Crop Profile for Greenhouse Lettuce in Canada, 2023

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Preface

National crop profiles are developed by the Pest Management Centre of Agriculture and Agri-Food Canada (AAFC). The crop profiles provide baseline information on production and pest management practices and document growers' needs to address pest management gaps and issues for specific crops grown in Canada. This information is developed through extensive consultation with stakeholders and data collected from reporting provinces. Reporting provinces are selected based on their acreage of the target crop (>10 % of the national production) and provide qualitative data on pest occurrence and integrated pest management practices used by growers in those provinces. For greenhouse lettuce production, the reporting provinces are British Columbia, Alberta, Ontario and Quebec.

Information on pest issues and management practices is provided for information purposes only. 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. For guidance about crop protection products registered for pests on greenhouse lettuce, the reader is referred to provincial crop production guides and Health Canada's Pesticide label database.

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 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, is grown in greenhouses. 'Prior' and 'Cortina' are the most common butterhead lettuce cultivars.

The primary product of greenhouse lettuce is the leaf which is produced in heads and is used mainly for salads. Pre-washed and pre-cut packaged salad mixes have become popular with consumers.

Crop Production

Industry Overview

Greenhouse lettuce production in Canada has tripled in the last decade. In 2023, 14,750 metric tonnes of lettuce was grown in 35.8 hectares of greenhouse area. The farm gate value of greenhouse lettuce in 2023 was $74.3 million. Lettuce exports (field and greenhouse) amounted to $60.1 million while imports of greenhouse lettuce amounted to $3.3 million in 2023 (Table 1).

Table 1. General production information for greenhouse lettuce in Canada, 2023

	Greenhouse Lettuce
Canadian Production[1]	14,750 metric tonnes
	35.8 hectares
Farm Gate Value[1]	$74.3 Million
Availability[2]	7.77 kg/person
Export[3]	$60.1 Million
Import[4]	$3.3 Million

[1]Source: Statistics Canada. Table 32-10-0456-01 – Production and value of greenhouse fruits and vegetables (accessed: 2024-07-11).
[2]Source: Statistics Canada. Table 32-10-0054-01 – Food available in Canada (accessed: 2024-07-11).
[3]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0705.19.00 – Lettuce, fresh or chilled nes (accessed: 2024-07-11).
[4]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0705.19.90.10 – Lettuce, greenhouse, fresh or chilled, nes (accessed: 2024-07-11).

Production Regions

In the last two years, Alberta has overtaken Quebec as the largest greenhouse lettuce producing province in Canada. Although 47 percent of national harvested area is found in Quebec, Alberta has greater marketed production (40 percent of national production) and farm gate value (38 percent of national farm gate value). Other provinces with significant greenhouse lettuce production include Ontario and British Columbia with 16 and 17 percent of national harvested area, respectively (Table 2).

Table 2. Distribution of greenhouse lettuce production in Canada, 2023[1]

Production Regions	Harvested Area (national percentage)	Marketed Production (national percentage)	Farm Gate Value (national percentage)
British Columbia	6.1 hectares (17%)	1,246 metric tonnes (8%)	$5.1 Million (7%)
Alberta	--*	5,850 metric tonnes (40%)	$28.5 Million (38%)
Ontario	5.8 hectares (16%)	3,139 metric tonnes (21%)	$16.4 Million (22%)
Quebec	17.0 hectares (47%)	4,400 metric tonnes (30%)	$22.8 Million (31%)
Canada	**35.8 hectares**	**14,750 metric tonnes**	**$74.3 Million**

*Suppressed to meet the confidentiality requirements of the *Statistics Act*

[1]Source: Statistics Canada. Table 32-10-0456-01 – Production and value of greenhouse fruits and vegetables (accessed: 2024-07-11).

Cultural Practices

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

Greenhouse lettuce is grown primarily in soilless 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. Seeds are covered with polystyrene sheets for two days to facilitate germination and protect against heat stall. Supplemental lighting is provided at all times during the propagation stage and production period. A germination temperature of 15 to 18 °C and water with an electrical conductivity (EC) of 1.0 to 1.5 mS/cm is ideal. Seedlings grown in peat-perlite are transplanted to Rockwool mini-blocks or foam media when the first true leaves appear (seven to 10 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. In BC, seedlings grown in peat-perlite are transplanted after two to three weeks dependent on demand in the main growing area and seedling vigor. Depending on the variety and time of year, four to seven weeks are required

from trough planting to harvest for summer and winter crops. Generally, there are eight to 10 greenhouse lettuce 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 polystyrene 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 °C (10 to 13 °C in BC) and a day temperature ranging from 17 to 19 °C on cloudy days and to 19 to 22 °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 (100 micromoles/m^2) on a variable photoperiod duration is 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 or vapor pressure deficit is also closely monitored and controlled for greenhouse lettuce crops. During production, a relative humidity (RH) of 75 to 85 percent is generally sought whereas during storage, the RH is maintained between 80 to 90 percent. For optimal growth and development, the level of CO_2 is also monitored and adjusted to 600 to 1200 ppm, depending on various parameters of production.

The concentration of nutrient salts (EC) 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 5.8 and EC of 2.2 to 3.0 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. At transplanting, fungicides may be applied preventatively against root and stem rot diseases.

A schedule for cultural and pest management practices for growing greenhouse lettuce in Canada in presented in *Table 3*.

Table 3. General greenhouse lettuce production and pest management schedule in Canada

Time of Year	Activity	Action
Seeding and Transplant Production	Plant Care	Maintenance of proper temperature, humidity and moisture for seed germination.
	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, shore fly and aphid populations.
Crop Production	Plant Care	Maintenance of appropriate temperature, light, relative humidity or vapor pressure deficit and CO_2 levels to prevent disease 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 protectant fungicide drenches for root and stem rot after transplanting, as needed if used. Monitoring for *Botrytis*, powdery mildew and downy mildew, and application of fungicides, if necessary. Maintenance of aeration of re-circulating water to minimize Pythium root rot; Maintenance of correct temperature and humidity to minimize disease pressure. Sterilization of water via UV light and/or copper, as necessary.
	Insect Management	Monitoring for the presence of thrips, aphids, cabbage looper and whiteflies, and applying insecticides, if necessary. Utilization 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, sanitization and disinfection of the greenhouse between crops, if applicable; Prompt removal and destruction of infected plant debris.
	Insect Management	Cleaning, sanitization and disinfection of the greenhouse between crops, if applicable; 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 will reduce leaf and head quality. Storage temperatures that are too high promote further leaf development, resulting in a less appealing product. Sudden changes in temperature can favour disease development by causing condensation on leaves or increasing 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 gray 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, 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 and organic growing systems.

- There is a need for new fungicides and biofungicides including those for which application methods differ from traditional sprays (e.g., sulfur burners) for the management of powdery mildew.

- For provincial ratings of key disease occurrence, see Table 4.

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

Disease	British Columbia	Alberta	Ontario	Quebec
Bottom rot				
Damping-off				
Downy mildew				
Drop / sclerotinia rot				
Gray mold				
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 pest 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.				

[1]Source: Greenhouse lettuce stakeholders in reporting provinces (British Columbia, Alberta, Ontario, Quebec); the data reflect the 2021, 2022 and 2023 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

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

Practices	Damping off and root rot	Downy mildew	Gray mold	Powdery mildew
Avoidance:				
Rotation with non-host crops				
Optimizing fertilization for balanced growth				
Minimizing wounding to reduce attractiveness to pests				
Control of disease vector				
Varietal Selection / use of resistant or tolerant varieties				
Prevention:				
Equipment sanitation				
End of season crop residue removal and clean-up				
Use of a 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 disease introduction and spread				
Monitoring:				
Regular monitoring throughout crop cycle				
Maintaining records to track pests				
Use of indicator plants				

…continued

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

Practices	Damping off and root rot	Downy mildew	Gray mold	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				
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 biopesticide and pesticide application techniques				
Follow sanitation practices				
This practice is used to manage this pest by at least some growers in the province.				
This practice is not used by growers in the province to manage this pest.				
This practice is not applicable for the management of this pest.				

[1]Source: Greenhouse lettuce stakeholders in reporting provinces (British Columbia, Alberta, Ontario, Quebec); the data reflects the 2021, 2022 and 2023 production years.

Bottom Rot (*Rhizoctonia solani*)

Pest Information

Damage: Symptoms of 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 Bottom Rot

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

Damping-off and Root Rot (*Pythium aphanidermatum* and Other spp.)

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 soft, brown 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 these pathogens. Additional management practices for damping-off and root rot are listed in *Table 5*.

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

Issues for 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. There is a need for new fungicides with short pre-harvest intervals for the management of Pythium damping-off and root rot 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 20 °C but infection can occur at lower temperatures as well. The disease does not develop when the temperature is over 25 °C.

Pest Management

Cultural Controls: Maintaining low humidity and preventing dew formation on the leaves, controlling the night temperature and ensuring adequate greenhouse ventilation will reduce the occurrence of downy mildew. 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*.

Resistant Cultivars: None available.

Issues for Downy Mildew

1. There is a need for the development of downy mildew resistant lettuce cultivars suitable for greenhouse production.
2. There is a need for the development of more rotational fungicide options with low pre-harvest and re-entry intervals.

Drop / Sclerotinia Rot (*Sclerotinia sclerotiorum* and *S. minor*)

Pest Information

Damage: 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. Infected lettuce heads become a wet, slimy mass due to the development of secondary bacterial rots and are 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. The ascospores are blown by wind to the aerial portions of plants and 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 drop, 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 Drop / Sclerotinia Rot

None identified.

Gray Mold (*Botrytis cinerea*)

Pest Information

Damage: Gray mold of greenhouse lettuce is characterized by basal stem rot and gray-green shrivelled leaves.

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

Pest Management

Cultural Controls: Avoiding plant injury 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 which is more susceptible to disease development, is also helpful. Additional management practices for Botrytis gray mold are listed in *Table 5*.

Resistant Cultivars: None available.

Issues for Gray Mold

1. New fungicides with different modes of action are required for effective disease control and resistance management.

Powdery Mildew (*Golovinomyces 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 percent 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 gray mold, downy mildew and other diseases. Additional management practices for powdery mildew are listed in *Table 5.*

Resistant Cultivars: None available.

Issues for Powdery Mildew

1. There is a need for 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.

Insects and Mites

Key Issues

- There is a need for new conventional and non-conventional pest control products, including biopesticides, for a number of greenhouse lettuce insect pests including aphids, thrips, greenhouse whitefly and fungus gnats. Products need to kill pests quickly and have a short pre-harvest interval to accommodate the short lettuce production cycle.

- There is a need for the development of biological control options for pests including whitefly, fungus gnats, shore flies, thrips and aphids.

- For provincial ratings of key insect and mite pest occurrence, see Table 6.

Table 6. Occurrence of insect and mite pests in greenhouse lettuce production in Canada[1,2]

Insect / Mite	British Columbia	Alberta	Ontario	Quebec
Aphid, Green peach				
Aphid, Lettuce				
Aphid, Melon				
Fungus gnats and shore flies				
Twospotted spider mite				
Western flower thrips				
Whitefly, Greenhouse				
Whitefly, Sweet potato				
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 pest pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.				
Pest not present.				
Data not reported.				

[1]Source: Greenhouse lettuce stakeholders in reporting provinces (British Columbia, Alberta, Ontario, Quebec); the data reflect the 2021, 2022 and 2023 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 7. Adoption of integrated insect and mite pest management for greenhouse lettuce production in Canada[1]

Practices	Aphids	Caterpillars	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 7. Adoption of integrated insect and mite pest management for greenhouse lettuce production in Canada[1] (continued)

Practices	Aphids	Caterpillars	Fungus gnats and shore flies	Whiteflies
Suppression:				
Use of biopesticides				
Release of arthropod biological control agents				
Use of banker plants as reservoirs or refuges for beneficial insects and mites				
Trapping				
Use of diverse product 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 lettuce aphid				
Control of algae in substrate				

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

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

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

[1]Source: Greenhouse lettuce stakeholders in reporting provinces (British Columbia, Alberta, Ontario, Quebec); the data reflects the 2021, 2022 and 2023 production years.

Table 8. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1-3]

Pest	Biological Control Agent	Description
Aphids	*Aphelinus abdominalis* *Aphidius colemani* *Aphidius ervi* *Aphidius matricariae*	Parasitic Wasp
	Adalia bipunctata *Hippodamia convergens*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Eupeodes americanus	Predatory hoverfly larva
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Aphidoletes aphidimyza	Predatory midge
	Anystis baccarum	Predatory mite
Caterpillars	*Trichogramma* spp.	Parasitic wasp
	Dicyphus hesperus *Nabis americoferus*	Predatory bug
	Chrysoperla carnea	Predatory lacewing
Fungus gnats	*Steinernema carpocapsae* *Steinernema feltiae*	Entomopathogenic nematode
	Dalotia (*Atheta*) *coriaria*	Predatory beetle
	Gaeolaelaps gillespiei *Stratiolaelaps scimitus* (*Hypoaspis miles*)	Predatory mite
Leafminers	*Steinernema carpocapsae* *Steinernema feltiae*	Entomopathogenic nematode
	Dacnusa siberica *Diglyphus isaea*	Parasitic wasp
Mites	*Stethorus punctillum*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea	Predatory lacewing
	Feltiella acarisuga	Predatory midge
	Amblydromalus limonicus *Amblyseius andersoni* *Amblyseius swirskii* *Anystis baccarum* *Iphiseius* (*Amblyseius*) *degenerans* *Neoseiulus* (*Amblyseius*) *californicus* *Neoseiulus* (*Amblyseius*) *cucumeris* *Neoseiulus* (*Amblyseius*) *fallacis* *Phytoseiulus persimilis*	Predatory mite
Mealybugs	*Cryptolaemus montrouzieri*	Predatory beetle
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Anystis baccarum	Predatory mite

…continued

Table 8. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1-3] (continued)

Pest	Biological Control Agent	Description
Thrips	*Heterorhabditis bacteriophora* *Steinernema feltiae* *Steinernema carcocapsae*	Entomopathogenic nematode
	Dalotia (*Atheta*) *coriaria*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Amblydromalus limonicus *Amblyseius andersoni* *Amblyseius swirskii* *Anystis baccarum* *Gaeolaelaps gillespiei* *Iphesius* (*Amblyseius*) *degenerans* *Neoseiulus* (*Amblyseius*) *cucumeris* *Stratiolaelaps scimitus* (*Hypoaspis miles*)	Predatory mite
Whiteflies	*Encarsia formosa* *Eretmocerus eremicus*	Parasitic wasp
	Delphastus catalinae	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Amblydomalus limonicus *Amblyseius swirskii* *Anystis baccarum*	Predatory mite

[1]Source: CABI BioProtection Portal. bioprotectionportal.com (accessed: 2024-07-09).
[2]Source: R. Buitenhuis, Director, Biological Crop Protection. Vineland Research and Innovation Centre, Vineland Station, ON, Canada.
[3]For biological control suppliers, see the Association of Natural Biocontrol Producer's Member Directory: anbp.org/members

Aphids: Green Peach Aphid (*Myzus persicae*), Lettuce Aphid (*Nasonovia ribisnigri*), and Melon Aphid (*Aphis gossypii*)

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 mold, 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 prefers 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. Aphids can also transmit lettuce mosaic virus (LMV).

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.

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 7*.

Biological Controls: Refer to *Table 8* 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 new conventional and non-conventional pest control products for the management of aphids.

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. Cabbage loopers usually move into Canada as adult moths from the south in July and August. However, this pest 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, the larvae hatch, develop through five instars 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 entry by adult moths.

Biological Controls: Arthropod biological control agents available for the management of cabbage loopers in greenhouse lettuce are listed in *Table 8*.

Resistant Cultivars: None available.

Issues for Cabbage Looper

1. There is a need for new conventional and non-conventional pest control products 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.

Caterpillars (order Lepidoptera)

Pest Information

Damage: Caterpillars chew holes in lettuce leaves.

Life Cycle: Adult moths enter the greenhouse and lay eggs on lettuce leaves. The eggs hatch and larvae feed and develop through a number of instars 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 7*.

Biological Controls: Refer to *Table 8* for a list of organisms available for the management of caterpillars in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Caterpillars

None identified.

Fungus Gnats (*Bradysia* spp. and *Corynoptera* spp.) and Shore Flies (*Ephydridae* spp.)

Pest Information

Damage: Fungus gnat and shore fly adults 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* species.

Life Cycle: Mature female fungus gnats lay eggs in moist soils, potting mixes and hydroponic media. The larvae feed on decaying organic matter, root hairs and tender lower stems 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 7*.

Biological Controls: Several biological control agents are commercially available and can be used to manage fungus gnats and shore flies. Refer to *Table 8* for the management of fungus gnats and shore flies in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Fungus Gnats and Shore Flies

1. There is a need for new conventional and non-conventional pest control products for the control of fungus gnats in greenhouse lettuce.
2. There is a need to develop effective non-chemical control options, including biological controls, for fungus gnats and shore flies.

Twospotted Spider Mite (*Tetranychus urticae*)

Pest Information

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

Life Cycle: Twospotted 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 eggs on the lower leaf surface and can complete their lifecycle in as little as three days at 32 °C, but typically this 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* 8 for a list of available organisms.

Resistant Cultivars: None available.

Issues for Twospotted Spider Mite

None identified.

Western Flower Thrips (*Frankliniella occidentalis*)

Pest Information

Damage: Feeding by thrips 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.

Life Cycle: The life cycle of thrips consists of five stages: egg, larval, pre-pupal, pupal and adult. Thrips lay eggs inside soft plant tissues including flowers, leaves, buds and stems. Pupation occurs in soil or growing medium. 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 percent relative humidity) will prevent the rapid increase in thrips populations.

Biological Controls: As thrips have developed resistance to many registered insecticides, biological control is now the primary strategy for controlling thrips in greenhouse vegetable production. Refer to *Table 8* for a list of organisms available for the management of thrips in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Thrips

1. New pest control products compatible with biological control agents are needed to control thrips. Methods must take into account the short production cycle.
2. There is a need for the identification and development of additional biological control agents for the control of thrips.

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

Pest Information

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

Life Cycle: The adult whitefly lays eggs on the underside of leaves. Eggs hatch and the first nymphal stage, the mobile crawlers, move around and find a suitable spot to feed and complete nymphal development. Following pupation, adults emerge. Whiteflies can also transmit viruses. Sweet potato whitefly is reported to be able to transmit over 60 different viral diseases, whereas greenhouse whitefly is reported to spread beet pseudo-yellows virus in cucumber.

Pest Management

Cultural Controls: The entry of whiteflies into greenhouses can be minimized by screening vents and keeping doorways and other openings 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 7.*

Biological Controls: Refer to *Table 8* for a list of biological control agents that can be used for the management of whiteflies in greenhouse lettuce.

Resistant Cultivars: None available.

Issues for Whiteflies

1. New conventional and non-conventional pest control products for the management of greenhouse whitefly in greenhouse lettuce are needed, as resistance against currently registered pesticides is developing in whitefly populations.
2. There is a need for the development of additional biological controls for whitefly in lettuce.

Weeds

Weed management in and around greenhouses is important as weeds can be an alternate host for insects and disease causing organisms. 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 10 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.

Resources

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

Alberta Ministry of Agriculture, Food, and Rural Development. *Commercial greenhouses: Best practices for managing commercial greenhouses in Alberta*. https://www.alberta.ca/greenhouses

British Columbia Ministry of Agriculture. *Greenhouse Vegetables Production*. Plant Health. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/crop-production/greenhouse-vegetables

Centre de Référence en Agriculture et Agroalimentaire du Québec (CRAAQ). Agri-Réseau. (in French only) https://www.agrireseau.net/legumesdeserre

Ontario Ministry of Agriculture, Food and Rural Affairs. 2020. *Publication 835, Crop Protection Guide for Greenhouse Vegetables, 2020-2021*. https://www.publications.gov.on.ca/store/20170501121/Free_Download_Files/300239.pdf

Provincial Contacts

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	AgriService BC www2.gov.bc.ca/gov/content/industry/agriservice-bc	Rajiv Dasanjh Rajiv.Dasanjh@gov.bc.ca	Caroline Bédard Caroline.Bedard@gov.bc.ca
Alberta	Alberta Agriculture and Irrigation www.alberta.ca/agriculture-and-irrigation	N/A	Gayah Sieusahai Gayah.Sieusahai@gov.ab.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs omafra.gov.on.ca	Cara McCreary Cara.McCreary@ontario.ca	Joshua Mosiondz Joshua.Mosiondz@ontario.ca
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (in French only) www.mapaq.gouv.qc.ca	Philippe-Antoine Taillon Philippe.Antoine.Taillon@mapaq.gouv.qc.ca	Mathieu Coté Mathieu.Cote@mapaq.gouv.qc.ca

Provincial and National Greenhouse Grower Organizations

Alberta Greenhouse Growers Association: agga.ca

British Columbia Greenhouse Growers' Association: bcgreenhouse.ca

Canadian Federation of Agriculture: www.cfa-fca.ca

Canadian Organic Growers: cog.ca

Fruit and Vegetable Growers of Canada: fvgc.ca

Ontario Greenhouse Vegetable Growers: www.ogvg.com

Ontario Greenhouse Alliance: www.theontariogreenhousealliance.com

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 reporting province is provided in Tables 4 and 6 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>Gray</td></tr>
</table>

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