed or slug bait are stored.

Pest Management

Cultural Controls: Maintaining a weed-free zone around the perimeter of the greenhouse, installing tight-fitting screens over doors and windows and placing wire screens over basement windows and vents are practices that will help deter rodents from entering the greenhouse. Sheet-metal plates at the base of wooden doors will prevent rodents from chewing through the doors. Feeding and nesting sites can be eliminated by cleaning up debris and cull piles around the greenhouse and storage buildings. Feed and seed, including slug bait can be stored in metal, rodent-proof containers, and all garbage containers provided with tight-fitting lids. Various trapping methods exist but are not consistently effective.

Resistant Cultivars: None available.

Issues for Rodents

None identified.

Resources

Integrated pest management / integrated crop management resources for greenhouse lettuce production in Canada

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Ontario Ministry of Agriculture Food and Rural Affairs. (2010). *Publication 836, Growing Greenhouse Vegetables in Ontario*. 146 pp. http://www.omafra.gov.on.ca/english/crops/pub836/p836order.htm

Pest Management Regulatory Agency. https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca/english	Cara McCreary Cara.mccreary@ontario.ca	Jim Chaput jim.chaput@ontario.ca
		Shalin Khosla Greenhouse Vegetable Specialist shalin.khosla@ontario.ca	
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec www.mapaq.gouv.qc.ca	Liette Lambert liette.lambert@mapaq.gouv.qc.ca	Mathieu Coté mathieu.cote@mapaq.gouv.qc.ca
		Mahmoud Ramadan Mahmoud.ramadan@mapaq.gouv.qc.ca	

Provincial Greenhouse Grower Organizations

Ontario Greenhouse Vegetable Growers
http://ogvg.com/

Ontario Greenhouse Alliance
https://www.theontariogreenhousealliance.com/

Syndicat de producteurs en serre du Québec
www.spsq.info/

National Grower Organizations

Canadian Horticultural Council / Conseil canadien de l'horticulture
https://www.hortcouncil.ca/en/

Canadian Organic Growers / Cultivons Biologique Canada
https://www.cog.ca/

Canadian Federation of Agriculture / Fédération Canadienne de l'Agriculture
http://www.cfa-fca.ca/

Appendix 1

Definition of terms and colour coding for pest occurrence table of the crop profiles.

Information on the occurrence of disease and insect and mite pests in each province is provided in Tables 4 and 7 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and pressure in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th>Colour Code</th></tr>
<tr><td rowspan="12">Present</td><td rowspan="10">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="6">Yearly - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">Widespread - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>High - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>Moderate - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>Low - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">Localized - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="6">Sporadic - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">Widespread - as above</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>Yellow</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="3">Localized - as above</td><td>High - see above</td><td>Yellow</td></tr>
<tr><td>Moderate -see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data not available</td><td colspan="3">Not of concern: The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">Is of concern: The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td>Blue</td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>Black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>Grey</td></tr>
</table>

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