# Crop Profile for Greenhouse Lettuce in Canada

**Prepared by:**

**Pesticide Risk Reduction Program**

**Pest Management Centre**

**Agriculture and Agri-Food Canada**

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**Pest Management Centre**
**Pesticide Risk Reduction Program**
**Agriculture and Agri-Food Canada**
960 Carling Avenue, Building 57
Ottawa, Ontario
K1A 0C6
CANADA

This profile is based on a report prepared on contract (01B68-3-0042) by:

**Dr. Janice Elmhirst**
**Elmhirst Diagnostics and Research**
**5727 Riverside St.**
**Abbotsford, BC, CANADA**
**V4X 1T6**

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# Crop Profile for Greenhouse Lettuce in Canada

Lettuce was cultivated as early as 4500 BC in the Mediterranean for the oil extracted from the seeds. Since then, production of the annual plant has spread world wide. 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. *captain*), 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 head or leaf, which is used mainly for salads. A good source of Vitamin A, E and folacin, lettuce is considered a healthy food and its popularity is on the rise as consumers make more healthy food choices. Recently, pre-washed and pre-cut packaged salad mixes have become popular with consumers.

## General Production Information

| | |
|---|---|
| Canadian Production (2005) | 3.3 million heads<br>3.2 hectares |
| Farm gate value (2005) | $2.9 million |
| Domestic consumption (2004)[1] | 10.99 kg/person |
| Export (2005)[1] | $12.2 million |
| Imports (2005)[1] | $220.0 million |
| Source(s): Statistics Canada | |

[1]Includes both field-grown and greenhouse lettuce.

### *Production Regions*

Greenhouse lettuce is grown in Canada in areas where light and energy costs favour greenhouse crop production and where production is close to major markets. Major production areas by hectares (2003 data) are QC (9.87 ha or 80% of the national acreage); ON (1.12 ha or 9 %); and BC (1.36 ha or 11 %). Nova Scotia produces about 0.13 ha or 1.0 % of the national acreage and there is a small amount produced in Alberta.

### *Cultural Practices*

The development of greenhouse procedures for producing lettuce has allowed growers to produce lettuce year round. The continual supply of lettuce is made possible by using a two-stage production system: plant raising and plant 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 into 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. Seed trays in the growth room are covered with clear poly, transparent lids or misted frequently to ensure they do not dry out. Seedlings grown in peat-perlite are transplanted to rockwool mini-blocks or foam media when the first true leaves appear (7-10 days). Seedling plugs are then transplanted to temporary NFT troughs under supplemental lighting (24 hour photoperiod). At two to three weeks after germination during the summer, or four to six weeks after germination in the winter, the seedling plugs (3-4 leaves) are placed in permanent NFT troughs. Depending on the variety, six to seven weeks or 10-12 weeks are required from seeding to harvest for summer and winter crops, respectively. Generally, there are 8 -10 production cycles per year.

There are many different NFT trough systems. All consist of a support or cover through which the transplant is placed, with the plant roots suspended in a trough through which the nutrient solution flows. An alternative system is Floating Culture, 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.

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 clam-shell container. Some lettuce may be harvested and bagged without roots. Proper storage temperature and humidity is essential to maintain crop quality.

Different plant densities are used depending on the time of year and different pest management practices, pesticides and fertilizers are used at different stages of development. Water quality (salts and pH) and tissue and solution nutrient levels are checked frequently. Fungicides for root and stem rot diseases are often applied preventatively at transplanting.

## Production Issues

Production of greenhouse lettuce requires strict control of temperature, light, carbon dioxide concentration and relative humidity (RH). Greenhouse lettuce is susceptible to tip burn when environmental and nutritional factors are imbalanced and the crop is under stress.

**Table 1. Canadian greenhouse lettuce production and pest management schedule**

| Time of Year | Activity | Action |
|---|---|---|
| Seeding and Transplant Production | Plant Care | Maintain proper temperature, humidity and moisture for seed germination. |
| | Media Care | Ensure seeding medium is clean and use clean trays; practice good sanitation. |
| | Disease Management | Dip seeds in thiram fungicide before sowing. Treat seedlings with fungicide to prevent damping off and seedling rot. |
| | Insect Management | Minimize conditions favorable for fungus gnats and shore flies. |
| Crop Production | Plant Care | Maintain appropriate temperature, light, RH, $CO_2$ levels to avoid diseases and tip burn. |
| | Media Care | Monitor pH and nutrient content and ensure good aeration of nutrient solution. |
| | Disease Management | Drench with protectant fungicide for root and stem rot after transplanting. Monitor for Botrytis, powdery mildew and downy mildew and apply registered fungicides if available. Ensure good aeration of re-circulating water to reduce Pythium root rot. Maintain temperature and humidity to avoid condensation on crop. |
| | Insect Management | Monitor for aphids, cabbage loopers and whiteflies and apply insecticides as needed. Maintain weed-free zone around the greenhouse. Seal cracks and keep doors closed and screen vents when possible. |
| Harvest and Post-Harvest | Plant Care | Harvest promptly and ensure proper storage conditions to maintain crop quality. |
| | Media Care | Clean reservoir tanks, lines, etc. of algae and build-up between crops. |
| | Disease Management | Clean, sanitize and disinfect greenhouse between crops. Remove plant debris promptly and destroy. |
| | Insect Management | Clean, sanitize and disinfect greenhouse between crops. Remove plant debris promptly and destroy. |

## *Abiotic Factors Limiting Production*

### *Key Issues*

- Availability of light, temperature and affordable energy are the main abiotic factors limiting greenhouse lettuce production in Canada.
- Tip burn is the most common abiotic (environmental) disorder. There is a need for new cultivars with greater tolerance to tip burn.

### Temperature

The temperature of the greenhouse is strictly regulated depending on the stage of development. Too high a temperature will prevent seed germination and in the production stage, will reduce leaf and head quality. Sudden changes in temperature can favour disease development by causing condensation on leaves or increase the incidence of tip burn. The temperature for germination and seedling production should be 15-18$^{o}$C. During crop growth and production, cooling fans, high pressure foggers, ventilation and moveable shade cloths or whitewash are used to maintain a night temperature of 15-18$^{o}$C and a day temperature ranging from 18-19$^{o}$C on

cloudy days, to 19-22$^{o}$C on sunny days. In winter, when light levels are low, lettuce is often grown at cooler temperatures (10$^{o}$C night and 15-18$^{o}$C day), which lengthens the days to harvest. After harvest, lettuce must be stored at 2-4$^{o}$C under high relative humidity. Lettuce is highly sensitive to freezing, which damages the leaves. Too high storage temperatures promote further leaf development, resulting in a less appealing product.

## Light

To optimize plant growth rate, supplemental, artificial lighting in the form of HPS (high pressure sodium) lights at 20 watts/m$^2$ on a 24 hour photoperiod, 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 cloudy periods and winter months.

## Other climactic factors

Humidity is also closely monitored and controlled for greenhouse lettuce crops. Too high humidity, especially under cool temperatures, will favour condensation on the leaves and the development of diseases, such as Botrytis grey mould. Excessive humidity will also increase the risk of tip burn by reducing transpiration. A relative humidity (RH) of 75-85% (VDP of 0.4-0.8 kPa) is generally targeted during production. The RH in storage should be 80-90%. For optimal growth and development, the levels of $CO_2$ are also monitored to maintain a concentration of 1000 ppm.

## Nutrient solution quality

The concentration of nutrient salts (EC) and the pH of the nutrient solution are tested and monitored regularly as these have a significant impact on the growth of greenhouse lettuce. Fluctuations in EC levels will promote tip burn. A pH of 6.0 is optimal for plant growth. Fertilizer and acid 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.

## Tip burn and glassiness

Tip burn is caused by a calcium deficiency and is characterized by browning of the edges and tips of the young, inner 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 provide sufficient calcium ions to the growing tips. Environmental conditions that reduce the transpiration rate, such as sudden temperature changes, too high RH, too low light or low temperature, can result in tip burn. Increasing ventilation and air circulation with fans will increase transpiration. In addition, limiting growth by reducing nitrogen application, harvesting the lettuce slightly before maturity and keeping the night-time humidity of the greenhouse at 75-85%, will reduce the incidence of tip burn.

Glassiness results from excess water uptake by the roots, followed by inadequate water loss from the leaves (evapo-transpiration). 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 in the storage facility. Tan to brown spots appear along leaf veins. Numerous or large spots make the product unmarketable.

## Leaf yellowing

Premature leaf yellowing is associated with warm temperatures, high humidity and low light levels in late fall and early spring, which result in reduced $CO^2$ absorption, high respiration rates and thus leaf senescence. Lowering humidity and increasing ventilation and air circulation and using supplemental lighting will help to prevent this condition.

# Diseases

## *Key Issues*

- The registration of new, reduced-risk fungicides is needed for the control of botrytis, downy mildew and pythium damping off and root rot and to reduce the risk of development of pathogen resistance.

**Table 2. Degree of occurrence of diseases in Canadian greenhouse lettuce production**

| | Degree of occurrence | | | | |
|---|---|---|---|---|---|
| **Major Diseases** | **BC** | **AB** | **ON** | **QC** | **NS** |
| Botrytis grey mould | E | E | E | E | E |
| Downy mildew | E | DNR | DNR | DNR | DNR |
| Powdery mildew | DNR | E,D | E,D | DNR | DNR |
| Pythium damping-off and root rot | E | E | E | E | E |
| **Minor Diseases** | **BC** | **AB** | **ON** | **QC** | **NS** |
| White mould/drop | E | DNR | E | E | E |
| Butt rot (*Pseudomonas* spp.) | E | DNR | DNR | DNR | DNR |
| Stem rot (*Pseudomonas chicorii*) | E | DNR | DNR | DNR | DNR |
| Anthracnose | E | DNR | DNR | DNR | DNR |
| Bottom rot (Rhizoctonia) | E | DNR | E | E | DNR |
| Lettuce mosaic virus | DNR | DNR | DNR | DNR | DNR |
| Aster yellows | DNR | DNR | DNR | DNR | DNR |
| Big vein virus | DNR | DNR | DNR | DNR | DNR |
| Cucumber mosaic virus | DNR | DNR | DNR | DNR | DNR |

| |
|---|
| Widespread yearly occurrence with high pest pressure |
| Localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure |
| Widespread yearly occurrence with low to moderate pest pressure |
| Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low to moderate pest pressure |
| Pest not present |
| DNR - Data not reported |
| E – established |
| D – invasion expected or dispersing |

Source(s): Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec; BC Ministry of Agriculture, Food & Fisheries Crop Profile for Greenhouse Lettuce (DRAFT); Ontario Ministry of Agriculture and Food Publ. 371.

## *Major Diseases*

### Pythium damping off and root rot *(Pythium aphanidermatum; Pythium* spp.*)*

***Pest Information***

*Damage:* This soil and water-borne pathogen (protist) attacks the roots of lettuce and can destroy seedlings before or after emergence. Infection after transplanting may also reduce yield. Pythium diseases can be a problem in NFT systems, if solution flow rate, temperature, and particularly aeration is poor, causing the plants to be stressed. Plants wilt and have brown, soft roots, although in some cases, obvious signs of disease may not be visible, if the pathogen is affecting only the tiny feeder roots.

*Life Cycle:* The disease can spread rapidly through the nutrient solution. Sporangia produce zoospores that infect root tips and wounds. Sporangia can be spread in and on fungus gnats and shore flies.

***Pest Management***

*Chemical Controls:* Thiram fungicide is available as a seed treatment and a seedling drench (oxine benzoate) is available. There are no registered products for control of *Pythium* in the production phase of the crop.

*Cultural Controls:* Seeds should be sown in sterile propagation media and care should be taken to minimize overcrowding and overwatering seedlings. The maintenance of good aeration of the re-circulating solution helps to minimize pythium pressure.

*Alternative Controls:* None available.

*Resistant Cultivars:* None available.

***Issues for Pythium root rot***

1. The registration of new pesticides for the control of pythium root rot in re-circulating water, particularly during the production phase of lettuce culture, is needed.

### Downy mildew *(Bremia lactucae)*

***Pest Information***

*Damage:* This disease is more severe on greenhouse lettuce than field lettuce. Symptoms include yellow patches on leaves, which shrivel up and turn brown.

*Life Cycle:* Spores (sporangia) of downy mildew are produced on the underside of infected leaves. Spores spread on air currents, in water and by handling. The optimum temperature for infection and disease development is 15-20$^{o}$C but these can occur at lower temperatures. The disease does not develop when the temperature is over 25$^{o}$C.

***Pest Management***

*Chemical Controls:* Fosetyl-Al is registered for the control of downy mildew in British Columbia only.

*Cultural Controls:* The prevention of dew formation on the leaves by controlling the night temperature and ensuring adequate ventilation, will reduce the occurrence of this disease as will maintaining reduced humidity. New crops should not be planted near older ones and old crop debris should be removed from the greenhouse.

*Alternative Controls:* None available.

*Resistant Cultivars:* Some resistant cultivars may be available; these should be evaluated on a local basis to determine suitability.

***Issues for downy mildew***

1. There is a need for registration of new, reduced-risk fungicides to manage the development of resistance.
2. Research is needed to develop resistant cultivars suitable for greenhouse production.

## Botrytis Grey mould *(Botrytis cinerea = Sclerotinia fuckeliana)*

***Pest Information***

*Damage:* Grey mould is the most common disease of greenhouse lettuce. It is characterized by basal stem rot and grey-green, shrivelled leaves.

*Life Cycle:* Powdery, grey, spore masses produced by the causal agent under humid conditions, are the main source of new infections. *Botrytis cinerea* may infect lettuce by entering at the stem of a lettuce plant or at the base of leaves. Botrytis overwinters in soil, on perennial plants, and on plant debris as black sclerotia.

***Pest Management***

*Chemical Controls:* Iprodione is registered but resistance is suspected in some populations. Fungicides are applied before the onset of disease when cool and moist conditions prevail. Ferbam is registered but is not used due to crop injury.

*Cultural Controls:* Avoiding injury of plants will reduce infections, as wounds provide an entry route for this disease. Sources for disease spread can be reduced by good sanitation practices when handling plants and the frequent removal of crop residue from the greenhouse. Controlling ventilation and night temperatures to prevent condensation on the leaves will reduce disease development.. Nitrogen levels should be monitored to prevent lush growth, that is more susceptible to the disease.

*Alternative Controls:* None available.

*Resistant Cultivars:* None available.

***Issues for Botrytis grey mould***

1. The registration of new, reduced-risk fungicides is needed for control of Botrytis grey mould and to avoid disease resistance.
2. There is a concern that resistance to iprodione may be developing in the pathogen population.

## Powdery mildew *(Erysiphe cichoracearum)*

***Pest information***

*Damage:* Round, white spots on the upper surface of older leaves are initial symptoms of this disease. These spots enlarge and cover the entire surface of the leaf , occasionally spreading to leaf petioles and stems as well. This disease has appeared in some greenhouses and is expected to be an increasing problem.

*Life Cycle:* Conidia are produced on the leaf surface of infected plants and are dispersed by air currents. The main survival stages of powdery mildew are the cleistothecia and thick-walled mycelium, which survive in dry crop residue and cause new infections in successive crops.

***Pest Management***

*Chemical Controls:* None available.

*Cultural Controls:* Maintaining a low, uniform relative humidity (70-80%), and prompt removal of infected leaves can help to prevent infection. Disinfection of the greenhouse between crops is also helpful in reducing the incidence of powdery mildew.

*Alternative Controls:* Spraying the plants every 2-3 days with water may reduce spore buildup, but may also predispose plants to Botrytis grey mould, downy mildew and other diseases.

*Resistant Cultivars:* None available.

***Issues for powdery mildew***

1. The registration of fungicides for control of powdery mildew is needed. This disease is present in some provinces and threatens to spread.
2. Climate management is key to the control of this disease and should be used as a primary method of control.

# *Minor Diseases*

## Butt rot (head rot) *(Pseudomonas fluorescens = P. marginalis)*

***Pest Information***

*Damage:* Symptoms of butt rot include a black to green, firm rot that may spread from infected stems along the veins of the lower leaves. The disease may also progress down the roots. Infection by secondary organisms results in wilt or collapse of the plant.

*Life Cycle*: Excessive leaf wetness and low light select for this bacterial disease. Infection may follow mechanical injury of the plant.

***Pest Management***

*Chemical Controls:* None available.

*Cultural Controls:* Control of bacterial diseases is usually possible by proper heating, ventilation and sanitation.

*Alternative Controls:* Adjusting the fertilization routine so that plants are not overly soft, avoiding frequent wetting of the foliage and reducing humidity and condensation by

controlling ventilation and temperature of the greenhouse, will help to reduce disease development.

*Resistant Cultivars:* The severity of disease varies among cultivars.

***Issues for Butt rot***

1. None identified.

## Stem rot *(Pseudomonas cichorii)*

***Pest Information***

*Damage:* Symptoms of stem rot include firm, dark brown rot and streaking of the petioles of the inner leaves. The wrapper leaves show no symptoms and the disease is impossible to detect without their removal.

*Life Cycle:* Excessive leaf wetness and low light select for this bacterial disease. Infection usually follows mechanical injury of the plant, but not always.

***Pest Management***

*Chemical Controls:* None available.

*Cultural Controls:* Control of bacterial diseases is usually possible by proper heating, ventilation and sanitation.

*Alternative Controls:* Adjusting fertilization so that plants are not overly soft, avoiding frequent wetting of the foliage and reducing humidity and condensation by controlling ventilation and temperature of the greenhouse will help to minimize disease development.

*Resistant Cultivars:* The severity of disease varies among cultivars.

***Issues for stem rot***

1. None identified.

## Drop (white mould) *(Sclerotinia minor, S. sclerotiorum = Whetzelinia sclerotiorum)*

***Pest Information***

*Damage:* This fungus rots the base of the stem and crown, resulting in collapse of the plant.

*Life Cycle:* The disease typically occurs when temperatures are above 22ºC and humidity is high. Tough, overwintering sclerotia develop on decaying plant tissue and produce spores in the spring for new infections.

***Pest Management***

*Chemical Controls:* Iprodione is registered for control of sclerotinia drop.

*Cultural Controls:* The removal and destruction of all infected plants and trimmings and other sanitation practices, will help minimize this disease.

*Alternative Controls:* None available.

*Resistant Cultivars:* None available.

***Issues for drop (Sclerotinia white mould)***

1. None identified.

## Bottom rot (*Rhizoctonia solani*)

### *Pest Information*

*Damage:* Symptoms 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 over the entire midrib and cause the leaf blade to collapse. Under favorable conditions, this disease will rot the leaves one by one as it moves inward and upward.

*Life Cycle:* This fungal disease is less common in hydroponic crops. The 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*

*Chemical Controls:* None available.

*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.

*Alternative Controls:* Alternative controls include the application of registered disinfectants to greenhouse structures after cleaning between crops.

*Resistant Cultivars:* None available.

### *Issues for bottom rot*

1. The registration of fungicides for the control of bottom rot is needed as there are no fungicides registered for the control of this disease.

## Anthracnose (ring spot, fire of endive) *(Microdochium panattonianum, = Marssonina panattoniana)*

### *Pest Information*

*Damage:* Tiny, water-soaked lesions enlarge to form straw-coloured spots, which turn white and frequently drop out, giving a "shot hole" appearance to the leaf. Outer leaves wilt and, if disease is severe, the inner leaves may rot. Lesions on the midrib are red. Infected plants tend to be stunted and yellow-brown.

*Life Cycle:* This fungal disease is more prevalent in winter crops and during cool, wet conditions although it can develop in warm, humid conditions if condensation occurs on the leaves. The fungus typically survives as conidia, mycelium and microsclerotia in residue from diseased plants and in wild hosts. Inoculum may also be spread by wind or water, and infection and disease development can occur between 15 and 34ºC.

### *Pest Management*

*Chemical Controls:* None available.

*Cultural Controls:* Good sanitation practices will minimize spread of this disease. Tools, clothing and equipment should be disinfected and soil or plant residues eliminated from them. Plant debris and trimmings should be properly composted or destroyed.

*Alternative Controls:* None available.

*Resistant Cultivars:* None available.

### *Issues for anthracnose*

1. There are no fungicides registered for the control of this disease in greenhouse lettuce.

## Lettuce mosaic *(Lettuce mosaic virus = LMV )*

***Pest information***

*Damage:* Lettuce mosaic is the most important viral disease of greenhouse lettuce. This virus can have a significant impact on both plant size and quality.

*Life Cycle:* Lettuce mosaic virus is vectored by aphids.

***Pest Management***

*Chemical Controls:* None available.

*Cultural Controls:* Indexed seed that is free of mosaic virus, should be used. Blocks of lettuce should be isolated to minimize the spread of the virus from crop to crop. Diseased plants should be removed and destroyed and aphid populations destroyed.

*Alternative Controls:* A number of alternative controls are available for aphids (see below).

*Resistant Cultivars:* None available .

***Issues for Lettuce mosaic***

1. The registration of new insecticides for the control of aphids will reduce the incidence of lettuce mosaic virus.

## Big vein (Big-vein virus)

***Pest Information***

*Damage:* Although this disease is not typically highly destructive to the crop, it can cause undesirable symptoms in greenhouse lettuce plants. Symptoms include clearing of the tissue adjacent to the leaf veins. This makes the veins appear thicker than usual. Infected areas may also appear puffy and ruffled at the margins. Plants infected early may die or remain stunted.

*Life Cycle:* The big vein virus is vectored by the soil-borne fungus *Olpidium brassicae*. The fungal vector infects the roots of numerous different species of plants.

***Pest Management***

*Chemical Controls:* None available.

*Cultural Controls:* The growth media should be disinfected. Water systems, tools and all equipment must be sterilized before and during use. Good sanitation and hygiene will help minimize this disease.

*Alternative Controls:* None available.

*Resistant Cultivars:* Lettuce cultivars differ in tolerance to big vein.

***Issues for big vein***

1. None identified.
2.

## Cucumber mosaic (Cucumber mosaic virus =CMV)

***Pest Information***

*Damage:* Symptoms vary with stage of growth at the time of infection, time of year, cultivar and strain of virus. Symptoms include stunting and yellow mottle or necrotic spotting on the leaves.

*Life Cycle:* Cucumber mosaic virus is transmitted mechanically or by aphid vectors. There is no evidence that this disease is seed transmitted in lettuce.

***Pest Management***

*Chemical Controls:* Chemical control of aphids may reduce the spread of this disease.

*Cultural Controls:* Infected plants should be remove and destroyed.

*Alternative Controls:* None available.

*Resistant Cultivars:* None available.

***Issues for cucumber mosaic virus***

1. None identified.

## Aster yellows (*Phytoplasma*)

***Pest Information***

*Damage:* The centre leaves show symptoms first, appearing chlorotic. Abnormal development is also common, resulting in short stubs or twisted and curled leaves.

*Life Cycle:* The aster yellows phytoplasma can overwinter in perennial weeds and ornamentals. It can be transmitted to lettuce and other crops by several species of leafhoppers. It is not a common disease of greenhouse lettuce crops.

***Pest Management***

*Chemical Controls:* None available.

*Cultural Controls:* Controlling weeds around the greenhouse will help reduce the risk of the leafhopper vectors.

*Alternative Controls:* None available.

*Resistant Cultivars:* None available.

***Issues for aster yellows***

1. None identified.

**Table 3. Disease control products, classification and performance for Canadian greenhouse lettuce production**

| Regulatory status as of May 12, 2006 | | | | | Stakeholders comments6 | |
|---|---|---|---|---|---|---|
| **Control active ingredient / organism (product)[1]** | **Classification[2]** | **Mode of action – resistance group[2]** | **PMRA status of active ingredient[3]** | **Pests or group of pests targeted[4]** | **Performance of product according to recommended use[5]** | **Notes** |
| **fosetyl-aluminum (Aliette WDG)** | ethyl phosphonate fungicide | 33 | R | Downy mildew | $A^P$ | Registered in British Columbia only. |
| **iprodione (Rovral WP, Rovral WDG** | Dicarboximide fungicide | 2 | R | Botrytis grey mould | $A^P$ | Disease resistance to Rovral is suspected. |
| | | | | Sclerotinia drop | $A^P$ | |
| **ferbam (Ferbam 76WDG)** | Dithiocarbamate fungicide | M3 | R | Botrytis grey mould | $A^P$ | Not used: causes a black residue on leaves. |
| **thiram (Thiram 75WP)** | Dithiocarbamate fungicide | M3 | RE | Pythium damping-off | $A^P$ | Seed treatment only. |
| **oxine benzoate (No-Damp)** | Inorganic fungicide | M2 | R | Pythium damping-off | $A^P$ | Seedling drench only. |

[1] Common trade name(s), if provided in brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.

[2]The classification and the mode of action group are based on the classification presented in the Pest Management Regulatory Agency Regulatory Directive DIR99-06, Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action. The document is under revision and up-to-date information can be found on the following web sites: herbicides:http://www.plantprotection.org/HRAC/Bindex.cfm?doc=moa2002.htm ; insecticides:http://www.irac-online.org/documents/moa/MoAv5_1.pdf ; fungicides:http://www.frac.info/frac/index.htm

[3] R-full registration (non-reduced risk), RE-under re-evaluation (yellow), DI (red) -discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA, BI-biological, RR-reduced risk (green), OP-organophosphate replacement, NR-not registered. Not all end-use products will be classed as reduced-risk. Not all end use products containing this active ingredient may be registered for use on this crop. Individual product labels should be consulted for up to date accurate information concerning specific registration details. The information in these tables should not be relied upon for pesticide application decisions. Consult individual product labels for specific registration details. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp

[4] Please consult the product label on the PMRA web site (http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp) for specific listing of pests controlled by each active ingredient.

[5] A – Adequate (green) (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), Ap – Provisionally Adequate (yellow) (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (red) (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control)

[6]Source(s): Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec; BC Ministry of Agriculture, Food & Fisheries Crop Profile for Greenhouse Lettuce (DRAFT); Ontario Ministry of Agriculture and Food Publ. 371

**Table 4. Adoption of disease pest management approaches for Canadian greenhouse lettuce production**

| | Practice \ Pest | Botrytis | Downy mildew | Pythium | Powdery mildew |
|---|---|---|---|---|---|
| Prevention | residue removal / management | | | | |
| | water, humidity management | | | | |
| | equipment and greenhouse sanitation | | | | |
| | row spacing / seeding depth | | | | |
| | removal of alternative hosts (weeds/volunteers) | | | | |
| Avoidance | resistant varieties | | | | |
| | planting / harvest date adjustment | | | | |
| | crop rotation | | | | |
| | use of disease-free seed | | | | |
| | optimizing fertilization | | | | |
| | reducing mechanical damage / insect damage | | | | |
| | thinning / pruning | | | | |
| Monitoring | scouting - monitoring | | | | |
| | records to track pests | | | | |
| | environmental monitoring for disease forecasting | | | | |
| | grading out infected produce | | | | |
| Suppression | use of thresholds for application decisions | | | | |
| | biological pesticides | | | | |
| | beneficial organisms & habitat management | | | | |
| | pesticide rotation for resistance management | | | | |
| | covers / physical barriers | | | | |
| | controlled atmosphere storage | | | | |
| | forecasting for applications | | | | |

**no information regarding the practice is available**

**available/used**

**available/not used**

**not available**

Source(s): Information in the crop profile for individual pests

## Insects and mites

### Key Issues

- There is a need for the registration of new, reduced-risk, IPM-compatible insecticides as replacements for organophosphate and organochlorine products.
- Because the entire above-ground, leafy part of the lettuce crop is sold and consumed, there is virtually zero consumer tolerance for the presence of foliar insects or cosmetic damage. As a result, biological control agents alone, while helpful in reducing pest numbers, do not provide sufficient pest control.
- More than one product is needed for control of major pests, to reduce risk of resistance development.

**Table 5. Degree of occurrence of insect and mite pests in Canadian greenhouse lettuce production**

| | Degree of occurrence | | | | |
|---|---|---|---|---|---|
| **Major Pests** | **BC** | **AB** | **ON** | **QC** | **NS** |
| Aphids: Lettuce aphid and other spp. | E | E | E | E | E |
| Cabbage looper | E | E | E | E | E |
| Fungus gnats | E | E | E | E | E |
| Whiteflies: Greenhouse and other spp. | E | E | E | E | E |
| **Lesser Pests** | **BC** | **AB** | **ON** | **QC** | **NS** |
| Thrips | E | DNR | DNR | DNR | DNR |
| Shore flies | E | DNR | E | DNR | DNR |
| Two-spotted spider mite | E | DNR | DNR | DNR | DNR |
| Slugs and snails | E | DNR | DNR | DNR | DNR |

| |
|---|
| Widespread yearly occurrence with high pest pressure |
| Localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure |
| Widespread yearly occurrence with low to moderate pest pressure |
| Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low to moderate pest pressure |
| Pest not present |
| DNR - Data not reported |
| E – established |
| D – invasion expected or dispersing |

Source(s): Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec; BC Ministry of Agriculture, Food & Fisheries Crop Profile for Greenhouse Lettuce (DRAFT); Ontario Ministry of Agriculture and Food Publ. 371.

## *Major Insects and Mites*

### Aphids: Lettuce aphid *(Nasonovia ribisnigri) and other species (Green peach aphid (Myzus persicae) and melon aphid (Aphis gossypii).*

***Pest Information***

*Damage:* Most damage is caused by the lettuce aphid, but other aphids can affect lettuce also. Severely-infested plants may be stunted, have discoloured foliage or curled leaves and buds may be damaged or malformed. Plants may also become covered in aphid secretions (honeydew), shed aphid skins and black, sooty mould, which often grows on the honeydew. Aphids can also transmit lettuce mosaic virus (LMV). Even in small numbers, the presence of aphids may make the crop unmarketable. Because aphid populations can grow very quickly, failure to control populations at first appearance may result in severe yield reduction or even total crop loss.

*Life Cycle*: Aphids overwinter as eggs on alternative 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 alternative hosts outdoors, mate and lay eggs.

***Pest Management***

*Chemical Controls:* Imidacloprid, a systemic neonicotinoid product taken up by roots, has an emergency registration only in British Columbia until Dec. 31, 2006. Otherwise, growers use nicotine smoke (Plant-Fume) plus foliar sprays of malathion and spot sprays of endosulfan. Insecticidal soap is also registered for aphid control but has low residual activity and can damage lettuce leaves at higher temperatures.

*Cultural Controls:* Screening of greenhouse vents and maintenance of a weed and garden-free area around the greenhouse can help to control aphids. Close monitoring should be conducted in the spring for the appearance of first aphids on the crop.

*Alternative Controls:* Several predatory mites (*Amblyseius* spp. and *Phytoseiulus* spp.) and parasitic wasps, as well as ladybeetles, are available commercially for biological control of aphids in greenhouse vegetable production. These provide suppression of the aphid population, but do not provide a commercially acceptable level of control on greenhouse lettuce.

*Resistant Cultivars:* None available.

***Issues for aphids***

1. The registration of new, reduced-risk and low-toxic aphicides available in the U.S. and Europe is needed, as replacements for organophosphates. There is a zero tolerance for aphids on greenhouse lettuce.
2. Some resistance to endosulfan is suspected within aphid populations.

## Cabbage looper (*Trichopulsia 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 through feeding on leaf tissue during its development. Larval damage to leaves makes the crop unmarketable and may also provide entry for secondary disease organisms.

*Life Cycle:* The cabbage looper does not typically over-winter 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, 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 3-4 days. Five instars follow over the next 2-3 weeks. Pupae encase themselves in a loose cocoon for about two weeks, after which a mature moth emerges.

***Pest Management***

*Chemical Controls:* Tebufenozide is registered. Malathion, an organophosphate is not specifically labelled for cabbage looper but will kill larvae. Most growers treat virtually 100 % of the crop with both of these products, as well as *Bacillus thuringiensis* var. *kurstaki* (Btk).

*Cultural Controls:* Vents are screened and doorways and other openings to the greenhouse are kept closed, especially at night, to minimize entry of adult moths.

*Alternative Controls:* A nuclear polyhedrosis virus has been effective in controlling cabbage looper larvae in research trials, but has not yet been developed as a commercial insecticide. The bacterial insecticide Btk is registered for control of cabbage looper.

Resistant Cultivars: None available.

Efficacy of Controls: Btk and tebufenozide are generally used only at peak infestation times in the summer; resistance is a risk with repeated use of tebufenozide.

***Issues for Cabbage looper***

1. Registration of new, reduced-risk products available in the U.S. and Europe, is needed to replace organophosphates and reduce risk of resistance to tebufenozide.
2. There is a general lack of effective control products.

## Fungus gnats (*Bradysia* spp. *Corynoptera* spp.)

***Pest Information***

*Damage:* Although adults are occasionally a nuisance to workers through sheer numbers, larvae are the most damaging stage and feed on roots and root hairs. Growth reduction may occur but plants are rarely killed by these insects. In addition, fungus gnats can carry and facilitate the introduction of soil-borne diseases such as pythium root rot.

*Life Cycle:* Mature females lay eggs in moist soils, potting mix and hydroponic media. Two to four days later, the eggs hatch and the resulting larvae feed on roots, root hairs and mycelium. Pupation occurs 14-16 days later, and adults emerge about 3-5 days later.

***Pest Management***

*Chemical Controls:* A spray or drench application of insecticides to control other pests may also control fungus gnat larvae and adults.

*Cultural Controls:* Good sanitation, including the removal of waste material, is used to minimize fungus gnats. Vents are screened and doorways and other openings to the greenhouse are closed to minimize entry by adult gnats.

*Alternative Controls:* Only Vectobac (*Bacillus thuringiensis* var. *israelensis*) is specifically labelled for the control of fungus gnats in greenhouse vegetable crops. Fungus gnat larvae may be suppressed by predatory nematodes (*Heterorhabditis* spp., *Steinernema feltiae*) or a predatory mite (*Hypoaspis miles*), but predators alone do not provide commercially acceptable control in greenhouse lettuce.

*Resistant Cultivars:* None available.

***Issues for fungus gnats***

1. Lack of effective control products is a problem since cultural and alternative controls are only partially effective. There is a need for the registration of new control products. This has been identified as a high priority by the industry
2. The use of predatory spiders for the control of this pest needs to be examined.

### Greenhouse Whitefly (*Trialeurodes vaporariorum*), Silverleaf whitefly (*Bemisia argentifolii*) and sweet potato whitefly (*Bemisia tabaci*).

***Pest Information***

*Damage:* Adults suck sap from the plant, thereby reducing plant vigour and excrete honeydew. The honeydew provides a food source for secondary fungi, and feeding injury also provides an entry point for secondary fungal moulds. The greenhouse whitefly occurs across Canada. The silverleaf whitefly has been reported in Ontario and the sweet potato whitefly has been reported in British Columbia. The sweet potato whitefly is more damaging to greenhouse crops than the other two species and transmits some plant viruses.

*Life Cycle:* The adult whitefly lays eggs on the underside of leaves. Eggs hatch within 10-14 days and the nymphs go through three moults in about 14 days. They then pupate and the adult emerges about 6 days later. Adults live for 30-40 days and can lay eggs as early as 4 days after emergence.

***Pest Management***

*Chemical Controls:* Malathion is registered for the control of whiteflies in greenhouse lettuce. Insecticidal soap is also registered for whitefly control but has low residual activity and can damage lettuce leaves at higher temperatures.

*Cultural Controls:* The entry of adult whiteflies can be minimized by screening off vents and keeping doorways and other openings to the greenhouse closed. Yellow sticky traps, distributed at a rate of 1-2 traps per 2-5 plants, can be used to monitor for whiteflies and may also be used to reduce the adult population.

*Alternative Controls:* A parasitic wasp, *Encarsia formosa* is often released as a biocontrol agent. *Eretmocerus* spp. and the minute pirate bug, *Orius* sp., are also used. These will suppress the greenhouse whitefly but may be less effective on the sweet potato whitefly. The eggs of greenhouse whitefly are also preyed upon by a ladybeetle, *Delphastus pusillus*, and many general predators, such as lacewing larvae and predatory bugs.

*Resistant Cultivars:* None available.

***Issues for whitefly***

1. Since alternative controls provide suppression only, registration of new, reduced-risk insecticides is needed.

## *Minor Insects and Mites*

### Shore flies (*Ephydridae*)

***Pest Information***

*Damage:* Although shore flies do not feed directly on lettuce, they are widespread and can be a nuisance to workers and may contaminate lettuce at harvest. Shore flies can also spread fungal diseases.

*Life Cycle:* The life cycle is similar to that of fungus gnats, above, although shore flies prefer wetter environments. The larvae feed on algae.

***Pest Management***

*Chemical Controls:* None. Insecticides applied for fungus gnats will generally control shore flies also.

*Cultural Controls:* The entry of adult shore flies can be minimized by screening off vents and keeping doorways and other openings to the greenhouse closed. Minimizing open standing water and algal growth will also reduce shore fly numbers.

*Alternative Controls:* None available.

*Resistant Cultivars:* None available.

***Issues for shore flies***

1. Products for the control of shoreflies are required.
2. The use of predatory spiders for the control of this pest need to be examined.

## Thrips: Onion thrips (*Thrips tabaci*); Western flower thrips (*Frankliniella occidentalis, Echinothrips americanus*)

***Pest Information***

*Damage:* Thrips are rasping feeders. Feeding on leaves causes white, bleached to brown flecks or streaks on leaves. Thrips may also feed in growing buds causing distorted leaves and buds. Plant growth may be reduced by severe infestations. The seriousness of damage to greenhouse lettuce across Canada is uncertain.

*Life Cycle:* Thrips lay eggs inside leaf and bud tissue. Pupation occurs in soil or potting media. Outdoors, thrips often move on wind currents, but inside greenhouses they can spread rapidly by flying.

***Pest Management***

*Chemical Controls:* Malathion and nicotine are registered for control of thrips on greenhouse lettuce. If needed, spot sprays of malathion are generally used to eliminate early hot spots.

*Cultural Controls:* Vents are screened and doorways kept closed, to minimize entry of thrips. A 3-metre-wide weed-free zone, around the perimeter of the greenhouse, is maintained to reduce the risk of thrips entry.

*Alternative Controls:* Several biological predators will help to control thrips, if released early, before populations build up. These include the predatory mites *Amblyseius cucumeris*, other *Amblyseius spp.* and *Hypoaspis miles* and predatory bugs, such as the minute pirate bug, *Orius* sp. or other species such as *Deraeocoris brevis*.

*Resistant Cultivars:* None available.

***Issues for thrips***

1. There is concern of the lack of effective control products; control with malathion is poor, and biologicals provide population suppression only.

## Two-spotted spider mite *(Tetranychus urticae)*

### *Pest Information*

*Damage:* Outbreaks of the two-spotted spider mite can result in moderate to severe losses and under some circumstances can result in total loss of a crop. Symptoms of mite feeding on the plant include small, yellow or white, speckled lesions and if severe, leaf death and yield reduction occurs. Fine webbing may be present on the underside of the leaf and a silver sheen on damaged surfaces may also occur.

*Life Cycle:* The two-spotted spider mite occurs across southern Canada and has a broad host range. Adult females lay approximately 100 eggs on the lower leaf surface (5-8 eggs per day). The life cycle may be completed in as little as 3.5 days at 32ºC, but typically takes two weeks to complete. The two-spotted spider mite spreads by hanging from the plant by silken strands, which easily attach to people and equipment. The female overwinters in dark crevices in the greenhouse.

### *Pest Management*

*Chemical Controls:* Malathion is registered for spider mite control in greenhouse vegetables. Insecticidal soap is also registered for mite control but has low residual activity and can damage lettuce leaves at higher temperatures.

*Cultural Controls:* Spider mite infestations are monitored by examination of the leaves. Sanitation is very important to control this pest. A three metre wide weed-free zone is maintained around the perimeter of the greenhouse to reduce the risk of mite invasion. Movement of workers, equipment and plants from infested to non-infested areas is restricted. If the mite becomes a problem at the end of the growing season, the infested crop may be treated with a miticide, then removed and destroyed.

*Alternative Controls:* The predatory mite *Phytoseiulus persimilis* is widely used across Canada and is effective in suppressing two-spotted spider mite. To be successful, *P. persimilis* must be introduced when the two-spotted spider mite population is low. Other predatory mite species and predatory beetles may be used also.

*Resistant Cultivars:* None available.

### *Issues for two-spotted spider mite*

1. The two-spotted spider mite has developed resistance to many miticides in other crops.
2. There is a lack of effective control products for mites.

## Slugs and snails

### *Pest Information*

*Damage:* Slugs and snails feed on leaf and stem tissue of a wide range of plants and leave a silvery slime trail. On leaves, tissue is generally removed between the veins and leaf skeletonization can be extensive. Slugs and snails are rarely a pest of greenhouse lettuce.

*Life Cycle:* Slug eggs, immatures and adults can be spread through contaminated material, soil and debris and can enter the greenhouse through unsealed cracks and doorways. .

### *Pest Management*

*Chemical Controls:* Slug baits of ferric phosphate (low toxicity) or metaldehyde can be used.

*Cultural Controls:* Trapping with boards and baits can be effective near entry-ways. Keeping the greenhouse sealed and doorways closed and practicing good sanitation will help minimize problems due to slugs and snails.
*Alternative Controls:* None available.
*Resistant Cultivars:* None available.

***Issues for slugs and snails***

1. None identified.

**Table 6. Insect and mite control products, classification and performance for Canadian greenhouse lettuce production**

| Regulatory status as of May 12, 2006 | | | | | Stakeholders comments[6] | |
|---|---|---|---|---|---|---|
| **Control active ingredient / organism (product)[1]** | **Classification[2]** | **Mode of action – resistance group[2]** | **PMRA status of active ingredient[3]** | **Pests or group of pests targeted[4]** | **Performance of product according to recommended use[5]** | **Notes** |
| **endosulfan (Thiodan 4EC)** | cyclodiene organochlorine insecticide | 2A | RE | Aphids (green peach) | A[P] | Used as a spot spray only. |
| **malathion (Malathion 25W, Malathion 50EC, Fyfanon 50%EC)** | organophosphate insecticide | 1B | RE | Aphids | A[P] | Max. 2 applications/crop; PHI 14 days for leaf lettuce. |
| | | | | Whitefiles | A[P] | |
| | | | | Thrips | A[P] | |
| | | | | Spider mites | A[P] | |
| ***Bacillus thuringiensis* subsp. *israelensis* (Vectobac 600L)** | *B.t.* subsp. *Israelensis* | 11A1 | RE | Fungus gnats | A[P] | |
| ***Bacillus thuringiensis* var. *kurstaki* (Foray 48BA; BioProtec)** | *B.t.* subsp. *Kurstaki* | 11B2 | RR/RE | Cabbage loopers | A[P] | Used in summer when looper numbers peak. |
| **nicotine (Plant-Fume Nicotine)** | Nicotine insecticide | 4B | R | Aphids | A[P] | Fumigant. |
| | | | | Thrips | A[P] | Fumigant. |
| **tebufenozide (Confirm 240F)** | diacylhydrazine | 18A | RR | Cabbage loopers | A[P] | Used only in summer when looper numbers peak. PHI 14 days. Risk of resistance |

| Regulatory status as of May 12, 2006 | | | | | Stakeholders comments[6] | |
|---|---|---|---|---|---|---|
| **Control active ingredient / organism (product)[1]** | **Classification[2]** | **Mode of action – resistance group[2]** | **PMRA status of active ingredient[3]** | **Pests or group of pests targeted[4]** | **Performance of product according to recommended use[5]** | **Notes** |
| **imidacloprid (Intercept 60WP)** | neonicotinoid insecticide | 4A | temp. registration in BC until Dec.31, 2006 | Aphids | $A^P$ | Emergency registration only in BC until Dec. 31/06. PHI 21 days. Only one drench application allowed to seedling plug trays before transplanting |
| **potassium salt of fatty acid (Insecticidal Soap)** | Organic insecticide | | RR | Aphids, Whiteflies, Spider Mites | | Low residual activity and can damage lettuce leaves at higher temperatures. |
| **Metaldehyde (Slug-EM)** | molluscicide | | R | Slugs | $A^P$ | Bait |
| **ferric phosphate** | inorganic molluscicide | | RR | Slugs | $A^P$ | Low toxic bait |

[1] Common trade name(s), if provided in brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.

[2]The classification and the mode of action group are based on the classification presented in the Pest Management Regulatory Agency Regulatory Directive DIR99-06, Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action. The document is under revision and up-to-date information can be found on the following web sites: herbicides:http://www.plantprotection.org/HRAC/Bindex.cfm?doc=moa2002.htm ; insecticides:http://www.irac-online.org/documents/moa/MoAv5_1.pdf ; fungicides:http://www.frac.info/frac/index.htm

[3] R-full registration (non-reduced risk), RE-under re-evaluation (yellow), DI (red) -discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA, BI-biological, RR-reduced risk (green), OP-organophosphate replacement, NR-not registered. Not all end-use products will be classed as reduced-risk. Not all end use products containing this active ingredient may be registered for use on this crop. Individual product labels should be consulted for up to date accurate information concerning specific registration details. The information in these tables should not be relied upon for pesticide application decisions. Consult individual product labels for specific registration details. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp

[4] Please consult the product label on the PMRA web site (http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp) for specific listing of pests controlled by each active ingredient.

[5] A – Adequate (green) (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), Ap – Provisionally Adequate (yellow) (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (red) (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control).

[6]Source(s): Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec; BC Ministry of Agriculture, Food & Fisheries; AgraPoint International Inc.; Ontario Ministry of Agriculture and Food

**Table 7.Adoption of insect and mite pest management approaches for Canadian greenhouse lettuce production**

| | Practice \ Pest | aphids | cabbage looper | fungus gnats | whiteflies |
|---|---|---|---|---|---|
| **Prevention** | residue removal / management | | | | |
| | water management | | | | |
| | equipment sanitation | | | | |
| | Exclusion | | | | |
| | removal of alternative hosts (weeds/volunteers) | | | | |
| **Avoidance** | resistant varieties | | | | |
| | planting / harvest date adjustment | | | | |
| | crop rotation | | | | |
| | perimeter spraying | | | | |
| | use of pest-free transplants | | | | |
| | reducing mechanical damage / insect damage | | | | |
| **Monitoring** | scouting – trapping | | | | |
| | records to track pests | | | | |
| | grading out infected produce | | | | |
| **Suppression** | use of thresholds for application decisions | | | | |
| | biological pesticides | | | | |
| | Pheromones | | | | |
| | sterile mating technique | | | | |
| | beneficial organisms & habitat management | | | | |
| | pesticide rotation for resistance management | | | | |
| | covers / physical barriers | | | | |
| | controlled atmosphere storage | | | | |
| | forecasting for applications | | | | |

| |
|---|
| **no information regarding the practice is available** |
| **available/used** |
| **available/not used** |
| **not available** |
| Source(s): Information in the crop profile for individual pests |

# Weeds

A three metre wide vegetation-free zone should be maintained around the outdoor perimeter of the greenhouse by the use of general, broad-spectrum herbicides such as glyphosate (Round-up).

# Vertebrate Pests

## Rodents: Field mice (voles), House mice and Norway rats

***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 or fruit 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. All of these rodents are attracted to sources of food, water and shelter for nesting, for example areas where garbage containers, cull piles, piles of sawdust, old planting media, building debris, burlap or styrofoam are left outdoors, or where bags of seed or slug bait are stored.

***Pest Management***

*Chemical Controls:* Poison bait stations containing diphacinone (highly toxic to dogs); chlorophacinone; or zinc phosphide baits can be used for field mice. These products, plus brodifacoum, bromadiolone or warfarin can be used for both house mice and rats. Scilliroside can be used for rats. Bait stations are placed in areas where rodents or their signs (droppings, chewing, burrows, or sounds) have been observed. Bait stations should be covered and secure from access by dogs and cats, birds or children.

*Cultural Controls:* Maintaining a weed-free zone around the perimeter of the greenhouse and installing tight-fitting screens over doors and windows and wire screens over basement windows and vents will reduce rodent problems in the greenhouse. Sheet-metal plates at the base of wooden doors will prevent rodents from chewing through. Cleaning up debris and cull piles around the greenhouse and storage buildings will eliminate feeding and nesting sites. Feed and seed, including slug bait should be stored in metal, rodent-proof containers. All garbage containers must have tight-fitting lids.

*Alternative Controls*: Various trapping methods exist but are not consistently effective.

*Resistant Cultivars:* None available.

***Issues for Rodents***

1. None identified.

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Greenhouse, Sod and Nursery Industries, 2003. Statistics Canada, Agriculture Division, April 2004. Cat. No. 22-202-X1B; ISSN 1481-9872.

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Pesticides Homologués dans les Cultures de Serres en 2004. Bulletin d'Information No. 19, March 2004. Réseau d'Avertissements Phytosanitaires. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Quebec.

## IPM / ICM resources for production of greenhouse lettuce in Canada

WEBSITES

British Columbia Ministry of Agriculture, Food, and Fisheries. http://www.gov.bc.ca/agf

InfoBasket. British Columbia Ministry of Agriculture, Food and Fisheries. http://infobasket.gov.bc.ca/

BC Greenhouse Growers' Association. http://www.bcgreenhouse.ca/

Ontario Ministry of Agriculture and Food. http://www.gov.on.ca/omafra/english/crops/hort/greenhouse.html

Ontario Greenhouse Vegetable Growers. www.ontariogreenhouse.com

Centre de Référence en Agriculture et Agroalimentaire du Quebec (CRAAQ). Agri-Réseau. http://www.agrireseau.qc.ca/

Quebec Centre d'information et développement expérimental en serriculture. http://www.cides.qc.ca

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Quebec (MAPAQ) http://www.mapaq.gouv.qc.ca

Alberta Greenhouse Grower's Association. http://www.agga.ca

Alberta. Red Hat Cooperative. http://www.rehatco-op.com

Alberta Ministry of Agiculture and Food. http://www.agric.gov.ab.ca/index.html

Canadian Horticulture Council. http://www.hortcouncil.ca/chcmain.htm

Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON. http://res2.agr.ca/harrow/index_e.htm

**Table 8**. **Research contacts related to pest management in Canadian greenhouse lettuce production**

| Name | Organization | Pest type | Specific pests | Type of research |
|---|---|---|---|---|
| **Gillian Ferguson** | Ontario Ministry of Agriculture and Food, Harrow, ON | all | | extension and applied research on pests and diseases of greenhouse vegetables |
| **Shalin Khosla** | Ontario Ministry of Agriculture and Food, Harrow, ON | | | greenhouse crop management |
| **Amandeep Bal (Mary-Margaret Gaye, director)** | BC Greenhouse Growers' Association, Surrey, BC | all | | research coordinator for the BC greenhouse vegetable industry |
| **Jennifer Curtis** | BC Ministry of Agriculture, Food and Fisheries, Abbotsford, BC | all | | greenhouse vegetable industry specialist, extension and industry development |
| **Dr. Bob Costello** | BC Ministry of Agriculture, Food and Fisheries, Abbotsford, BC | insects | | diagnosis and extension in pest management: all greenhouse crops |
| **Dr. Siva Sabaratnum** | BC Ministry of Agriculture, Food and Fisheries, Abbotsford, BC | diseases | | diagnosis and extension in disease management: all greenhouse crops |
| **Liette Lambert** | Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, St. Rémi, Quebec | all | | greenhouse vegetable industry specialist, extension and industry development |
| **Dr. M. Andre Gosselin** | Centre de recherche en horticulture de l'Université Laval | all | | crop and pest management: all greenhouse vegetables |
| **Michel Cournoyer (Claude Laniel, director)** | Centre d'information et développement expérimental en serriculture (CIDES) | insects and mites | | applied research and advisory services: all greenhouuse vegetable crops |
| **Dr. Zamir Punja** | Simon Fraser University, BC | diseases | all | plant pathology: all greenhouse vegetable crops |
| **Dr. Raj Utkhede** | Agriculture and Agri-Food Canada, Agassiz, BC | diseases | all | plant pathology: all greenhouse vegetable crops |
| **Dr. David Gillespie** | Agriculture and Agri-Food Canada, Agassiz, BC | insect and mite | all | entomology and biological control for pests of greenhouse vegetables |
| **Dr. David Ehret** | Agriculture and Agri-Food Canada, Agassiz, BC | | | greenhouse crop management |

| | | | | |
|---|---|---|---|---|
| **Dr. Tom Papadopoulos**<br>**Dr. Xiuming Hao** | Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON | | | greenhouse crop management |
| **Dr. Les Shipp**<br>**Dr. David Hunt** | Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON | insects and mites | | entomology, biological control, insect pest management: all greenhouse crops |
| **Dr. Ray Cerkauskas**<br>**Dr. Mike Tu** | Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON | diseases | | plant pathology; biological control, disease management: all greenhouse crops |
| **Dr. Martine Dorais** | Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON | plant physiology | | greenhouse crop production |
| **Dr. Albert Liptay** | Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON | | | greenhouse vegetable transplant production |
| **Dr. Ron Pitblado, director** | University of Guelph, Ridgetown College, ON | all | | applied research on insect and disease pests of greenhouse vegetables and greenhouse transplant production |