# Crop Profile for Greenhouse Cucumber in Canada, 2023


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Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Canada

Sixth Edition – 2024
*Crop Profile for Greenhouse Cucumber in Canada, 2023*
Catalogue No.: A118-10/15-2023E-PDF
ISBN: 978-0-660-71635-0
AAFC No.: 13214E

Fifth Edition – 2021
*Crop Profile for Greenhouse Cucumber in Canada, 2020*
Catalogue No.: A118-10/15-2020E-PDF
ISBN: 978-0-660-37570-0
AAFC No.: 13067E

Fourth Edition – 2020
*Crop Profile for Greenhouse Cucumber in Canada, 2017*
Catalogue No.: A118-10/15-2017E-PDF
ISBN: 978-0-660-34287-0
AAFC No.: 13017E

Third Edition – 2016
*Crop Profile for Greenhouse Cucumber in Canada, 2014*
Catalogue No.: A118-10/15-2014E-PDF
ISBN: 978-0-660-05462-9
AAFC No.: 12502E

Second Edition – 2013
*Crop Profile for Greenhouse Cucumber in Canada, 2011*
Catalogue No.: A118-10/15-2013E-PDF
ISBN: 978-1-100-22323-0
AAFC No.: 12042E

First Edition – 2006
*Crop Profile for Greenhouse Cucumber in Canada*
Catalogue No.: A118-10/15-2006E-PDF



Electronic version available at publications.gc.ca
Paru également en français sous le titre: « *Profil de la culture du concombre de serre au Canada, 2023* »
For more information reach us at agriculture.canada.ca or call us toll-free 1-855-773-0241.

# 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 cucumber production, the reporting provinces are British Columbia, Alberta and Ontario.

Information on pest issues and management practices is provided for information purposes only. For detailed information on growing greenhouse cucumber, 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 cucumber, 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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# Crop Profile for Greenhouse Cucumber in Canada

The cucumber plant (*Cucumis sativus* var. sativus) is believed to have originated in India. Cucumbers were consumed in Western Asia, Greece and ancient Egypt as many as 3000 years ago. It is known that cucumbers were imported to the Tigris Valley and eaten as pickles in 2030 BC. They are mentioned at least twice in the Old Testament. Cucumbers were introduced to the Americas by Christopher Columbus. The pickled cucumber was of great importance to early North American pioneers as it was the only zesty green vegetable available for many months of the year. Today, cucumbers are produced both in the field and greenhouse. This crop profile covers greenhouse-grown cucumbers only.

In addition to the long English cucumber grown in greenhouses, there is significant production of mini- or gherkin-type cucumbers in protected environments. Mini-cucumbers have become popular with consumers as their convenient small size requires minimal preparation. All greenhouse-grown cucumbers are sold for the fresh market.

## Crop Production

### *Industry Overview*

Cucumbers are the second largest greenhouse produced crop in Canada, after tomatoes. In 2023, Canada produced 289,465 metric tonnes of greenhouse cucumbers with a farm gate value of $869.3 million. Canadian exports of fresh or chilled greenhouse cucumbers and gherkins were $679.1 million in 2023 while Canadian imports were $80.8 million (Table 1).

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

| | **Greenhouse Cucumber** |
|---|---|
| **Canadian Production[1]** | 289,465 metric tonnes |
| | 575.9 hectares |
| **Farm Gate Value[1]** | $801.8 Million |
| **Availability[2]** | 2.16 kg/person |
| **Export[3]** | $679.1 Million |
| **Import[4]** | $80.8 Million |

[1]Source: Statistics Canada. Table 32-10-0456-01 – Production and value of greenhouse fruits and vegetables (accessed: 2024-05-10).
[2]Source: Statistics Canada. Table 32-10-0054-01 – Food available in Canada (accessed: 2024-06-26).
[3]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0707.00.10 – Cucumbers and gherkins, greenhouse, fresh or chilled (accessed: 2024-05-10).
[4]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0707.00.99.11 –

Cucumber & gherkins,certified organic,greenhouse,o/t for processing,fr/chd,nes; HS # 0707.00.99.19 – Cucumbers & gherkins,certified organic,o/t for process/greenhouse,fresh/chd,nes; HS # 0707.00.99.80 – Cucumbers & gherkins, greenhouse,o/t for process/certified organic,fresh/chd,nes; HS # 0707.00.99.90 – Cucumbers & gherkins,o/t for process/certified organic/greenhouse,fresh/chd,nes (accessed: 2024-05-10).

## *Production Regions*

In 2023, Ontario continued as the largest producer of greenhouse cucumbers in Canada with 74 percent of harvested area totaling approximately 425.5 hectares. British Columbia and Alberta produced 64.0 hectares (11 percent of national production) and 35.4 hectares (6 percent of national production) respectively (Table 2).

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

| Production Regions | Harvested Area (national percentage) | Marketed Production (national percentage) | Farm Gate Value (national percentage) |
|---|---|---|---|
| **British Columbia** | 64.0 hectares (11%) | 27,972 metric tonnes (10%) | $69.9 Million (9%) |
| **Alberta** | 35.4 hectares (6%) | 21,701 metric tonnes (7%) | $64.2 Million (8%) |
| **Ontario** | 425.5 hectares (74%) | 215,963 metric tonnes (75%) | $556.6 Million (71%) |
| **Canada** | **575.9 hectares** | **289,465 metric tonnes** | **$801.8 Million** |

[1]Statistics Canada. Table 32-10-0456-01 – Production and value of greenhouse fruits and vegetables (accessed: 2024-05-10).

## *Cultural Practices*

Greenhouse cucumbers are grown hydroponically, generally in Rockwool blocks placed on slabs containing Rockwool, coir (coconut fibre) or sawdust (BC only). Seeds are sown directly into the blocks or into flats containing vermiculite and then transplanted into the blocks after emergence in propagation houses. Many growers purchase three week old seedlings from commercial propagators to reduce time to harvest. Planting density depends on growing method, variety and harvesting method. Generally, a plant density of 1.5 to 2.4 plants/$m^2$ with two stems per plant is used for hand-harvested long English cucumbers grown on trellises (the common low wire system). The winter crop with supplemental lighting is usually planted at a lower density of 1.1 to 1.5 plants/$m^2$ (2 to 3 stems/$m^2$). When three to five leaves have developed, the seedlings are transplanted into final growing bags (slabs), soaked with nutrient solution and strung-up. The plant is trained along horizontal wires to the next plant or up to the wire with lateral shoots trained in an umbrella fashion. The high wire system has become popular in newly constructed high gutter greenhouses. In this system a single stem or two stems per plant are trained along the strings with all side shoots pruned off. Plants are generally grown in paired rows with a walkway between each pair. Heating pipes are located in the walkway or within the rows. Plant spacing varies depending on the production system.

Throughout the growing season, growing points and older leaves are pruned off to allow lateral stems to grow downward and along the wires. This allows for good light penetration that ensures

optimum fruit development and colour. In high wire production systems, all side shoots are removed and fruit develops on a single stem. Cucumber fruit is also pruned to ensure a proper balance between foliage and fruit load. Fruit load varies with time of planting (winter, spring, fall or late fall). Pruning programs vary depending on the growing and training system used. Growing conditions (e.g., the number of irrigation cycles, pH of the nutrient solution, $CO_2$ levels, media and greenhouse temperature, light intensity, aeration of re-circulating nutrient solution) are optimized to ensure strong growth and plant vigour, which aids in improved plant health. Drip fertigation supplies nutrients and water to plants. Computer control systems continually monitor and regulate temperature, light, humidity, irrigation and nutrient solutions in the greenhouse. The electrical conductivity (EC) and pH of nutrient solutions are monitored continually during the crop growth cycles and nutrient levels are adjusted accordingly. Silicon, in the form of silicate, may also be micro-dosed to improve the cell wall of the cucumber which can reduce the incidence of powdery mildew.

A cucumber plant can produce mature fruit 14 to 21 days after transplanting and will continue to produce fruit for approximately 60 to 150 days. Cucumbers are parthenocarpic, as they do not require pollination for fruit set. Pollination from field cucumbers can cause the fruit to become bitter. The time from flowering to harvest is about 10 to 14 days. At harvest, the fruit stalk is cut cleanly to promote rapid healing of the wound and to minimize disease development. Fruit is harvested daily or every other day depending on production and the time of year. Fruit is stored at 13 °C, in an area free from drafts and sources of ethylene, which can cause the fruit to yellow. The fruit is shrink-wrapped, often on-site, to avoid desiccation.

At least a dozen varieties of long English cucumber are grown across Canada. Varieties which are powdery mildew tolerant have been available for a few years, but these generally produce a lower yield. As a result, growers often grow standard varieties early in the year then switch to powdery mildew tolerant varieties later in the season when light conditions are more favourable for these cultivars. However, some growers use powdery mildew tolerant varieties year-round due to powdery mildew disease pressure and the greater tolerance of these varieties to low light levels during the winter months.

Typically, three crops per year are grown to maintain quality. However, a few large growers are using a four-crop system to produce a crop 50-weeks per year, and alternatively, some growers are switching to two-crop systems. Better root health management technologies are being used to maintain plant vigor and fruit quality. For example, rootstocks like Flexifort, are grafted onto the desired scion (the fruit-producing shoot) to develop a stronger, more vigorous root system. Not only does this reduce the incidence of root borne diseases, it can also help improve the quality and yield of the cucumbers.

Mini-cucumbers or gherkins make up a small portion of the total crop, however production of these are expanding in British Columbia, Alberta, and Ontario.

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

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

| Time of Year | Activity | Action |
|---|---|---|
| Seeding | Greenhouse and Media Care | Preparation of the propagation house to ensure it is clean and free of pests and crop debris; Setting of appropriate temperature for seed germination. |
| | Handling Seedlings from Propagators | Unpack seedlings as soon as possible after arrival; Isolate in an area to check for insects and diseases; Check pH and EC of the grow blocks. |
| | Disease Management | Sowing of fungicide-treated seed; Maintenance of appropriate temperature and moisture levels to promote germination and to prevent disease development. |
| | Insect Management | Monitoring and control of fungus gnats. |
| Plant Raising | Plant Care | Maintenance of appropriate temperature and wetness of the Rockwool or coir blocks; Use of supplemental lighting as needed; Spacing and staking of plants. |
| | Disease Management | Application of seedling fungicide drenches to control damping-off; Control of fungus gnats that can spread root rot organisms with biological control agents or other methods. |
| | Insect Management | Monitoring and control of fungus gnats, thrips, whiteflies, loopers and lygus bugs, as needed; Maintaining beneficial insect populations and application of insecticides, as needed. |
| | Weed Management | Maintenance of a three metre wide vegetation-free zone around the greenhouse. |
| Production and Harvest | Plant Care | Fruit pruning, lateral pruning and training throughout the harvest period as appropriate to the time of year and variety; Monitoring of nutrient solution EC and pH; Removal of two to three lower leaves every 10 to 14 days; Maintenance of appropriate environmental controls: temperature, light intensity, $CO_2$, humidity, etc. |
| | Disease Management | Use of disease preventative approaches when harvesting: clean, sharp knives and tools disinfected periodically; Harvesting into disinfected bins and promptly storing; Monitoring for diseases and applying fungicides as needed; Maintenance of adequate greenhouse environment (temperature, humidity, light, etc.) to prevent condensation on the plants; Application of proper irrigation to avoid excessive or inadequate moisture in the slabs and to ensure adequate nutrient levels. |
| | Insect Management | Maintenance of the greenhouse to keep insect pests out: repair of cracks, use of screens, etc.; Weekly monitoring for insect and mite pests using sticky cards and plant inspection; Use of beneficial predators and parasites as appropriate and judicious application of insecticides, if necessary. |
| | Weed Management | Maintenance of a three metre wide vegetation-free zone around the greenhouse. |
| Post-Harvest | Fruit Care | Storage and shipping at appropriate temperature (13 °C), away from drafts or sources of ethylene; Shrink-wrapping fruit to reduce moisture loss. |
| | Greenhouse Care | Thorough cleaning between crops; Removal and proper disposal of plant debris; Disinfection of greenhouse at the end of the year. |

# *Abiotic Factors Limiting Production*

## Temperature

Greenhouse cucumbers are highly sensitive to temperature extremes and sudden changes in temperature. Temperature affects the rate of plant development, fruit length, colour and the balance between vegetative growth and fruit development. Low temperatures may harm greenhouse cucumber fruit on the vine or in post-harvest storage. The optimum temperature for seed germination is 26 to 28 °C and temperature is maintained at an average of 21 °C in the production house for an optimum balance between vegetative and fruit growth. Day temperatures are manipulated by venting. Lowering the day or night temperature too quickly or below the recommended minimum can result in chilling injury. Symptoms are more severe on certain cultivars and under low light conditions. Preventing cold drafts and avoiding the use of cold water when spraying the plants with pesticides lessens the risk of chilling injury.

## Other Environmental Factors

Humidity is closely monitored and controlled for greenhouse cucumber crops. Humidity that is too high or that fluctuates significantly will favour the development of diseases such as powdery mildew and gummy stem blight. Sudden changes in temperature that could lead to condensation on the leaves favour the development of diseases including botrytis gray mold, downy mildew, gummy stem blight, *Fusarium* diseases and others.

The levels of $CO_2$ are also monitored and modified according to the cultivar and stage of plant development. Temperature, humidity and $CO_2$ levels are adjusted for light conditions. Low light intensity or fluctuations in light intensity can cause curled or pale fruit.

## Media and Nutrient Solution Quality

Nutrients and water are provided to greenhouse cucumber plants through a recirculating (hydroponic) water system with drippers delivering the nutrient solution to each plant. The salt concentration or electrical conductivity (EC) and the pH of the nutrient solution are tested frequently. The concentration of fertilizer and amount of water applied varies depending on the time of year, the size of the plant and the environmental conditions in the greenhouse.

Cucumbers are susceptible to drought stress and up to 30 irrigation cycles may be applied per day in hot sunny conditions. However, over-saturation of the media and subsequent lack of oxygen in the root zone favours the development of Pythium root rot. During fruiting, a higher EC solution may be applied to increase fruit quality and shelf life. Calcium deficiency is the most common nutritional problem and results in light green or yellowish areas on mid-section leaves. Calcium deficiency can occur in the younger rapid plant growth stage. When this occurs, upper leaves become rounded and cupped downward and may have yellow to brown edges. Excesses of major or minor nutrients can result in toxicity symptoms on the plants.

## Premature Fruit Yellowing

Premature fruit yellowing or light-coloured fruit is associated with low nitrogen (low EC), high temperatures, over-maturity, low light levels and high humidity. The following measures may reduce fruit yellowing: increasing the amount of light reaching the fruit, reducing the number of fruits per plant and increasing the concentration of fertilizer in the nutrient solution.

## Root Death

Stresses such as temperature extremes, high EC levels, poor oxygenation of the nutrient solution or too heavy a fruit load can cause sudden root death. Plants wilt abruptly and die within five to eight hours. Once sudden root death occurs, it is irreversible.

## Other Physiological Disorders

Soft neck, which occurs when the stem shrivels and loses water just after harvest, is associated with low relative humidity, the harvesting of immature fruit and a large fruit load.

Black discoloured fruit is associated with lack of plant vigour, water (drought) stress, high EC and sudden cloudy / sunny transitional weather.

Aborted fruit is associated with high fruit load, low light levels, a poor root system and high temperatures during periods of low light. This can also be caused by feeding activity from thrips and diseases such as gummy stem blight.

Fruit curling is associated with fluctuations in light intensity and moisture, mechanical injury, chilling injury and other factors such as thrips feeding injury.

## Diseases

### Key Issues

- The registration of new classes of conventional and non-conventional fungicides, including biofungicides, are needed for the management of a variety of diseases in greenhouse cucumber and for resistance management. It is important that new pest control products have short pre-harvest intervals and short re-entry times to facilitate frequent plant care activities and harvesting of the crop.

- The development of resistant cultivars or root grafting stock is required for the management of a number of diseases of greenhouse cucumber.

- Diseases such as black rot, Fusarium rot and wilts, and Pythium root rots cause severe problems in organic production systems. There is a need for the development of cultural approaches, biopesticides and other conventional control products.

- There is a need for the development of new greenhouse cucumber cultivars resistant to powdery mildew, cucumber green mottle virus and melon necrotic diseases.

- Ontario and Alberta have reported the first cases of melon necrotic spot virus in commercial greenhouse cucumber production facilities. Information on how the virus is transmitted and managed is needed.

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

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

| Disease | British Columbia | Alberta | Ontario |
|---|---|---|---|
| Crazy roots / root mat disorder | | | |
| Damping-off | | | |
| Downy mildew | | | |
| Fusarium wilt | | | |
| Gray mold | | | |
| Gummy stem blight | | | |
| Powdery mildew | | | |
| Pythium fruit rot and root rot | | | |
| White mold / sclerotinia rot | | | |
| Cucumber green mottle mosaic virus | | | |
| Cucumber mosaic virus | | | |
| Melon necrotic spot virus | | | |
| Pseudoyellows | | | |
| 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 cucumber stakeholders in reporting provinces (British Columbia, Alberta, Ontario); 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 cucumber production in Canada[1]**

| Practices | Gray mold | Downy mildew | Fusarium wilt | Gummy stem blight | Powdery mildew | Pythium crown and root rot |
|---|---|---|---|---|---|---|
| **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 cucumber production in Canada[1] (continued)**

| Practices | Gray mold | Downy mildew | Fusarium wilt | Gummy stem blight | Powdery mildew | Pythium crown and root rot |
|---|---|---|---|---|---|---|
| **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 | | | | | | |
| **Crop-specific practices:** | | | | | | |
| Management of greenhouse environment to prevent condensation on foliage | | | | | | |
| Use of vertical fans for air movement | | | | | | |
| Use of vapour pressure deficit (VPD) for climate control | | | | | | |
| 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 cucumber stakeholders in reporting provinces (British Columbia, Alberta, Ontario); the data reflects the 2021, 2022 and 2023 production years.

## Crazy Roots / Root Mat Disorder (*Rhizobium rhizogenes* and *R. radiobacter*)

### *Pest Information*

*Damage:* Crazy roots affect both greenhouse tomatoes and cucumbers. The disease causes excessive root growth throughout Rockwool growing media. In greenhouse production, roots invade the growing substrate and can block the drip irrigation system. Affected plants develop more vegetative growth and set fewer fruits. Crazy roots result in reduced yields and the production of lower quality fruit. While *Rhizobium rhizogenes* causes above ground damage, *R. radiobacter* causes below ground damage. However, infection by both species results in excessive root growth.

*Life Cycle:* Although the primary source of the bacterium has not been established, it can survive in soil, growing media, recirculating nutrient solutions and on greenhouse surfaces.

### *Pest Management*

*Cultural Controls:* Following strict sanitation practices in the greenhouse, including the disinfection of tools, drip irrigation systems and gutters, will help reduce the spread of crazy root. Disinfecting the nutrient solution and avoiding contact between roots and drip irrigation outlets will also minimize spread. Thorough cleaning and disinfecting of the greenhouse structure between crops and the use of new growing media will help reduce the likelihood of disease carryover into the next crop.

*Resistant Cultivars:* None available.

### *Issues for Crazy Roots / Root Mat Disorder*

None identified.

## Damping-off (*Pythium* spp., *Fusarium* spp. and other fungi)

### *Pest Information*

*Damage:* Seedlings are susceptible to damping-off before or after emergence. Symptoms of infection include pale-brown and water-soaked stem tissue which usually collapses and causes the seedling to wilt and fall over.

*Life Cycle:* Damping-off pathogens are common in various non-sterilized growing media. Optimum temperatures vary for different species of *Pythium* and other fungi associated with damping-off. Infection is favoured by high moisture in the growing medium. The pathogens can be spread in irrigation water. Fungus gnats spread *Pythium* sporangia (spore producing structures) and their feeding wounds on roots create entry points for damping-off organisms.

### *Pest Management*

*Cultural Controls:* Sowing seeds in sterile propagation media and minimizing the overcrowding of seedlings will help prevent disease. Strict water regulation and avoiding seedling stress will reduce disease development. Good water management is key to minimizing *Pythium* rot problems. Avoiding well water or stream water may prevent the spread of disease as these may carry *Pythium.*

*Resistant Cultivars:* None available.

### *Issues for Damping-off*

1. While most damping-off in greenhouse cucumber is associated with *Pythium* spp., damping-off due to *Fusarium* spp. is becoming more common.

## Downy Mildew (*Pseudoperonospora cubensis*)

### *Pest Information*

*Damage:* Downy mildew is common in fall crops or where ventilation is inadequate and humidity is high. Symptoms appear as angular light green patches between the veins of leaves. Leaves may shrivel up and turn brown if severely infected. Although downy mildew usually does not directly affect the fruit, fruit may be undersized and of poor quality due to the loss of leaves.

*Life Cycle: Pseudoperonospora cubensis* is an obligate parasite that overwinters in areas without killing frosts. However, it can overwinter on living cucurbit plant material growing in greenhouses. Sporangia typically are carried into Canada from the US by wind and get into the greenhouse in the summer months. Spores may also spread by water and on clothing and tools. To germinate and cause infection, sporangia require a film of water on the leaf. After landing on a leaf, sporangia release zoospores, which can swim in the film of water and enter the plant tissue through the leaf stomata. Optimum infection occurs at temperatures ranging from 16 to 22 °C. About four to five days after infection, new spores are produced and released into the air and spread the disease to other plants.

### *Pest Management*

*Cultural Controls:* Preventing condensation on the leaves by controlling the night temperature and ensuring adequate ventilation so leaves dry quickly will result in conditions less favourable for disease development. Segregating new crops from older ones and practicing good sanitation, including the removal of old crop debris promptly from the greenhouse, will minimize disease spread. 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 registration of new conventional and non-conventional pest control products for the management of downy mildew.

## Fusarium Root and Stem Rot (*Fusarium oxysporum* f. sp. *radicis-cucumerinum*)

### *Pest Information*

*Damage:* Symptoms of Fusarium root and stem rot include wilting of the upper leaves and declining plant vigour. The stem develops tan-pink coloured streaks extending up to 30 cm from the base and stems may become girdled. Underlying tissue becomes soft and may produce a slight odour. Roots develop a brown-black necrosis, starting from the tips. Infection will cause most damage in the first four weeks after planting.

*Life Cycle:* The fungus can grow on Rockwool blocks and in sawdust bags. Infection is favoured by high moisture in the growing media. Spores are mostly spread by water and by handling. Because the spores are contained within a slimy material, they are not easily dispersed by air. Fungus gnats and shore flies may spread spores and their feeding wounds on roots can create entry points for infection. The disease can also be carried on infected seed.

### *Pest Management*

*Cultural Controls:* Good sanitation practices are important in minimizing the impact of this disease. The control of fungus gnats and shore flies and disinfection of greenhouse structures, reservoirs and irrigation lines thoroughly between crops will reduce the spread of the pathogen. Other sanitation practices including the frequent disinfection of pruning shears and harvest knives when working in infected areas, and the prompt removal and destruction of plant debris will also help reduce disease spread. Additional management practices for Fusarium root and stem rot are listed in *Table 5.*

*Resistant Cultivars:* None available.

### *Issues for Fusarium Root and Stem Rot*

1. New conventional and non-conventional pest control products, including biopesticides, suitable for use in organic systems, are required for the management of Fusarium root and stem rot.
2. The development of cultivars or root grafting stock resistant to Fusarium root and stem rot would provide a useful tool for the management of this disease.
3. There is a need for further development of climate control strategies and other cultural practices for the management of and Fusarium root and stem rot.

## Gray Mold (*Botrytis cinerea*)

### *Pest Information*

*Damage: Botrytis cinerea* may infect the stem, petiole, base of the leaf, fruit stem or flowers. The initial symptoms of gray mold are often seen on fruit peduncles at the top of the plant in summer when fluctuating day and night temperatures result in morning condensation on the plants. Other symptoms include basal stem cankers or rotted tissue and gray-green shriveled leaves. Severe infection results in the girdling of the stem or petiole and can result in death of lateral branches, fruit stems and entire plants.

*Life Cycle:* Gray spore masses are produced by the fungus under humid conditions on infected plant parts and are the main cause of new infections. Spores can become airborne and will spread quickly in the greenhouse. The fungus overwinters as black sclerotia in soil, on perennial plants and on plant debris.

### *Pest Management*

*Cultural Controls:* Preventing condensation on leaves by controlling ventilation and gradually raising temperatures prior to sunrise will make conditions less hospitable for the pathogen. As wounds provide an entry route for this disease, it is important to minimize wounding of the plants. Good sanitation between crops and when handling the plants, as well as the use of sharp, clean knives for harvesting fruit, will reduce disease. Harvesting in the morning when fruit and foliage are dry will also reduce disease development. The prompt removal of crop residue from the greenhouse will help eliminate sources of inoculum. Pruning and avoiding excessive nitrogen to maintain a proper balance between foliage and fruit load is also helpful since lush growth is more susceptible to infection and a heavy canopy will slow the drying of leaves. Additional management practices for gray mold are listed in *Table 5*.

*Resistant Cultivars:* None available.

### *Issues for Gray Mold*

1. The registration of new conventional and non-conventional fungicides, including those suitable for use in organic production systems, are needed for the control of gray mold on greenhouse cucumber. New chemistries will also reduce the development of resistance in the pathogen population.
2. There is a need for further development of climate control strategies and other cultural practices for the management of gray mold in the greenhouse.

## Gummy Stem Blight (*Stagonosporopsis* spp.)

### *Pest Information*

*Damage:* Gummy stem blight can affect stems, foliage and fruit. The first sign of gummy stem blight is an amber-red gummy exudate on the stem tissue where the fungal infection occurred. Associated lesions grow, girdle and eventually the plant tissue above the lesion dies. Infected fruit becomes shriveled at the flower end. Traces of brown rotting tissue may also occur internally in diseased fruit. This disease may cause post-harvest problems because healthy looking fruit that is infected by gummy stem blight may spoil before it reaches the market. This disease renders plants more susceptible to other diseases such as gray mold and powdery mildew, and also makes them more attractive to aphids.

*Life Cycle:* The gummy stem blight pathogen may stay dormant for up to two years as mycelium in undecomposed plant debris. It produces two types of spores, one that can be spread by splashing water (conidia) and another that can be spread by air currents (ascospores). Spores can also be spread by physical contact with workers' clothing and tools. Moisture on leaves makes the cucumber plant susceptible to infection by this fungus. Secondary spores may be produced on diseased plants in as little as four days after initial infection and these can then infect flowers and wounded tissue.

### *Pest Management*

*Cultural Controls:* The removal of all crop debris from the greenhouse at the end of each crop cycle and the placement of cull piles away and downwind of the greenhouse will help to reduce sources of infection. The cleaning and disinfection of pruning shears and other tools and equipment in contact with cucumber plants will also help to minimize spread of the disease. Other practices that help reduce disease development include preventing condensation on the plants by providing good ventilation and gradually raising temperatures prior to sunrise, harvesting fruit in the morning when it is cool and dry, and harvesting frequently to avoid over ripening of fruit. Ultraviolet (UV)-absorbing plastic films may help reduce the incidence of gummy stem blight as UV light is required for spore production. Additional management practices for gummy stem blight are listed in *Table 5*.

*Resistant Cultivars:* None available.

### *Issues for Gummy Stem Blight*

1. The registration of new conventional and non-conventional fungicides, including biofungicides, are required for the control of gummy stem blight. New chemistries will also reduce the development of resistance in the pathogen population. As cucumbers are harvested daily, it is important that newly registered materials have short re-entry intervals and short pre-harvest intervals.
2. The development of cultivars resistant to gummy stem blight is required.
3. There is a need for further development of climate control strategies and other cultural practices for the management of gummy stem blight in the greenhouse.

## Powdery Mildew (*Golovinomyces cichoracearum*)

### *Pest Information*

*Damage:* Powdery mildew causes round white patches of fungal mycelium and spores on the upper surface of older leaves. These patches enlarge and can eventually cover the entire surface of the leaf. Occasionally the disease appears on petioles and stems as well. The fungus absorbs nutrients from the leaf cells. Diseased leaves eventually dry up and die. Plants infected early, during fruit development, have a lower fruit count and produce smaller fruits.

*Life Cycle:* Powdery mildew spores can germinate under conditions of low relative humidity (20 percent); however, infection rates are higher with higher humidity levels. Spores are usually present in mid-summer when temperatures range between 20 and 26 °C. Spores may survive for as long as 10 days in the greenhouse. Secondary spores are produced in lesions five to seven days after the initial infection of the leaf surface. They spread easily with air currents in the greenhouse. The disease often appears first in corners near vents or doorways, where humidity and temperature are less well controlled. Spores may survive outdoors on cull piles and crop debris or on field cucurbit crops.

### *Pest Management*

*Cultural Controls:* Sanitation practices to reduce powdery mildew disease sources include the removal and destruction of infected leaves when the disease is first seen, good sanitation between crops and the prompt removal and destruction of cull piles and old crop debris. Maintaining a uniform relative humidity of 70 to 80 percent will reduce disease development. Spraying the plants every two to three days with water may reduce spore buildup, but may also predispose plants to other diseases such as gummy stem blight and gray mold. Additional management practices for powdery mildew are listed in *Table 5*.

*Resistant Cultivars:* Powdery mildew tolerant cultivars are available but do not yield as well as standard cultivars. As such, they are generally planted for late spring or early summer crops when conditions are most favourable for disease development.

### *Issues for Powdery Mildew*

1. The registration of new conventional and non-conventional fungicides, including biofungicides, are required for the management of powdery mildew and to facilitate fungicide rotation to minimize the risk of resistance development.
2. There is a need for the development of powdery mildew resistant or tolerant cultivars that provide good yield.
3. There is a need for further development of cultural and environmental controls for powdery mildew.

## Pythium Crown Rot and Root Rot (*Pythium aphanidermatum* and other *Pythium* spp.)

### *Pest Information*

*Damage:* Pythium crown rot affects plants primarily in the spring at early fruit set or later in the season (summer crops). Infected crowns become orange-brown with a soft dry rot. When only tiny feeder roots are infected, they appear soft and water soaked and the plants wilt, although the crown may remain white and healthy. *Pythium* is a water mold and can cause severe problems in crops produced with recirculating irrigation systems. Other *Pythium* species, such as *P. irregulare* and *P. ultimum*, are also known to cause damage in greenhouse cucumber. *Pythium* outbreaks can lead to significant yield loss.

*Life Cycle: Pythium* species survive in soil, root debris, propagation mixes, plug transplants and untreated water. Sporangia spread in recirculating water and germinate to produce tiny zoospores that infect root tips or wounds on the root. Fungus gnats and shore flies can also spread *Pythium* spp., and their root feeding wounds provide points of entry for the pathogen.

### *Pest Management*

*Cultural Controls:* Disinfection of irrigation troughs, tanks and supply lines for water between crops will prevent the carryover of *Pythium* to the next crop. Reducing water and temperature stress on the plants and ensuring good aeration of recirculating water also helps to reduce *Pythium* infection. Regular monitoring for slightly wilting plants and checking cucumber stem bases for discoloration can be helpful to diagnose the disease. A strict greenhouse sanitation program during the year followed by a full year-end clean up will eliminate sources of disease in the greenhouse. Additional management practices for Pythium crown rot and root rot are listed in *Table 5.*

*Resistant Cultivars:* None identified.

### *Issues for Pythium Crown Rot and Root Rot*

1. New reduced risk products, especially those with short pre-harvest intervals and biopesticides, are required for the management of *Pythium* diseases.
2. Cultural and biological approaches are required for the management of *Pythium* in soil, particularly for use in organic production systems.

## White mold / Sclerotinia Rot (*Sclerotinia sclerotiorum*)

### *Pest Information*

*Damage:* This disease infects the stem and the fruit of cucumber through senescent tissues. Infected tissues appear water soaked and wilted. *Sclerotinia* is not common in greenhouse cucumber production under artificial media.

*Life Cycle: Sclerotinia sclerotiorum* forms hard black bodies (sclerotia) in the pith of the stem and on the surface of the fruit. Sclerotia produce apothecia which release ascospores. Ascospores can be blown by the wind from outside the greenhouse to the aerial portions of greenhouse plants.

### *Pest Management*

*Cultural Controls:* This disease can be reduced by good sanitation practices inside and outside the greenhouse. Steam sterilization will kill sclerotia in soil media used in organic greenhouse production. Preventing condensation on plants, especially at flowering, will help reduce the development of disease. Good weed control around the greenhouse will eliminate potential hosts of the pathogen. Regular elimination and destruction of plant debris from the greenhouse will eliminate a potential source of infection.

*Resistant Cultivars:* None available.

### *Issues for White mold / Sclerotinia Rot*

None identified.

## Beet Pseudoyellows Virus (BPYV, genus *Crinivirus*)

### *Pest Information*

*Damage:* Beet pseudoyellows virus (BPYV) causes yellowing and yellow spotting between the veins of older and intermediate-aged leaves. Diseased plants are less productive.

*Life Cycle:* The virus is spread by the greenhouse whitefly and can be easily transmitted through plant to plant contact.

### *Pest Management*

*Cultural Controls:* To minimise infections, the greenhouse whitefly must be controlled. See whitefly management description below.

*Resistant Cultivars:* None available.

### *Issues for Pseudoyellows Virus*

None identified.

## Cucumber Green Mottle Mosaic Virus (CGMMV, genus *Tobamovirus*)

### *Pest Information*

*Damage:* Cucumber green mottle mosaic virus (CGMMV) causes leaf mottling, blistering and deformities. Plant growth may be stunted. Symptoms vary depending on the strain of the virus. Damage from this disease can be extensive and can result in substantial yield loss.

*Life Cycle:* The virus is seed-borne and can be easily transmitted through plant to plant contact, through recirculation of nutrient solutions and by handling of plants. For greenhouse grafted cucumber plants, both the scion (the fruit-producing shoot) and the rootstock may harbor the virus.

### *Pest Management*

*Cultural Controls:* When planting a new crop, using CGMMV-free seeds and seedlings will help prevent the introduction of the virus. Close observation in the first two to three weeks after planting for the presence of the virus will allow early intervention measures to be implemented, such as removal of virus-infected seedlings, in order to restrict viral spread. Avoiding recirculation of the nutrient solution during this two to three week period is also helpful to prevent the spread of the virus. Strict sanitation between crops will prevent virus carryover to the new crop.

*Resistant Cultivars:* None available.

### *Issues for Cucumber Green Mottle Mosaic Virus*

1. Disinfection protocols and other management practices are required to help growers prevent the spread of CGMMV.
2. The development of cultivars resistant to or tolerant to CGMMV are required for the management of this disease.

## Cucumber Mosaic Virus (CMV, genus *Cucumovirus*)

### *Pest Information*

*Damage:* Plants infected at an early stage with CMV turn yellow, become stunted and may be killed by this virus. Newly infected leaves become wrinkled and mottled and show slight downward curling of the edges. Small greenish translucent lesions may also appear on young leaves. Plants that become infected at a later stage set few fruits. Cucumber fruits that do develop have a yellow-green mottle over the surface, often interspersed with dark green raised areas.

*Life Cycle:* Cucumber mosaic virus has a wide range of hosts including more than 40 angiosperm (flowering plant) families. It typically overwinters in perennial weeds. The virus is spread by aphids and in some cases by tools such as pruning knives and handling.

### *Pest Management*

*Cultural Controls:* The spread of the disease may be restricted by controlling aphid vectors within the crop and screening greenhouse vents to prevent the entry of aphids. Working first in areas of the greenhouse with healthy plants, and finishing in diseased areas, will reduce the potential of transferring the disease to healthy plants.

*Resistant Cultivars:* None available.

### *Issues for Cucumber Mosaic Virus*

1. Research to improve our understanding of the biology and epidemiology of cucumber mosaic virus is required to aid in the management of this disease. Further information is required on the potential for seed transmission, effective seed treatments, infection cycle, varietal susceptibility and environmental controls to prevent infection.

## Melon Necrotic Spot Virus (MNSV, genus *Carmovirus*)

### *Pest Information*

*Damage:* Chlorotic lesions appear on cotyledons and leaves of infected plants. Brown pinpoint lesions develop and enlarge within these lesions causing affected tissues to wilt and die. Lesions are not observed on fruit produced by affected plants.

*Life Cycle:* The virus is seed-borne, soil-borne and vector-borne. Vectors include a soil fungus (*Olipidium bornovanus*) and cucumber beetles (*Diabrotica undecimpunctata* and *D. balteata*). MNSV can also be mechanically transmitted. Symptoms develop under cool, low light conditions.

### *Pest Management*

*Cultural Controls:* The spread of MNSV can be restricted by removing and destroying infected plants, sterilizing growing media (e.g., a minimum of 10 minutes at 60 °C) and ensuring pruning tools are disinfected between uses.

*Resistant Cultivars:* None available.

### *Issues for Melon Necrotic Spot Virus*

1. Ontario and Alberta have reported the first cases of melon necrotic sport virus in commercial greenhouse cucumber production facilities. Information on how the virus is transmitted and managed is needed.

## Insects and Mites

### Key Issues

- Many greenhouse insect and mite pests are resistant to commonly used greenhouse pesticides. New conventional and non-conventional pest control products that are safe for beneficial insects are required for the control of common insect and mite pests and for resistance management.

- There is a need for the development of improved sanitation products and practices to help reduce the number of pest infections in cucumber greenhouses. Developing strategies that assist cucumber greenhouses in end of year crop clean out and improved sanitation practices to help reduce significant crop loss during the growing season are needed. Access to disinfectants used in other greenhouse cucumber productions from around the world would also be beneficial.

- Although stink bugs are not yet a pest in greenhouse cucumber, there is potential for it to become a pest, as observed in greenhouse pepper production.

- Integrated pest management (IPM) strategies need to be researched to find better ways to help manage cucumber beetle.

- Recently, broad spectrum control product registrations were revoked. There is a need for the development of end-of-crop insecticides to limit the carryover of pests to newly transplanted crops.

- The sector needs to be on alert for new invasive species.

- For provincial evaluations of insect and mite occurrence by species, see Table 6.

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

| Insect/Mite | British Columbia | Alberta | Ontario |
|---|---|---|---|
| Fungus gnats and shore flies | | | |
| Melon aphid | | | |
| Cabbage looper | | | |
| Spotted cucumber beetle | | | |
| Striped cucumber beetle | | | |
| Tarnished plant bug | | | |
| Broad mite | | | |
| Twospotted spider mite | | | |
| European f1ower thrips | | | |
| Eastern f1ower thrips | | | |
| Onion thrips | | | |
| Western f1ower thrips | | | |
| Greenhouse whitefly | | | |
| Sweet potato whitefly | | | |
| 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. | | | |
| Data not reported. | | | |

[1]Source: Greenhouse cucumber stakeholders in reporting provinces (British Columbia, Alberta, Ontario); 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 management practices for greenhouse cucumber production in Canada[1]**

| Practices | Aphid | Caterpillars (various species) | Twospotted spider mites | Whiteflies | Thrips |
|---|---|---|---|---|---|
| **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 management practices for greenhouse cucumber production in Canada[1] (continued)**

| Practices | Aphid | Caterpillars (various species) | Twospotted spider mites | Whiteflies | Thrips |
|---|---|---|---|---|---|
| **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:** | | | | | |
| 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 cucumber stakeholders in reporting provinces (British Columbia, Alberta, Ontario); 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*<br>*Aphidius colemani*<br>*Aphidius ervi*<br>*Aphidius matricariae* | Parasitic wasp |
| | *Adalia bipunctata*<br>*Hippodamia convergens* | Predatory beetle |
| | *Dicyphus hesperus*<br>*Nabis americoferus*<br>*Orius insidiosus* | Predatory bug |
| | *Eupeodes americanus* | Predatory hoverfly larva |
| | *Chrysoperla carnea*<br>*Micromus variegatus* | Predatory lacewing |
| | *Aphidoletes aphidimyza* | Predatory midge |
| | *Anystis baccarum* | Predatory mite |
| Caterpillars | *Trichogramma* spp. | Parasitic wasp |
| | *Dicyphus hesperus*<br>*Nabis americoferus* | Predatory bug |
| | *Chrysoperla carnea* | Predatory lacewing |
| Fungus gnats | *Steinernema carpocapsae*<br>*Steinernema feltiae* | Entomopathogenic nematode |
| | *Dalotia* (*Atheta*) *coriaria* | Predatory beetle |
| | *Gaeolaelaps gillespiei*<br>*Stratiolaelaps scimitus* (*Hypoaspis miles*) | Predatory mite |
| Leafminers | *Steinernema carpocapsae*<br>*Steinernema feltiae* | Entomopathogenic nematode |
| | *Dacnusa siberica*<br>*Diglyphus isaea* | Parasitic wasp |
| Mites | *Stethorus punctillum* | Predatory beetle |
| | *Dicyphus hesperus*<br>*Nabis americoferus*<br>*Orius insidiosus* | Predatory bug |
| | *Chrysoperla carnea* | Predatory lacewing |
| | *Feltiella acarisuga* | Predatory midge |
| | *Amblydromalus limonicus*<br>*Amblyseius andersoni*<br>*Amblyseius swirskii*<br>*Anystis baccarum*<br>*Iphiseius* (*Amblyseius*) *degenerans*<br>*Neoseiulus* (*Amblyseius*) *californicus*<br>*Neoseiulus* (*Amblyseius*) *cucumeris*<br>*Neoseiulus* (*Amblyseius*) *fallacis*<br>*Phytoseiulus persimilis* | Predatory mite |
| Mealybugs | *Cryptolaemus montrouzieri* | Predatory beetle |
| | *Chrysoperla carnea*<br>*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*<br>*Steinernema feltiae*<br>*Steinernema carcocapsae* | Entomopathogenic nematode |
| | *Dalotia* (*Atheta*) *coriaria* | Predatory beetle |
| | *Dicyphus hesperus*<br>*Nabis americoferus*<br>*Orius insidiosus* | Predatory bug |
| | *Chrysoperla carnea*<br>*Micromus variegatus* | Predatory lacewing |
| | *Amblydromalus limonicus*<br>*Amblyseius andersoni*<br>*Amblyseius swirskii*<br>*Anystis baccarum*<br>*Gaeolaelaps gillespiei*<br>*Iphesius* (*Amblyseius*) *degenerans*<br>*Neoseiulus* (*Amblyseius*) *cucumeris*<br>*Stratiolaelaps scimitus* (*Hypoaspis miles*) | Predatory mite |
| Whiteflies | *Encarsia formosa*<br>*Eretmocerus eremicus* | Parasitic wasp |
| | *Delphastus catalinae* | Predatory beetle |
| | *Dicyphus hesperus*<br>*Nabis americoferus*<br>*Orius insidiosus* | Predatory bug |
| | *Chrysoperla carnea*<br>*Micromus variegatus* | Predatory lacewing |
| | *Amblydomalus limonicus*<br>*Amblyseius swirskii*<br>*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

## Broad Mite (*Polyphagotarsonemus latus*)

### *Pest Information*

*Damage:* Broad mites attack a variety of greenhouse ornamentals and vegetable crops. They feed on young growing (meristematic) tissues of flower and leaf buds. While feeding, they inject toxins into the tissues that cause thickening and deformities of the new growth. Affected cucumber leaves may show downward curling and affected fruit may be misshapen or cracked.

*Life Cycle:* Broad mites lay eggs on foliage or in the growing points of plants. They develop through five developmental stages: egg, protonymph, two deutonymph stages including a quiescent stage and adult. Development from egg to adult may take less than a week in the summer but up to 18 days in the winter. The broad mite can be spread through the greenhouse by plant to plant contact, on air currents, by workers and by other insects. Female nymphs and adults may be moved to new leaves by male broad mites.

### *Pest Management*

*Cultural Controls:* Thorough cleanup and sanitation of the greenhouse at the end of a crop will eliminate the carryover of mites to the next crop. Close monitoring of crops and of new plant material brought into the greenhouse is important for early detection. Restricting the movement of people, equipment and plants from infested to non-infested plant areas is also beneficial.

*Biological Controls:* Biological control agents commercially available for the management of mites in the greenhouse are listed in *Table 8*.

*Resistant Cultivars:* None available.

### *Issues for Broad Mites*

1. There is a need for conventional and non-conventional pest control products for the control of broad mites in greenhouse cucumber crops.

## Cabbage Looper (*Trichoplusia ni*) and Other Caterpillars (order Lepidoptera)

### *Pest Information*

*Damage:* Caterpillars chew holes in leaves and fruit. Cabbage looper larvae can cause significant damage by feeding on leaf tissue. Damage to leaves reduces yield and may also provide entry sites for secondary disease organisms.

*Life Cycle:* Adult moths enter the greenhouse from outside and lay eggs on cucumber leaves near the edges or underside. Eggs hatch in three to four days and larvae develop through five instars (stages) over two to three weeks 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. The cabbage looper does not typically overwinter in Canada, it generally moves into Canada from the southern US as an adult moth in July and August. It has also been known to overwinter in greenhouses.

### *Pest Management*

*Cultural Controls:* The screening of vents, doorways and other openings to the greenhouse, especially at night, will minimize the entry of adult moths. Additional management practices for caterpillars are listed in *Table 7*.

*Biological Controls:* Biological control agents commercially available for the management of caterpillars in the greenhouse are listed in *Table 8*.

*Resistant Cultivars:* None available.

### *Issues for Cabbage Looper and Other Caterpillars*

1. There is a need for new conventional and non-conventional pest control products, including biopesticides, for the management of cabbage looper and for resistance management. Pest control products that can be applied as drench applications with low pre-harvest intervals are preferable.
2. Other Lepidopteran species are now becoming more of a problem in greenhouse cucumber production.

## Cucumber Beetles: Striped Cucumber Beetle (*Acalymma vittatum*) and Spotted Cucumber Beetle (*Diabrotica undecimpunctata howardi*)

### *Pest Information*

*Damage:* Early beetle populations are generally the most damaging; however, late-season feeding on the fruit may reduce marketable yields. Adults feed on the leaves, resulting in a "shot-hole" appearance. They also feed on stems and flowers, which reduces yield and may result in broken stems. Larvae feed on plant roots and tunnel into them, which may result in wilting. Damage is generally minimal on older, established plants. Adult cucumber beetles are vectors of bacterial wilt and cucumber mosaic virus.

*Life Cycle:* Adult beetles overwinter in weeds and crop debris and become active in early spring. They typically do not enter greenhouses until mid-summer. Outdoors, adults feed on pollen, petals and leaves of various plants and mate and lay eggs in the ground near host plants. The larvae hatch in about 10 days and feed on the roots of the plants for about one month. Larvae pupate in the soil and adults emerge after two weeks. There is typically only one generation per year.

### *Pest Management*

*Cultural Controls:* Screening vents and other openings of the greenhouse, maintaining a weed-free border around the greenhouse and eliminating crop debris will minimize beetle entry into the greenhouse.

*Biological Controls:* None available.

*Resistant Cultivars:* None available.

### *Issues for Cucumber Beetles*

1. There is a need for new conventional and non-conventional pest control products for the control of cucumber beetles in greenhouse cucumber crops.

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

### *Pest Information*

*Damage:* Adults of these species 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 causes stunting. Feeding wounds provide entry sites for fungal pathogens such as *Pythium*, *Phytophthora*, *Fusarium* and *Rhizoctonia*. Fungus gnats have been shown to transmit *Pythium* diseases.

*Life Cycle:* Mature female fungus gnats lay eggs in moist soils, potting mixes and hydroponic media. The eggs hatch in two to four days. Larvae feed for about two weeks before pupating and maturing into adults. The life cycle of shore flies is similar to that of fungus gnats.

### *Pest Management*

*Cultural Controls:* Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult insects. Other cultural controls include avoiding overwatering, removing waste plant material and practicing good sanitation. Adult flies 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:* Biological control agents commercially available for the management of fungus gnats and shore flies in the greenhouse are listed in *Table 8*.

*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 and shore flies in greenhouse cucumber crops.

## Leafhoppers

### *Pest Information*

*Damage:* Leafhoppers feed with piercing-sucking mouthparts causing circular or "v" shaped lesions on the leaf margins that are yellow in colour. Toxins are injected as the pest feeds, interfering with vascular flow.

*Life Cycle:* Leafhoppers have a broad range of hosts. The potato leafhopper (*Empoasca fabae*) does not overwinter in Canada, instead dispersing each year on wind currents from the US. The aster leafhopper (*Macrosteles quadrilineatus*) overwinters in Canada as an egg in plant tissues but may also be carried northward on wind currents from the US. Leafhoppers develop from egg through several nymphal stages to become adults.

### *Pest Management*

*Cultural Controls:* When nearby forage crops are harvested, leafhoppers may move into greenhouses. Leafhoppers can be monitored by using sticky traps inside and outside of greenhouses.

*Biological Controls:* There are no commercially available biological control agents that target leafhoppers.

*Resistant Cultivars:* None available.

### *Issues for Leafhoppers*

1. Leafhoppers are becoming an emerging pest in greenhouse cucumbers.

## Melon Aphid (*Aphis gossypii*)

### *Pest Information*

*Damage:* The melon aphid feeds on a variety of plants and vegetable crops. Heavy feeding causes leaves to wilt and collapse. Younger leaves may become dark green and stunted. Aphids secrete honeydew that supports the growth of black sooty mold, reducing fruit quality. Aphids may also transmit cucumber mosaic virus. Aphid populations can increase very quickly, especially under warm humid conditions and an unchecked infestation may result in severe yield reduction and possibly crop failure. Even in small numbers, aphids may make a crop unmarketable due to their presence.

*Life Cycle:* Melon aphids are adapted to high temperatures. Under ideal conditions, populations can increase by as much as 10- to 12-fold per week on cucumber. Adults produce on average 40 nymphs in seven days. Once a colony becomes crowded, winged adults migrate to neighboring plants. Winged adults are usually the source of primary infestations, often moving into greenhouses from the outdoors.

### *Pest Management*

*Cultural Controls:* Screening vents and maintaining a weed-free zone around the greenhouse will help to prevent aphids from entering the greenhouse. Avoiding the growing of ornamental plants and other vegetable crops in the greenhouse will also eliminate sources of aphids. Additional management practices for aphids are listed in *Table 7*.

*Biological Controls:* Biological control agents commercially available for the management of aphids in the greenhouse are listed in *Table 8*.

*Resistant Cultivars:* None available.

### *Issues for Melon Aphid*

1. There is a need for new conventional and non-conventional pest control products that are not harmful to biological control agents and permit the rotation of chemicals for resistance management.

## Tarnished Plant Bug (*Lygus lineolaris*) and Other Lygus Bugs

### *Pest Information*

*Damage:* Lygus bugs are found on a wide range of wild plants and crops including vegetables. The tarnished plant bug commonly infests greenhouse pepper and, to a lesser extent, greenhouse cucumbers. Damage to cucumbers may include destruction of the growing point of young seedlings and "ragging" of leaves, which appear crinkled and may have several perforations.

*Life Cycle:* Lygus bugs overwinter as adults in sheltered areas between leaves of plants and long dry grasses outside the greenhouse. They usually begin emerging from these sites in April and early May at temperatures as low as 8 °C and start to feed, mate and lay eggs in young plant tissue.

### *Pest Management*

*Cultural Controls:* The presence of lygus bugs on greenhouse crops occurs each spring. Weed suppression in the immediate vicinity of the greenhouse will prevent the development of large populations during the fall and will discourage overwintering in these areas. Monitoring the upper canopy of the crop is essential for early detection. Yellow sticky cards used for monitoring other pests in greenhouse crops also attract lygus bugs. Regular examination of young flowers and leaves of cucumbers also helps to detect their presence and provides an indication of the population level in the crop.

*Biological Controls:* There are no commercially available biological control agents that target lygus bugs.

*Resistant Cultivars:* None available.

### *Issues for Tarnished Plant Bug and Other Lygus Bugs*

1. There is a need for new conventional and non-conventional pest control products, including biopesticides, for the management of lygus bugs.

## Thrips: Western Flower Thrips (*Frankliniella occidentalis*), Onion Thrips (*Thrips tabaci*), Eastern Flower Thrips (*F. tritici*) and European Flower Thrips (*F. intonsa*)

### *Pest Information*

*Damage:* Damage by thrips in cucumber is first noticed on the lower leaves. Nymphs and adults feed on the leaves and fruit of the plant by piercing the surface and sucking the contents of the plant cells. This results in the formation of silvery white streaks or spots on the leaf or fruit surface. Insect frass may also be present. Excessive feeding reduces plant yield and can cause severe distortion or curling of cucumber fruit. Western flower thrips are the most important vector of tospoviruses in greenhouse crops.

*Life Cycle:* Thrips go through five developmental stages: egg, larval, pre-pupal, pupal and adult. The life cycle can be completed in about 15 days at 25 ºC. Eggs are inserted individually into leaves, stems and flowers where they hatch into nymphs. Nymphs will then feed on leaves and flowers and then move into the soil or growing medium and enter the non-feeding pre-pupal and pupal stages. Adults emerge within a week, mate and lay eggs. The adults are weak fliers, taking short flights from leaf to leaf or plant to plant. Nevertheless, they disperse rapidly throughout the greenhouse.

### *Pest Management*

*Cultural Controls:* Monitoring and trapping of adult thrips with blue or yellow sticky traps is an integral practice of greenhouse pest management. The screening of greenhouse vents and other entry points will help prevent thrips from entering the greenhouse. The elimination of weeds and ornamental plants from around the perimeter of the greenhouse and avoiding moving non-crop material into the greenhouse will eliminate insect sources. Effective sanitation can eliminate or significantly reduce thrips in the greenhouse. Maintaining an optimal relative humidity of 80 percent can slow the development of thrips populations. Heating an empty greenhouse to 35 ºC for five days or 40 ºC for two to three days will starve any emerging adults. At the end of the growing season, infested crops can be fumigated and then removed and destroyed to eliminate sources of thrips. Additional management practices for thrips are listed in *Table 7*.

*Biological Controls:* Biological control agents commercially available for the management of thrips in the greenhouse are listed in *Table 8*.

*Resistant Cultivars:* None available.

### *Issues for Thrips*

1. There is a need for new conventional and non-conventional pest control products for thrips control and for resistance management. Specifically, products that can be applied as drench or irrigation treatments are needed.
2. The sector needs to be on alert for new invasive thrips species.

## Twospotted Spider Mite (*Tetranychus urticae*)

### *Pest Information*

*Damage:* Infestations of twospotted spider mites can result in significant and sometimes total crop losses. Mites feed on the plant by puncturing the surface resulting in small yellow or white speckled feeding lesions which lead to leaf necrosis and death. Mites appear first on the underside of leaves. Fine webbing may be present and damaged leaf surfaces have a silver sheen.

*Life Cycle:* Although twospotted spider mites have a broad host range, greenhouse cucumber is a preferred host. They go through five developmental stages: egg, larva, protonymph, deutonymph and adult. The cycle may be completed in as little as three to four days at 32 ºC, but typically takes two weeks to complete when temperatures are lower. Adult females lay approximately 100 eggs on the lower leaf surface. The twospotted spider mite spreads by hanging from the plant by silken strands that easily attach to people and equipment. The female mite overwinters in dark crevices in the greenhouse and does not feed during this time.

### *Pest Management*

*Cultural Controls:* Monitoring for twospotted spider mite infestations is done by routine examination of the lower surface of the leaves. Good sanitation, including the removal of weeds, especially chickweed, from around the perimeter of the greenhouse and the maintenance of a three metre wide weed-free zone will help to minimize mite populations. Restricting the movement of people, equipment and plants from infested to non-infested plant areas is also beneficial. Mite problems at the end of the growing season are often controlled by fumigation followed by the removal and destruction of all plant material. Misting plants and raising the humidity will help suppress spider mite populations.

*Biological Controls:* Biological control agents commercially available for the management of twospotted spider mites in the greenhouse are listed in *Table 8*.

*Resistant Cultivars:* None available.

### *Issues for Twospotted Spider Mites*

1. Twospotted spider mite populations have developed resistance to a number of registered pest control products. There is a need for new conventional and non-conventional pest control miticides that are compatible with biological control agents and will contribute to resistance management.

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

### *Pest Information*

*Damage:* Whiteflies can cause severe damage to greenhouse cucumbers by decreasing fruit quality and yield. Adults can vector the persistent beet pseudo-yellows virus, causing year-round problems. Adults suck sap from cucumber plants and fruit, reducing plant vigour. Whiteflies secrete honeydew, a waste product that can coat the plant. Feeding injury provides an entry point for diseases. Secondary fungi (sooty mold) grow on the honeydew, reducing fruit quality.

*Life Cycle:* The adult female whitefly lays eggs on the underside of leaves. Eggs hatch within 10 to 14 days and the first nymphal stage or crawler seeks a suitable feeding site. The second and third nymphal stages are immobile. Nymphs feed for about 14 days and then pupate. The adult emerges about six days later. Adults live for 30 to 40 days but can lay eggs as early as four days after emergence.

### *Pest Management*

*Cultural Controls:* Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult whiteflies. The crop can be monitored for the presence of whiteflies with the use of sticky traps and by visual plant inspection. Populations of adults can be reduced with the use of yellow sticky traps at a rate of one to two traps per two to five plants. Additional management practices for whiteflies are listed in *Table 7*.

*Biological Controls:* Biological control agents commercially available for the management of whiteflies in the greenhouse are listed in *Table 8*.

*Resistant Cultivars:* None available.

### *Issues for Whiteflies*

1. There is a need for new conventional and non-conventional pest control products for whiteflies that are compatible with beneficial organisms and that could be used as resistance management tools.

## *Weeds*

Weed management in and around greenhouses is important as weeds can be an alternate host for insects, mites and diseases. Weeds within the greenhouse can be eliminated by hand weeding and through the use of ground coverings. Weeds external to the greenhouse can be reduced by mowing and by maintenance of a 10 m wide lawn area. These measures will reduce the chances of pests entering the greenhouse from outside. Herbicides may be used in the vicinity of greenhouses for the control of weeds; however, it is important that measures be taken to reduce the potential of spray drift from entering the greenhouse.

# Resources

## Integrated pest management / integrated crop management resources for greenhouse cucumber 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<br>www2.gov.bc.ca/gov/content/industry/agriservice-bc | Rajiv Dasanjh<br>Rajiv.Dasanjh@gov.bc.ca | Caroline Bédard<br>Caroline.Bedard@gov.bc.ca |
| **Alberta** | Alberta Agriculture and Irrigation<br>www.alberta.ca/agriculture-and-irrigation | N/A | Gayah Sieusahai<br>Gayah.Sieusahai@gov.ab.ca |
| **Ontario** | Ontario Ministry of Agriculture, Food and Rural Affairs<br>omafra.gov.on.ca | Cara McCreary<br>Cara.McCreary@ontario.ca | Joshua Mosiondz<br>Joshua.Mosiondz@ontario.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 7 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and pressure in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th>Colour Code</th></tr>
<tr><td rowspan="12">Present</td><td rowspan="10">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="5">**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>

## References


Agriculture and Agri-Food Canada. 1992. Revised by W.R. Jarvis. *Cucumber diseases*. Pub. No. 1684E. ISBN: 0-662-19867-0. https://publications.gc.ca/collections/collection_2015/aac-aafc/A43-1684-1992-eng.pdf

Alberta Agriculture and Forestry. 2016. Agri-Facts: *Managing cucumber green mottle mosaic virus in Alberta greenhouses.* Agdex 256/635-1. https://open.alberta.ca/dataset/ba4a1311-a775-4f3c-9e88-2e6d8d2f27c2/resource/803e64a0-b495-435a-9c3f-0fa70b156aa3/download/256-635-1.pdf

Alberta Agriculture. 2015. *Pests of greenhouse sweet peppers*. https://www.alberta.ca/pests-of-greenhouse-sweet-bell-peppers-and-their-biological-control

British Columbia Ministry of Agriculture. 2018. *Pythium diseases of greenhouse vegetables*. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/plant-health/af_pythium_diseases_of_greenhouse_vegetables_june_2024.pdf

Ferguson, G. 2010. *Greenhouse Grower notes: common cucumber viruses.* Greenhouse Canada. https://www.greenhousecanada.com/september-2010-2414/

Howard R. J., J. Allan Garland, W. Lloyd Seaman (Eds.) 1994. *Diseases and pests of vegetable crops in Canada.* Canadian Phytopathological Society and Entomological Society of Canada, Ottawa. https://phytopath.ca/publications/diseases-of-vegetable-crops-in-canada/

Lecoq H., C. Desbiez. 2012. *Viruses and Virus Diseases of Vegetables in the Mediterranean Basin*. Advances in Virus Research. https://www.sciencedirect.com/bookseries/advances-in-virus-research/vol/84/suppl/C

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

Ontario Ministry of Agriculture Food and Rural Affairs. 2010. *Publication 836, Growing Greenhouse Vegetables in Ontario*. https://www.publications.gov.on.ca/browse-catalogues/livestock/horticultural-crops/greenhouse-crops-general/growing-greenhouse-vegetables-in-ontario

Ontario Ministry of Agriculture, Food and Rural Affairs. 2014. *Mite pests in greenhouse crops: description, biology and management.* https://www.ontario.ca/page/mite-pests-greenhouse-crops-description-biology-and-management

Ontario Ministry of Agriculture, Food and Rural Affairs. 2014. *Thrips in greenhouse crops - Biology, damage and management.* https://www.ontario.ca/page/thrips-greenhouse-crops-biology-damage-and-management

Ontario Ministry of Agriculture, Food and Rural Affairs. 2014. *Whiteflies in greenhouse crops - Biology, damage and managemen*t. https://www.ontario.ca/page/whiteflies-greenhouse-crops-biology-damage-and-management

Ontario Ministry of Agriculture, Food and Rural Affairs. 2014. *Fungus gnats and shore flies in greenhouse crops*. https://www.ontario.ca/page/fungus-gnats-and-shoreflies-greenhouse-crops

Ontario Ministry of Agriculture, Food and Rural Affairs. 2012. *Managing the lygus bug in greenhouse crops.* https://www.ontario.ca/page/managing-lygus-bug-greenhouse-crops

Vineland Research and Innovation Centre. 2017. *Grower guide: Quality assurance of biocontrol products*. Compiled by Rose Buitenhuis. https://www.vinelandresearch.com/wp-content/uploads/2020/02/Grower-Guide.pdf