



Agriculture and  
Agri-Food Canada

Agriculture et  
Agroalimentaire Canada



# CIPRA - Computer Centre for Agricultural Pest Forecasting



## Crop Guide



# CIPRA

## Computer Centre for Agricultural Pest Forecasting

---

*Dominique Plouffe (1)*  
*Gaétan Bourgeois (1)*  
*Nathalie Beaudry (1)*  
*Gérald Chouinard (2)*  
*Danielle Choquette (1)*

*1 AAFC-Horticulture R&D Centre, Saint-Jean-sur-Richelieu, QC*

*2 Institut de recherche et de développement en agroenvironnement Inc., Saint-Bruno-de-Montarville, QC*





CIPRA - Computer Centre for Agricultural Pest Forecasting

© Her Majesty the Queen in Right of Canada, represented by the Minister of Agriculture and Agri-Food (2014).

Catalogue No. A42-119/2013E-PDF

ISBN 978-1-100-22932-4

AAFC No. 12147E

Paru également en français sous le titre

CIPRA - Centre Informatique de Prévision des Ravageurs en Agriculture. Guide des cultures

For more information reach us at [www.agr.gc.ca](http://www.agr.gc.ca) or call us toll-free 1-855-773-0241.



## **CIPRA - Information on crops**

### **WARNING**

Mathematical models are developed under specific climatic conditions and in particular regions. Before using a model that has not been validated in a region, it should be tested under local conditions for a few seasons to ensure that it works in that area. Some models assume certain conditions that are not necessarily found everywhere. It is therefore important to understand that models are tools to assist in decision-making and should be used in conjunction with other tools available to stakeholders in agriculture for a better understanding of what is happening in the field.

### **Acknowledgements**

*The authors wish to sincerely thank all those who worked and participated actively in the development of CIPRA software over the years, including many students and trainees. Their collaboration and support has greatly contributed to the diffusion of this tool for decision aid, very useful in the context of sustainable agriculture respectful of the environment. A special thanks to Alessandro Dieni Lafrance for the time spent on the revision of the apple section.*



# Table of Contents

<b>INTRODUCTION .....</b>	<b>7</b>
<b>APPLE .....</b>	<b>8</b>
MCINTOSH PHENOLOGY .....	9
POSTHARVEST DISORDERS .....	15
<i>Low temperature breakdown.....</i>	15
<i>Superficial scald.....</i>	17
DISEASES .....	18
<i>Apple scab .....</i>	18
<i>Fire blight.....</i>	22
INSECTS.....	24
<i>Apple maggot .....</i>	24
<i>Codling moth .....</i>	26
<i>Dogwood borer .....</i>	28
<i>European apple sawfly.....</i>	30
<i>European red mite .....</i>	32
<i>Fruit tree leafroller.....</i>	34
<i>Obliquebanded leafroller.....</i>	36
<i>Oriental fruit moth .....</i>	39
<i>Plum curculio.....</i>	42
<i>Redbanded leafroller.....</i>	44
<i>Speckled green fruitworm .....</i>	46
<i>Spotted tentiform leafminer.....</i>	48
<i>Tarnished plant bug .....</i>	50
<b>CARROT .....</b>	<b>52</b>
DISEASES .....	53
<i>Alternaria blight.....</i>	53
<i>Cercospora blight.....</i>	55
INSECTS.....	57
<i>Carrot rust fly.....</i>	57
<i>Carrot weevil .....</i>	59
<b>CRANBERRY .....</b>	<b>61</b>
CRANBERRY PHENOLOGY .....	62
INSECTS.....	65
<i>Cranberry fruitworm .....</i>	65
<i>Cranberry tipworm.....</i>	67
<b>CRUCIFER (BROCCOLI, BRUSSELS SPROUTS, CABBAGE).....</b>	<b>69</b>
BROCCOLI PHENOLOGY .....	70
INSECTS.....	72
<i>Diamondback moth .....</i>	72
<i>Imported cabbageworm.....</i>	74
<b>GRAMINEOUS (BARLEY, SPRING WHEAT) .....</b>	<b>76</b>
DISEASE .....	77



<i>Fusarium</i> .....	77
<b>LEEK</b> .....	<b>79</b>
INSECT .....	80
<i>Leek moth</i> .....	80
<b>LETTUCE</b> .....	<b>82</b>
DISEASE .....	83
<i>Downy mildew</i> .....	83
<b>ONION</b> .....	<b>84</b>
DISEASE .....	85
<i>Botrytis leaf blight</i> .....	85
INSECT .....	87
<i>Onion maggot</i> .....	87
<b>POTATO</b> .....	<b>89</b>
DISEASE .....	90
<i>Late blight</i> .....	90
INSECT .....	93
<i>Colorado potato beetle</i> .....	93
<b>STRAWBERRY</b> .....	<b>95</b>
STRAWBERRY PHENOLOGY .....	96
DISEASE .....	99
<i>Leaf spot</i> .....	99
INSECT .....	101
<i>Bud weevil</i> .....	101
<b>SWEET CORN</b> .....	<b>103</b>
INSECT .....	104
<i>European corn borer univoltine</i> .....	104
<b>TURFGRASS</b> .....	<b>108</b>
INSECTS.....	109
<i>Annual bluegrass weevil</i> .....	109
<i>Black cutworm</i> .....	114
<i>Black turfgrass ataenius</i> .....	117
<b>VINEYARD</b> .....	<b>119</b>
VINEYARD PHENOLOGY .....	120
DISEASE .....	124
<i>Grape powdery mildew</i> .....	124
INSECT .....	127
<i>Grape berry moth</i> .....	127
<i>Leafhoppers</i> .....	131
<b>BIBLIOGRAPHY</b> .....	<b>134</b>



## Introduction



### **CIPRA: Centre Informatique de Pr vision des Ravageurs en Agriculture** (Computer Centre for Agricultural Pest Forecasting)

A number of models for predicting disease progression, pest development and crop growth are described in the literature. However, only a few of the models are in wide use because the others are not very user friendly. The CIPRA system is a tool developed to permit broader use of these models and make them accessible to agricultural stakeholders such as advisors, agronomists, researchers and producers. It is the fruit of collaborative efforts by several institutions working to implement agriculture-related forecasting models for Quebec and Canada with real-time capability.

CIPRA is a user friendly software that allows the user to visualize forecasts of insect development or risk of disease and the phenology of certain crops. By using mathematical models with real-time weather data, CIPRA generates graphs permitting rapid estimates of the risk level for certain diseases, insect population development and the growth of given crops.

This guide was generated by the CIPRA software and it compiles all the information found in the “Help” menu. In this way, it is a work in progress and it will be updated with the latest models included in CIPRA on a regular basis.

### ***Development team***



Agriculture and  
Agri-Food Canada

Agriculture et  
Agroalimentaire Canada

**Ga tan Bourgeois**, Nathalie Beaudry, Dominique Plouffe, Danielle Choquette  
Horticultural Research and Development Centre, Saint-Jean-sur-Richelieu

Ren  Audet  
Soils and Crops Research and Development Centre, Qu bec



**G rald Chouinard**  
Centre de recherche de Saint-Bruno, Saint-Bruno-de-Montarville



Environment  
Canada

Environnement  
Canada

**Ga tan Deaudelin**



# Apple



## McIntosh Phenology

### Postharvest disorders

Low temperature breakdown  
Superficial scald

### Diseases

Apple scab  
Fire blight

### Insects

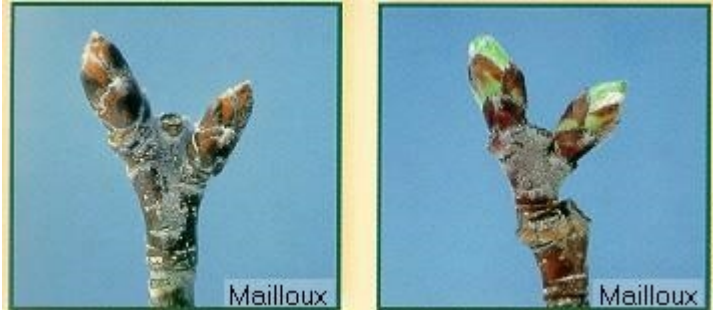
Apple maggot  
Codling moth  
Dogwood borer  
European apple sawfly  
European red mite  
Fruit-tree leafroller  
Obliquebanded leafroller  
Oriental fruit moth  
Plum curculio  
Redbanded leafroller  
Speckled green fruitworm  
Spotted tentiform leafminer  
Tarnished plantbug



## McIntosh Phenology



### APPLE BENCHMARK STAGES (Mailloux, 1982)



#### 1) Dormant

The buds are dormant during the winter. At times, they may show a slight swelling. This is the first sign of growth in the spring.

#### 2) Bud break

The buds burst and a green tip appears. The leaves are still folded inwards into the buds. This stage is often called bud burst.



#### 3) Half-inch green

Two or three leaves measuring 5 to 10 mm have opened up. Other leaves are visible but are still folded.

#### 4) Tight cluster

All buds have emerged, forming clusters. Short pedicels are present. Red petals can sometimes be seen on dominant buds.



#### 5) Pink

All the buds are generally open. The sepals are spread apart, revealing the folded pink petals.

#### 6) Late pink



The petals have elongated but not spread; they have a pinkish white colour. Sometimes, the petals on the dominant bud are slightly spread.



#### **7) Bloom**

All the petals are completely unfolded and the flowers are open.

#### **8) Calyx (petal fall)**

Stage reached when 90% of the petals have fallen.



#### **9) Fruit set**

The fruits are visible on the fertilized blossoms and are about 5 mm in diameter.

In the spring, all fruit trees go through well-defined growth stages. Since the emergence and development of insect pests and diseases are closely linked to apple phenology, it is crucial to monitor tree development and identify the different benchmark stages so that a precise schedule of pest control treatments can be established. Although the timing of these phenological stages varies from year to year, they do not usually occur until a fixed number of degree-days has accumulated. A heat constant, or number of accumulated degree-days, has therefore been established for each stage, along with an average date of occurrence and extreme dates (earliest and latest recorded dates). Furthermore, based on this information and on weather forecasts, the expected dates of occurrence can now be derived with a fair degree of accuracy.

Predictions about apple phenology can also be used to assess the risk posed by spring frost, since a cultivar's vulnerability depends largely on the state of apple bud development. The extent of damage is directly related to the lowest temperatures and their duration.

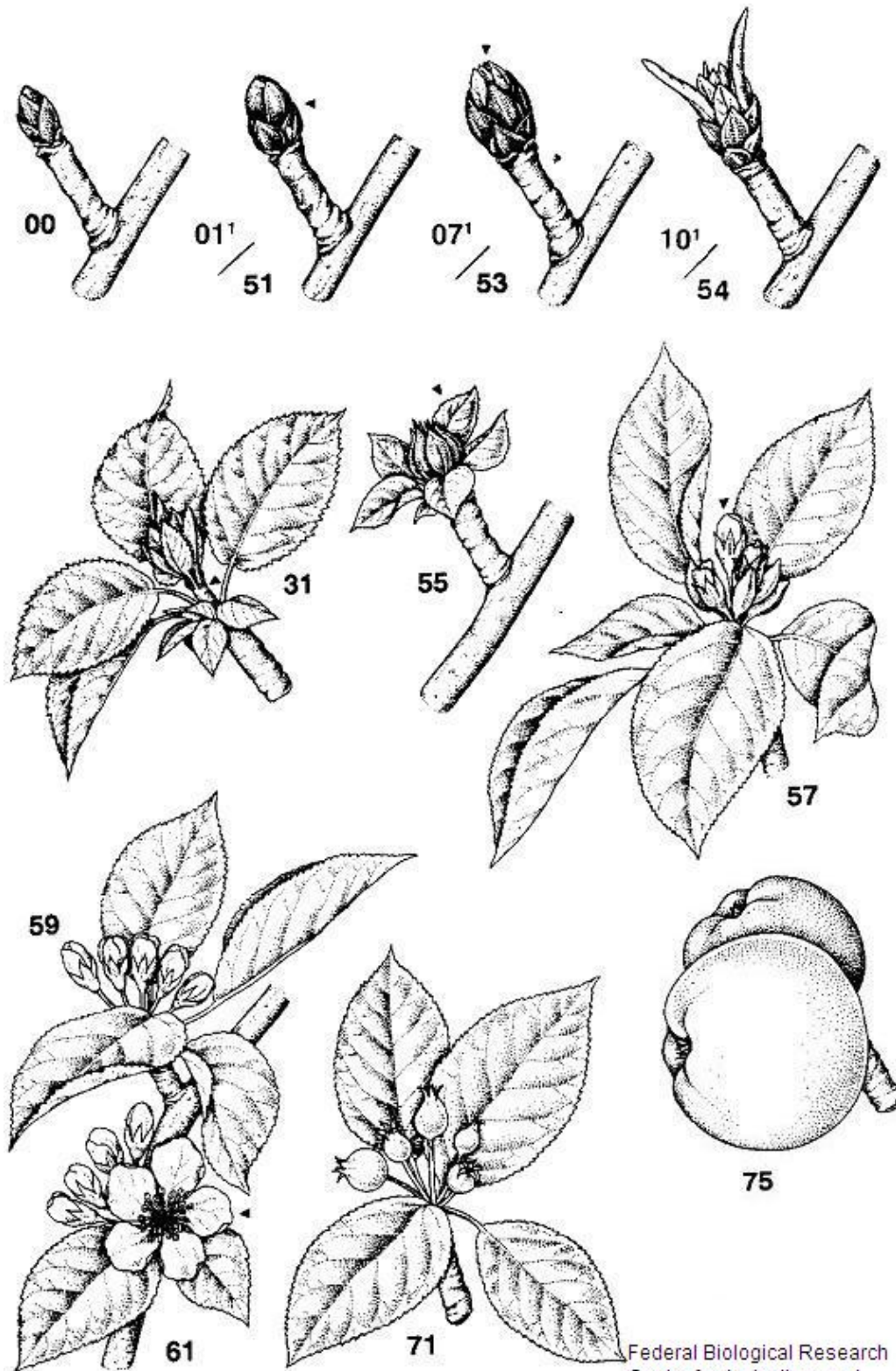
A benchmark phenological stage is considered to have been reached when 75% of the buds have developed to a point corresponding to the description for that stage.



Phenological stages: equivalence with the BBCH scale		
Stages (Mailloux, M. 1982)		BBCH stages (Meier <i>et al.</i> , 2001)
1	Dormancy: leaf buds and the thicker inflorescence buds closed and covered by dark brown scales	0
2	Beginning of bud break: first green leaf tips just visible	7
3	First leaves unfolded (others still unfolding)	11
4	End of bud swelling: light coloured bud scales visible with parts densely covered by hairs	52
5	Flower buds visible (still closed)	55
6	Pink bud stage: flower petals elongating; sepals slightly open; petals just visible	57
7	Full flowering: at least 50% of flowers open, first petals falling	65
8	End of flowering: all petals fallen	69
9	Fruit size up to 10mm; fruit fall after flowering	71



**Phenological growth stages and identification keys of pome fruit (Meier et al., 2001)**  
 (apple = *Malus domestica* Borkh)



Federal Biological Research  
 Centre for Agriculture and  
 Forestry, Ernst Halwaß, 2001.



Code	Description
<b>Principal growth stage 0: Sprouting/Bud development</b>	
00	Dormancy: leaf buds and the thicker inflorescence buds closed and covered by dark brown scales
01	Beginning of leaf bud swelling: buds visibly swollen, bud scales elongated, with light coloured patches
03	End of leaf bud swelling: bud scales light coloured with some parts densely covered by hairs
07	Beginning of bud break: first green leaf tips just visible
09	Green leaf tips about 5 mm above bud scales
<b>Principal growth stage 1: Leaf development</b>	
10	Mouse-ear stage: Green leaf tips 10 mm above the bud scales; first leaves separating
11	First leaves unfolded (others still unfolding)
15	More leaves unfolded, not yet at full size
19	First leaves fully expanded
<b>Principal growth stage 3: Shoot development (from terminal bud)</b>	
31	Beginning of shoot growth: axes of developing shoots visible
32	Shoots about 20% of final length
33	Shoots about 30% of final length
3..	Stages continuous till . . .
39	Shoots about 90% of final length
<b>Principal growth stage 5: Inflorescence emergence</b>	
51	Inflorescence buds swelling: bud scales elongated, with light coloured patches
52	End of bud swelling: light coloured bud scales visible with parts densely covered by hairs
53	Bud burst: green leaf tips enclosing flowers visible
54	Mouse-ear stage: green leaf tips 10 mm above bud scales; first leaves separating
55	Flower buds visible (still closed)
56	Green bud stage: single flowers separating (still closed)
57	Pink bud stage: flower petals elongating; sepals slightly open; petals just visible
59	Most flowers with petals forming a hollow ball
<b>Principal growth stage 6: Flowering</b>	
60	First flowers open
61	Beginning of flowering: about 10% of flowers open
62	About 20% of flowers open
63	About 30% of flowers open
64	About 40% of flowers open
65	Full flowering: at least 50% of flowers open, first petals falling
67	Flowers fading: majority of petals fallen
69	End of flowering: all petals fallen
<b>Principal growth stage 7: Development of fruit</b>	
71	Fruit size up to 10 mm; fruit fall after flowering
72	Fruit size up to 20 mm
73	Second fruit fall
74	Fruit diameter up to 40 mm; fruit erect (T-stage: underside of fruit and stalk forming a T)
75	Fruit about half final size
76	Fruit about 60% final size
77	Fruit about 70% final size
78	Fruit about 80% final size
79	Fruit about 90% final size



## REFERENCE FOR THE MODEL

**McIntosh Phenology (DD)** : model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre (HRDC) of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, in collaboration with Gérard Chouinard of the Institut de recherche et de développement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1977 to 2005 from 13 different Quebec orchards.

**McIntosh Phenology (BBCH)** : model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre (HRDC) of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu using data collected between 2005 and 2009 at the experimental farm at Frelighsburg.

### Cumulative degree days for each threshold development

Base temperature = 5°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Apple	Degree Days (°C)
Green tip	79
Half-inch green	116
Tight cluster	158
Pink	197
Full pink	224
Full bloom	255
Petal fall	313
Fruit set	371

[Apple tree](#)



## Postharvest disorders

### Low temperature breakdown



#### DESCRIPTION



In low-temperature storage, some apple cultivars develop metabolic disorders distinct from those caused by senescence. Among these, vascular breakdown, also known as vascular browning, is a browning of the main vascular bundles and some adjacent tissue of the apple while the cortex remains apparently normal (Meheriuk et al., 1994). Since the symptoms are not visible from the outside, the browning is not directly detectable. During the 1992-1993 season, in Quebec and Eastern North America, the damage caused by vascular browning were particularly serious, causing significant economic losses. This physiological disorder develops in storage following cool and rainy conditions during the months of July and August. In Quebec, McIntosh and Cortland cultivars are the most sensitive to this disorder.

#### REFERENCE FOR THE MODEL

Model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, using meteorological data from several sites in Quebec over a period of about 20 years between 1985 and 2006.

#### INTERPRETATION OF THE CURVE

In CIPRA, it is possible to display the risk level for a given Quebec region, namely Lower Laurentides, Eastern Townships, Montérégie-east, Montérégie-west and Quebec. The colored areas were calculated from historical weather data of 30 years for each of these regions. Thus, 8 out of 10 years, the risk of vascular browning is located in green (0-20%) and yellow (20-80%) areas. The red area corresponds to a high level of risk. If the browning index for a selected station is located in the green zone, the risks are low. If the curve is in the yellow zone, risks are medium, while in the red zone, the risk level is high and approaches the worst conditions of browning observed for this region.



When browning index predicted by the model is high for a given season, a few simple measures can be applied:

- Early harvest of susceptible varieties for fruit stored during prolonged time in controlled atmosphere (CA). The more the harvest date is delayed, the more fruit maturity makes them susceptible to browning.
- Change in marketing strategy to sell sensitive apples as soon as possible after harvest.
- Rapid cooling of storage rooms.
- Conservative CA storage conditions: 3 °C, 3% O<sub>2</sub> and 4.5% CO<sub>2</sub>. Do not store below 1.5 to 2 °C for the McIntosh variety.
- Reduce storage time of McIntosh to less than 3 months.

[Apple tree](#)



## Superficial scald



### DESCRIPTION



Agriculture and Agri-Food Canada

Superficial scald is a physiological disorder that affects many common apple cultivars during storage. It appears as a diffuse browning of the skin, somewhat roughened in severe cases, which becomes more extensive after a few days at room temperature. On red cultivars the scald lesion is often confined to the unblushed areas of the skin. This can become a limiting factor for long term storage of apples, especially those intended for the fresh market, and can cause significant losses in market value since the severely affected fruit can only be sold for transformation.

Probable causes of scald are related to environmental conditions of apples during their growth and development. Generally, scald is more severe in years when weather conditions are hot and dry during the last weeks before harvest. Exposure to temperatures below 10 °C for a period of time before harvest tends to reduce its development.

### REFERENCES FOR THE MODEL

Model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu on Cortland apples.

### INTERPRETATION OF THE CURVE

The model uses the cumulative number of hours where the temperature is below 10 °C starting 1 August. The accumulation of these cool hours reduces the risk of scald development. The 100% risk zone is between 0 and 65 hours of temperatures below 10 °C. After 65 hours, the risk drops to 40% between 120 and 130 hours. At 250 hours, the risk is virtually zero.

[Apple tree](#)

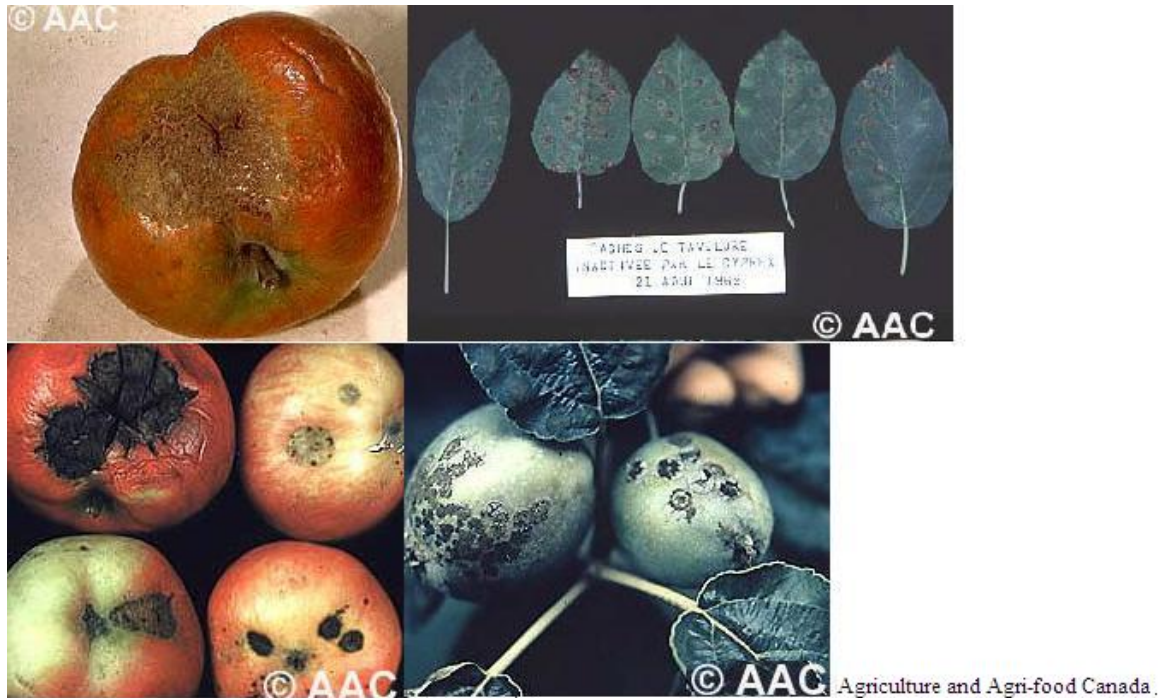


## Diseases

### Apple scab



#### DISEASE DESCRIPTION



Apple scab is an endemic disease. Dark brown spots with feathery margins appear 7 to 21 days following infection by the pathogenic fungus *Venturia inaequalis*. These scabs can help spread the infection, eventually defoliating the entire tree along with other trees nearby. Infected apples develop corky lesions which make them unmarketable. Recent observations indicate that an atypical form of the disease may occur fairly frequently. It has reddish veins surrounded by discoloured tissue.

The fungus overwinters on old scabbed leaves in the form of reproductive structures called pseudothecia. In the spring, the pseudothecia discharge a certain quantity of mature ascospores every time it rains. Whereas the Saint-Arnaud model describes the degree of ascospore maturity as a function of accumulated degree-days, the Mills Table indicates how much time it will take spores to penetrate apple leaves and cause infection depending on certain temperature and wetness conditions. The primary infection period, during which ascospores are discharged, ends when the pseudothecia stop producing mature ascospores. In Quebec, this happens around the time of the St.Jean Baptiste (June 24) holiday. Afterward, scab lesions produced by the primary infection have the potential to cause secondary infections. More specifically, it is the asexual spores (conidia) produced by the scabs which spread the infection.



## REFERENCE FOR THE MODEL

### Mills' model:

Mills, W.D. 1944. Efficient use of sulfur dusts and sprays during rain to control apple scab. Cornell extension bulletin. 630 : 1-4.

### Mills' modified model:

MacHardy W.E. and D.M. Gadoury. 1989. A revision of Mills' criteria for predicting apple scab infection periods. Phytopathology. 79: 304-310.

### St-Arnaud-Neumann's model:

St-Arnaud, M. et P. Neumann. 1990. Un modèle d'estimation de l'état d'avancement de la période d'infection primaire par le *Venturia inaequalis* en verger de pommier. Phytoprotection. 71 : 73-84.

## Infection risk tables

### Mills

Date for starting calculations: NA

Host: apple	Infection index
Low	1
Intermediate	2
High	3

### AAFC / IRDA

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Infection index
Minimum	1
Low	2
Intermediate	3
High	4



## INTERPRETATION OF THE CURVE<sup>1 2 3</sup>

To use CIPRA to make an informed decision about using fungicides against apple scab, both the original Mills Table and the modified Mills Table must be employed in conjunction with the Saint-Arnaud-Neumann curve.

An AAFC/IRDA version of the Mills table is available now.

### **AAFC/IRDA model**

The AAFC /IRDA model has been developed to replace the module in the Mills table. The main difference between the two models relates to the graphic representation of infections. Unlike the earlier version, the AAFC/IRDA model includes the timing of the start and end of rainfall events, the end of the risk period and it also incorporates the rate of infection progression. Furthermore, the risk curves cover all potential infection scenarios, including infection by conidia. The calculation rules are the same as in the previous version, only the graphical representation has been modified to display the additional data.

#### **Start of rainfall event**

The apple scab risk index increases as soon as the rainfall begins. Graphically, the risk curve begins to increase as soon as the rain begins.

#### **End of rainfall event**

The apple scab risk index stops increasing when relative humidity falls below the 85% threshold. Graphically, the curve becomes flat.

#### **End of the risk period**

The apple scab risk index drops to zero when relative humidity has been below 85% for 4 hours or more. Graphically, the curve goes back down to 0.

#### **Rate of progression of infection**

The rate of infection progression can be assessed by looking at the slope of the risk index curve; the faster the progression, the steeper the curve. This information may be useful to extrapolate current weather conditions and determine without any doubt when the infection period will begin.

#### **Risk indices**

The risk of infection is represented using a scale from 0 to 4. Between 0 and 1, infection cannot occur even if conditions such as inoculum level and phenological stage are optimal. Between 1 and 2, infection can only occur under very specific conditions related to inoculum and phenological stage. The severity of a risk rating of 2 to 4 depends on the amount of inoculum present in the orchard, the cultivar involved and the phenological stage.

0 to 1 = no infection can occur

1 to 2 = minimum threshold: infection can occur only when there is an extremely high level of inoculum or when conidia are present (secondary infections)

2 to 3 = light threshold: corresponds to a light infection according to the Mills table

3 to 4 = moderate threshold

4 and over = severe threshold

---

Text prepared in collaboration with:

<sup>1</sup> Odile Carisse, phytopathologist at the Horticultural Research and Development Centre of Agriculture and Agri-food Canada, Saint-Jean-sur-Richelieu, Québec.

<sup>2</sup> Léon Tartier, retired plant pathologist with the Centre de recherche en production végétale de Saint-Hyacinthe, Quebec MAPAQ (Ministry of Agriculture, Fisheries and Food, Québec).

<sup>3</sup> Vincent Phillon, phytopathologist at the Institut de recherche et de développement en agroenvironnement (IRDA) at Saint-Bruno-de-Montarville.



### Mills Table

The Mills Table tracks the conditions that *Venturia inaequalis* spores require in order to cause infection. It compiles periods of leaf wetness in relation to temperature. In essence, the warmer the temperature is, the faster the spores can penetrate apple leaves. The Mills Table ranks infections as light, moderate or severe depending on whether the conditions for infection have been at a minimum level or an optimum level. When the Saint-Arnaud-Neumann curve starts rising, that is, when the spores are mature, it is advisable to keep track of the **minimum** infection threshold (the "1") in the Mills system.

The Mills curve, as employed by CIPRA, shows the severity of infection. It **does not allow** the user to determine the precise time at which an infection period will begin: for example, a light infection will occur after about 14 hours at 10°C. The curve will merely show a rising trend at the 14th hour, although the first spores may have initiated the infection process much earlier than this. A warning of this type may be useful in cases where a fungicide has to be selected based on its period of efficacy (24- or 48-hour eradicant).

### Modified Mills Table

The modified Mills curve was devised in order to more effectively monitor periods of discharge of *Venturia inaequalis* ascospores. The original Mills curve was developed primarily to assess the infection conditions for summer apple scab, which is spread by conidia produced by the fungus. The new curve takes account of the fact that only a small percentage of ascospores are discharged during the night. In addition, it is more conservative than the original Mills curve because it systematically cuts three hours from the time required for infection. The latter characteristic has made this model highly controversial, given the low inoculum currently found in commercial orchards and the existence of less susceptible cultivars than those used when Mills constructed the original table.

### Saint-Arnaud-Neumann curve

The Saint-Arnaud-Neumann curve, developed to suit conditions in Quebec, can be used to monitor changes in the status of primary infections. In fact, the model designed by Saint-Arnaud-Neumann estimates the number of asci that have been depleted (emptied) in relation to the accumulated degree-days and periods of precipitation. The model is particularly useful at two strategic moments: the beginning and end of the primary spore discharge period. Producers should begin to follow the Mills curves when the Saint-Arnaud-Neumann curve shows an upward trend. This means that, from this point on, when conditions are conducive to infection, enough mature spores are present to trigger infection. At this stage, two major strategies are available: treatment can be applied as soon as the first ascospores are mature to avoid any risk of infection, or the initial fungicide applications can be delayed by taking into account the inoculum level and the susceptibility of the different cultivars in the orchard (or the concentration of ascospores in the orchard as measured with samplers). The primary infection season ends when the Saint-Arnaud-Neumann curve reaches a plateau, that is, when about 95% of the asci are depleted. The small remaining percentage of full asci will not produce enough spores to cause an infection.

The model can be used in determining the best time for making field observations, which are essential. As well, the pseudothecia should be observed under the microscope to validate all the information derived from the model. However, if the curve is followed, microscopic analyses can be omitted during much of the season, such as when it is known that spore discharges will continue for some time. This allows growers to concentrate on the critical time periods at the beginning and end of the primary infection season.

[Apple tree](#)



## Fire blight



### DISEASE DESCRIPTION



Agriculture and Agri-Food  
Canada, 2000.



Ministry of Agriculture, Food and  
Rural Affairs, Ontario, 2008

Fire blight is disease caused by a bacterium, *Erwinia amylovora* (Burrill), which infects hosts in the Rosaceae family. The bacteria *E. amylovora* is found in most areas of the province where apples are grown and some years, whole orchard blocks have been destroyed due to severe infections. Blossom blight is observed in the spring when flowers are infected. Infected blooms first appear water soaked and later begin to wilt, shrivel and turn brown or black. Pollinating insects visiting contaminated flowers spread the disease to non-infected flowers. Succulent shoots and suckers (water sprouts) can also become infected resulting in shoot blight and often the first symptoms are observed several weeks after bloom. Apple trees with several severely infected shoots appear scorched by fire. Bacterial ooze along the mid-vein of infected leaves and the stem of infected shoot is also common. The bacteria in the ooze act as source of inoculum that is spread to other tissues or trees by visiting insects and splashing rain during wet periods.

Fire blight bacteria overwinter at the edges of cankers. In the spring, as temperatures increase above 18°C, cankers become active and droplets containing high numbers of bacteria ooze out of infected bark



tissue. Once favourable environmental conditions occur, bacteria multiply rapidly and enter susceptible tissue resulting in infection and disease. The bacteria grow over a range of temperatures from 4-32°C, with rapid multiplication leading to infection occurring most frequently when temperatures are between 24-28°C. Hot, wet weather for an extended period of time favours the multiplication of the pathogen and infection, and encourages the succulent growth of susceptible plant tissue.

## REFERENCE FOR THE TABLE

**Fire blight:** T.J. Smith. 1999. Report on the development and use of CougarBlight 98C - A situation-specific fire blight risk assessment model for apple and pear. Acta Hort. 489:429-436.

### Infection risk table

Infection risk relative to the *degree hour total* of the last 4 days at the time **flowers are wetted 3 or more hours**.

Orchard situation: Potential for pathogen presence?	Low	Moderate	High
No fire blight in your area for the past 2 seasons	0 to 200 <i>DH</i>	200 - 270 <i>DH</i>	270 - 430 <i>DH</i>
Fire blight occurred in your area 2 seasons ago	0 to 160 <i>DH</i>	160 - 270 <i>DH</i>	270 - 400 <i>DH</i>
Fire blight occurred in your local area last season	0 to 135 <i>DH</i>	135 - 240 <i>DH</i>	240 - 380 <i>DH</i>
Fire blight occurred in your orchard or your neighbours' orchard last year	0 to 110 <i>DH</i>	110 - 200 <i>DH</i>	200 - 270 <i>DH</i>
Active fire blight cankers or strikes are now in or nearby your orchard	0 to 30 <i>DH</i>	30 - 100 <i>DH</i>	110 - 200 <i>DH</i>

[Apple tree](#)

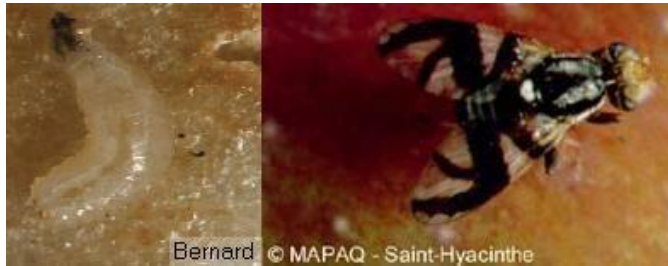


## Insects

### Apple maggot



#### PEST DESCRIPTION



Bernard Drouin, MAPAQ.

MAPAQ, 2000.

The apple maggot is a fly, smaller than the common housefly, ranging from 5 to 6 mm in length. Adult flies are black with a yellowish head and legs; they have white crossbands on the abdomen. Female flies have four crossbands; males have three. Also, they have a distinctive white dot on their back, at the inferior thorax apex, and their wings have characteristic black bands resembling an upside-down "F". The eggs, which are cream-coloured and fusiform, are barely visible to the naked eye. The white, sometimes yellowish, maggot has no legs or eyes. Although very small on hatching, maggot grows to a length of 7 or 8 mm at maturity. The pupa is enclosed in a smooth, oval case that is brownish and resembles a kernel of wheat. The apple maggot is the most serious pest of apple trees in North America. Damage results from egg-laying by females (small red dot on the skin that sometimes go unnoticed) and burrowing by maggots. In Quebec, male flies first appear in late June or early July. Females emerge a few days later and begin laying eggs when they become mature, 5 to 10 days after leaving the ground. The type of soil can affect the timing of their emergence, which tends to be earlier for light and sandy soils than for heavy, wet soils.

Females lay eggs singly under the skin of the fruit, and the young maggots grow inside the apples, which usually fall or are harvested before the maggots are fully developed (Chouinard et al., 2014).

#### REFERENCE FOR THE MODEL

**Apple maggot:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with G rald Chouinard of the Institut de recherche et de d veloppement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1991 to 2006 from 6 different Quebec orchards.



## Cumulative Degree days for each threshold development

Base temperature = 6.4°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
5% adults	963
50% adults	1244
98% adults	1572

## INTERPRETATION OF THE CURVE<sup>1</sup>

If not effectively suppressed, apple maggots can cause an incredible amount of damage. The model presented here can be used to predict the emergence of the first adult. This is the signal to set out traps and begin careful monitoring for apple maggots, one or two weeks before the date predicted by the model. In orchards with a history of severe damage and where there is no scouting, treatment could be necessary as soon as the first captures are made, if the threshold is reached. Subsequent interventions are based solely on captures.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with Gérald Chouinard, researcher entomologist at the Institut de recherche et de développement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Codling moth



### PEST DESCRIPTION



The codling moth is about 12 mm long and predominantly grayish-brown with two coppery markings in the brown area on its forewing tips. The eggs, measuring roughly 1 mm in diameter, are white and disc-shaped. Larvae are 13 to 19 mm long at full development, at 5<sup>th</sup> instar, and flesh-tone pink, with a brown head and black-spotted thorax.

Codling moth larvae attack the fruits of apple, pear and other fruit trees. They bore into the side or calyx of the fruit, leaving a characteristic mound of brown-reddish frass at the tunnel entrance, similar to sawdust, which can be observed mainly in July (first generation) and August (second generation). The frass resembles that of the European apple sawfly, which emerges earlier, in June.

The moths emerge when the apple trees are in bloom, at the end of May in Québec. Females lay eggs singly on leaves, but some may also be found on small branches and on fruit. Immediately after hatching, the larvae enter the small apples and tunnel directly to the core, where they eat the seeds. They later leave the fruit and make their way to the ground by climbing down the tree trunk, dangling from a silk thread or emerging from a fallen apple. A second generation of adults appears in August (Chouinard et al., 2014).

### REFERENCE FOR THE MODEL

**Codling moth:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with G  rald Chouinard of the Institut de recherche et de d  veloppement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1977 to 2006 from 12 different Quebec orchards.



## Cumulative Degree days for each threshold development

Base temperature = 10°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
1 <sup>st</sup> generation, 5% adults	199
1 <sup>st</sup> generation, 20% adults	273
1 <sup>st</sup> generation, 50% adults	374
2 <sup>nd</sup> generation, 5% adults	749
2 <sup>nd</sup> generation, 20% adults	793
2 <sup>nd</sup> generation, 50% adults	865

## INTERPRETATION OF THE CURVE<sup>1</sup>

The codling moth is one of the three insects, along with the apple maggot and the plum curculio that can cause the most damage to apples if not controlled effectively. Steadily increasing for 20 years, it is now considered the number one insect pest of apple in Quebec (Chouinard et al., 2014).

The model can be used to determine when scouting operations for caterpillars and moths should begin, as well as the optimum time for preventative measures against caterpillars in orchards where damage has occurred previously. The critical stages in the model are as follows:

- First emergence of adults (5% capture, first generation): install pheromone traps a few weeks before this stage to pinpoint the date of the first capture of adult moths in your own orchard. This date can then be used as the reference point to calculate the first egg hatch based on models developed in Ontario and Michigan. To determine the first egg hatch, calculate 360 degree days (DD) 50F after the date of the first capture (Michigan) or 50 DD 11C after the peak of capture (Ontario). For the egg hatching of the second generation, calculate 700 DD 11C after the date of the first capture for the first generation (Ontario). CIPRA model also calculates the date of first egg hatch using Quebec data (see below).
- First egg hatch (20% capture, first generation): favourable period for a traditional preventive treatment using larvicide.
- Peak adult catch (50% captures, first and second generations): peak adult catch of the first generation is sometimes used to predict the beginning of egg laying, a good period for preventive treatment with ovicide. However, the exact date for ovicide intervention depends on the product used and population level, the contribution of an advisor is recommended.

Note: curative sprays (recommended in other situations) are applied as soon as adult populations exceed the action thresholds, independently of model predictions (Chouinard et al., 2014).

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with G rald Chouinard, researcher entomologist at the Institut de recherche et de d veloppement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Dogwood borer



### PEST DESCRIPTION



The adult of the dogwood borer is a moth (10 mm) with a blue-black body, encircled with yellow markings. It has translucent wings that measure 18 - 22 mm, and looks like a wasp. The larva is a cream-coloured caterpillar with a reddish head capsule, and measures 15 mm at maturity.

The dogwood borer overwinters in the feeding tunnel that it digs inside the trunk of apple trees or on the main limbs of bigger trees. It becomes a chrysalis (pupa) between the end of May and the beginning of June. Moths start emerging in mid-June and continue until mid-August, with a peak of activity in mid-July. Females deposit their eggs individually on the rough surface of the bark, on wounds caused by the European canker, on burr knots (rounded aggregations of tender root tissues that develop on the above ground portion of the apple dwarfing rootstocks), or on other injuries on the bark.

Direct damage is the result of injuries caused by the caterpillars, which dig tunnels under the bark and into the sap conducting tissues. When feeding, the caterpillars create accumulations of reddish frass at the tunnel exits. When these accumulations are observed on the bark or on the burr knots, this indicates the presence of the insect. Borer primarily affects trees around the graft swelling, particularly in plantations of dwarf apple trees, on M.26 rootstock. When prolonged infestations occur, tree vigour is affected and its yield decreases. The indirect damage caused by the dogwood borer is the result of the caterpillar's cohabitation with pathogenic organisms. In fact, tunnels created by the borer present access routes for diseases such as cankers (Chouinard et al., 2014).

### REFERENCE FOR THE MODEL

**Dogwood borer:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with G  rald Chouinard of the Institut de recherche et de d  veloppement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1977 to 2006 from 12 different Quebec orchards.



## Cumulative degree days for each threshold development

Base temperature = 4°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
5% adults	730
50% adults	1082
95% adults	1465

## INTERPRETATION OF THE CURVE<sup>1</sup>

The degree-day accumulation model predicts the arrival of the first adults (5% capture), which is a reliable indicator of the onset of the insect's activity. Growers can use this as an indication that it is time to set their traps, which should actually be done a little before this event.

*Curative* treatments, which are recommended in most situations, are applied independently of model predictions, following scouting for the larvae on the trunks.

Growers should keep in mind that they should only intervene in cases that are so serious that the potential damage caused by the infestation is more costly than the cost of the treatment itself.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with G rald Chouinard, researcher entomologist at the Institut de recherche et de d veloppement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## European apple sawfly



### PEST DESCRIPTION



The adult European apple sawfly is 5 mm in length and is similar to a small wasp. Its body is black. Its legs and the ventral side of the abdomen are orange to yellow in colour; the head is yellowish with a black spot and all four wings are transparent. The larva is a yellowish caterpillar with a dark brown head. It measures 12 mm in length. It has three pairs of legs on the front of its body and seven pairs of false legs on the abdomen. The eggs are shiny and white and they are individually inserted into the receptacles of blossoms.

The larva feeds in the fruit and causes two types of damage:

- 1) After hatching, the young larva munch beneath the skin creating winding tunnels that leave brown corky, ribbon-like scars; this is the primary damage that can be detected on some fruit at harvest;
- 2) The young larva then penetrates into fruit, boring deep holes of about 3 mm in diameter. Excrement and brown frass with a strong smell drip out of the hole. This is known as secondary damage. These secondary damages are similar to those of codling moth. However, apples infested with codling moth are larger, since the damage is done in July instead of June, as is the case for sawfly.

The European apple sawfly overwinters as a pupa in the soil. First adults emerge at the pink stage of apple trees. The adults' activity peaks during full bloom. After mating, females deposit their eggs individually at the base of the blossoms' receptacle. The larva hatches 10 - 12 days later, around the petal fall stage (Chouinard et al., 2014).

### REFERENCE FOR THE MODEL

**European apple sawfly:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with G  rald Chouinard of the Institut de recherche et de d  veloppement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1981 to 2006 from 11 different Quebec orchards.



## Cumulative Degree days for each threshold development

Base temperature = 4.5°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
5% adults	249
50% adults	324
98% adults	441

## INTERPRETATION OF THE CURVE<sup>1</sup>

The predicted date for the first adults appearance (5% capture) serves as a reliable warning for growers that their traps should be set, preferably shortly before this event occurs. The end of the capture period (98% capture) indicates that insect activity on the apple trees has ceased and scouting can be terminated.

The peak catch period does not represent the peak of insect activity since traps are not very attractive to insects during flowering. Instead, the large number of flowers lures insects. Maximum activity occurs around the peak flowering period, but unless exception, treatments cannot be applied at this stage due to their harmful effects on bees.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with G rald Chouinard, researcher entomologist at the Institut de recherche et de d veloppement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## European red mite



### PEST DESCRIPTION



Guide d'identification des insectes des pommiers et des poiriers, bayer crops science 2007.  
MAPAQ, 2000.

The European red mite is phytophagous, that is, it feeds on plants. Barely visible to the naked eye, the elliptically-shaped adult female (0.4 mm) is dark red and has four rows of long curved hairs on its back, embedded in a whitish protuberance. The male is a little smaller, about 0.3 mm long during the adult stage. The colour of the eggs varies over the season from bright red to dark orange, and overwintering eggs are generally a darker red colour. European red mites cause damage by feeding on the sap in the leaves. Whereas light invasions cause speckling of leaves, heavy ones cause discoloration of foliage. A severe attack can cause premature leaf fall, impede tree growth, weaken the fruit buds and make the fruit smaller and of poorer quality.

Eggs hatch around the pink stage, and the immature mites migrate to leaves and begin feeding on them. From petal fall (calyx stage), first generation females lay their eggs on the underside of leaves. In Québec, there may be from six to eight or more generations per year, depending on climatic conditions. If the weather is warm and dry, the mites will reproduce fast, at a rate of one generation every two weeks. Since the generations overlap, European red mites representing every developmental stage can be found on apple trees during the summer. In Québec, peak densities occur in late July and early August (Boulé et al., 1999).

### REFERENCE FOR THE MODEL

**European red mite:** Model developed and evaluated by Mailloux between 1977 and 1986.

#### Cumulative Degree days for each threshold development

Base temperature = 5°C

Optimal temperature = 40°C

Method = single average

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
Hatching of winter eggs	140



## INTERPRETATION OF THE CURVE<sup>1</sup>

Repression of European red mite overwintering eggs is a basic operation in integrated fruit production (Chouinard et al., 2014)

The egg hatch period identified by the model is the critical time for making an oil application. After this critical stage, oil treatment will no longer be effective, because motile mites will become almost immune to this product. In addition, the oil that is commonly used (superior oil) may be phytotoxic after the tight cluster stage. This type of control measure cannot be deferred, unless another type of miticide is employed.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with G rald Chouinard, researcher entomologist at the Institut de recherche et de d veloppement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Fruit tree leafroller



### PEST DESCRIPTION



Although outbreaks of this insect occurred in the 1930s and 1940s, it is still a secondary pest today. The adult's forewings (2.5 cm span) are brown with two light spots in the anterior portion. This leafroller larvae are caterpillars (2-19 mm) yellowish green with dark brown head; they roll the leaves. They appear at the pink stage and feed on leaves, buds and fruits until late June.

The insect overwinters in the egg stage. Eggs are laid in clusters of 25 to 125 on twigs, branches and sometimes the trunk of apple trees. Hatching begins around tight cluster and continues until the calyx stage, or even later some years. The larvae feed on the leaves, buds and fruit until about three weeks after petal fall. They then pupate in a cocoon made of rolled-up leaves, or under bark debris. In July, the moths emerge and, after mating, the females deposit their egg masses, which will not hatch until the following spring.

The larvae chew on the leaves, buds and fruit. They like to make a shelter by webbing leaves and fruit together with silky threads; they then feed on the leaves and fruit from this hiding place. Most of the damaged apples will drop prematurely, and those that remain on the tree until harvest will have little or no commercial value (Beaulieu, 1957).

### REFERENCE FOR THE MODEL

**Fruit-tree leafroller:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with Gérard Chouinard of the Institut de recherche et de développement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1977 to 1998 from 7 different Quebec orchards.



## Cumulative Degree days for each threshold development

Base temperature = 5°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
5% adults	797
50% adults	979
95% adults	1164

## INTERPRETATION OF THE CURVE<sup>1</sup>.

The accumulated degree-day model predicts the arrival of the first adults (5% capture). This is a reliable indication of the onset of insect activity, allowing growers to set their traps at the opportune time, which is a little before this event.

It is difficult to use the peak in adult catches (50% capture) to predict the appearance of the first summer larvae, which usually occurs from 5 to 28 days after the adult peak. This event is used in some cases to time *preventive* treatments. *Curative* treatments (recommended in most situations) should be applied, as soon as caterpillar populations exceed the action threshold, independently of the model's predictions.

It should be kept in mind that the fruittree leafroller is not a serious orchard pest in Quebec.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with Gérald Chouinard, researcher entomologist at the Institut de recherche et de développement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Obliquebanded leafroller



### PEST DESCRIPTION



The obliquebanded leafroller is a moth slightly over 12 mm long with pale brown wings that have a pinkish tinge. Wingspread is about 25 mm in females and 20 mm in males. On the forewings, there are three oblique darker bands, hence the insect's common name. The light green eggs are laid in clusters on the leaves. The caterpillar ranges in colour from light to dark green, and is 2 to 25 mm long. It has a brown to black head capsule, which distinguishes it from the redbanded leafroller. The larvae tend to wrap themselves in leaves and, when disturbed, to spin a thread from which they dangle. There are two generations of obliquebanded leafroller per year: the spring generation (overwintering larvae) and the summer generation. In addition to feeding on buds and leaves, the larvae of the spring generation can attack the young fruits; they eat into them, leaving corky areas resembling the damage caused by the speckled green fruitworm; most of the affected fruit will drop prematurely, but with little damage to crop. Larvae of the summer generation occur on the growing shoots and fruit. During this period, the leafroller feeds on the surface of fruit without deforming it, but remains hidden most of the time on the underside of a leaf it has tied to the fruit. Summer generation larvae significantly damage the crop.

In Québec, the first larvae emerge in mid-May and feed on the buds and leaves and then the fruits. Other larvae become active later and remain active until the petal fall stage. The first generation of adults is present from mid-June to late July. Females deposit masses of eggs (up to 600 eggs) on the upper surface of leaves. The larvae of the summer generation are present from early July to mid-August and cause most of the damage observed on fruits at harvest. The obliquebanded leafroller produces two generations annually. However, each generation is active over such a long period that all developmental stages may co-exist at some point during the summer (Chouinard et al., 2014).



## REFERENCE FOR THE MODEL

**Obliquebanded leafroller:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with Gérald Chouinard of the Institut de recherche et de développement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1977 to 2006 from 13 different Quebec orchards.

### Cumulative Degree days for each threshold development

Base temperature = 6°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
1 <sup>st</sup> generation, 5% adults	486
1 <sup>st</sup> generation, 50% adults	642
5% egg hatch	686
50% egg hatch	819
2 <sup>nd</sup> generation, 5% adults	1292
2 <sup>nd</sup> generation, 50% adults	1530

## INTERPRETATION OF THE CURVE<sup>1</sup>

This model is useful for determining when scouting for moths should begin, and also for determining the optimum time for applying treatments against caterpillars in orchards where damage has occurred before. The critical stages of the model are as follows:

- First adults, first generation: install pheromone traps a few weeks before this stage to pinpoint the date of the first capture of moths in your own orchard. This date can then be used as the reference point for your own calculations of certain critical stages for control. To determine the first egg hatch date, calculate 200 degree days (DD) 6C after the date of the first capture and for the peak hatch date for summer larvae, 333 DD 6C after the first capture. The model also predicts these periods, but using the accumulated degree-days beginning on March 1.
- Peak adult catch, first generation: sometimes used to predict the appearance of the first summer larvae, which usually occurs 10-12 days from this date, although this may vary considerably. In some situations, this is a good time for preventive spraying but the conventional intervention against caterpillars is usually recommended at the time of the first pupation, if the action threshold is reached, or 5 to 7 days after the calyx phenological stage.
- First egg hatch date: good time for a long-acting preventive treatment (e.g., insect growth regulators).
- Peak in egg hatching: begin visual scouting for caterpillars to determine if localized treatments are needed in summer (recommended in rare cases).

Note: curative sprays are applied as soon as the caterpillar population exceeds the action threshold, independent of model predictions.

---

<sup>1</sup>Text written in collaboration with Gérald Chouinard, researcher entomologist at the Institut de recherche et de développement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



Since obliquebanded leafrollers have become increasingly resistant to pesticides, it is important to monitor the development of populations more closely.

The latest edition of this text was made on July 2014.

[Apple tree](#)



## Oriental fruit moth



### PEST DESCRIPTION



This moth can produce up to six generations per year depending on the geographical region. In Ontario, up to four generations can occur each year. Mature larvae overwinter in cocoons. The cocoons are usually in the soil or in crevices under bark, or in old fruit containers or packing sheds. Pupation occurs in early spring and the first brood of moths appear when the trees are in blossom, with the peak of emergence occurring about the last week of May. The adult moth are generally weak fliers with average flights not exceeding 25 m, but flights of over 3 km have been reported for adults in search of a suitable host. When a host is found, eggs are laid on the leaves or on new shoots. In early June the newly hatched first generation larvae bore into the tips of terminal shoots and tunnel downward until they reach harder woody tissue, at this point they exit the shoot and enter another one. The tips of infested shoots soon wilt and die. A single larva may destroy two to five shoots before it matures. The mature larvae exit the shoots and drop via silken threads to the ground or the trunk of the tree, where they spin cocoons and pupate. Summer cocoons are more fragile than overwintering ones. The life cycle is repeated and the second brood larvae hatch between July 10 and 20. This generation also attacks shoots but by midsummer the new shoots begin to harden. At this time many of the partly grown larvae exit the shoots and attack the young fruit. They may tunnel to the centre or feed near the surface, producing large masses of gum mixed with sawdust-like castings (frass). Emerging larvae of later broods may bore into the soft stems of the fruit, being too small to attack the hard fruit directly. As the fruit ripens and softens it no longer produces gum when attacked and young larvae can enter it directly. Larvae that bore into the stems may tunnel down into the ripening fruit. Larvae of later broods attack the ripe fruit leaving no visual signs of infestation and it is not until the fruit is cut open that the larvae are discovered (Ref.: Canadian Food Inspection Agency).

### REFERENCE FOR THE MODEL

**Michigan** : Michigan State University Extension. Fruit IPM Fact Sheet.

**Pennsylvania** : Hull, A. L., G. Krawczyk & N. Ellis. 2001. Management Tactics for the Oriental Fruit Moth (*Grapholita molesta*) in Pennsylvania Apple Orchards. Pennsylvania Fruit News, 81(2): 23-36

**Penn/AAC**: this model was developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, using a combination of the other two models.



### Cumulative Degree days for each threshold development

#### Michigan

Base temperature = 7.2°C

Optimal temperature = 32.2°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple Michigan	Degree Days (°C)
1 <sup>st</sup> generation, 5% adults	97
1 <sup>st</sup> generation, 5% egg-laying	139
1 <sup>st</sup> generation, 50% adults	181 to 236
1 <sup>st</sup> generation, 50% egg-laying	292
2 <sup>nd</sup> generation, 5% adults	528
2 <sup>nd</sup> generation, 5% egg-laying	611
2 <sup>nd</sup> generation, 50% adults	722 to 792
2 <sup>nd</sup> generation, 50% egg-laying	833
3 <sup>rd</sup> generation, 50% adults	1222 to 1361
3 <sup>rd</sup> generation, 50% egg-laying	1389

#### Pennsylvania

Base temperature = 7.2°C

Optimal temperature = 32.2°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> sustained moth captures

Host: apple Pennsylvania	Degree Days (°C)
1 <sup>st</sup> generation, 8 to 10% egg hatch	83 to 94
1 <sup>st</sup> generation, 95% egg hatch	359
2 <sup>nd</sup> generation, 8 to 10% egg hatch	625 to 639
2 <sup>nd</sup> generation, 95% egg hatch	1083
3 <sup>rd</sup> generation, 8 to 10% egg hatch	1250 to 1267
3 <sup>rd</sup> generation, 95% egg hatch	1765



**PENN / AAFC**

Date for starting calculations = 1<sup>st</sup> sustained moth captures

Host: apple	% egg hatch
Action threshold 1	10 to 20
Action threshold 2	50 to 60

[Apple tree](#)



## Plum curculio



### PEST DESCRIPTION



The adult plum curculio is black, brown or greyish with a rough, bumpy back. It is about 5 mm long and has a long curved snout (rostrum) that accounts for a third of its body length. Eggs are whitish-grey and elliptical. The larva measure about 5-7 mm and is whitish-yellow with a small black head.

The plum curculio is a key pest of pome and stone fruits in the east of North America. In Quebec, it attacks apples, pears and plums. Four types of damage may occur:

- 1) crescent-shaped scars left by egg-laying activities in the spring;
- 2) internal damage caused by larval feeding activities on the flesh of seeds and fruit;
- 3) early drop (end of June - beginning of July) of the majority of afflicted fruit;
- 4) circular punctures in the skin, caused at the end of the summer by the new generation of feeding adults.

Damage generally appears as crescent-shaped cuts on the fruit surface. The plum curculio is a formidable pest, since one female can lay up to 200 eggs (potentially 200 cuts) in a few weeks. Because this insect is not highly mobile from one tree to the next, damage is often limited to certain areas or trees where, however, fruit can be severely injured (Boulé et al., 1997).

### REFERENCE FOR THE MODEL

**Plum curculio (Chouinard):** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with G  rald Chouinard of the Institut de recherche et de d  veloppement en agroenvironnement (IRDA) at Saint-Bruno. The model was developed from historical data of an orchard in Frelighsburg (QC), from 1984 to 1988. It was then validated with data collected in different Quebec orchards from 1994 to 2001 (Chouinard et al. 2002).

#### Table of thresholds activity

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Activity level
Threshold 1	25
Threshold 2	50
Threshold 3	75



## INTERPRETATION OF THE CURVE<sup>1</sup>

The model calculates the hourly rate of weevil activity (proportion of weevils who are not at rest) based on weather conditions. As it is primarily a nocturnal insect, only activity between 18:00 and 08:00 is considered valid. An egg-laying index, superimposed on forecast, indicates the risk that activity predicted by the model includes egg-laying activity and results in damage to fruit.

The model can be used to identify the most favorable nights to the weevil activity and thereby better target interventions during the egg-laying period.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with G rald Chouinard, researcher entomologist at the Institut de recherche et de d veloppement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Redbanded leafroller



### PEST DESCRIPTION



These small gray-brown moths (8 mm) have forewings with a band that shades from red to dark brown. Eggs are pale yellow and 1 mm in diameter. The larvae, which are pale green to yellowish with a straw-coloured head, appear near calyx stage (petal fall) and reach about 16 mm long when mature. Damage is caused by the larvae, which infest either the leaves or the fruits. The larvae skeletonize the leaves; they do this by webbing leaves together and then feeding on the undersurface of the leaves, near the midrib. The redbanded leafroller chews on the surface of fruits, particularly those touching the leaves. It is the larvae of the second generation which attack mainly the fruit.

Shortly after budbreak, in late April in Québec, the adult moth emerges. Later, the females deposit flattened masses of eggs on the undersides of branches. Hatching occurs about the time of petal fall, and the young larvae immediately begin feeding on the leaves and later the fruits. In late June, they pupate and the adults emerge in early July (Boulé et al., 1999).

### REFERENCE FOR THE MODEL

**Redbanded leafroller:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with G  rald Chouinard of the Institut de recherche et de d  veloppement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1977 to 1998 from 10 different Quebec orchards.



### Cumulative Degree days for each threshold development

Base temperature = 0°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
1 <sup>st</sup> generation, 5% adults	229
1 <sup>st</sup> generation, 50% adults	350
1 <sup>st</sup> generation, 95% adults	562
2 <sup>nd</sup> generation, 5% adults	1312
2 <sup>nd</sup> generation, 50% adults	1583
2 <sup>nd</sup> generation, 95% adults	1976
3 <sup>rd</sup> generation, 5% adults	2222
3 <sup>rd</sup> generation, 50% adults	2431

### INTERPRETATION OF THE CURVE<sup>1</sup>

The accumulated degree-day model predicts the arrival of the first adults (5% capture, first generation). This is a reliable indicator of the onset of insect activity, allowing growers to set their traps at the opportune time, which is a little before this event.

The peak adult capture (50%, first generation) is sometimes used to predict the occurrence of the first summer larvae, which may vary considerably, 14 to 21 days on average after the adult peak occurs. This date is used in rare cases to time *preventive* treatments. However, if 21 days have elapsed, visual scouting operations for the caterpillars should be undertaken to determine whether localized summer treatments are required. *Curative* treatments (recommended in most situations) are applied as soon as caterpillar populations exceed the action threshold, independently of model predictions.

This leafroller is not a serious orchard pest and growers should keep in mind that they should only intervene in cases that are so serious that the potential damage caused by the infestation is more costly than the cost of the treatment itself.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

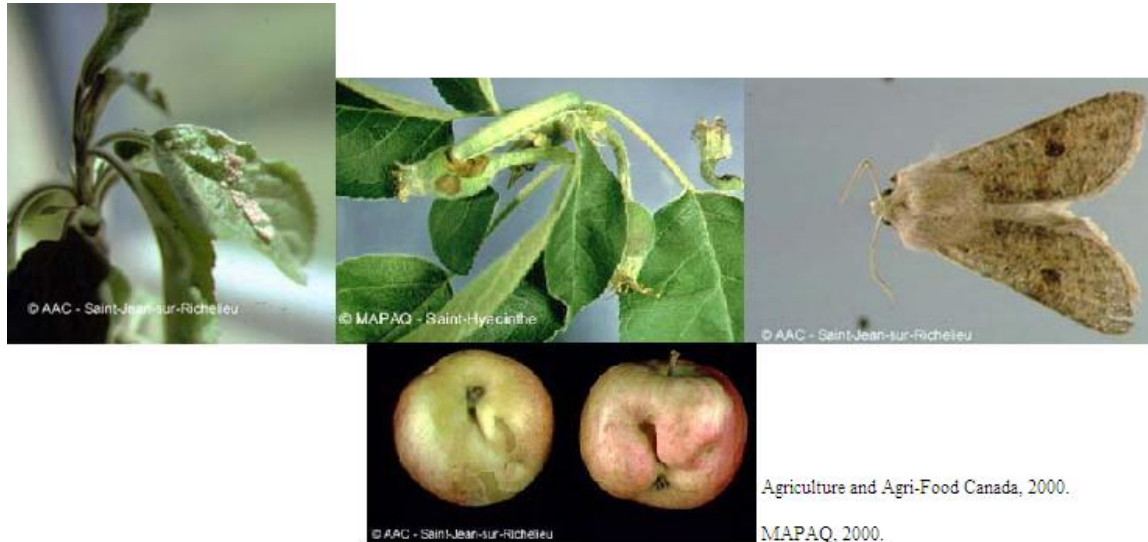
<sup>1</sup> Text written in collaboration with G rald Chouinard Researcher entomologist at the Institut de recherche et de d veloppement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Speckled green fruitworm



### PEST DESCRIPTION



The speckled green fruitworm is a grey to brown moth of 20 mm wingspan. Its head and thorax are densely covered with hair. Each wing is marked by two purplish grey spots. The larva is a pale green caterpillar with three white longitudinal stripes on its back. It passes through 6 larval instars and reaches 30 - 40 mm in length at maturity. The head capsule is green like the rest of the body. The speckled green fruit worm overwinters as a chrysalis (pupa) in the soil. Adults emerge before the green tip stage of the apple. Females lay their eggs individually on twigs. Hatching begins at the tight cluster stage and ends at petal fall. The young caterpillars feed on flower buds while older ones mostly feed on young fruit. There is only one generation per year.

Damage occurs when caterpillars feed on flower and fruit buds. They dig large holes that sometimes go through the entire apple. The fruit will fall if its core has been attacked, but usually will remain on the tree until harvest, exhibiting deep corky scars (Chouinard et al., 2014).

### REFERENCE FOR THE MODEL

**Speckled green fruitworm:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with Gérald Chouinard of the Institut de recherche et de développement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1981 to 2006 from 12 different Quebec orchards.



## Cumulative Degree days for each threshold development

Base temperature = 3°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
5% adults	70
50% adults	141
95% adults	241

## INTERPRETATION OF THE CURVE<sup>1</sup>

The degree-day accumulation model for this pest forecasts the arrival of the first adults (5% capture). This is a reliable indicator for the beginning of insect activity; traps should be set shortly before this stage.

The peak adult catch (50% capture) is sometimes used to predict the occurrence of the first summer larvae, which usually occurs a few days after this event. This is used as a reference point to begin visual scouting for caterpillars and, under rare circumstances, for the timing of *preventive* treatments. *Curative* treatments (recommended in most situations) are applied independently of the models, after scouting for the larvae.

Growers should keep in mind that they should only intervene in cases that are so serious that the potential damage caused by the infestation is more costly than the cost of the treatment itself.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with Gérald Chouinard, researcher entomologist at the Institut de recherche et de développement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Spotted tentiform leafminer



### PEST DESCRIPTION



The tentiform leafminer is a small, golden brown moth (4 -5 mm long) with white bands on its wings. Eggs are laid singly on the undersides of leaves; they are translucent, flat and circular, and can be seen with a magnifying glass (10X). The dark brown pupa is 7 mm long. The first three larval instars, which feed on the sap, are legless, flat and creamy white, and about 1 mm long. The last three instars, which feed on foliar tissues, are yellowish, have short legs and range up to 4 mm in length. The larva's head is a slightly darker colour than the rest of its body. Tentiform leafminers damage only the leaves of apple trees. Each larva feeds on sap and plant tissues in a small area inside the leaf, called a mine. The mine excavated by the first three instars (sap feeders) is visible only on the lower surface of leaves. However, raised areas with small discoloured spots appear on the upper surface of the leaves when older larvae (tissue feeders) are at work. A serious infestation of leafminers (5 to 10 mines per leaf in third generation) can cause leaves to fall, premature ripening and fruit dropping.

The leafminer overwinters as a pupa in fallen leaves, and the adult moths emerge around the half-inch green stage. At tight cluster, females lay eggs on the undersides of leaves. After hatching, the larvae mine into the leaves to feed (Chouinard et al., 2014).

### REFERENCE FOR THE MODEL

**Spotted tentiform leafminer:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with G rald Chouinard of the Institut de recherche et de d veloppement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1989 to 2006 from 8 different Quebec orchards.



### Cumulative Degree days for each threshold development

Base temperature = 6.7°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
1 <sup>st</sup> generation, 5% adults	91
1 <sup>st</sup> generation, 50% adults	157
2 <sup>nd</sup> generation, 5% adults	569
2 <sup>nd</sup> generation, 50% adults	781
3 <sup>rd</sup> generation, 50% adults	1362

### INTERPRETATION OF THE CURVE<sup>1</sup>

The model computes the accumulated degree-days needed for different critical stages in the management of this foliage pest. Since populations of this pest frequently do not attain harmful levels (notably in orchards where a minimum amount of pesticide is used), it is imperative that the populations be monitored to determine whether control measures need to be applied. When the curve reaches the 5% threshold for the first generation, it is time to install traps for monitoring the populations.

The conventional treatment for leafminers entails destroying the females that are about to lay eggs and the larva (first three instars). These pesticide applications target the first generations and when adult populations are high enough, spraying can be carried out either when the first generation peaks (against adults) or when the first captures of the second generation appears (against first instars), that is, when the model indicates 50% 1<sup>st</sup> generation and 5% 2<sup>nd</sup> generation thresholds. The model also predicts these thresholds for subsequent generations, but owing to the overlapping of populations and the presence of predators during this period, summer treatments are reserved for emergency situations.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with G rald Chouinard, researcher entomologist at the Institut de recherche et de d veloppement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Tarnished plant bug



### PEST DESCRIPTION



The tarnished plant bug is flat, oval-shaped and brownish and about 6 mm long. Its forewings with their translucent tips are folded on its back. Except in cold weather, this insect is very shy and will fly away quickly when disturbed. The yellowish green nymph resembles a green apple aphid, but is rarely found on apple trees. The tarnished plant bug is indigenous to North America, where it is widespread and polyphagous. In fact, these bugs may feed on more than 300 species of plants, causing damage to over 50 different crops, including potatoes, alfalfa, clover, large and small fruits, vegetables and flowers. In fruit orchards, the nutrition insect hole on the growing bud causes the occurrence of a drop of sap called exudate. Damage manifests itself in two ways depending on apple development stage. Insect holes made between bud break and tight cluster cause premature dropping of flower buds, in part or in full. Insect holes made from pink stage cause either bud fall or occurrence of a funnel-shaped depression on the fruit, sometimes with corky scars that may downgrade the fruit.

In Quebec, the insect overwinters as an adult primarily under leaf litter near fields and woods. In the spring, adult tarnished plant bugs resume their activity about the time of bud break, feeding on the buds on until after fruit set. After that, they gradually leave the apple trees and begin feeding on and laying eggs on ground cover species (legume or other cover crops). The next two generations of larvae and adults will not feed on apple trees (Chouinard et al., 2014).

### REFERENCE FOR THE MODEL

**Tarnished plant bug:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu, in collaboration with G rald Chouinard of the Institut de recherche et de d veloppement en agroenvironnement (IRDA) at Saint-Bruno. The data were obtained from 1980 to 2006 from 12 different Quebec orchards.



## Cumulative Degree days for each threshold development

Base temperature = 0°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: apple	Degree Days (°C)
5% adults	160
50% adults	276
95% adults	464

## INTERPRETATION OF THE CURVE<sup>1</sup>

The occurrence date of the first adults (5% capture) predicted by the model serves as a warning for growers, alerting them that they need to monitor the insect during the next few warm, sunny days. Visual scouting and the use of traps must be initiated right away. The end of the capture period (95% capture) indicates that the insects are no longer active on the trees and scouting can be ended.

The latest edition of this text was made on July 2014.

[Apple tree](#)

---

<sup>1</sup> Text written in collaboration with G rald Chouinard, researcher entomologist at the Institut de recherche et de d veloppement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.



## Carrot



### Insects

Carrot rust fly  
Carrot weevil

### Diseases

Alternaria blight  
Cercospora blight



## Diseases

### Alternaria blight



#### PEST DESCRIPTION



Alternaria blight is the most common foliar disease of carrot. It can lower yields by reducing the leaf area available for photosynthesis and by destroying the carrot tops, which are necessary for mechanical harvesting. Early infection of seedlings can cause damping-off. Foliar lesions on mature plants resemble those caused by *Cercospora carotae* but are more irregularly shaped. The lesions generally first appear along the leaflet margins and are dark brown to black with a yellow border. When numerous, the spots grow together and the leaflets shrivel and die, giving a blighted appearance to the plant. Under cool, humid conditions, a velvety surface layer of mycelial growth and conidia on the leaves is visible to the naked eye. Merging of the lesions can girdle the petiole and the entire leaf may collapse and die. Blighted carrot tops may break off when gripped by mechanical harvesters, leaving the roots in the ground. Fleshy roots are not attacked by *Alternaria dauci*. In commercial fields, alternaria blight often appears later than cercospora blight because older leaves are more susceptible than younger leaves to *Alternaria* (Howard et al., 1994).



## REFERENCE FOR THE MODEL

**Alternaria blight:** Gillespie, T.J. and J.C. Sutton. 1979. A predictive scheme for timing fungicide applications to control Alternaria leaf blight in carrots. Can. J. Plant Pathol. 1:95-99.

Model was evaluated by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu from data collected by Agro-Production Lanaudière between 1999 and 2001 in the Lanaudière region of Québec.

### Infection risk table

Date for starting calculations = 1<sup>st</sup> April

Host: carrot	Infection index
Low	1
Moderate	2
High	3

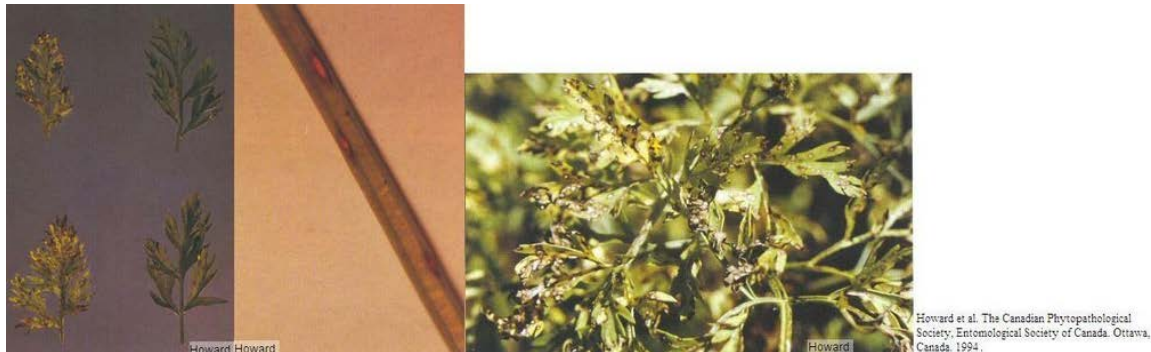
[Carrot](#)



## Cercospora blight



### PEST DESCRIPTION



*Cercospora* blight is frequently serious on carrots. In Quebec, it is more severe than alternaria blight. Generally, cercospora blight occurs earlier than alternaria blight. With both diseases, crop losses are due mainly to the carrots that are left behind by mechanical harvesters.

Primary lesions appear on leaflet margins and cause lateral curling. These lesions are elongated, while those that are not along the margin tend to be roughly circular. On the leaf, the lesions first appear as small chlorotic specks that soon enlarge into small, tan, brown or almost black spots with a necrotic centre surrounded by a yellowish area having no clear border. As the lesions increase in number and size, they grow together and the entire leaflet withers and dies. On the petioles and stems, lesions are elliptical and brownish with a paler centre, while in humid weather the spots are darker and the lower surface of the lesions appears light gray or silvery because of the mass of hyaline conidia, which is characteristic. Lesions may merge and girdle the stem, eventually causing collapse and death of the entire leaf. When mechanical harvesters grip the blighted carrot, the tops break easily, leaving the roots in the ground. When floral parts on carrot grown for seed are infected early, they shrivel before the seed is produced. However, when the infections occur later, the pathogen may enter the seed and serve as seed-borne inoculum. *Cercospora carotae* does not attack the fleshy roots (Brodeur *et al.*).

### REFERENCES FOR THE MODEL

- Carisse, O. and A.C. Kushalappa. 1990. Development of an infection model for *Cercospora carotae* on carrot based on temperature and leaf wetness duration. *Phytopathology* 80:1233-1238.
- Carisse, O. and A.C. Kushalappa. 1992. Influence of interrupted wet periods, relative humidity and temperature on infection of carrots by *Cercospora carotae*. *Phytopathology* 82:602-606.

**Development of the model:** The system used derives from an improved system designed by Odile Carisse (1992). Developed in 1993 using data from 1987, 1988 and 1990. It has been evaluated by CIPRA since 1995.



## Infection risk table

Date for starting calculations: NA

Host: cercospora blight	Infection index
Treatment threshold	2

## INTERPRETATION OF THE CURVE<sup>1</sup>

The system calculates infection severity indices on a scale ranging from 0 to 10. These indices are highly concrete and have been validated in the field. For example, when the index is below 2, this means that few or no spots have appeared on the foliage after the incubation period of 8 to 12 days.

The index is a multiplication factor, that is, if the index is 5 and no spots are observed in the field, the risk of an outbreak of the disease is very low. However, treatment may sometimes be necessary even if the index value is low. For example, if the index is 3, but the field is already appreciably infected and the weather forecasts point to a prolonged wet period, or the prediction curve is still rising, it is best to treat.

The decision on whether to treat or not is entirely up to the user and depends on numerous factors such as the age of the carrots, the cultivar, the harvest date, the number of previous infections, the extent of fungicide coverage, and naturally, the weather forecasts. The Conseil des productions végétales du Québec (Quebec plant production board) recommends that treatment not be initiated until the carrots are about 15 cm tall. It also recommends that users hold off treatment until the leaf canopy half covers the row, unless the weather is exceptionally wet. Furthermore, early-maturing carrots generally do not need to be treated. Beginning in September, there is no further risk from cercospora blight. However, in some cases, another disease, [Alternaria leaf blight](#), may develop during cool weather.

Alternatives to treating while maintaining the crop yield can be found in the information bulletin: "La cercosporose de la carotte - Stratégies de lutte." <http://publications.gc.ca/collections/Collection/A42-86-1998E.pdf>. See bibliography.

The latest edition of this text was made on March 1998.

[Carrot](#)

---

<sup>1</sup> Agrologist, Productions en régie intégrée du Sud de Montréal, enr. (PRISME), Sherrington, Québec.



## Insects

### Carrot rust fly



#### PEST DESCRIPTION



Carrot rust fly adults are black, about 6 mm in length with a small, reddish head and long yellow legs. The larva is legless and cream-white with dark mouthhooks. The pupa is cylindrical, about 4.5 mm in length, and red-brown.

Damage by the carrot rust fly is caused by the larvae. They are attracted by carbon dioxide emitted by the carrot plant, and feed on the root radicles. Young carrot plants may die from damage to the radicles. Roots of older carrot plants may become forked, stunted, or fibrous because of these early attacks. Older larvae enter the main root and tunnel in the lower third, root portion. In Quebec and Ontario, the first summer-generation matures before it can damage early carrots. Most damage is caused by the second summer-generation and, in British Columbia, also by the first and third summer-generations. Areas near shelter-plants are more likely to show damage, whereas carrot crops in open areas generally are not affected by this insect. The adult carrot rust fly does not transmit pathogens. However, bacteria and fungi can invade the carrot root through tunnels made by the larvae, and late-maturing larvae can cause important post-harvest damage to carrots in storage (Howard *et al.*, 1994).

#### REFERENCE FOR THE MODEL

**Carrot rust fly:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu. The data used to calibrate the model were collected at the experimental farm in Sainte-Clotilde by Dr Guy Boivin's entomology team from 1983 to 2009.

The results were compiled by Dominique Plouffe in the spring of 2011.



## Cumulative Degree days for each threshold development

Base temperature = 3°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: carrot	Degree Days (°C)
1 <sup>st</sup> generation, 5% adults	444
1 <sup>st</sup> generation, 50% adults	538
1 <sup>st</sup> generation, 95% adults	718
2 <sup>nd</sup> generation, 5% adults	1806
2 <sup>nd</sup> generation, 50% adults	2034
2 <sup>nd</sup> generation, 95% adults	2247

## INTERPRETATION OF THE CURVE<sup>1, 2</sup>

To use the carrot rust fly development model, it is imperative to have a good idea of the size of the fly population. This requires identifying this insect in sticky trap catches, a task which some people may find difficult. It is also important to have precise knowledge of the field's history in order to avoid unnecessary treatment. The carrot rust fly is seldom a problem in Quebec. The model is theoretical and predicts catches of adult insects.

If treatment is considered necessary based on the previous history of damage, an insecticide application should be made between the first catches and the date on which catches are expected to reach 50% (according to the curve). During this window of opportunity, however, producers should treat only if the weather conditions are particularly favourable, because these insects do not fly well and they tend to hide when it is very windy. Applying insecticide during calm periods will maximize the effect of the treatment and also reduce drift.

Keep in mind that insecticide applications, where required, can often be made near shelterbelts. According to some people, crop rotation virtually eliminates the need for control measures. Based on findings from recent studies, carrots that are to be harvested before early October do not need to be treated. If the field has a previous history of damage and no crop rotations have been made, it might be a good idea to sow earlier.

The latest edition of this text was made on March 1998.

### [Carrot](#)

---

<sup>1</sup> Text written in collaboration with Pierre Sauriol, agrologist, Productions en régie intégrée du Sud de Montréal, enr. (PRISME), Sherrington, Québec.

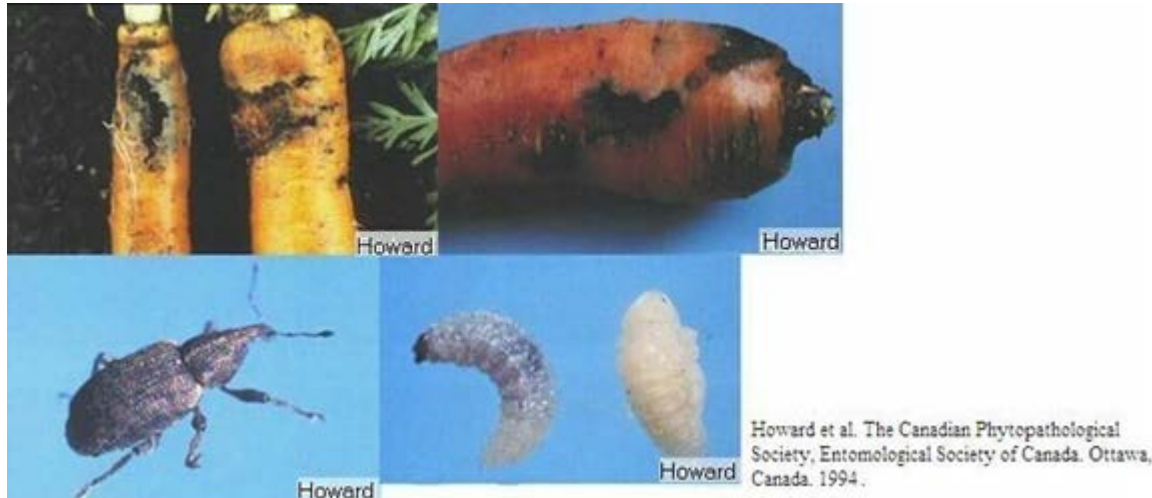
<sup>2</sup> Text written in collaboration with Mario Asselin, retired agrologist, Ministère de l'Agriculture des Pêcheries et de l'Alimentation of Québec, Saint-Rémi, Québec.



## Carrot weevil



### PEST DESCRIPTION



Carrot weevil adults are elongated and dark brown to black with a striped pattern on the thorax and forewings. They average 7 mm in length and 2.5 mm in width, males generally being smaller than females. Eggs measure 0.8 by 0.5 mm, are pale yellow when laid, darken with age, and turn black just prior to hatching.

On carrots, the larvae of the carrot weevil causes economic damage by tunneling into the petiole, heart, and root of the plant. The tunnels of young larvae are small. Tunnels of later-instar larvae may be as much as 5 to 8 mm wide. The feeding larva leaves a thin layer of cells, which eventually collapses during the season, leaving visible scars on the roots. Generally, larval tunnels are present in the upper third of the root. Young carrot plants may wilt or die as a result of attack by carrot weevil larvae, and bacteria and fungi may invade carrot roots through the tunnels made by the larvae. Damage to poorly treated, commercial fields may reach 12%. In untreated fields, however, the carrot weevil can damage up to 70% of a carrot crop (Howard *et al.*, 1994).

### REFERENCE FOR THE MODEL

**Carrot weevil:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu. The data used to calibrate the model were collected at the experimental farm in Sainte-Clotilde by Dr Guy Boivin's entomology team from 1983 to 2008.

The results were compiled by Dominique Plouffe in the spring of 2011.



## Cumulative Degree days for each threshold development

Base temperature = 4°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> adults capture

Host: carrot	Degree Days (°C)
5% adults	127
50% adults	246
95% adults	508

## INTERPRETATION OF THE CURVE<sup>1</sup>

Each of the infection curves developed for the carrot weevil is important in its own way. When the curve indicates that oviposition is beginning, it is time to set out traps. A threshold of 10% indicates that egg-laying has started and a decision should be made on whether or not to treat. An insecticide application should be made only where the carrots have reached the second true leaf stage and where the disease history of the field and/or scouting indicates that weevil numbers may exceed the economic threshold. It is important to remember that for small fields there is always a greater risk of reaching the economic threshold than in large fields where the margins can be treated. Carrot weevils do not disperse very much.

When the curve shows that egg-laying has reached 90%, the number of catches can be expected to stop rising, although this applies solely to the current generation. Indeed, over the past few years, carrot weevils have succeeded in producing a second generation in Quebec. If this happens, it is a good idea to consult your advisor.

The latest edition of this text was made on March 1998.

[Carrot](#)

---

<sup>1</sup> Text written in collaboration with Pierre Sauriol, retired agrologist, Ministère de l'Agriculture des Pêcheries et de l'Alimentation of Québec, Saint-Rémi, Québec.



## Cranberry



Cranberry Phenology

### Insects

Cranberry tipworm

Cranberry fruitworm



## Cranberry Phenology



### DESCRIPTION (Guérin, 2009a)



Michigan state University, Mark Longstroth, 2000-2003.

#### 1) Dormant

The leaves are generally purple. The terminal buds have not begun to swell.

#### 2) Swollen bud

Three- to fourfold increase in the size of the buds. There are three different stages of bud swell:



Tight bud



Bud swell



Anonymous et Cabbagehead



Anonymous

University of Wisconsin-Madison, Steven Gordon, 1995.

Michigan state University, Anonyme, 2000-2003.



Mark



Anonymous



Anonymous

Michigan state University, Mark Longstroth, 2000-2003.

University of Wisconsin-Madison, 1995.

#### 3) Cabbagehead

The bud scales separate revealing the new leaves.

#### 4) Bud elongation

Leaves and flower bracts emerge from the bud. All new growth is held tightly and parallel to the stem.





University of Wisconsin-Madison.  
Steven Gordon. 1995.

University of Wisconsin-Madison.  
Ben Lear. 1995.

#### 5) Roughneck

Significant elongation of the stem; all flower buds and bracts are visible. New leaves are still oriented parallel to the stem. Flower pedicels have not elongated yet.

#### 6) Hook

Flower pedicels elongate, starting with the lowest flower buds and continuing toward the tip. The flower bud droops, forming the characteristic hook shape. The new leaves are oriented perpendicularly to the stem. This stage can be evaluated as a percentage.



Michigan state University. Mark  
Longstroth. 2000-2003.

#### 7) Bloom

Flowers open on the stem, starting from the lowest buds and continuing toward the tip. Flowering can be expressed as a percentage.

#### 8) Fruit set

Start of fruit formation. Stage following fertilization of the ovules. Fruit set may be expressed as a percentage.



Michigan state University, 2000-2003.

Michigan state University, Mark Longstroth,  
2000-2003.

#### 9) Fruit growth

Can be expressed as a percentage of final size. May also be evaluated in millimetres (6, 8, 10, 12, 15 and 18 mm)

#### 10) Fruit coloring

The fruits begin to turn red.





Michigan state University.  
Mark Longstroth. 2000-2003.

### 11) Harvest

The fruits have reached maturity and are ready to be harvested.

## REFERENCE FOR THE MODEL

**Cranberry phenology:** model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected by the "Club environnemental et technique Atocas Québec" (CETAQ) in 2007 and 2008 in the Centre-du-Québec region.

Results were compiled by Samanta Fortin Guérin during the 2009 fall.

### Cumulative Degree days for each threshold development

Base temperature = 5°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Cranberry	Degree Days (°C)
Beginning of elongation	365
Beginning of flower hook	503
10% flowering	663
50% flowering	756
10% fruit set	777
95% flowering	867
50% fruit set	877
95% fruit set	949

[Cranberry](#)



## Insects

### Cranberry fruitworm



#### PEST DESCRIPTION



Anonymous



Anonymous



Anonymous



Anonymous

Insectes ravageurs de la canneberge  
au Québec, Québec 2001.

Cranberry fruitworm is an insect pest belonging to the order Lepidoptera and the family Pyralidae. The adult is a small grey moth, 9 to 10 mm long, with two white spots on the forewings that distinguish it from other pyralid moths. Larval coloration ranges from brown in young larvae to shiny green in mature larvae. Larvae have 3 pairs of true legs on the thorax and 5 pairs of prolegs. They attain a length of 12 to 16 mm. The eggs are oval and about 0.4 mm in size. Freshly laid eggs are greenish in colour; an orange line appears on the eggs just before they hatch.

Cranberry fruitworm completes only one life cycle per year, hence producing only one generation in the summer. The insect goes through a winter diapause, overwintering as a mature larva inside a cocoon made of silk and sand particles and remains in or on the soil all winter long. Early in spring, the larva transforms into a pupa from which the adult emerges five weeks later. Adult emergence takes place from mid-June to end of July inclusively. The moths are rarely observed in fields because they are nocturnal, preferring to hide among the plants during the day.

Egg laying coincides with the fruit set stage in cranberry. Each female deposits about 50 eggs, singly, in the calyx cup area of the immature fruit. The eggs hatch about 5 to 10 days later. A small larva emerges and moves to the stem end of the fruit, close to the peduncle, where it bores a hole. After the larva enters the berry, it spins a silken window over the hole and begins feeding on the pulp. Once the larva has consumed all the inner flesh, it exits, leaving behind a frass- and silk-filled hollowed-out fruit. The larva migrates to another berry and starts feeding again. When the larvae move to subsequent berries, they do not necessarily enter at a specific point and they do not block the entrance hole with silk. Each larva can consume 5 to 8 berries during its life. This larval stage generally lasts from July through September. When the larvae reach maturity, they drop to the ground and spin a cocoon in which to hibernate.

Owing to the serious economic consequences that fruitworm infestations can have in the absence of control measures, cranberry fruitworm is considered a serious pest in Quebec. Damage can be seen only



on the fruit. Infested berries turn red prematurely and then wrinkle and wither. The dried up berries are blackish-brown and look like raisins. As the larva moves from berry to berry, it produces webs of silk and frass that encompass both infested berries and healthy ones. This results in the loss of a number of healthy berries (Guérin, 2009b).

## REFERENCE FOR THE MODEL

**Cranberry fruitworm:** model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected by the "Club environnemental et technique Atocas Québec" (CETAQ) in 2007 and 2008 in the Centre-du-Québec region.

Results were compiled by Samanta Fortin Guérin during the 2009 fall.

### Cumulative Degree days for each threshold development

Base temperature = 10°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: cranberry	Degree Days (°C)
5% adults	265
50% adults	364
95% adults	492

[Cranberry](#)



## Cranberry tipworm



### PEST DESCRIPTION



Lutte intégrée. Health Canada, 2004.

Insectes ravageurs de la  
canneberge au Québec, Québec  
2001.

Cranberry tipworm belongs to the order Diptera and the family Cecidomyiidae. The adult is a tiny, grey fly just 2 to 3 mm long. Adult females have a reddish abdomen. The eggs are translucent, slender and cylindrical with a reddish-orange pigment. The larvae progress through three instars, with all the larval stages lasting 7 to 10 days, depending on the temperature and the number of larvae present on the terminal shoot. All of the larval instars are legless.

Cranberry tipworm has a very short life cycle, allowing it to complete three generations on average every summer in Quebec. Each generation lasts 2 to 4 weeks, except in winter when the insect goes through diapause. During that period, the insect overwinters as a pupa inside a silken cocoon on the ground. The pupa is initially orange but darkens in colour before adult emergence. The adults usually emerge around mid-May just as the shoots begin to elongate. The adults mate, and the female moths fly to cranberry plants and lay their eggs near the base of terminal leaves. A female can lay 1 to 5 eggs. After a short incubation period, the eggs hatch and the larvae emerge.

The larva then pupates inside a cocoon. This stage lasts about 3 days when conditions are conducive to the development of another generation; otherwise, the larva will overwinter as a pupa in the soil and emerge the following spring to begin a new breeding cycle.

The cranberry tipworm is considered a major pest in Quebec because it is well adapted to cranberry crops and, in the absence of control measures, it can cause significant economic damage. Larval feeding on the terminal growth of shoots causes cupping to complete closure of the leaves. Eventually the leaves turn brown to black and fall off. The damage is sometimes mistaken for frost injury or blight. The loss of these leaves is critical since tipworm larvae infest the young inner leaves of uprights that would normally



bear flowers and fruit later in the season. Affected cranberry plants develop new lateral branches in response to the loss of uprights. Cranberry plants typically recover from early-season damage caused by the first generation of larvae by developing new shoots. However, second-generation larvae are more abundant and often cause more significant damage in terms of the quantity of fruit produced. The amount of damage that occurs depends on the length of the growing season. In regions with a sufficiently long growing season, less damage occurs because the plants have time to produce lateral branches. The third generation is usually smaller and therefore causes less damage (Guérin, 2009c).

## REFERENCE FOR THE MODEL

**Cranberry tipworm:** model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected by the "Club environnemental et technique Atocas Québec" (CETAQ) from 2007 to 2009 in the Centre-du-Québec region.

Results were compiled by Samanta Fortin Guérin during the 2009 fall.

### Cumulative Degree days for each threshold development

Base temperature = 10°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: cranberry	Degree Days (°C)
1 <sup>st</sup> generation, 5% egg-laying	174
1 <sup>st</sup> generation, 50% egg-laying	214
1 <sup>st</sup> generation, 95% egg-laying	262
2 <sup>nd</sup> generation, 5% egg-laying	327
2 <sup>nd</sup> generation, 50% egg-laying	401
2 <sup>nd</sup> generation, 95% egg-laying	481
3 <sup>rd</sup> generation, 5% egg-laying	585
3 <sup>rd</sup> generation, 50% egg-laying	660
3 <sup>rd</sup> generation, 95% egg-laying	738

[Cranberry](#)



## Crucifer (broccoli, brussels sprouts, cabbage)



Broccoli

### Broccoli Phenology

#### Insects

Diamondback moth  
Imported cabbageworm



Brussels sprouts

#### Insects

Diamondback moth  
Imported cabbageworm



Cabbage

#### Insects

Diamondback moth  
Imported cabbageworm



## Broccoli Phenology



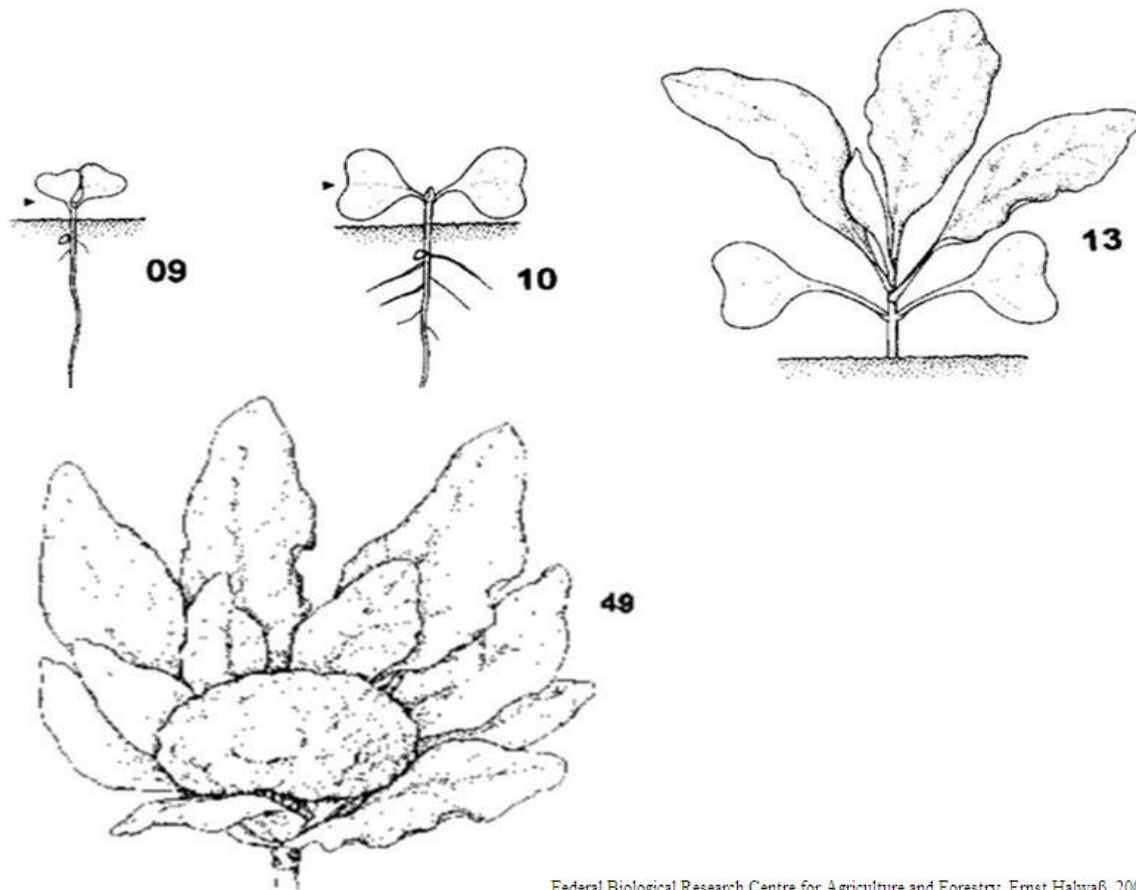
### DESCRIPTION

The BBCH scale used in the broccoli phenology model consists of a two-digit code that provides a precise description of the primary and secondary stages of crop development. The model encompasses two consecutive stages: foliar and commercial.

### Phenological growth stages and BBCH-identification keys of other brassica vegetables

(Meier, 2001)

(Brussels sprout = *Brassica oleracea* L. var. *gemmifera* DC./Zenk., cauliflower = *Brassica oleracea* L. var. *botrytis*, broccoli = *Brassica oleracea* L. var. *italica* Plenck)



Federal Biological Research Centre for Agriculture and Forestry, Ernst Halwaß, 2001.



Date for starting calculations:

Code	Description
<b>Principal growth stage 0: Germination</b>	
00	Dry seed
01	Beginning of seed imbibition
03	Seed imbibition complete
05	Radicle emerged from seed
07	Hypocotyl with cotyledons breaking through seed coat
09	Emergence: cotyledons break through soil surface
<b>Principal growth stage 1: Leaf development (Main shoot)</b>	
10	Cotyledons completely unfolded; growing point or true leaf initial visible
11	First true leaf unfolded
12	2nd true leaf unfolded
13	3rd true leaf unfolded
1 .	Stages continuous till . . .
19	9 or more true leaves unfolded
<b>Principal growth stage 2: Formation of side shoots</b>	
21	First side shoot visible
22	2nd side shoot visible
23	3rd side shoot visible
2 .	Stages continuous till . . .
29	9 or more side shoots visible
<b>Principal growth stage 4: Development of harvestable vegetative plant parts</b>	
41	Cauliflower heads begin to form; width of growing tip > 1 cm <sup>3</sup>
43	30% of the expected head diameter reached
45	50% of the expected head diameter reached
46	60% of the expected head diameter reached
47	70% of the expected head diameter reached
48	80% of the expected head diameter reached
49	Typical size and form reached; head tightly closed

## REFERENCE FOR THE MODEL

**Broccoli phenology:** model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (HRDC) in Saint-Jean-sur-Richelieu. The following data were used to calibrate the model:

- Data from growth chamber experiments carried out between 1999 and 2003
- Data collected from farmers' fields in the Lanaudière and Montérégie Est regions in 2007 and 2008.

The results were compiled by Marianne Blondin in the spring of 2009.

### Beginning of BBCH stages

Cultivars : Domador, Legacy, Monaco and Patron

Beginning of calculations = variable (date of sowing, transplantation or observation)

[Broccoli](#)



## Insects

### Diamondback moth



### PEST DESCRIPTION



The diamondback moth (family Plutellidae; Yponomeutidae also is used) gets its name from three silvery white, diamond-shaped marks that are distinguishable when the adult is at rest with its wings folded. The egg is less than 0.5 mm in length, oval, and yellowish to pale green. Larvae may reach 12 mm in length. They are relatively hairless, green to gray-green, and subcylindrical. They wriggle when disturbed and suspend themselves on silk threads. When mature, they pupate in a loose, open-mesh cocoon. The pupa is less than 8 mm long. Initially it is pale green but it darkens as it matures. The adult is gray-brown with a wingspan of about 13 mm.

The first-instar larva mines the leaf tissues. Older larvae feed on the lower leaf-surface, chewing irregular patches in the foliage. Only the upper epidermis may remain intact on severely damaged leaves, giving the leaf a silvery appearance. Older larvae feed on the florets of broccoli and cauliflower and bore into the edible portions of Brussels sprouts and cabbage. On rutabaga, larvae occasionally damage the crowns.

The diamondback moth is not known to disseminate plant pathogens but larval damage to plants may allow entry of secondary organisms (Howard et al., 1994).

### REFERENCE FOR THE MODEL

**Egg-laying model:** Godin C., and G. Boivin. 1998. Seasonal occurrence of lepidopterous pests of cruciferous crops in southwestern Quebec in relation to degree-day accumulations. *The Canadian Entomologist*, 130: 173-185.

**Larvae model:** developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected by the scouting group PRISME (Productions en Régie Intégrée du Sud de Montréal enr.) in the Ste-Clotilde region of Montérégie (QC) from 2000 to 2004.

Results were compiled by Caroline Dubé during the 2005 winter.



## Cumulative Degree days for each threshold development

### Egg-laying

Base temperature = 10°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> April

Hosts: cabbage / Brussels sprouts / broccoli	Degree Days (°C)
1 <sup>st</sup> generation, 10% egg-laying	170
1 <sup>st</sup> generation, 50% egg-laying	201
2 <sup>nd</sup> generation, 10% egg-laying	425
2 <sup>nd</sup> generation, 50% egg-laying	521
3 <sup>rd</sup> generation, 10% egg-laying	724
3 <sup>rd</sup> generation, 50% egg-laying	780

### Larva

Base temperature = 7.5°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> April

Hosts: cabbage / Brussels sprouts / broccoli	Degree Days (°C)
1 <sup>st</sup> generation, 10% larvae	377
1 <sup>st</sup> generation, 50% larvae	431
2 <sup>nd</sup> generation, 10% larvae	645
2 <sup>nd</sup> generation, 50% larvae	710
3 <sup>rd</sup> generation, 10% larvae	955
3 <sup>rd</sup> generation, 50% larvae	1037
4 <sup>th</sup> generation, 10% larvae	1269
4 <sup>th</sup> generation, 50% larvae	1330

[Broccoli](#)

[Cabbage](#)

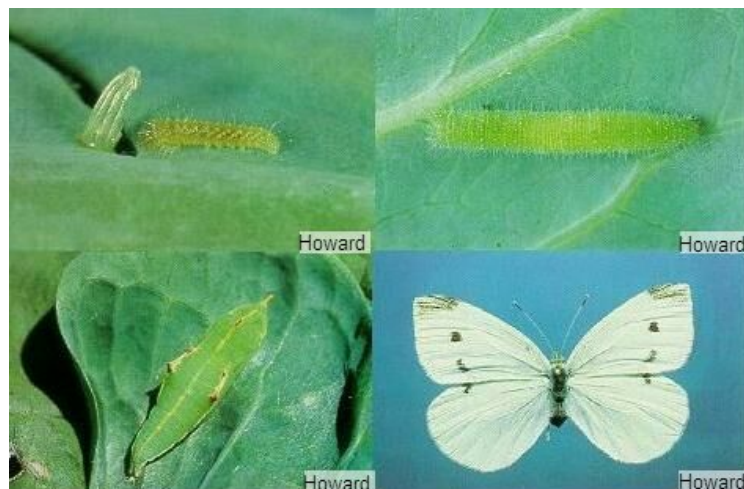
[Brussels sprouts](#)



## Imported cabbageworm



### PEST DESCRIPTION



Howard et al. The Canadian Phytopathological Society, Entomological Society of Canada. Ottawa, Canada. 1994.

The adult is the white butterfly (family Pieridae) familiar to gardeners. The egg is elliptical, pointed at the distal end, and flat where it touches the leaf. There are 12 lengthwise ridges on its surface. When laid, the egg is creamy white; it changes to light yellow as the embryo matures. The larva is a caterpillar 30 mm in length and pale green when fully grown, with five abdominal legs, a yellow-orange stripe along the length of the dorsal midline, and faint lateral bands at the level of the spiracles. Short, white hairs give it a velvety appearance. The chrysalis (pupa) is about 18 mm in length, and green to brown, depending on the substrate to which it is attached. The wings of the adult are white and reach 50 mm across, females being slightly larger than males. Males have a single black spot in the middle of the forewing. Females have two such spots. The forewing in both sexes has a dark patch at the apex and black scales along the leading edge. The hindwing has a small black patch at the outer edge.

The larvae chew holes in the leaves of the plants. Once the heads have started to form, feeding by a single larva can render a cabbage or cauliflower head unmarketable. When crops of broccoli, cabbage, and cauliflower become well established, the plants can tolerate extensive larval feeding. Larval frass contaminates the edible leaves and flower-heads.

The adult of the imported cabbageworm does not transmit plant pathogens but damage by the larvae may allow entry of secondary organisms (Howard et al., 1994).

### REFERENCE FOR THE MODEL

**Egg-laying and larvae models:** developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected by the scouting group PRISME (Productions en Régie Intégrée du Sud de Montréal enr.) in the Ste-Clotilde region of Montérégie (QC) from 2000 to 2004.

Results were compiled by Caroline Dubé during the 2005 winter.



## Cumulative Degree days for each threshold development

### Egg-laying

Base temperature = 8°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> April

Hosts: cabbage / Brussels Sprouts / broccoli	Degree Days (°C)
1 <sup>st</sup> generation, 10% egg-laying	189
1 <sup>st</sup> generation, 50% egg-laying	208
2 <sup>nd</sup> generation, 10% egg-laying	597
2 <sup>nd</sup> generation, 50% egg-laying	668
3 <sup>rd</sup> generation, 10% egg-laying	964
3 <sup>rd</sup> generation, 50% egg-laying	1054
4 <sup>th</sup> generation, 10% egg-laying	1266
4 <sup>th</sup> generation, 50% egg-laying	1311

### Larva

Base temperature = 10°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> April

Hosts: cabbage / Brussels Sprouts / broccoli	Degree Days (°C)
1 <sup>st</sup> generation, 10% larvae	161
1 <sup>st</sup> generation, 50% larvae	198
2 <sup>nd</sup> generation, 10% larvae	551
2 <sup>nd</sup> generation, 50% larvae	601
3 <sup>rd</sup> generation, 10% larvae	843
3 <sup>rd</sup> generation, 50% larvae	909
4 <sup>th</sup> generation, 10% larvae	1123
4 <sup>th</sup> generation, 50% larvae	1138

[Broccoli](#)

[Cabbage](#)

[Brussels sprouts](#)



## Gramineous (barley, spring wheat)



**Barley**

Disease

[Fusarium](#)



**Spring wheat**

Disease

[Fusarium](#)



## Disease

### Fusarium



#### DISEASE DESCRIPTION



Champeil, A. UMR d'Agronomie  
INRA/INRA P-G. Institut National  
Agronomique Paris-Grignon. 2004.

*Fusarium* head blight is mostly caused by *Gibberella zeae*, an ascomycete of Pyrenomycetes subclass, in Sphaeriales order and from Hypocreaceae family (Dewdney and Bourgeois, 2001). Affected wheat grains are small, light (the kernel is degraded), wrinkled and sometimes covered with a white or pink down. Rings or oval stains with brown edges and clear centres may be visible on the back of the grain and on the external surface of the glumes. *Fusarium* can engage up to 50% of lost yield for a culture. It results from the development of a complex of two genera of pathogenic fungi: *fusarium* (from *Ascomycetes* group) and *Microdochium* (from *Deuteromycetes* group, phylogenetically close to *Ascomycetes*). Fungus doesn't seem to migrate in the plant.

The risk of the *fusarium* group is its possible production of mycotoxins, when a stressful situation is followed by fungus adaptation. Mycotoxins reduce kernel quality and therefore, of the yield, generating negative effects on malting for beer or on fermenting for bread. Production of mycotoxins is hard to predict because it is not always correlated to visible damage of *fusarium*. Furthermore, visible damage does not systematically reduce yield. Also, the nutritive value of the grain reduces increasingly until it becomes poison for animals. Poisoning incidents cause nausea, which is the principal symptom, lethargy, fatty and cancerous infiltrations in tissue or cells and possibly even death. Levels of the mycotoxins, mainly produced by *Fusarium*, cannot be reduced after harvest by means of classical transformation procedures. Limits are 750 µg/kg (750 ppb) in raw cereal and 500 µg/kg in cereal-based products such as flour. Having a greatly ploughed soil may reduce mycotoxins threshold. Nevertheless, fungicides aren't really effective on *fusarium* for some unknown reasons (Champeil, 2004). Fungi can even survive up to 13 months of saprophytic state on harvest debris, when humidity rate is high (Dewdney and Bourgeois, 2001).



## REFERENCE FOR THE MODEL

### Infection risk tables

#### Hooker

Date for starting calculations = sowing date

Host: wheat	Concentration of DON (µg/g)
Low	0,1
Moderate	1
High	2
Very high	5

#### Wolf, model I

Date for starting calculations = sowing date

Host: wheat	Risk index (%)
50%	50

#### Wolf, model II

Date for starting calculations = sowing date

Host: wheat	Risk index (%)
79.6%	79.6

#### Wolf, model III

Date for starting calculations = sowing date

Host: wheat	Risk index (%)
50.2%	50.2

[Barley](#)

[Spring wheat](#)



## Leek



Insect

Leek moth

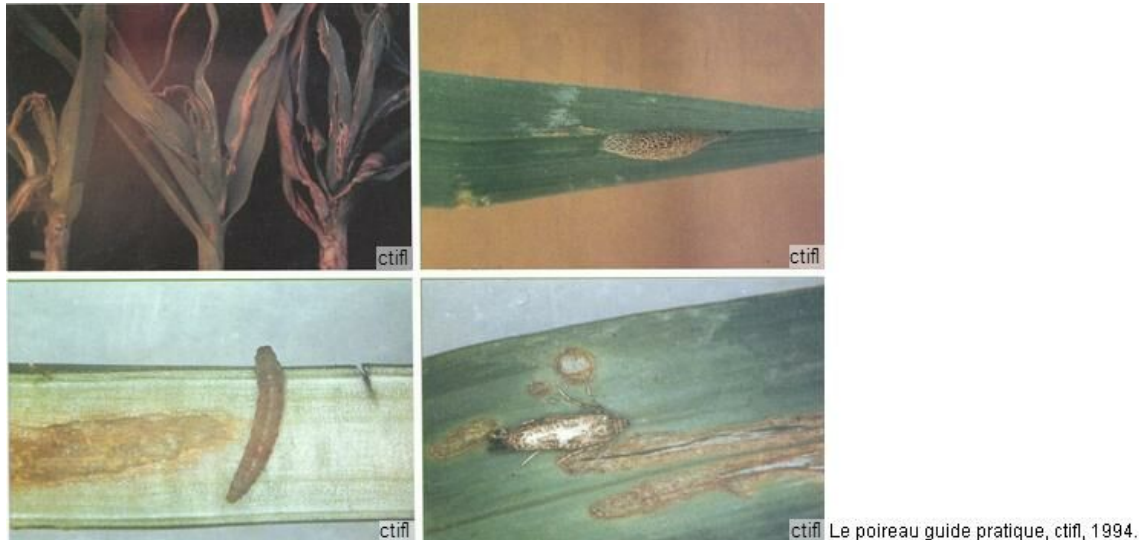


## Insect

### Leek moth



#### PEST DESCRIPTION



#### Biology and crop damage

Leek moth is a tiny insect which has four developmental stages: egg, larva (caterpillar), pupa (in a cocoon) and adult (moth). The larva is the stage that damages crops, since the caterpillar feeds on the leaves of leek plants.

The insect overwinters as an adult (moth) in tall weeds or clutter areas. Leek moths mate in early spring, and the females start laying eggs 2 to 6 days later, depending on the temperature. Eggs are laid singly at the base of leaves. After completing their development, the larvae climb out onto the foliage and spin their cocoons. Pupae can generally be found on the underside of leaves along the midrib.

In Quebec, the leek moth can complete three generations per year. The first generation of moths is sparse owing to heavy winter mortality (beginning of June capture); the second generation is modest in size (end of June to early July); the third generation is large (August) and can therefore cause more crop damage.

Leek moths can adversely affect the commercial value of leek crops, since damaged leek stalks are unmarketable.

Early-planted fields (harvested in August and September) are at greatest risk. When the crop is harvested in October, the plants have all of September to grow. Therefore, the damage inflicted by the third generation affects foliage higher up on the plants sparing the marketable portion.

#### Timing of insecticide applications<sup>1</sup>

French literature reports indicate that the best time to treat is when most of the larvae are mobile. During this stage (11-15 days after the first moths are captured or 2-5 days after hatch), the larvae start moving



around and are therefore more vulnerable to insecticide sprays. An application made about 12 days after the moths become active should eliminate a large number of the caterpillars. With a long egg-laying period, a second application should be made 7 days after the first treatment (Leblanc, 2006).

<sup>1</sup>Other alternative measures, described in the guide listed in the bibliography, may be helpful.

## REFERENCE FOR THE MODEL

**Leek moth:** model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data compiled by Mario Leblanc, MAPAQ (Ministry of Agriculture, Fisheries and Food, Québec) between 2004 and 2012 in several regions of Québec. The model was validated using data from Québec (2008) and Ontario (2004).

Results were compiled by Dominique Plouffe during the 2013 spring.

### Cumulative Degree days for each threshold development

Base temperature = 6°C

Optimal temperature = 36°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: leek	Degree Days (°C)
1 <sup>st</sup> generation, 50% adults	258
2 <sup>nd</sup> generation, 5% adults	586
2 <sup>nd</sup> generation, 20% adults	655
2 <sup>nd</sup> generation, 50% adults	739
2 <sup>nd</sup> generation, 80% adults	831
2 <sup>nd</sup> generation, 95% adults	914
3 <sup>rd</sup> generation, 5% adults	1122
3 <sup>rd</sup> generation, 20% adults	1202
3 <sup>rd</sup> generation, 50% adults	1282
3 <sup>rd</sup> generation, 80% adults	1357

[Leek](#)



## Lettuce



Disease

Downy mildew



## Disease

### Downy mildew



#### DISEASE DESCRIPTION



Howard et al. The Canadian Phytopathological Society, Entomological Society of Canada, Ottawa, Canada, 1994.

Downy mildew is a common fungal disease wherever lettuce is grown. It is a disease of cool, wet weather. It is most damaging in the field on early spring or late fall crops. It can also be a major disease of greenhouse lettuce. Isolates of *Bremia lactucae* from cultivated lettuce are restricted in host range to species of the same taxonomic sub-section of *Lactuca*.

Early infection of seedlings causes a cessation of cotyledon growth that leads to stunting or death of the plant. Sporulation occurs on both sides of the cotyledons, which become chlorotic. Cotyledons become less susceptible as they age and true leaves are less susceptible than cotyledons. Leaves of infected seedlings display slight chlorosis and a rolling of the leaf margins. Severe early infection may delay maturity and result in crops of inferior quality. On older plants, the first sign may be the appearance of sporangiophores from leaf stomata. These appear as discrete white projections that are visible to the naked eye. The sporangiophores are usually confined to the undersurfaces of mature leaves but, occasionally, they may occur on the upper leaf surface. On older leaves, lesions appear as light green or yellow areas delimited by large leaf veins on the upper surfaces. These chlorotic lesions turn necrotic or translucent and become brittle, especially near the leaf margin. The fungus may become systemic in the plant and cause a black-brown discoloration of stem tissues and leaf bases near the shoot tips of mature heads. Diseased leaves often become infected by soft rot bacteria and fungi. Downy mildew is frequently complicated by the presence of secondary soft-rotting bacteria and trimming waste may be considerable in marketed produce (Howard et al., 1994).

#### REFERENCE FOR THE MODEL

##### Infection risk table

Date for starting calculations = NA

Host: lettuce	Infection index
Treatment threshold	4

[Lettuce](#)



## Onion



### Disease

Botrytis leaf blight

### Insect

Onion maggot



## Disease

### Botrytis leaf blight



#### DISEASE DESCRIPTION



Botrytis leaf blight is one of the major foliar diseases of onion in cool climate areas. In Canada, it occurs annually in most areas where onions are grown. The severity of epidemics depends on local weather conditions. Levels of disease affecting less than 11% of leaf area do not decrease yield, but when disease is severe and leaves die back the bulbs may be small and fail to mature properly. Severely affected bulbs may not dry down enough for proper storage. They may also have fleshy leaf tissue at the neck rather than dry papery scales and are therefore more susceptible to storage rots. Rapid senescence of the leaves may also interfere with the application of sprout inhibitors, thus reducing the storage life of bulbs.

The first symptom is discrete, circular to elliptical, grayish white leaf spots, about 1 to 3 mm, which later become brownish-white and desiccated. Some lesions may extend through the wall of the leaf and split open with age, exposing the inside (lacuna) of the leaf. Newly formed lesions are often surrounded by an area where the epidermis has separated from the underlying leaf tissue giving the appearance of a silvery-white "halo" with uneven margins. This is characteristic of *Botrytis squamosa* infection on onion. The gray mold fungus *Botrytis cinerea* may also infect onion leaves, but the resulting lesions are smaller, do not penetrate to the inside of the leaf and do not develop halos. *Botrytis aclada* can cause limited foliar spotting, but it usually remains in a latent state until the bulb is mature or the leaf has senesced. Whitish flecks and spots caused by ozone injury lack the distinct margin and silvery halo characteristic of botrytis leaf blight.

Under favourable conditions, the number of lesions on a leaf increases, the lesions expand and merge, and the leaves begin to die back. Dieback usually begins at the leaf tip and may extend down the entire leaf. The lower, older leaves are usually the first to die. Sporulation occurs on necrotic leaf tips and occasionally on large lesions. Several species of *Botrytis* are associated with neck rot symptoms; that caused by *B. squamosa* is known as small sclerotial neck rot (Howard et al., 1994).



## REFERENCE FOR THE MODEL

### Lacy model

Lacy, M.L. and G.A. Pontius. 1983. Prediction of weather-mediated release of conidia of *Botrytis squamosa* from onion leaves in the fields. *Phytopathology* 73:670-676.

This model has been evaluated using CIPRA since 1995.

A modified version of the *Lacy* model was developed by Gaétan Bourgeois to obtain a better match with observations during warm, wet weather.

### Cumulative Degree days for each threshold development

#### Lacy and Lacy modified

Date for starting calculations = NA

Host: onion	Sporulation index
Intermediate risk	50
High risk	80

## INTERPRETATION OF THE CURVE<sup>1, 2</sup>

The *Botrytis* leaf blight model has two sporulation indices, namely a high risk index (80%) and a moderate risk index (50%). It is used not only to predict sporulation periods and thus plan control measures for fields, but also to gauge the level of inoculum. For example, if many periods of sporulation have occurred during the early part of the season, conditions are likely to be conducive to disease development. In such a case, the moderate risk threshold can be employed in making decisions about control measures. Similarly, in Quebec fungicide applications are not usually applied before June 20 or 25; however, if a number of infection periods have been recorded in early summer, it is advisable to adopt a different approach. Conversely, during a fairly dry summer, the 80% threshold should be used above all.

It is imperative to take into account the crop's development and to hold off treatment until the onion plants are at least 15 cm tall (when about 20% of the first leaves are dead). In addition, the type of cultivar being grown has a considerable bearing on the decision about whether or not to treat. For example, a producer growing a variety that is sensitive to *Botrytis* leaf blight will have to make a lot more fungicide applications than in the case of a tolerant variety.

The latest edition of this text was made on March 1998.

### [Onion](#)

<sup>1</sup> Text written in collaboration with Pierre Sauriol, agrologist, Productions en régie intégrée du Sud de Montréal, enr. (PRISME), Sherrington, Québec.

<sup>2</sup> Text written in collaboration with Mario Asselin, retired agrologist, Ministère de l'Agriculture des Pêcheries et de l'Alimentation of Québec, Saint-Rémi, Québec.



## Insect

### Onion maggot



#### PEST DESCRIPTION



The onion maggot adult is a pale gray fly that resembles the common house fly but is smaller (6 mm long) and has longer legs. Eggs are about 1 to 1.5 mm long and are white, with a striated surface. Larvae are legless, cream-colored maggots that taper toward the anterior end, with a pair of black mouthhooks. Fully grown larvae are about 6 to 8 mm long. Pupae are 5 to 7 mm long, chestnut-brown and resemble grains of wheat.

The onion maggot is the most serious insect pest of onion in temperate regions. It was introduced into eastern North America from Europe around 1875 and is now present throughout all commercial onion-growing areas of Canada.

The greatest economic damage to commercial onion is caused by first-generation larvae in the spring, when the plants are small. The larvae can destroy 20 to 30 onion seedlings in the loop stage, because they readily move between adjacent plants. Also, because females lay eggs in batches, damage appears clumped within onion beds. Damage from the first-generation larval attack usually can be seen by early June in British Columbia or by mid- to late June in eastern Canada. Above-ground damage symptoms depend on the growth stage of the plants. When damage occurs at the loop stage or earlier, onion may simply wilt and disappear. Plants that are attacked in the two- to three-leaf stage develop a gray cast, wilt, turn pale green to yellow, and usually remain in place within the row. When these wilted plants are pulled, they often break just below the soil surface, exposing the feeding maggot inside the rotting stem. Onion plants attacked in late June or early July are not killed and above-ground symptoms are difficult to detect. Fewer plants are damaged at this time because maggots no longer migrate between onion bulbs. However, plants damaged at mid-season will have misshapen bulbs that often are secondarily infected with fungi and bacteria. Damage from later generations of larvae causes little economic loss to growers because most onions will already have been lifted for curing in windrows in the field by the time the females are ovipositing. Eggs are often laid on windrowed onions or in the surrounding soil but very few maggots enter healthy, undamaged bulbs at that time of year. Annual losses to commercial onion crops average about 2 to 5% across Canada, despite heavy use of costly insecticides. In the absence of insecticidal treatments, average yearly losses to onion maggot would be in the order of 40 to 45% in commercial fields and could reach 100% in small plots or home gardens (Howard et al., 1994).



## REFERENCE FOR THE MODEL

**Onion maggot:** Boivin, G. and D.L. Benoit. 1987. Predicting onion maggot (Diptera: Anthomyiidae) flights in southwestern Québec using degree-days and common weeds. *Phytoprotection* 68:65-70.

### Cumulative Degree days for each threshold development

Base temperature = 4°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> April

Host: onion	Degree Days (°C)
Overwintering generation, 5% adults	269
Overwintering generation, 50% adults	572
1 <sup>st</sup> generation, 5% adults	1072
1 <sup>st</sup> generation, 50% adults	1368
2 <sup>nd</sup> generation, 5% adults	1803
2 <sup>nd</sup> generation, 50% adults	1947

## INTERPRETATION OF THE CURVE<sup>1, 2</sup>

The main preventive strategy for onion maggot is rotating crops. The models for this insect pest are designed primarily for planted onions (Spanish onions especially) and leeks. Producers commonly apply a granular insecticide to the soil during sowing, which solves the problem in the case of bunch onions and storage onions (yellow or dry onions).

The model may be useful where granular insecticide treatment has not been very effective. If damage has occurred, a large population of first generation insects may develop (the previous generation being the overwintering one). In such a case, it is a good idea to use the model that predicts adult catches. Foliar applications can be made even if they are not very effective. Where suitable, treatments may be scheduled 15 days after the emergence of the first adults (at that point, 25 to 30% of the adults that have emerged will be sexually mature).

The second generation of maggots, which arises at the end of the season and is covered by the model, is not a problem for Quebec growers. Nevertheless, they are considered a serious pest in New York State, where they cause considerable damage to stored onion bulbs.

The latest edition of this text was made on March 1998.

### Onion

<sup>1</sup> Text written in collaboration with Pierre Sauriol, retired agrologist, Ministère de l'Agriculture des Pêcheries et de l'Alimentation of Québec, Saint-Rémi, Québec.

<sup>2</sup> Text written in collaboration with Mario Asselin, agrologist, Productions en régie intégrée du Sud de Montréal, enr. (PRISME), Sherrington, Québec.



## Potato



Disease

Late blight

Insect

Colorado potato beetle



## Disease

### Late blight



#### DISEASE DESCRIPTION



Before the general use of foliar fungicides, late blight was the most destructive fungal disease of potatoes. The first symptoms of late blight usually appear on older leaves soon after flowering, following warm and wet or humid weather. Dark green, water-soaked areas at the leaf tips spread inward and become dark brown and brittle in one or two days. On the underside of infected leaves, lesion edges may exhibit a fluffy white fungal growth that is visible on dewy mornings and during periods of high humidity. This fluffy mildew produces sporangia that are spread by rain and wind to other plants. Under suitably wet or humid conditions, the disease can spread rapidly within the crop, resulting in defoliation, plant death and yield loss.

Late blight lesions can resemble those of early blight in the early stages of development. However, late blight will obliterate the pattern of venation on leaves, whereas early blight does not. Tubers at or near the soil surface can be infected. Lesions on the surface of tubers are irregular, sunken and usually appear in and around the eyes. Affected tissue is granular and reddish in appearance and it may penetrate up to 2 cm into the tuber. Storage of diseased tubers can result in infection of other tubers and cause extensive crop loss (Howard et al., 1994).

#### REFERENCES FOR THE MODEL

**Late blight:** Hyre (1954) developed the model that was greatly modified for the province of Quebec by Roger Léonard from Environment Canada and Léon Tartier from the Quebec Ministry of Agriculture, Fisheries and Food. Then, it was evaluated during 20 years all over the province and validated for the Montreal region. That model is a statistical model based on observations.

Léonard, R. et L. Tartier. 1981. Étude sur la prévision du mildiou de la pomme de terre. Rapport interne #36. c.m.d. Environnement Canada, Montréal.

Léonard, R. et L. Tartier. 1991. Vérification du modèle de prévision du mildiou de la pomme de terre utilisé au Québec par L'Assomption et Sainte-Clotilde de 1979 à 1987. Rapport interne #37. c.m.d. Environnement Canada, Montréal.



## Infection risk tables

### Hyre-Tartier

With initialization

Date for starting calculations = variable

Host: potato	Favourable days
Threshold for first treatment	8
Threshold for other treatments	5

Without initialization

Date for starting calculations = NA

Host: potato	Favourable days (last 7 days)
Treatment threshold	5

### Wallin

With initialization

Date for starting calculations = variable

Host: potato	Severity values
Threshold for first treatment	18
Threshold for other treatments	3

Without initialization

Date for starting calculations = NA

Host: potato	Severity values (last 7 days)
Treatment threshold	3



## Blitecast and Blitecast-Tartier

With initialization

Date for starting calculations = variable

Host: potato	Risk index
Low risk	1
Intermediate risk	2
High risk	3

Without initialization

Date for starting calculations = NA

Host: potato	Risk index
Low risk	1
Intermediate risk	2
High risk	3

## INTERPRETATION OF THE CURVE<sup>1</sup>

Late blight of potato is endemic, and unlike the situation with most crop diseases and pests, fungicide applications are required regardless of field history and the results of scouting. Following fungicide treatment, growers can simply keep track of the five-consecutive-day threshold for the disease.

Late blight is a disease that reaches epidemic proportions and requires yearly fungicide applications during periods when weather conditions are conducive to its development. Rigorous monitoring, field scouting and monitoring of conditions favourable to its appearance are necessary in order to determine the best timing for preventive fungicide applications. Early in the growing season, when potato plants are higher than 15 to 20 cm, it is recommended that a treatment be made as soon as the eight-consecutive-day threshold is reached, as indicated by the forecasting model.

After the first fungicide application, the recommendations change. Further applications should be made in the week after the model shows five consecutive days of conditions favourable to disease, or when the foliage is no longer protected. Rainfall in excess of 25 mm is generally considered sufficient to have washed all the fungicide off the potato plant leaves.

The latest edition of this text was made on March 1998.

### [Potato](#)

---

<sup>1</sup> Text prepared in collaboration with Léon Tartier, retired plant pathologist with the Centre de recherche en production végétale de Saint-Hyacinthe, Quebec Department of Agriculture, Fisheries and Food.

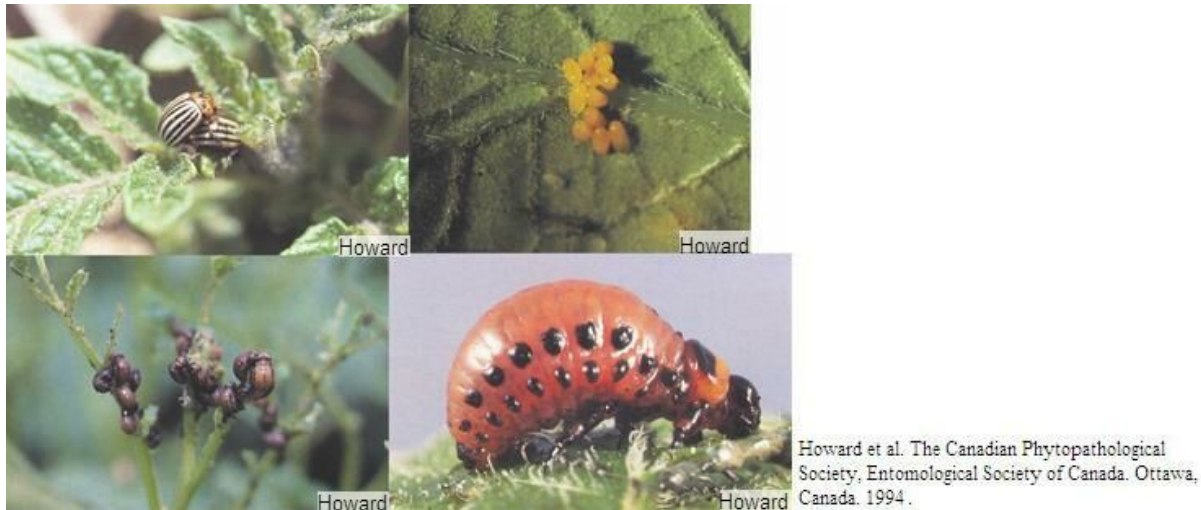


## Insect

### Colorado potato beetle



#### PEST DESCRIPTION



The Colorado potato beetle adult is about 10 mm long and 7 mm wide, and somewhat rounded. Its head and anterior thorax are brown-orange to yellow and covered with variously shaped black markings. Ten black lines run the length of the forewings, which otherwise are pale yellow. The eggs are elongated and yellow to orange, and usually they are laid on the underside of leaves in clusters of about 30. The larva is humpbacked, and red-orange with two rows of black spots along the sides of the body.

The adult and all larval stages feed mostly on foliage, chewing irregular holes in and along leaf margins, but they also may attack stems. High populations can completely defoliate plants throughout large portions of a field. Extensive feeding at any time during the season, especially when the crop is in bloom, can reduce yield. Generally, a reduction in leaf surface decreases the ability of potato plants to produce nutrients for storage in the tubers (Howard et al., 1994).

#### REFERENCE FOR THE MODEL

**Colorado potato beetle:** model developed by the Bioclimatology and Modelling research team of the Agriculture and Agri-Food Canada's Horticulture Research and Development Centre at St-Jean-sur-Richelieu, using data collected by the scouting groups Phytodata and Agréco from 1990 to 1998. Data came from about 30 commercial fields located on the South Shore of Montreal and in the Centre-du-Quebec region (QC).

Results were compiled by Maude Lachapelle during the summer 2007.



### Cumulative degree days for each threshold development

Base temperature =10°C

Optimal temperature =40°C

Method = single sine

Date for starting calculations = variable (starting point for calculations, sowing date, 5% adults or 5% egg-laying)

Host: potato	Degree Days (°C)
5% adults	147
5% egg-laying	197
5% larvae, 1 <sup>st</sup> and 2 <sup>nd</sup> instar	275
5% larvae, 3 <sup>rd</sup> and 4 <sup>th</sup> instar	321
85% larvae, 1 <sup>st</sup> and 2 <sup>nd</sup> instar	339

[Potato](#)



## Strawberry



Strawberry Phenology

Insect

Bud weevil

Disease

Strawberry leaf spot



## Strawberry Phenology



**DESCRIPTION OF THE BENCHMARK STAGES** (Photos: Urbain et al., 2010; Khanizadeh et al., 2005; Bostanian 1994)



**Stage 1** Onset of vegetative growth: first appearance of leaf buds and rudimentary leaves.

**Stage 2** Green bud: first appearance of flower buds among the rudimentary leaves. About 10% of the plants in the field have developed buds.



**Stage 3** White bud: peduncle over 2.5 cm in length in over 10% of plants in the field.

**Stage 4** First bloom: first appearance of a flower in bloom in the inflorescence.



**Stage 5** Beginning of petal fall: most of the petals of the first flower are shed and the first berry is set.

**Stage 6** First green fruit: small green berries visible on over 10% of the vines.





**Stage 7,5** First ripe fruit: first berry 100% red and physiologically ripe.

**Stage 8** First pick: first cluster of berries ready to be picked.

## REFERENCE FOR THE MODEL

**Strawberry phenology:** Mailloux, G. and N.J. Bostanian, 1991. The phenological development of strawberry plants and its relation to tarnished plant bug seasonal abundance. Adv. Straw. Prod., 10:30-36.

### Cumulative Degree days for each threshold development

**Cultivar: Bounty**

Base temperature = 0°C

Optimal temperature = 40°C

Method = single average

Date for starting calculations = 1<sup>st</sup> April

Strawberry: Bounty	Degree Days (°C)
Green bud	361
White bud	460
First bloom	492
Beginning of petal fall	570
First green fruit	625
First ripe fruit	954



**Cultivar: Redcoat**

Base temperature = 0°C

Optimal temperature = 40°C

Method = single average

Date for starting calculations = 1<sup>st</sup> April

<b>Strawberry: Redcoat</b>	<b>Degree Days (°C)</b>
Green bud	315
White bud	390
First bloom	450
Beginning of petal fall	534
First green fruit	598
First ripe fruit	877

[Strawberry](#)



## Disease

### Leaf spot



### DISEASE DESCRIPTION



Strawberry leaf spot is caused by an ascomycete fungus, *Mycosphaerella fragariae* (Tul.) Lindau (asexual state *Ramularia tulasnei* Sacc.). The disease is now found in several strawberry cultivars. The first symptoms of the disease are small lesions on the surface of young leaflets. The lesions enlarge, forming more or less circular spots, measuring 3 to 6 mm in diameter. As the spots enlarge, the centres turn gray to white and are surrounded by reddish borders, hence the name *bird's eye spot*. The lighter centre distinguishes leaf spot from leaf scorch, which is caused by *Diplocarpon earliana*, and which appears as small dark-purple spots. When weather conditions are favourable, the spots multiply and coalesce, causing the entire leaf to dry up and die. All aerial parts of the plant, particularly sepals, can eventually be attacked and black spots can appear on the achenes of the fruit when the disease reaches epidemic levels. Apparition of symptoms depends on strawberry cultivar, fungus breed and temperature at time of infection. Usually, plants are more sensitive at the beginning and end of season, during active foliage growth (Brodeur et al.).

### REFERENCE FOR THE MODEL

**Leaf spot:** Carisse, O., Bourgeois, G., Duthie, J. A. 2000. Influence of temperature and leaf wetness duration on infection of strawberry leaves by *Mycosphaerella fragariae*. *Phytopathology* 90(10): 1120-1125.



### Infection risk table

Date for starting calculations = 1<sup>st</sup> April

Host: strawberry	Infection index
Moderate	1.5
High	3

[Strawberry](#)

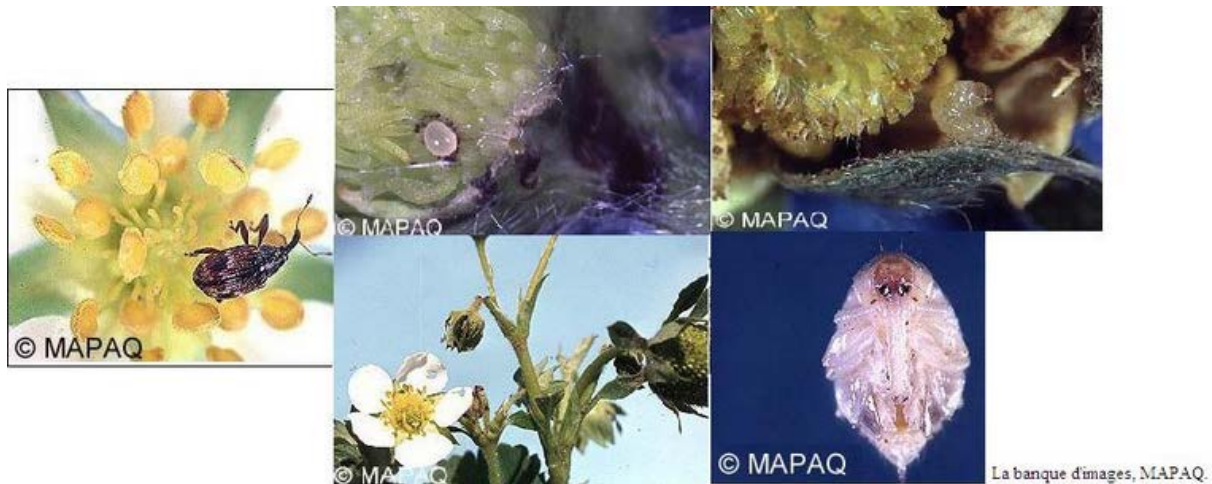


## Insect

### Bud weevil



#### PEST DESCRIPTION



This little weevil is a native insect that feeds on wild strawberry, dewberry, brambles, and redbud, in addition to cultivated strawberries. The adult is a brown snout beetle with black patches on the wings, and is scarcely 3 mm in length. Larvae are correspondingly small white thick-bodied curved grubs. Hibernating beetles emerge in early spring, feeding first on whatever food plant is available. When strawberry blossom buds are formed the beetles lay eggs in the feeding punctures that they make in this part of the plant. Then they move down a short distance and partly cut through the stem, causing the bud to wilt, fall over at a sharp angle, or drop to the ground. Because of this habit the insect is sometimes known as the "clipper". In the buds the larvae complete their development before mid-summer, change to pupae, and emerge as adults. After a short feeding period they go into hibernation; there is one generation each year (Davidson, 1979).

#### REFERENCE FOR THE MODEL

**Bud weevil:** Mailloux, G. and N.J. Bostanian. 1993. Development of the strawberry bud weevil (Coleoptera:Curculionidae) in strawberry fields. *Entomol. Soc. Am.* 86(3)384-393.



### Cumulative Degree days for each threshold development

Base temperature = 0°C

Optimal temperature = 35°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> April

Host: strawberry	Degree Days (°C)
1 <sup>st</sup> eggs	321
1 <sup>st</sup> larvae, 1 <sup>st</sup> instar	486
1 <sup>st</sup> larvae, 2 <sup>nd</sup> instar	542
1 <sup>st</sup> larvae, 3 <sup>rd</sup> instar	742
1 <sup>st</sup> pupae	992
1 <sup>st</sup> adults	1153

[Strawberry](#)



## Sweet corn



Insect

European corn borer

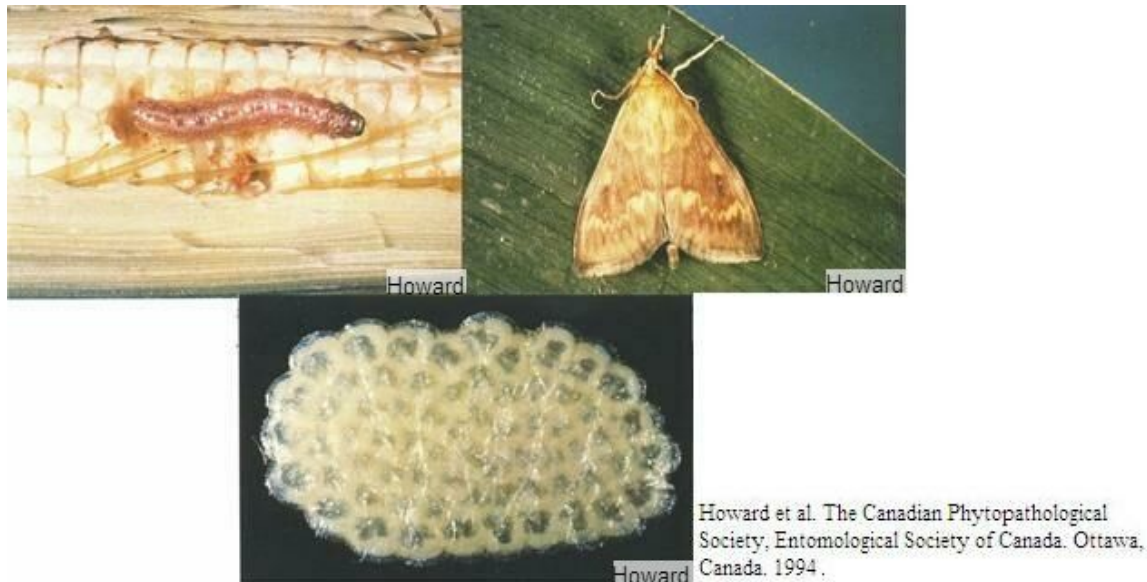


## Insect

### European corn borer univoltine



### PEST DESCRIPTION



The European corn borer larva is a caterpillar about 3 cm in length at maturity, and gray to tan above with brown, spot-like plates with setae. The adult moth's wingspan is about 2.5 cm; the wings are light brown with dark wavy bands. The male is smaller and darker than the female.

Since its introduction into southwestern Ontario in 1920, the European corn borer has spread across Canada from the Maritime provinces to the Rocky Mountains. In Alberta, although detected and eradicated in the 1950s, a well-established infestation was discovered in 1981 in the Medicine Hat-Bow Island area and has since expanded throughout the southern part of that province.

Different strains of the corn borer cause different types of damage to sweet corn. Larval feeding on corn ears is the primary cause of yield loss but all parts of the plant are subject to attack. The larvae eat through the tightly rolled leaves developing in the whorl. This results in the first sign of damage, a row of "pin holes" in the leaves when they unroll from the whorl. As the leaves enlarge and the holes coalesce, midrib breakage may occur. Some larvae also may bore into the tassel, weakening it and increasing the likelihood of its breaking in the wind. Eventually, the larvae enter the stalk and developing ears, which may lead to stalk breakage, poor ear development and fallen ears. First-generation larvae cause mainly physiological damage to the growing plant; second-generation larvae are responsible for shank and ear damage.

In sweet corn, infestation of the ears is the major concern, regardless of the generation of corn borer involved. Not only are infested ears and damaged shanks unsuitable for fresh-market sale but small larvae may reside in kernels of sweet corn destined for processing (Howard et al., 1994).

For more information about sampling and decision support, refer to Duval et al. (2013) in the bibliography.



## REFERENCE FOR THE MODEL

**European corn borer, univoltine race:** model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected in several sites in south Québec by:

- 1) Marcel Hudon (insects bred in laboratory) from 1956 to 1970
- 2) MAPAQ (Ministry of Agriculture, Fisheries and Food, Québec) from 1975 to 1987 and from 1993 to 1996
- 3) Groupe Bio-Contrôle (Denis Bouchard) from 1996 to 1999
- 4) PRISME (François Charbonneau) in 1996
- 5) IRDA (Josée Boisclair) between 1977 and 2008

Results were compiled by Anne-Marie Fortier during the 2007 fall. Model was updated by Dominique Plouffe using data from IRDA, in the fall of 2009.

**European corn borer, bivoltine race:** model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected in several sites in south Québec by IRDA (Josée Boisclair) between 1977 and 2008.

Results were compiled by Dominique Plouffe during spring of 2010.

### Cumulative Degree days for each threshold development

#### Univoltine race

Base temperature = 10°C

Optimal temperature = 35°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> April

Host: sweet corn	Degree Days (°C)
5% pupae	231
50% pupae	340
5% adults	394
5% eggs	425
95% pupae	465
50% eggs	540
50% adults	562
95% eggs	678
95% adults	735



## Cumulative Degree days for each threshold development

### Bivoltine race

Base temperature = 10°C

Optimal temperature = 35°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> April

Host: sweet corn	Degree Days (°C)
1 <sup>st</sup> generation, 5% adults	190
1 <sup>st</sup> generation, 50% adults	281
1 <sup>st</sup> generation, 95% adults	395
2 <sup>nd</sup> generation, 5% adults	792
2 <sup>nd</sup> generation, 50% adults	919
2 <sup>nd</sup> generation, 95% adults	1027

## INTERPRETATION OF THE CURVE<sup>1</sup>

This model simulates the evolution of populations of the univoltine strain of European corn borer (pupa, adult and egg stages) in Quebec. It was developed by Gaétan Bourgeois using data collected in L'Acadie, Quebec by Marcel Hudon from 1956 to 1972 and in Centre-du-Québec and Montérégie by Prisme, MAPAQ (Ministry of Agriculture, Fisheries and Food, Québec) and Bio-Contrôle.

Based on the degree-days accumulated since April 1, the model predicts the beginning (5% of the population) of three important events: appearance of the first pupae in the spring, moth flight initiation, and beginning of egg laying. The peak population level (50%) is also available for each of these stages, together with the end (95%) of pupation and of egg laying. The univoltine strain (1 generation per crop year) is more common in Quebec than the bivoltine strain; it is present wherever sweet corn is grown. However, the bivoltine strain, formerly present mainly in southwestern Quebec, is now present in the Mauricie, Centre-du-Québec, Estrie, Lanaudière, Quebec City and Chaudière-Appalaches regions. The second generation, often larger than the first, is more damaging for corn crops, particularly late-planted corn fields, when the larvae attack the ears of corn, tunnelling into the shanks, husks and kernels.

Monitoring of corn borer development is of crucial importance not only for sweet corn producers but also for producers of other crops that are subject to attack by this pest, which has a wide host range. The corn borer can cause major damage to pepper and beans, and sometimes to raspberries and potato.

Consult information bulletin no. 05 (<http://www.agrireseau.qc.ca/Rap/documents/b05mai13.pdf>) of the Réseau d'Avertissements Phytosanitaires (June 7, 2013): « Pyrale du maïs dans le maïs sucré : biologie, surveillance, dépistage et stratégies d'intervention ».

Using this model, growers can set out traps two weeks before the forecast date of moth flight initiation. The traps should be checked twice a week until flight activity begins. Trapping of adults makes it possible to determine the peak flight period and therefore predict when egg laying will occur in corn fields. The start of egg laying is the next event to be monitored. Control measures should target the young larvae that still feed on leaves, because once they grow, they enter the stalks where they are protected from pesticide sprays. Spraying targeted against the univoltine strain must begin 5 days after the start of egg

<sup>1</sup> Text prepared by Anne-Marie Fortier in collaboration with François Charbonneau, agrologist, Productions en régie intégrée du Sud de Montréal, enr. (PRISME), Sherrington, Québec.



laying. Growers should check phytosanitary advisories and consult their local agricultural advisor or pest scout to determine what further steps should be taken, since the bivoltine strain, which has a second generation, may appear later in the season. The model may also be useful for producers who use parasitic wasps of the genus *Trichogramma* for corn borer control. These producers need to identify the egg-laying periods in order to synchronize releases of the wasps with the presence of the host. The release of *Trichogramma* should be timed to coincide with moth emergence, because once egg-laying begins, the wasps need to be active in fields that have reached the 4-to-6 leaf stage. Trapping of adults is important in conjunction with the use of a biological control agent such as *Bacillus thuringiensis* (B.t.), which must be applied a week after males are detected in pheromone traps.

The latest edition of this text was made on July 2014.

[Sweet corn](#)



## Turfgrass



### Insects

Annual bluegrass weevil

Aphodius

Black cutworm

Black turfgrass ataenius



## Insects

### Annual bluegrass weevil



#### PEST DESCRIPTION



#### Life cycle

In the field, annual bluegrass weevil (ABW) adults are relatively active walkers. Viewed up close they have long snouts they measure 3-4 mm long and their antennae arise from the tip of the snout and the hind margin of the eye is convex. Newly emerged adults are chestnut to brown in color. Mature adults are dark grey to black. Adults feed on grass blades, carving out notches on the edges, but cause insignificant damage. During oviposition, females chew holes and insert two or three eggs in the outer leaf sheath (Daniel et al., 2007; Simard, 2006). Eggs are deposited over several weeks rather than in a discrete time period (McGraw and Koppenhcefer, 2010).

Eggs are oval in shape, measure 0.25 x 0.8 and hatch in 4-5 days.

The young larvae live as stem borers and when they outgrow the stem, older larvae will drop down to the soil surface where they shape crude burrows and forage out to chew on surface roots and crowns. Larvae are legless with bodies that are straight to slightly curved. They have 5 development instars. Small larvae are 1mm long while mature larvae are the size (4.5mm) and color of creamy white rice grains except with brown heads. The mature fifth instar transforms to a prepupa around 1 cm higher then soil. It takes 2-5 days to build the cell in which the inactive pupa will reside.

After 3-9 days, the pupa transforms to the callow adult, which will stay in the pupal cell for 3-8 days before abandoning it for a life on the surface. The pupa resembles the adult, but remains creamy white until it darkens with maturation and takes on the brown coloration of the new adult.



By late fall, ABW adults overwinter away from where they develop during the warm season beginning in early spring (Daniel et al., 2007; Diaz and Peck, 2007). They tend to be into the litter and soil surface along defined tree lines and preferring white pine. They are also in other areas such as tall rough patches of weeds and edges of hedgerows. However, removing pine litter in the fall or even the trees themselves shows no evidence of effectiveness.

ABW complete 2 generations per year except for in northeastern Quebec where only one generation was observed (Simard, 2006). When there are two cycles, they each last for about 60 days.

### **Damage**

Annual bluegrass weevil is normally on close-cut habitats particularly on annual bluegrass although, at a smaller size, they have been reported to feed on creeping bentgrass and perennial ryegrass (Daniel et al., 2007). Only golf courses and tennis courts are affected, even though ABW and *P. annua* might be present elsewhere.

Most impact is attributed to the larvae weakening, breaking or killing up to 20 stems; the first generation is generally more destructive. ABW injury is generally expressed as growing areas of yellow and brown patches usually first noticed around the collar and perimeter of the greens, tees or fairways. The soil and root zone remain firm and not spongy.

### **Monitoring**

Overuse and poor timing of pyrethroid applications have led to the development of resistant weevil populations. Applying nematodes curatively against larvae as they enter the soil appears to be a great compromise (McGraw and Koppenhöfer, 2008). Refer to Daniel (2007) in the bibliography for more insecticide details.

## **REFERENCE FOR THE MODEL**

**Annual bluegrass weevil** : model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected by Louis Simard in 24 sites in Québec and 7 in Ontario, during the years 2002-2003 and 2006-2007, in behalf of his Doctorate thesis.

Results were first compiled by Louis Marchand during the 2006 fall and were then updated by Dominique Plouffe in the fall of 2012.



### Cumulative degree days for each threshold development

Base temperature = 10°C

Optimal temperature = 35°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: turfgrass	Degree Days (°C)
Overwintering generation, 5% adults	36
Overwintering generation, 50% adults	104
Overwintering generation, 95% adults	233
1 <sup>st</sup> generation, 5% larvae	298
1 <sup>st</sup> generation, 5% adults	393
1 <sup>st</sup> generation, 50% larvae	399
1 <sup>st</sup> generation, 50% adults	501
2 <sup>nd</sup> generation, 5% adults	708
2 <sup>nd</sup> generation, 50% adults	887

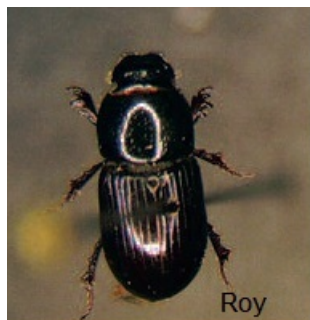
[Turfgrass](#)



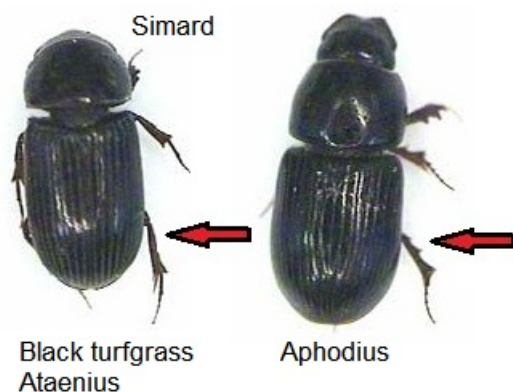
## Aphodius



### PEST DESCRIPTION



Simard et al. 2006  
Québec Vert. Jonathan  
Roy 2009



More than 100 species belonging to the genus *Aphodius* (order Coleoptera, Scarabaeidae family and subfamily Aphodinae) are currently identified in America, but only two species (*Aphodius granarius* L. and *Aphodius paradalis* Le Conte) are recognized as pests of turf especially on the fairways of golf courses. *Aphodius granarius* is the most common species and the one found on golf courses in Quebec. Adults closely resemble adult black turfgrass ataeinus. The length of *A. granarius* tends to be slightly smaller (3-5 mm) compared to black turfgrass ataeinus (4 to 5.6 mm). *Aphodius granarius* beetle and black turfgrass ataeinus differ by examining the tibia of the hind legs of adults. *A. granarius* has two spines on the tibia, which are absent in the black turfgrass ataeinus (Simard, 2006).

### Life cycle

The life cycle of *A. granarius*, like the black turfgrass ataeinus, includes the stages egg, larva (3), pupa and adult. Laying on the golf course seems to occur in the thatch. *Aphodius granarius* completes one generation per year, with sometimes a partial second generation in southwestern Quebec. The information available on *A. granarius* is similar to the black turfgrass ataeinus. The two species are often confused and their respective status is not well defined.

### Distribution and importance of insect damage

In Canada, damage was mentioned in fairways of a golf course for the first time in 1976 in Toronto, Ontario. This insect has been reported in several provinces including: British Columbia, Alberta, Manitoba, Ontario, Quebec, New Brunswick and Nova Scotia. Larvae of *A. granarius* attack essentially the same species of turfgrasses and cause damage similar to black turfgrass ataeinus. Adults do not cause damage to the grass and feed on debris, organic matter, compost, manure and animal dung.

### Control methods

The same control methods recommended against the black turfgrass ataeinus are used for *Aphodius*. The insect susceptibility to the various methods of control is currently poorly documented. Efficacy studies generally do not distinguish between the black turfgrass ataeinus and *Aphodius*. It should be noted that no insecticide is currently registered in Canada for use on golf courses against this pest.



## REFERENCE FOR THE MODEL

**Aphodius:** model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected by Louis Simard in 24 sites in Québec and 7 in Ontario, during the years 2001 to 2003 and 2006 to 2007, in behalf of his Doctorate thesis.

Results were compiled by Dominique Plouffe in the fall of 2012.

### Cumulative degree days for each threshold development

Base temperature = 5°C

Optimal temperature = 35°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: turfgrass	Degree Days (°C)
5% adults	189
50% adults	327
5% larvae	557
95% adults	630
50% larvae	734
95% larvae	987

[Turfgrass](#)



## Black cutworm



### PEST DESCRIPTION



### Life cycle

Black cutworm, *Agrotis ipsilon* Hufnagel, is a lepidopteran in the family Noctuidae, subfamily Noctuinae. Nocturnal and robust, the moth has a wingspan of 35 to 45 mm. Each forewing is grey with a lighter tip and a black marking in the middle, about 6 mm from the outer edge. The hindwings are whitish to grey with darker-coloured visible veins.

Cutworm eggs are about 0.5 mm in size. When freshly laid, the eggs are creamy white but they turn a dark orange colour shortly before hatching (3-6 days).

The larvae develop through 6 or 7 instars and measure about 30 to 45 mm long and 7 mm wide when full grown. They are essentially hairless. The upper part of the body (above the spiracles) is dark grey to nearly black; the lower part of the body (below the spiracles) is lighter grey. The spiracles are black. The larvae have a rear dorsal median stripe. They have three pairs of legs on the thorax and five pairs of prolegs on the abdomen. The larvae usually roll up when disturbed.

The pupae are about 19 mm long and dark brown in coloration; they may move their abdomen when disturbed.

The adults (moths) cannot survive the winter at latitudes higher than the 38th parallel; therefore, they need to migrate northward every spring to recolonize southern Canada. Shortly after emergence, the females can lay 1,200 to 1,600 eggs on the tips of grass blades over a period of 5 to 10 days. Late instar larvae hide in holes in the turf during the day. Pupation takes place in the ground.



Black cutworm has two overlapping generations. The life cycle lasts 40 to 80 days (Simard, 2006).

### **Distribution of the insect and damage**

Based on a 2001 survey, black cutworms are present on nearly 90% of the golf courses in Quebec. The adults feed on nectar and do not damage turfgrass. The larvae can cause considerable damage; they feed on grass blades around their burrows and are especially active between midnight and dawn. This feeding results in a number of circular patches of dead grass resembling the marks left by golf balls. Birds that seek out black cutworm larvae in their burrows make these holes larger. Larvae can cover a distance of up to 20 m in a single night.

### **Control methods**

After mowing, it is important to collect grass clippings and discard them far from the protected zone, thereby eliminating 80% to 90% of cutworm eggs. In addition, mowing very early in the morning provides mechanical control of black cutworms and helps to reduce damage. For information on insecticides, please see the article by Simard (2006) listed in the bibliography.

## **REFERENCE FOR THE MODEL**

**Black cutworm:** model developed by the Bioclimatology and Modelling research team of the Horticulture Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data collected by Louis Simard in 24 sites in Québec during the years 2001 to 2003 and 2006, in behalf of his Doctorate thesis.

Results were compiled by Louis Marchand during the 2006 fall.

### **Cumulative Degree days for each threshold development**

#### **Adults**

Base temperature = 2.4°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> adults capture

Host: turfgrass	Degree Days (°C)
1 <sup>st</sup> generation, 5% adults	13
1 <sup>st</sup> generation, 50% adults	139
1 <sup>st</sup> generation, 95% adults	281



**Damages**

Base temperature = 4.4°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = date of beginning of damages

Host: turfgrass	Degree Days (°C)
Event 1, 10% damages	42
Event 1, 50% damages	149
Event 1, 90% damages	281
Event 2, 10% damages	724
Event 2, 50% damages	899
Event 2, 90% damages	1063

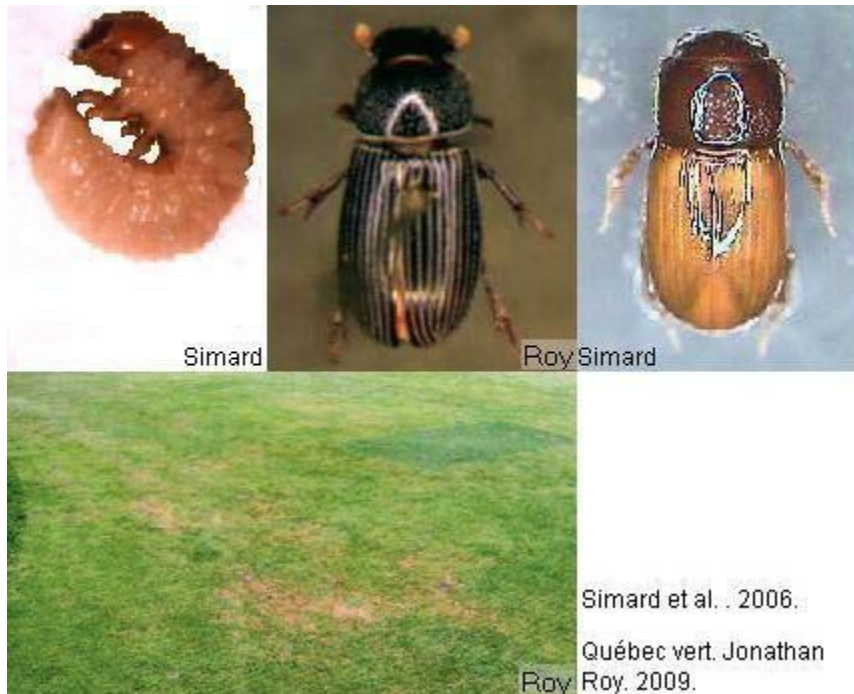
[Turfgrass](#)



## Black turfgrass ataenius



### PEST DESCRIPTION



Black turfgrass ataenius, *Ataenius spretulus* Haldeman, also called “black fairway beetle,” belongs to the order Coleoptera and the family Scarabaeidae, subfamily Aphodiinae. Mature adults are shiny black beetles, 4.9 mm long and 2.2 mm wide on average. Juvenile adult beetles are brown but darken and turn black after a few days. The adults have longitudinal grooves on the wing covers (elytra), which provide additional protection for the insect.

The eggs, averaging 0.72 mm long and 0.52 mm wide, are deposited in clusters of 11 to 12 within small cavities near the soil-thatch interface (Simard, 2006).

The larvae, commonly called “white grubs,” have three pairs of legs like the adults and develop through three instars. They can be distinguished by the C-shaped contour of their body and their creamy-white colour (Rothwell and Smitley, 1997; Simard, 2006). Mature larvae are fairly small, with an average length of 8.5 mm.

The pupa is 4.2 to 5.7 mm long, with developing wings and legs folded close to the body. Initially creamy white, they turn brownish shortly before the adults emerge.

The adults overwinter under plant debris in wooded areas with well-drained, sandy soil on the perimeter of golf courses. Approximately 90% of females are inseminated prior to diapause. There is typically only one generation in Canada, but no studies have been done yet in Quebec. Adult emergence occurs with the advent of warmer weather in the spring, particularly before or during light rainfall and at dusk.



### Distribution of the insect and damage

Black turfgrass ataenius is a pest of temperate zone turfgrasses such as annual bluegrass, Kentucky bluegrass and bentgrasses. This insect causes sporadic, but generally severe, damage on golf course fairways, with lesser damage to greens and tees. Black turfgrass ataenius may infest annual bluegrass and any other turfgrass that is kept short and well irrigated and has a compacted thatch layer. The species rarely infests residential lawns. The larva is the damaging stage. Early sign of damage is wilting of grass, similar to the effect of drought stress, followed by the appearance of irregular patches of dead grass. The failure of grass to recover in response to irrigation following drought also points to suspect the presence of black turfgrass ataenius. A density of 30 larvae/0.1 m<sup>2</sup> may be problematic.

### Control methods

The use of wetting agents in conjunction with nematodes provides white grub control equal to or greater than insecticides (Alm et al., 1992). For information about pesticides, read the article by Simard (2006) listed in the bibliography.

## REFERENCE FOR THE MODEL

**Black turfgrass ataenius:** model developed by the Bioclimatology and Modelling research team of the Agriculture and Agri-Food Canada's Horticulture Research and Development Centre at St-Jean-sur-Richelieu, using data collected by Louis Simard in 24 sites in Québec and 7 in Ontario, during the years 2001 to 2003 and 2006 to 2007, in behalf of his Doctorate thesis.

Results were first compiled by Louis Marchand during the 2006 fall and were then updated by Dominique Plouffe in the fall of 2012.

### Cumulative degree days for each threshold development

#### Adults and larvae

Base temperature = 5°C

Optimal temperature = 35°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: turfgrass	Degree Days (°C)
5% adults	182
50% adults	349
95% adults	642
5% larvae	650
50% larvae	899
95% larvae	1307

[Turfgrass](#)



## Vineyard



### Vineyard Phenology

#### Insect

Grape berry moth

Grape Phylloxera

Leafhoppers

#### Disease

Grape powdery mildew



## Vineyard Phenology



**PEST DESCRIPTION, EICHHORN & LORENZ CODE** (Photos: OMAFRA Staff, 2005)



03) Wool stage

05) Bud burst / green shoot



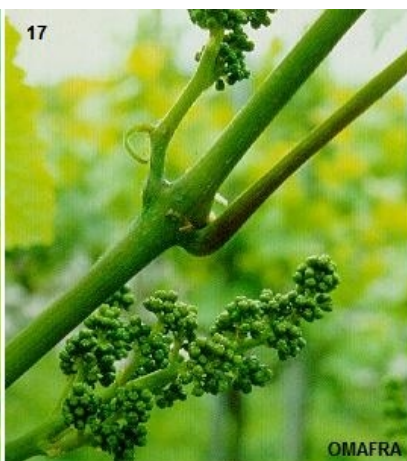
07) 1<sup>st</sup> leaf unfolded

09) 2 to 3 leaves unfolded





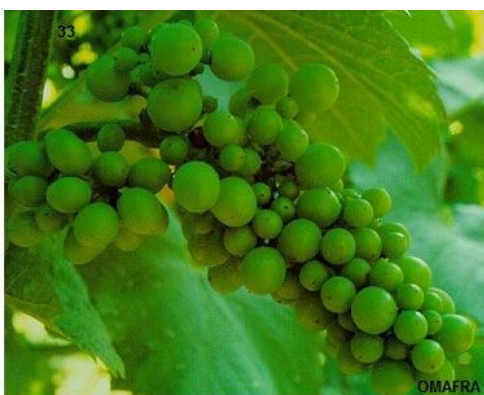
15) Inflorescence elongating



17) Flowers separating



25) 80% flowering



33) Beginning berry touch

Selected stages correspond to the following activities in the vineyard:

**03) Wool stage:** early visits to the field and scouting for grape flea beetle

**05) Bud burst / green shoot:** scouting and intervention against dead-arm disease of grapevine caused by *Phomopsis*

**07) 1<sup>st</sup> leaf unfolded:** scouting and intervention against anthracnose

**09) 2 to 3 leaves unfolded:** scouting and intervention against the following diseases: black rot, red fire (Brenner) and downy mildew

**15) Elongation of the inflorescence:** scouting and intervention against powdery mildew

**17) Inflorescence:** scouting and intervention against powdery mildew

**25) 80% flowering:** scouting and intervention against gray mold

**33) Closure of the cluster:** scouting and intervention against gray-mold rot



## REFERENCE FOR THE MODEL

**Phenology of grapevine:** models developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Horticulture Research and Development Centre (AAFC-HRDC) in Saint-Jean-sur-Richelieu.

Seyval blanc: data collected from 2001 to 2003 and from 2009 to 2011 in vineyards in different regions of Quebec. Results compiled by Dominique Plouffe during the winter of 2012.

Early and semi-late bud burst vine varieties: data collected from 2009 to 2011 by the "Centre de Recherche Agroalimentaire de Mirabel" (CRAM) and several extension consultants in grapevine, in different regions of Quebec. Results compiled by Myriam Cadotte during the summer of 2012.

### Cumulative degree days for each threshold development

Base temperature = 10°C

Optimal temperature = 40°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Seyval blanc (EL stages)	Degree Days (°C)
Wool stage (03)	70
Bud burst / green shoot (05)	93
1 <sup>st</sup> leaf unfolded (07)	118
2 to 3 leaves unfolded (09)	143
Inflorescence elongating (15)	223
Flowers separating (17)	282
80% flowering (25)	412
Beginning berry touch (33)	665

Early bud burst vine varieties (EL stages)	Degree Days (°C)
Wool stage (03)	55
Bud burst / green shoot (05)	75
1 <sup>st</sup> leaf unfolded (07)	100
2 to 3 leaves unfolded (09)	119
Inflorescence elongating (15)	212
Flowers separating (17)	265
80% flowering (25)	345
Beginning berry touch (33)	687



<b>Semi-late bud burst vine varieties (EL stages)</b>	<b>Degree Days (°C)</b>
Wool stage (03)	65
Bud burst / green shoot (05)	87
1 <sup>st</sup> leaf unfolded (07)	108
2 to 3 leaves unfolded (09)	132
Inflorescence elongating (15)	218
Flowers separating (17)	266
80% flowering (25)	374
Beginning berry touch (33)	729

[Vineyard](#)



## Disease

### Grape powdery mildew



#### DISEASE DESCRIPTION (Carisse et al., 2006)



#### Epidemiology

*E. necator* is an obligate parasite of grapevines, i.e., it can develop only on living grapevine tissue. In our climate, *E. necator* overwinters as cleistothecia, structures containing ascospores (or sexual spores). In the spring, the ascospores mature and infect the leaves growing in proximity to bark. Following infection, spots covered with asexual spores, called conidia, develop on the leaves. The conidia of *E. necator* do not need free water on the tissue to infect it. However, high relative humidity promotes germination of the conidia and therefore infections. Powdery mildew of grape is promoted by hot (optimum temperature of 25°C), dry (but humid) weather since water inhibits germination of the conidia.

#### Symptoms



**Leaves:** The first powdery mildew lesions are frequently found on the undersides of leaves. As the epidemic progresses, lesions become apparent on the upper sides of leaves as well. These lesions will increase in size and number if the disease is left unchecked. Severely infected leaves may become brittle and drop off. Starting as early as late July, very small orange to black spherical structures called cleistothecia develop on the upper and lower surfaces of leaves.





**Shoots:** Brown to black irregular blotches that can measure up to a few centimetres, follow the gradual degeneration of the fungus over the course of the season. The spots have indistinct margins and remain visible even following shoot lignification.

**Inflorescences and rachis:** Usually seen on rachis, powdery mildew has the appearance of a grey to whitish powder. Severe infections of the rachis can result in clusters being dropped, especially if mechanical harvesting is done. Symptoms on the rachis are similar to those on shoots.



**Berries:** Berries can be infected from immediately after bloom through 4 weeks post-bloom. They turn an ash grey colour and quickly become covered in spores, giving them a floury appearance. At the end of the season, cleistothecia also appear on the berries. Affected berries dry out and may drop off. Berries that infected later during the period of susceptibility are prone to splitting, making them susceptible to infection by *Botrytis*.

**Scouting Grape varieties:** Monitor susceptible varieties.

**When:** Start looking for powdery mildew at about 3-5 leaves and continue throughout the season.

**Where:** Throughout the vineyard.

**How:** Monitor for the appearance of discolored spots that turn whitish on the upper and lower leaf surfaces. Do not confuse with pesticide residues. When checking, change the angle of the leaf. The whitish spots are particularly visible when the leaf is held at an approximately 30° angle. Be sure to sample leaves from the interior of the canopy since disease development is favoured by shade (Carisse et al., 2006).



## REFERENCE FOR THE MODEL

### Cumulative Degree days for each threshold development

Base temperature = 6°C

Optimal temperature = 30,5°C

Method = standard modified

Date for starting calculations = green shoot (EL 06)

Risk index	Degree Days (°C)
Low	400 to 500
Intermediate	500 to 600
High	600 to 700

## INTERPRETATION OF THE CURVE

Accumulation of degree-days for the model starts from the date of green shoot stage (EL 06). The model can be used to determine the best time to start treatment based on the sensitivity of different varieties to the disease.

- Less than 500 accumulated degree-days = low risk: scouting is required. If white spots are found, fungal treatments begin.
- 500-600 accumulated degree-days = medium risk: the frequency of scouting is increased and treatment on susceptible varieties (Chancellor, Seyval, Vidal and Pinot, etc.) can begin.
- 600-700 accumulated degree-days = high risk: tolerance threshold is reached, scouting frequency is increased and treatment of moderately sensitive varieties (DeChaunac, Frontenac, Foch, St. Croix, etc.) may begin.

**Reference :** [Avertissement phytosanitaire No 08 - 2011](#)

[Vineyard](#)



## Insect

### Grape berry moth



#### PEST DESCRIPTION



The adult grape berry moth is 6 mm when fully grown and has a brown body with wings that are grey-blue near the body and cream with brown spots near the tips.

Young larvae have a cream body and dark brown head when they hatch. As they mature, they become green and then purple with a light brown head. Larvae are 10 mm long at maturity. First generation larvae web together buds, flowers and newly-set berries then chew them until they fall or they are stripped of their envelope; affected plant parts often drop from vine. Second generation larvae burrow into green berries near the berry stem or side where berries touch. A purple spot may form around the pin-head size hole. Berries may split, shrivel, become infected by disease, or fall off when damaged. Third generation larvae can cause direct fruit injury (tunnel directly into one berry and then move from berry to berry within the cluster) and lead to significant disease infection prior to harvest (OMAFRA. 2003)

Adults emerge in summer and females lay their first eggs on buds, small stems or newly grown bays and later, eggs are deposited directly on the fruits. The larvae develop in these structures and reach the first peak abundance in early July. The fifth stage larva weaves a shelter by folding an edge of leaf and linking it with a silk thread to complete pupation (metamorphosis into an adult). Preliminary studies suggest that there are one or two generations per year in Quebec. The latest generation of moths overwinters in the soil as a chrysalis.

The larvae feed on buds, stems and small growing bays. When sufficiently developed, they dig cavities inside the fruit and can damage several berries in a cluster, leaving traces of excrement and silk behind them.



## REFERENCE FOR THE MODEL

Tobin, P.C., S. Nagarkatti and M.C. Saunders. 2003. Phenology of Grape Berry Moth (Lepidoptera: Tortricidae) in Cultivated Grape at Selected Geographic Locations. Environmental Entomology, 32-2, pp. 340-346.

### Cumulative degree days for each threshold development

Base temperature = 8.4°C

Optimal temperature = 30°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: vineyard	Degree Days (°C)
1 <sup>st</sup> generation, 50% adults	190
1 <sup>st</sup> generation, 50% egg-laying	263
2 <sup>nd</sup> generation, 50% adults	687
2 <sup>nd</sup> generation, 50% egg-laying	760
3 <sup>rd</sup> generation, 50% adults	1184
3 <sup>rd</sup> generation, 50% egg-laying	1257
4 <sup>th</sup> generation, 50% adults	1681

[Vineyard](#)



## Grape Phylloxera



### PEST DESCRIPTION (Photos: Bergeron, 2010)



Leaf lightly affected: few galls



Leaf moderately affected: several galls



When severely affected, leaves close

Phylloxera is an aphid that attacks vine and causes pea-sized swellings on the undersurface of the leaf. Grape phylloxera adult females are wingless and oval, 0.7 mm to 1.0 mm long and about 0.5 mm wide. On the leaves, young adults are bright yellow to orange becoming brown with age. Newly deposited eggs are oval, bright yellow, approximately 0.4 mm long and 0.2 mm wide. Just prior to hatching, the eggs turn dark yellow with 2 visible red eye spots at one end. Emerging nymphs are similar in size to the egg. The nymphs progress through 4 developmental stages before reaching the adult stage. The winged adult female, emerging from the soil in late summer and early fall, is orange with a grey-black head and thorax with two pairs of lightly veined wings (OMAFRA, 1997).

The insect exists in two forms, a form called radicolous that lives on the roots, and a leaf form which lives on the leaves. The radicolous decimated many vineyards in Europe in the nineteenth century before the introduction of resistant rootstocks. American vines are much more resistant to that form. Foliar form, causing galls, produces about five generations per year and causes little damage to the vines. It normally affects neither the performance nor the quality of the grapes. However, in some cases the attack is so important that all the leaves are curled by the abundant presence of galls. A decrease of photosynthesis in this situation could have a negative effect on fruit ripening and hardening of plants. Egg laying by insects of earlier generations is very important, up to 500 eggs per female, and the insect pressure can be reduced for an entire season by removing the first leaves bearing galls of first and second generation, where possible (Bergeron, 2010).



## REFERENCE FOR THE MODEL

Johnson D., S. Sleezer, B. Lewis. Biology and Management of Grape Phylloxera. University of Arkansas, Agriculture and Natural Resources, publication FSA7074.  
[http://www.uaex.edu/Other\\_Areas/publications/PDF/FSA-7074.pdf](http://www.uaex.edu/Other_Areas/publications/PDF/FSA-7074.pdf)

Sleezer S., D.T. Johnson, B. Lewis, F. Goggin, C. Rothrock, M. Savin. 2011. Foliar Grape Phylloxera, *Daktulosphaira vitifoliae* (Fitch), Seasonal Biology, Predictive Model and Management in the Ozarks Region of the United States. Proc. 5<sup>th</sup> International Phylloxera Symposium. Acta Hort., 904, pp. 151-155.

### Cumulative Degree days for each threshold development

Base temperature = 6.4°C

Optimal temperature = 36°C

Method = single average

Date for starting calculations = observation date of 1<sup>st</sup> leaf unfolded

Host: vineyard	Degree Days (°C)
2 <sup>nd</sup> gen., beginning crawlers	303
2 <sup>nd</sup> gen. end crawlers	444
3 <sup>rd</sup> gen., beginning crawlers	667

## INTERPRÉTATION OF THE CURVE (Bergeron, 2010)

The model first threshold represents eggs hatch, when the young crawlers emerge from galls and migrate to new leaves to form new galls. Since crawlers are protected by galls under leaves, they are difficult to reach with insecticide; the application should ideally be made at this time in the case of major infections. Scouting should be done using a magnifying glass 16X because of the small size of insects. It will begin at the first appearance of galls, on first leaves deployed, by observing eggs in galls. Normally, there should be a first treatment 2 to 3 days after the start of egg-hatching, when a maximum of crawlers is migrating to the surface of the leaves. This point is considered reached when no there are no more eggs or larvae in the first galls.

The latest edition of this text was made on March 2014.

[Vineyard](#)



## Leafhoppers



### PEST DESCRIPTION

Nymphs of four species of leafhoppers compose the model implemented in CIPRA. They are *Empoasca fabae*, *Erythroneura comes*, *Erythroneura tricincta* and *Erythroneura vitis*. In Quebec, these four species reach their maximum abundance approximately at the same time and since they are difficult to distinguish visually from each other and they do the same kind of damage on the vine, they were grouped into one single model.



Potato leafhopper: a) adult; b) nymph

*Empoasca fabae* (potato leafhopper): pale green insect, sometimes yellowish, adults measuring 3 to 4 mm. Causes "hopper burn" in grapevines. *E. fabae* is highly polyphagous and attacks many plant species, vine being a secondary host and potato, the primary host. This species does not survive the winter in Canada. It migrates from the northern United States to Canada every spring, starting in mid-June, and is present all summer. *E. fabae* is often confused with *Empoasca vitis*, a species found in Europe and that presents the same color.



Eastern grape leafhopper

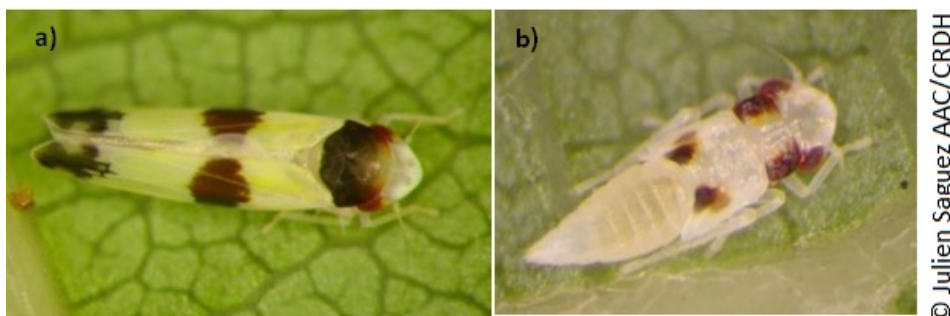
*Erythroneura comes* (Eastern grape leafhopper): adult has orange or red marks on a yellowish background. These marks are larger and darker near the base of the forewings and consist of small spots towards the tips. The adult is between 2.5 and 3.5 mm. Grapevines are essentially its host plant. *E. comes* occurs from early in the spring to late in the season.





Grapevine leafhopper: a) adult; b) nymphs of 2nd and 3rd instars; c) nymph of 5th instar

*Erythroneura vitis* (grapevine leafhopper): the adult is yellowish with three large bands perpendicular to the longitudinal axis of the body: one on the thorax, one in the centre of the abdomen and a darker one at the tip of the wings. Coloration appears gradually, first forming an orange U on the thorax in young nymphs, and then a brown square in the last larval stage. The adult measures between 2.5 and 3.5 mm and lives on grapevine and wild grapes. It is found from June to the end of September.



Three-banded leafhopper: a) adult; b) nymph

*Erythroneura tricincta* (three-banded leafhopper): yellow insect with three brown or black bands and red-brown eyes. The adult is between 2,5 and 3,5 mm and is sometimes confused with the adult of grapevine leafhopper, *Erythroneura vitis*. *E. tricincta* is yellower with narrower bands. It feeds and lives on grapevine and wild grapes. *E. tricincta* is present from late in the spring to the end of summer.

## REFERENCE FOR THE MODEL

Bostanian, N.J., G. Bourgeois, C. Vincent, D. Plouffe, M. Trudeau and J. Lasnier. 2006. Population Ecology; Modeling Leafhopper Nymphs in Temperate Vineyards for Optimal Sampling. *Environ. Entomol.* 35(6): 1477-1482.



### Cumulative Degree days for each threshold development

Base temperature = 8°C

Optimal temperature = 31°C

Method = single sine

Date for starting calculations = 1<sup>st</sup> March

Host: vineyard	Degree Days (°C)
5% nymphs	643
50% nymphs	850
95% nymphs	1155

[Vineyard](#)



## Bibliography

- Alm S.R., T. Yeh, J.L. Hanula and R. Georgis. 1992. Biological Control of Japanese, Oriental, and Black Turfgrass Ataenius Beetle (Coleoptera: Scarabaeidae) Larvae with Entomopathogenic Nematodes (Nematoda: Steinernematidae, Heterorhabditidae). Biological and microbial control, Entomological Society of America. 85(5): 1660-1665
- Beaulieu A.A. 1957. Manuel de pulvérisation du verger. Ministère de l'Agriculture du Québec, Québec.
- Bergeron L. 2010. Phylloxera de la vigne. Réseau d'avertissements phytosanitaires - Bulletin d'information No 02 - vigne - 6 mai 2010. Agriculture, Pêcheries et Alimentation Québec.  
<http://www.agrireseau.qc.ca/Rap/documents/b02vig10.pdf>
- Bostanian N.J. 1994. La punaise terne et la production de fraises. Agriculture et Agroalimentaire Canada. Bulletin technique 1994-1F.
- Boulé J., G. Chouinard, C. Vincent and Y. Morin. 1999. Biology and monitoring of principal insect and mite pests of apples. Pages 19-99 in Chouinard, G. (éd) : Quebec Apple Pest Monitoring Guide. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ).
- Brodeur C., O. Carisse et G. Bourgeois. La cercosporose de la carotte - Stratégies de lutte. Agriculture et Agroalimentaire Canada. Publication A42-86-1997F. No. cat. A42-86/1997F-IN.  
<http://publications.qc.ca/collections/Collection/A42-86-1997F.pdf>
- Brodeur C., O. Carisse et G. Bourgeois. La tache commune de la fraise - Stratégies de lutte. Agriculture et Agroalimentaire Canada. Publication A42-87-1997F. No. cat. A42-87/1997F-IN.  
<http://publications.qc.ca/collections/Collection/A42-87-1997F.pdf>
- Carisse O., R. Bacon, J. Lasnier et W. McFadden-Smith. 2006. Identification Guide to the Major Diseases of Grapes. Agriculture and Agri-Food Canada. Publication 10092E. Cat. No. A52-74/2006E-PDF.  
<http://publications.qc.ca/collections/Collection/A52-74-2006E.pdf>
- Champeil A. 2004. Contribution à la compréhension des effets des systèmes de culture sur l'infection des cultures de blé tendre d'hiver par la fusariose et la contamination des grains par les mycotoxines associées. UMR d'Agronomie INRA/INA P-G. Institut National Agronomique Paris-Grignon.
- Chouinard G. et coll. 2014. Guide de référence en production fruitière intégrée à l'intention des producteurs de pommes du Québec. Institut de recherche et de développement en agroenvironnement, Québec, QC.
- Chouinard G., D. Cormier and G. Bourgeois. 2002. A Temperature Dependent Model Describing Nocturnal Activity of Plum Curculio in Apple Trees Following Bloom. Acta Horticulturae 584: 201-205.
- Daniel C.P., M.D. Diaz and M. Seto. 2007. TURFGRASS Annual bluegrass weevil. Cornell University, Integrated Pest Management. NY United States.  
[www.nysipm.cornell.edu/factsheets/turfgrass/abw.pdf](http://www.nysipm.cornell.edu/factsheets/turfgrass/abw.pdf)
- Davidson R.H. and W.F. Lyon. 1979. Insect pests of farm, garden and orchard. Wiley, New York. 7<sup>th</sup> ed.
- Dewdney M. et G. Bourgeois. 2001. Évaluation et implantation de modèles prévisionnels de la fusariose de l'épi du blé et de l'orge dans le but de planifier les interventions phytosanitaires. Rapport de projet.
- Diaz M.D.C. and D.C. Peck. 2007. Overwintering of annual bluegrass weevils, *Listronotus maculicollis*, in the golf course landscape. The Netherlands Entomological Society 125: 259-268
- Duval B., P. Ferland, J. Boisclair et C. Jean. 2013. Pyrale du maïs dans le maïs sucré : biologie, surveillance, dépistage et stratégies d'intervention. Réseau d'avertissements phytosanitaires – Bulletin d'information No 05 - Maïs sucré - 7 juin 2013. Agriculture, Pêcheries et Alimentation Québec. <http://www.agrireseau.qc.ca/Rap/documents/b05mai13.pdf>



- Guérin S.F. 2009a. Élaboration d'un modèle bioclimatique de la phénologie de la canneberge (*Vaccinium macrocarpon*). Rapport présenté à Gaétan Bourgeois, Agriculture et Agroalimentaire Canada, Saint-Jean-sur-Richelieu.
- Guérin S.F. 2009b. Élaboration d'un modèle bioclimatique de la cécidomyie de la canneberge (*Dasineura oxycoccana*). Rapport présenté à Gaétan Bourgeois, Agriculture et Agroalimentaire Canada, Saint-Jean-sur-Richelieu.
- Guérin S.F. 2009c. Élaboration d'un modèle bioclimatique de la pyrale de l'atoca (*Acrobasis Vaccinii*). Rapport présenté à Gaétan Bourgeois, Agriculture et Agroalimentaire Canada, Saint-Jean-sur-Richelieu.
- Khanizadeh S. et J. DeEll. 2005. Our Strawberries = Les Fraisiers de chez nous. Agriculture and Agri-Food Canada = Agriculture et agroalimentaire Canada.  
[http://cyberfruit.info/book-poster/strawberry-book/pdf-file/strawberries\\_web.pdf](http://cyberfruit.info/book-poster/strawberry-book/pdf-file/strawberries_web.pdf)
- Leblanc M. 2006. Stratégie de lutte contre la teigne du poireau. Réseau d'avertissements phytosanitaires. Bulletin d'information No 03 - carotte, céleri, laitue...- 7 juillet 2006. Agriculture, Pêcheries et Alimentation Québec.  
<http://www.agrireseau.qc.ca/Rap/documents/b03tn06.pdf>
- Maas J.L. 1984. Compendium of strawberry diseases. American Phytopathological Society., St. Paul, Minn.
- Mailloux M. 1982. Atlas des stades phénologiques. Feuillet no.S-1. Service de recherche en défense des cultures, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec. Publication no B-505.
- McGraw B.A. and A.M. Koppenhöfer. 2008. Evaluation of two endemic and five commercial entomopathogenic nematode species (Rhabditida: Heterorhabditidae and Steinernematidae) against annual bluegrass weevil (Coleoptera: Curculionidae) larvae and adults. Biological control 46(3): 467–475
- McGraw B.A. and A.M. Koppenhöfer. 2010. Spatial distribution of colonizing *Listronotus maculicollis* populations: implications for targeted management and host preference. Journal of applied entomology Zeitschrift fcor angewandte Entomologie 134(4): 275-284
- Meheriuk M., R.K. Prange, P.D. Lidster and S.W. Porritt. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E.
- Meier U. 2001. Growth stages of mono-and dicotyledonous plants: BBCH Monograph. 2<sup>nd</sup> ed. Federal Biological Research Centre for Agriculture and Forestry.
- OMAFRA. 1997. Grape Phylloxera - Pest Management Program for Grape Series. Ministry of agriculture, food and rural affairs, Ontario. Order # 88-125.  
<http://www.omafra.gov.on.ca/english/crops/facts/88-125.htm>
- OMAFRA. 2003. Insect and Disease Identification Guide For Grapes. Ministry of agriculture, food and rural affairs, Ontario.
- OMAFRA. 2005. Growth Stages of Grapevines. Ministry of agriculture, food and rural affairs, Ontario.
- Richard C. et G. Boivin. 1994. Maladies et Ravageurs des Cultures Légumières au Canada. Société d'entomologie du Canada, Société Canadienne de Phytopathologie. Ottawa, Canada.
- Simard L. 2006. Distribution, abondance et écologie saisonnière des principaux insectes ravageurs du gazon sur les terrains de golf du Québec et évaluation du potentiel de contrôle de nématodes entomopathogènes indigènes. Département de phytologie, Faculté des sciences de l'agriculture et de l'alimentation, Université Laval. Québec.
- Simard L., J. Brodeur and J. Dionne. 2007. Distribution, Abundance, and Seasonal Ecology of *Listronotus maculicollis* (Coleoptera: Curculionidae) on Golf Courses in Québec, Canada. Horticultural Entomology 100(4): 1344-1352



- Smitley D.R., T W. Davis and N.L. Rothwell, 1998. Spatial distribution of *Ataenius spretulus*, *Aphodius granarius* (Coleoptera: Scarabaeidae), and predaceous insects across golf course fairways and roughs. *Environmental Entomology* 27: 1336-1349.
- Urbain L., M.M. Gingras (rév. 2010), D. Bernier, L. Boivin, F. Charrier, F. Demers, L. Lambert, G. Laplante, V. Méthot, R. Néron, M. Poulin, M. Robert, M. Roy et R. Turmel. 2010. Fraisier : Guide de protection 2010. Réseau d'avertissements phytosanitaires. Agriculture, Pêcheries et Alimentation Québec.  
<http://www.agrireseau.qc.ca/petitsfruits/documents/EVE017.pdf>