Agriculture et Agroalimentaire Canada
Agriculture and Agri-Food Canada

CIPRA - Computer Centre for Agricultural Pest Forecasting

Crop Guide

Canada

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CIPRA - Computer Centre for Agricultural Pest Forecasting: Crop Guide

Catalogue No. A42-119/2018E-PDF
ISBN 978-0-660-28719-5
AAFC No. 12875E

Paru également en français sous le titre
CIPRA - Centre Informatique de Prévision des Ravageurs en Agriculture : guide des cultures

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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.

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Introduction

CIPRA: Centre Informatique de Prévision 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

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Apple

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Insects
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Redbanded leafroller
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Spotted tentiform leafminer
Tarnished plantbug

Diseases
Apple scab
Fire blight

McIntosh Firmness

DESCRIPTION

In apple production, some indicators such as the ground color of the fruit skin, sugar level and firmness allow to target the optimal maturity date for harvest. The maturity stage of apple at harvest has a decisive influence on its suitability for storage and its quality. Apple fruit firmness is one of the main attributes indicating fruit quality at harvest and it is affected by numerous factors during the entire growing season. The effect of weather conditions during apple fruit development is often mentioned for its impact on attributes linked to fruit firmness: fruit size, calcium concentration, water content. The prediction of apple firmness at harvest could be helpful for producers to adjust their marketing and storage strategies according to apple quality level.

Lower temperature from 31 to 60 days after full bloom, higher temperature conditions and important precipitations from 61 to 90 days after full bloom have negative effect on 'McIntosh' apple firmness at harvest.

REFERENCE FOR THE MODEL

Lachapelle, M., Bourgeois, B. and J. R. DeEll. 2013. Effects of Preharvest Weather Conditions on Firmness of ‘McIntosh’ Apples at Harvest Time. HortScience 48(4): 474-480.

Model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu. Meteorological data from nine sites in Quebec and Ontario over 15 years (1996-2011) and firmness data from 'McIntosh' apple were used.

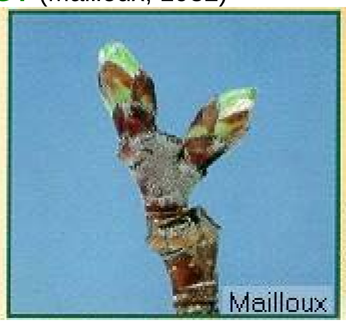
INTERPRETATION OF THE CURVE

Model predicts firmness in kilograms-force or pounds-force from the 90th day after flowering. The minimum firmness accepted by "Pommes Qualité Québec" for McIntosh is 12 pounds-force (5.4 kg-force).

Apple tree

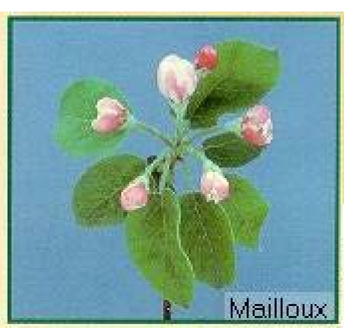
McIntosh Phenology

DESCRIPTION OF PHENOLOGY (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.

Photos source: Mailloux, M. Feuillet no.S-1. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec. Publication no B-505. 1982

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.

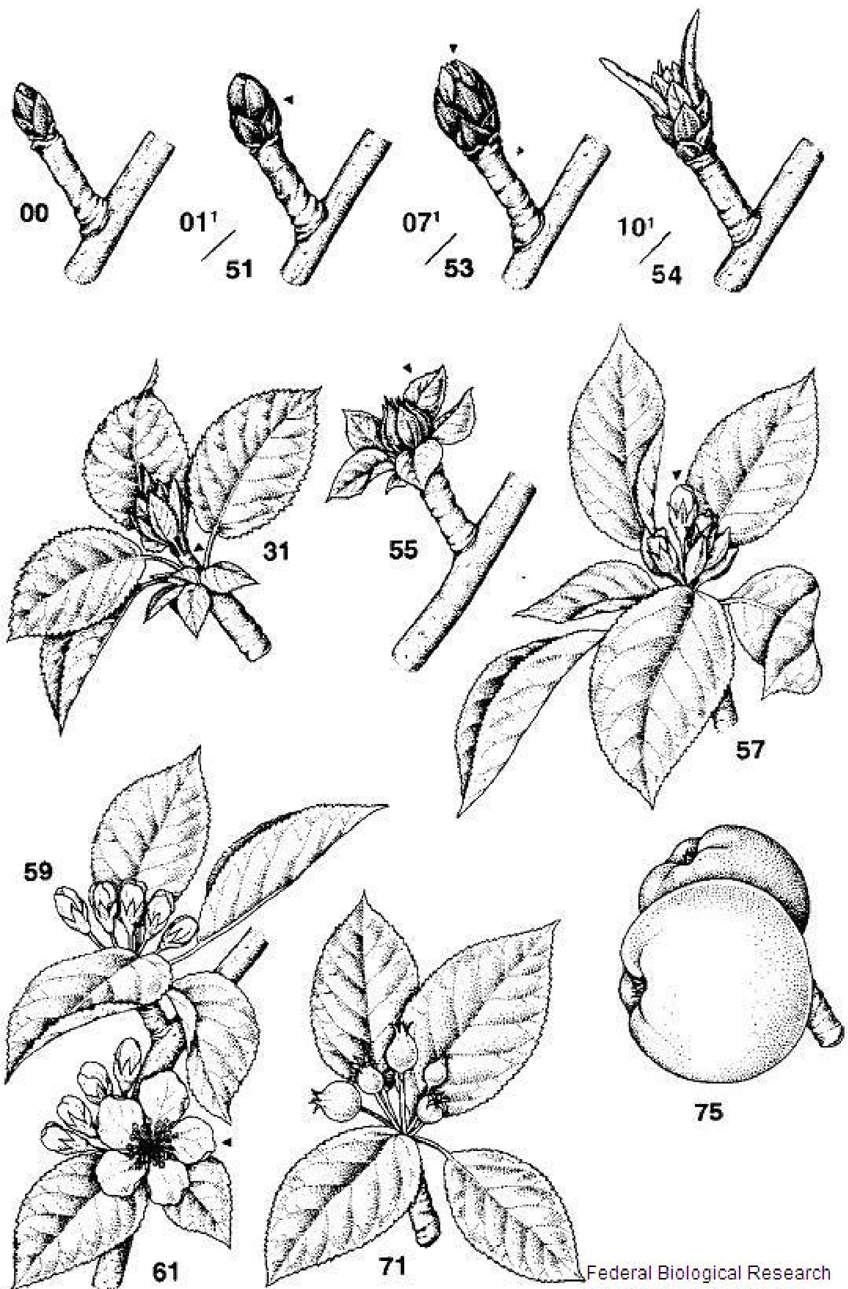
Predictions about apple phenology can also be used to assess the risk posed by spring frost, since a cultivar's vulnerability depends largely on the state of apple bud development. The extent of damage is directly related to the lowest temperatures and their duration.

A 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 *et al.,* 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 of pome fruit (Meier *et al.*, 2001)
(apple = Malus domestica Borkh)

Code	Description
Principal growth stage 0: Sprouting/Bud development	
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
Principal growth stage 1: Leaf development	
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
Principal growth stage 3: Shoot development (from terminal bud)	
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
Principal growth stage 5: Inflorescence emergence	
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
Principal growth stage 6: Flowering	
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
Principal growth stage 7: Development of fruit	
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



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

REFERENCE FOR THE MODEL

McIntosh Phenology (DD) : model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at St-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 2005 from 13 different Quebec orchards.

McIntosh Phenology (BBCH) : model developed by the Bioclimatology and Modelling research team of the Research and Development Centre 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 = 1st 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

Bitter pit (Honeycrisp)

DESCRIPTION

www.omafra.gov.on.ca

Bitter pit in apple fruits is a common physiological disorder related to low calcium concentrations that may appear at harvest or only after several weeks of cold storage. Affected fruits develop corky spots in the flesh, most commonly immediately under the skin. Externally, it appears as sunken brown dots of various sizes and usually develops near the calyx first before spreading towards the stalk. Bitter pit is due to a much localized calcium deficiency in the fruit. However, causes and preventives measures are not limited to calcium availability in the soil, irrigation and foliar calcium applications, as often referred to by the industry. Many factors like weather, soil conditions, cultivar characteristics and cultural practices all play a role, through complex interactions, in the development of bitter pit and its incidence for a given year in a given orchard. In Québec, most sensitive varieties include 'Honeycrisp' and 'Cortland' (Grégoire 2017).

REFERENCE FOR THE MODEL

Grégoire, V. 2017. Xylem functionality, phytohormones and weather: how they affect bitter pit incidence in apples. Master's thesis, McGill University, Montreal, Canada.

Model developed from Virginie Grégoire's work by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at Saint-Jean-sur-Richelieu on Honeycrisp apples. The data came from different plots in Quebec, Ontario and Nova Scotia between the years 2002 and 2017. The data were analyzed and compiled by Cyrille Viens and Antoine Plourde-Rouleau in summer and fall 2017.

INTERPRETATION OF THE CURVE

Depending on the region where the orchard is located, two bitter pit models are available, one for Quebec and one for Ontario. The model provides a bitter pit incidence index for the Honeycrisp variety during the growing season, specifically during fruit development. This index is based on weather data (temperature, precipitation and solar radiation) between dates of full bloom and harvest. For a better prediction of this disorder in a specific orchard, it is recommended to indicate the observed dates of flowering and harvesting. However, in CIPRA, a module is provided to estimate these dates from the McIntosh phenology model. The season is then separated into 6 sub-periods: 0-14 days after full bloom (DFB), 15-29 DFB, 30-44 DFB, 45-59 DFB, 60-89 DFB and 90 DFB-Harvest. At the end of each sub-period, a different equation generates a prediction of the incidence index based on weather data measured since full bloom. The quality of the predictions improves as the fruit grows, until fruits are harvested. The final prediction, obtained with the equation developed after sub-period 90 DFB-Harvest, gives an idea of the risks for the disorder to appear, according to weather conditions during the growing season.

Apple tree

Core browning (Empire)

DESCRIPTION

Core browning is a diffuse browning of flesh around the core and carpels, with no clear distinction between healthy and affected tissue. It develops after several months of cold storage and becomes more extensive at room temperature.
Core browning is more prevalent in fruit that are harvested after an extended period of cloudy, cool or wet weather. Incidence is reduced with advanced maturity, delayed cooling and storage, and low O_2 atmospheres (DeEll, 2007).

REFERENCE FOR THE MODEL

Model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at Saint-Jean-sur-Richelieu on Empire variety apples. The data came from different plots in Quebec and Ontario between the years 2010 and 2014. The data were analyzed and compiled by Cyrille Viens and Antoine Plourde-Rouleau in summer and fall 2017.

INTERPRETATION OF THE CURVE

The model provides a core browning index for the Empire variety during the growing season, more specifically during fruit development. This index is based on weather data (temperature, precipitation and solar radiation) between dates of full bloom and harvest. For a better prediction of this disorder in a specific orchard, it is recommended to indicate the observed dates of flowering and harvesting. However, in CIPRA, a module is provided to estimate these dates from the McIntosh phenology model. The season is then separated into 6 sub-periods: 0-14 days after full bloom (DFB), 15-29 DFB, 30-44 DFB, 45-59 DFB, 60-89 DFB and 90 DFB-Harvest. At the end of each sub-period, a different equation generates a prediction of the incidence index based on weather data measured since full bloom. The quality of the predictions improves as the fruit grows, until fruits are harvested. The final prediction, obtained with the equation developed after sub-period 90 DFB-Harvest, gives an idea of the risks for the disorder to appear, according to weather conditions during the growing season.

Apple tree

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 Research and Development Centre 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.

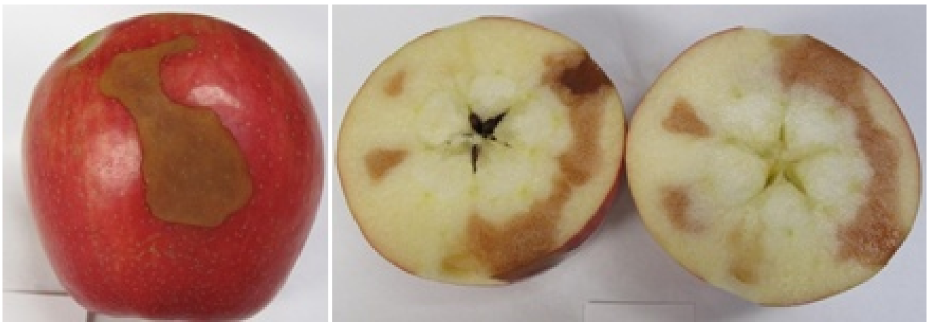
When browning index predicted by the model is high for a given season, a few simple measures can be applied:

- 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_2 and 4.5% CO_2. 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

Soft scald (Honeycrisp)

DESCRIPTION



Soft scald is a major storage chilling-related disorder that can develop in 'Honeycrisp'. It is characterized by sharply defined, irregularly shaped, smooth, brown lesions of the skin. Peel tissue is initially affected and then hypodermal tissue is damaged as the disorder continues to develop. Skin lesions are often then invaded by secondary pathogens, such as *Alternaria* or *Cladosporium*.

Multiple factors have been implicated in the development of soft scald, mainly over-maturity at harvest, light crops, large fruit and low temperature during storage. Delayed cooling, which involves retaining apples in a room at 10-20 °C for up to 7 days prior to storage is a technique used to reduce or completely suppressed soft scald. The apples are then stored at a temperature between 3 and 5 ° C (DeEll 2017, Prange 2008).

REFERENCE FOR THE MODEL

Lachapelle M., G. Bourgeois, J. DeEll, K.A. Stewart, P. Séguin. 2013. Modeling the Effect of Preharvest Weather Conditions on the Incidence of Soft Scald in ‘Honeycrisp’ Apples. Postharvest Biology and Technology 85: 57–66

Model developed from Maude Lachapelle’s work by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at Saint-Jean-sur-Richelieu on Honeycrisp apples. The data came from different plots in Quebec, Ontario and Nova Scotia between the years 2002 and 2017. The data were analyzed and compiled by Cyrille Viens and Antoine Plourde-Rouleau in summer and fall 2017.

INTERPRETATION OF THE CURVE

Depending on the region where the orchard is located, two soft scald models are available, one for Quebec and one for Ontario. The model provides a soft scald incidence index for the Honeycrisp variety during the growing season, specifically during fruit development. This index is based on weather data (temperature, precipitation and solar radiation) between dates of full bloom and harvest. For a better prediction of this disorder in a specific orchard, it is recommended to indicate the observed dates of flowering and harvesting. However, in CIPRA, a module is provided to estimate these dates from the McIntosh phenology model. The season is then separated into 6 sub-periods: 0-14 days after full bloom (DFB), 15-29 DFB, 30-44 DFB, 45-59 DFB, 60-89 DFB and 90 DFB-Harvest. At the end of each sub-period, a different equation generates a prediction of the incidence index based on weather data measured since full bloom. The quality of the predictions improves as the fruit grows, until fruits are harvested. The final prediction, obtained with the equation developed after sub-period 90 DFB-Harvest, gives an idea of the risks for the disorder to appear, according to weather conditions during the growing season.

Apple tree

Soggy breakdown (Honeycrisp)

DESCRIPTION



Honeycrisp apple is extremely susceptible to soggy breakdown. This physiological disorder is distinguished by soft, brown, spongy tissue within the fruit cortex. In severe cases complete rings of brown flesh tissue can form. Soggy breakdown is a storage chilling-related disorder and it typically develops at storage temperatures less than 2°C. Therefore, to reduce the incidence of soggy breakdown, it is recommended that Honeycrisp be stored at 3°C, but only after partial cooling (conditioning) at 10°C for the initial week of storage. This procedure will also help reduce soft scald development (DeEll 2017).
Many factors have been related to soggy breakdown development in apples, such as advanced maturity at harvest, light crops, large fruit size, and low temperature in storage. The most frequently mentioned factors are weather conditions before fruit harvest, with cooler temperature and excess moisture near harvest time inducing soggy breakdown (Lachapelle 2017).

REFERENCE FOR THE MODEL

Lachapelle M., G. Bourgeois, J. DeEll, K.A. Stewart, P. Séguin. 2017. Modeling the Effect of Preharvest Weather Conditions on the Incidence of Soggy Breakdown in ‘Honeycrisp’ Apples. HortScience 52(5): 756-763

Model developed from Maude Lachapelle’s work by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at Saint-Jean-sur-Richelieu on Honeycrisp apples. The data came from different plots in Quebec, Ontario and Nova Scotia between the years 2002 and 2017. The data were analyzed and compiled by Cyrille Viens, Antoine Plourde-Rouleau and Sabrina Cloutier in 2017 and 2018.

INTERPRETATION OF THE CURVE

Depending on the region where the orchard is located, two soggy breakdown models are available, one for Quebec and one for Ontario. The model provides a soggy breakdown incidence index for the Honeycrisp variety during the growing season, specifically during fruit development. This index is based on weather data (temperature, precipitation and solar radiation) between dates of full bloom and harvest. For a better prediction of this disorder in a specific orchard, it is recommended to indicate the observed dates of flowering and harvesting. However, in CIPRA, a module is provided to estimate these dates from the McIntosh phenology model. The season is then separated into 6 sub-periods: 0-14 days after full bloom (DFB), 15-29 DFB, 30-44 DFB, 45-59 DFB, 60-89 DFB and 90 DFB-Harvest. At the end of each sub-period, a different equation generates a prediction of the incidence index based on weather data measured since full bloom. The quality of the predictions improves as the fruit grows, until fruits are harvested. The final prediction, obtained with the equation developed after sub-period 90 DFB-Harvest, gives an idea of the risks for the disorder to appear, according to weather conditions during the growing season.

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

Bramlage W.J. 1993. Preharvest Factors Affecting Scald Development on Apples in the Northeastern United States. Washington State University Tree Fruit Postharvest Journal, vol. 4 (2): 6-7.

Model adapted by the bioclimatology and modelling team at Agriculture and Agri-Food Canada’s Research and Development Centre 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

Insects

Apple leafcurling midge (*Dasineura mali*)

PEST DESCRIPTION

1- Damage on apple leaf; 2- Adult; 3- Larvae; 4- Pupa
Photo 1: OMAFRA
Photos 2 to 4: Laboratoire de diagnostic en phytoprotection - MAPAQ

The adult apple leaf curling midge is a tiny, dark reddish-brown fly 1.5 to 2.5 mm long. It is covered in fine dark hairs and has long whitish legs and long antennae beaded with long hairs in males. The larva is a small wormlike maggot 2 to 3 mm long that is initially red, becoming white until the final larval stage, when it acquires a bright orange colour. The front end part of the larva tapers to a point, with a tiny head at the end. Eggs are pink to bright red and are laid in the leaf folds or along the margins of developing leaves. The pupa is an orange capsule wrapped in a white silken cocoon and is often found on the ground or even below the soil surface.

The larva attacks the leaves and flowers of apple trees, which is particularly damaging to the growth of young trees. The larva spends most of its life rolled up inside a leaf, which it feeds on during the initial larval stages. It then drops to the ground to pupate. Consequently, the presence of tightly curled leaves is the main observable symptom of infestation. Infested leaves turn brown, become brittle and fall from the tree. The insect primarily targets the terminal shoots of apple trees. In young trees, an apple leaf curling midge infestation can slow or even halt growth, potentially killing grafted scions. This pest is specific to apple trees and does not attack other crops.

Midges overwinter as pupae in soil under infested trees. First-generation adults emerge in May and mate. Females then lay eggs on developing leaves or, less often, on buds and developing flowers. Eggs take 2 to 10 days to hatch. The apple leaf curling midge was first reported in Quebec in 2006 and has been on the rise ever since, spreading to nearly every part of the province.

REFERENCE FOR THE MODEL

Apple leafcurling midge: model developed by the Bioclimatology and Modelling research team at Agriculture and Agri-Food Canada's Research and Development Centre in Saint-Jean-sur-Richelieu, in collaboration with the research team of Daniel Cormier of the Institut de recherche et de développement en agroenvironnement (IRDA) at Saint-Bruno-de-Montarville. Data used were collected from 2014 to 2016 in 11 sites in the Estrie, Montérégie and Laurentides (QC) regions by several apple extension consultants. Results compiled by Dominique Plouffe in winter 2017.

Cumulative degree days for each threshold development

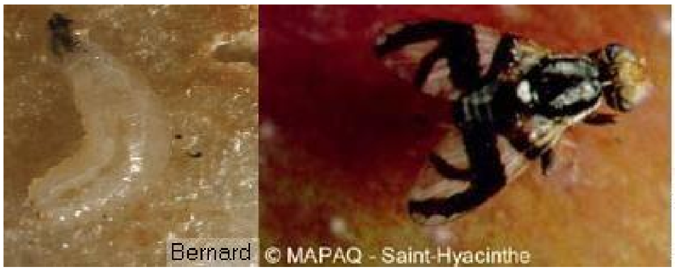
Base temperature = 9°C
Optimal temperature = 30°C
Method = single sine
Date for starting calculations = 1st March

Host: apple	Degree Days (°C)
1st generation, 5% adults	93
1st generation, 50% adults	159
1st generation, 95% adults	242
2nd generation, 5% adults	441
2nd generation, 50% adults	599
2nd generation, 95% adults	794
3rd generation, 5% adults	932
3rd generation, 50% adults	1078
3rd generation, 95% adults	1251

Apple tree

Apple maggot (*Rhagoletis pomonella* (Walsh))

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 research team at Agriculture and Agri-Food Canada’s Research and Development Centre in Saint-Jean-sur-Richelieu. Data used for the models were collected by several apple extension consultants, from 2006 to 2014 in different regions of Quebec. Results compiled by Dominique Plouffe in fall 2015.

Cumulative Degree days for each threshold development

Model 1
Base temperature = 6.4°C
Optimal temperature = 26°C
Method = single sine
Date for starting calculations = 1st March

Host: apple	Degree Days (°C)
5% adults	861
50% adults	1138
98% adults	1463

Model with biofix
Base temperature = 6.4°C
Optimal temperature = 26°C
Method = single sine
Date for starting calculations = 1st adult capture

Host: apple	Degree Days (°C)
50% adults	279
98% adults	603

INTERPRETATION OF THE CURVE[1]

If not effectively suppressed, apple maggots can cause an incredible amount of damage. Model 1 can be used to predict the arrival 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 this model. Model with biofix predicts the evolution of the population starting the date of first adult capture. 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 April 2016.

[Apple tree]

[1] 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 (*Cydia pomonella* (L.))

PEST DESCRIPTION

MAPAQ.

Ginette H. Laplante, 1995.

MAPAQ, 2000.

The codling moth is a twilight moth, 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 5th 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. In spring, the female lays most of the eggs on the upper surface of the leaves. In early summer, most eggs are laid on the underside of the leaves and later, most eggs are laid on the 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 Research and Development Centre in Saint-Jean-sur-Richelieu. Data used for the models were collected by several apple extension consultants, from 2006 to 2014 in different regions of Quebec. Results compiled by Dominique Plouffe in fall 2015. The model was then completed by adding stages based on the model developed by Agropomme (Cormier et al., 2016), and validated in Quebec with laboratory observations and commercial orchards (Pelletier et al., 2010). Other adjustments made by Marie-Pier Ricard in 2017.

Cumulative Degree days for each threshold development

<u>Model 1</u>
Base temperature = 10°C
Optimal temperature = 30°C
Method = single sine
Date for starting calculations = 1st March

Host: apple	**Degree Days (°C)**
1st generation, 5% adults	205
1st generation, 20% adults	290
1st generation, 50% adults	405
1st generation, 50% egg-laying	440
1st generation, 50% larvae 1-2	591
1st generation, 95% adults	635
1st generation, 50% larvae 3-5	751
1st generation, 50% chrysalis	848
1st generation, 50% hibernaculum	953
2nd generation, 50% adults	1018

<u>Model with biofix</u>
Base temperature = 10°C
Optimal temperature = 30°C
Method = single sine
Date for starting calculations = 1st adult capture

Host: apple	**Degree Days (°C)**
1st generation, 20% adults	85
1st generation, 50% adults	200
1st generation, 95% adults	430

INTERPRETATION OF THE CURVE[1]

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).

Model 1 can be used to determine when scouting operations for caterpillars and moths should begin and the timing of pheromone diffusers for sexual confusion control. Model with biofix predicts populations

[1] Text written in collaboration with Gérald Chouinard and Daniel Cormier, researchers entomologists at the Institut de recherche et de développement en agroenvironnement (IRDA) de Saint-Bruno, Saint-Bruno-de-Montarville, Quebec.

starting on the date of first adult capture. These two models are useful to determine the optimum time for preventative measures against eggs and caterpillars in orchards where damage has occurred previously. The critical stages are as follows:

- First adults (5% capture, first generation): install pheromone traps (and diffusers for sexual confusion, if applicable) 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 (model developed in Michigan).
- 20% capture, first generation (< 10% egg laying): favourable period for a preventive treatment using ovicide before egg laying.
- 50% captures, first generations (< 10% egg hatching): peak adult catch of the first generation is sometimes used to predict the beginning of treatments against larvae.
    - 50% captures: suitable time for preventive treatment with an ovicide-larvicide.
    - 50 % catch + 100 DJ_{10}: favourable period for a preventive treatment with a larvicide.

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 August 2018.

Apple tree

Brown marmorated stink bug (*Halyomorpha halys* (Stål))

PEST DESCRIPTION

Photos
1) Laboratoire de diagnostic en phytoprotection, MAPAQ
2) Kim Hoelmer, USDA
3) George Hamilton, Rutgers University

The adult is approximately 17.0 mm long (Photo 1). Its marbled brown body has the characteristic shield shape of stink bugs in the family Pentatomidae. Its forewings are tinged pale pink, and there are light bands on the last two segments of its antennae and alternating light and dark patches along the connexivum, the border of its abdomen. Females lay masses of eggs on the undersides of leaves from June to August (Photo 2). First instars are 2.4 mm long and are coloured orange with black and red spots (Photo 3). Later instars are 5.5 to 12.0 mm long and are darker in colour, with bands on their legs and antennae like adults.

Quebec's climate allows for only one generation per year, but up to five generations can be produced further south. The brown marmorated stink bug feeds on a wide range of fruit, vegetable and ornamental crops, as well as on soybean. It pierces the plant tissue and sucks out the sap, resulting in the formation of necrotic areas at feeding sites. Almost all aerial parts of plants can be targeted, including fruit, stems, leaves and buds. The worst damage occurs on fruit, causing discoloration or deformation and mushy flesh.

As of 2016, the brown marmorated stink bug had not yet been sighted in Quebec, despite the presence of a scouting network in southern Quebec. However, the observations that have been made confirm the insect's strong potential to be spread by human activity.

For more information: https://www.agrireseau.net/documents/Document_88951.pdf (in French).

REFERENCE FOR THE MODEL

Brown marmorated stink bug

Nielsen, A.L., G.C. Hamilton and D. Matadha. 2008. Developmental rate estimation and life table analysis for *Halyomorpha halys* (Hemiptera: Pentatomidae). *Environmental Entomology* 37:348-355.

Nielsen, A.L. et G.C. Hamilton. 2009. Life history of the invasive species *Halyomorpha halys* (Hemiptera: Pentatomidae) in Northeastern United States*. Annals of the Entomological Society of America* 102:608-616.

Cumulative degree days for each threshold development

Base temperature = 14°C
Optimal temperature = 30°C
Method = single sine
Date for starting calculations = 1st March

Host: apple, grain maize, soya, wheat	**Degree Days (°C)**
1% egg-laying	147
1% nymphs 1-3	208
50% egg-laying	222
99% egg-laying	297
50% nymphs 1-3	374
1% nymphs 4-5	451
50% nymphs 4-5	598
1% adults	655
50% adults	773
99% adults	891

Apple
Field crops

Dogwood borer (*Synanthedon scitula*)

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 Research and Development Centre in Saint-Jean-sur-Richelieu, in collaboration with Gérald Chouinard and his research team of the Institut de recherche et de développement 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 = 1st March

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

INTERPRETATION OF THE CURVE[1]

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

[1] 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.

European apple sawfly (*Hoplocampa testudinea*)

PEST DESCRIPTION

Bernard Drouin, MAPAQ.

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 research team at Agriculture and Agri-Food Canada's Research and Development Centre in Saint-Jean-sur-Richelieu. Data used for the models were collected by several apple extension consultants, from 2006 to 2014 in different regions of Quebec. Results compiled by Dominique Plouffe in winter 2016.

Cumulative Degree days for each threshold development

Base temperature = 4.5°C
Optimal temperature = 25°C
Method = single sine
Date for starting calculations = 1st March

Host: apple	Degree Days (°C)
5% adults	222
50% adults	277
98% adults	363

INTERPRETATION OF THE CURVE[1]

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

[1] 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.

European red mite (*Panonychus ulmi* (Koch))

PEST DESCRIPTION

Guide d'identification des insectes des pommiers et des poiriers, bayer cropscience 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 = 1st March

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

INTERPRETATION OF THE CURVE[1]

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.

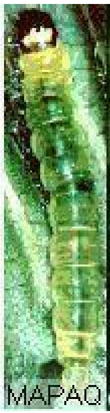
The latest edition of this text was made on July 2014.

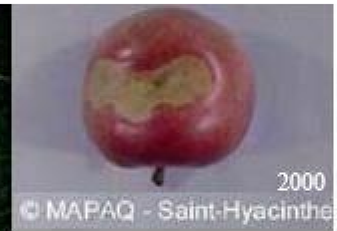
Apple tree

[1] 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.

Fruit tree leafroller (*Archips argyrospila* (Wlk.))

PEST DESCRIPTION





MAPAQ.

Lina Breton, Québec Minister of Forests.

MAPAQ, 2000.

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 Research and Development Centre 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 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 = 1st March

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

INTERPRETATION OF THE CURVE[1].

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.

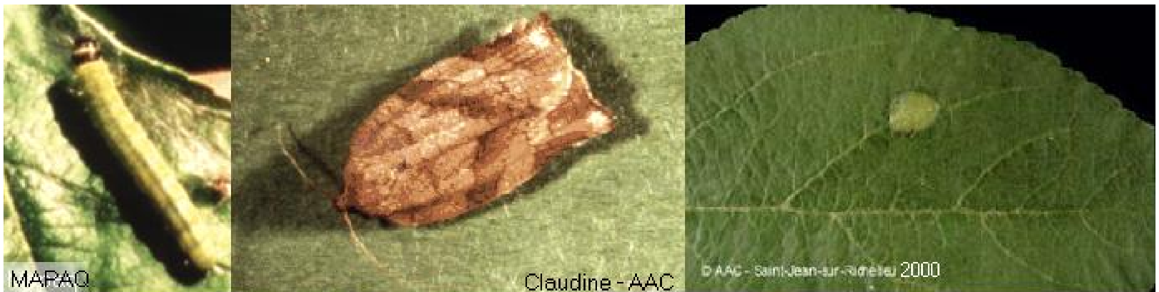
The latest edition of this text was made on July 2014.

Apple tree

[1] 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 (*Choristoneura rosaceana* (Harris))

PEST DESCRIPTION



MAPAQ.

Claudine Aubertin.

MAPAQ, 2000.

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 Research and Development Centre 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 = 1st March

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

INTERPRETATION OF THE CURVE[1]

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.

[1]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 (*Grapholita molesta*)

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.

Pennsylvanie : 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 Research and Development Centre 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 = 1st March

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

Pennsylvania
Base temperature = 7.2°C
Optimal temperature = 32.2°C
Method = single sine
Date for starting calculations = 1st sustained moth captures

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

PENN / AAFC

Date for starting calculations = 1st sustained moth captures

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

Apple tree

Plum curculio (*Conotrachelus nenuphar*)

PEST DESCRIPTION

MAPAQ

MAPAQ, 2000.

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.*, 1999).

REFERENCE FOR THE MODEL

Plum curculio (Chouinard): model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Research and Development Centre 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 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 = 1st March

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

INTERPRETATION OF THE CURVE[1]

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

[1] 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.

Redbanded leafroller (*Argyrotaenia velutinana* (Wlk.))

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 Research and Development Centre 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 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 = 1st March

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

INTERPRETATION OF THE CURVE[1]

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 rares 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

[1] 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.

Speckled green fruitworm (*Orthosia hibisci)*

PEST DESCRIPTION

Agriculture and Agri-Food Canada, 2000.

MAPAQ, 2000.

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 Research and Development Centre 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 = 1st March

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

INTERPRETATION OF THE CURVE[1]

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

[1] 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 (*Phyllonorycter blancardella* (Fabricius))

PEST DESCRIPTION

Bernard Drouin, MAPAQ.

MAPAQ, 2000.

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 Research and Development Centre 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 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 = 1st March

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

INTERPRETATION OF THE CURVE[1]

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% 1st generation and 5% 2nd 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.

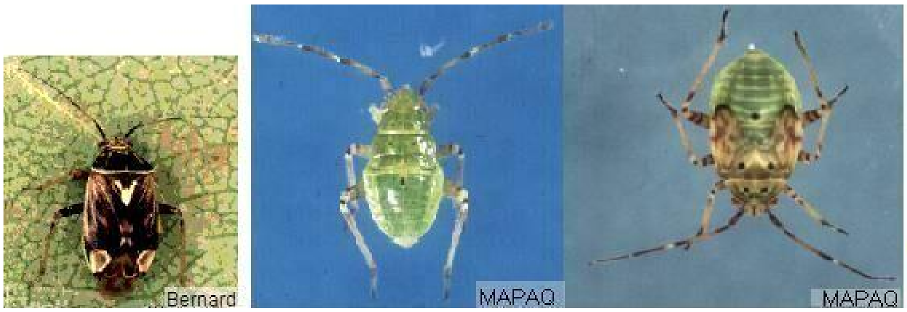
The latest edition of this text was made on July 2014.

Apple tree

[1] 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.

Tarnished plant bug (*Lygus lineolaris* (P. de B.))

PEST DESCRIPTION



Bernard Drouin, MAPAQ.

MAPAQ.

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 Research and Development Centre 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 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 = 1st March

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

INTERPRETATION OF THE CURVE[1]

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

[1] 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.

Diseases

Apple scab (*Venturia inaequalis* (Cke.) Wint.)

DISEASE DESCRIPTION

Agriculture and Agri-food Canada.

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 = 1st March

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

INTERPRETATION OF THE CURVE [1],[2],[3]

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.

Text prepared in collaboration with:
[1] Odile Carisse, phytopathologist at the Horticultural Research and Development Centre of Agriculture and Agri-food Canada, Saint-Jean-sur-Richelieu, Québec.
[2] Léon Tartier, retired plant pathologist with the Centre de recherche en production végétale de Saint-Hyacinthe, Quebec Department of Agriculture, Fisheries and Food.
[3] Vincent Philion, phytopathologist at the Research and Development Institute for the Agri-Environment (IRDA) at Saint-Bruno-de-Montarville.

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

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 momentsthe 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 (Erwinia amylovora)

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 18ºC, 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 4-32ºC, with rapid multiplication leading to infection occurring most frequently when temperatures are between 24-28ºC. 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 MODEL

Smith, T.J. and P.L. Pusey. 2011. CougarBlight 2010, a significant update of the CougarBlight fire blight infection risk model. Acta Hort. 896:331-336.

Infection risk table

Date for starting calculations: pink stage
Infection thresholds for fire blight vary according to 3 scenarios and it is essential to choose the appropriate one that corresponds to the studied region.

Scenario 1: This scenario can be used only when fire blight was not a problem the previous year in the contiguous region. It should not be used in any region where fire blight is a significant problem more frequently than once every eight or ten years.

Scenario 2: In regions that have fire blight to some degree almost yearly, with some years far worse than others, it is assumed that live cankers are likely scattered across the region every spring, but not necessarily near the orchard where infection risk is being evaluated.

Scenario 3: Orchards that had blight problems the previous year or that present live cankers this year enter in this category. The lowest range of thresholds are used in these regions.

Orchard situation: Potential for pathogen presence?	**Low**	**Intermediate**	**High**	**Extreme**
Scenario 1: No fire blight in your neighborhood last year	0 to 300	300 to 500	500 to 800	801 +
Scenario 2: Fire blight occurred in your neighborhood last year	0 to 100	100 to 200	200 to 350	350 to 500
Scenario 3: Active cankers and/or fire blight in your neighborhood	Not an option	0 to 100	100 to 200	200 to 300

INTERPRETATION OF THE CURVE

Meaning of risk category (Smith and Pusey, 2011)

Low: Wetting of flowers does not result in new infections. The flowers within a few meters of an active canker may be an exception.

Intermediate (caution)**:** Wetting of flowers during this period is not likely to lead to infection, but the possibility increases as values approach the upper range. Weather forecasts and risk values should be carefully monitored.

High: When the curve is in this risk threshold, serious outbreaks of fire blight may occurred. Orchards that recently had blight are especially vulnerable. The risk of severe damage from infection increases during the later days of the primary bloom period, and during petal fall, while blossoms are plentiful. Infection is common, but more scattered when late blossoms are wetted during high risk periods. The potential severity of infection increases if a series of high risk days occur.

Extreme: Some of the most damaging fire blight epidemics occur under these conditions, followed by blossom wetting. These infections often lead to severe orchard damage, especially during primary bloom or when numerous secondary blossoms are present. As the season progresses, secondary blossoms tend to form less frequently, and hot summer temperatures of 35°C and above greatly reduce the frequency of new blossom infections.

Monitoring precipitation forecasts, combined with the use of a predictive leaf wetness model, is essential to assess blossom wetting and to interpret the results given by the blight model. In CIPRA, you can use the Gleason model under the "**Weather models**" **-** "**Leaf wetness**" menu.

In any case, do not hesitate to contact your local agricultural advisor if you think that there are risks of fire blight in your neighborhood.

The latest edition of this text was made on March 2015.

Apple tree

Bean

Common bean Phenology

Common bean Phenology

DESCRIPTION OF PHENOLOGY

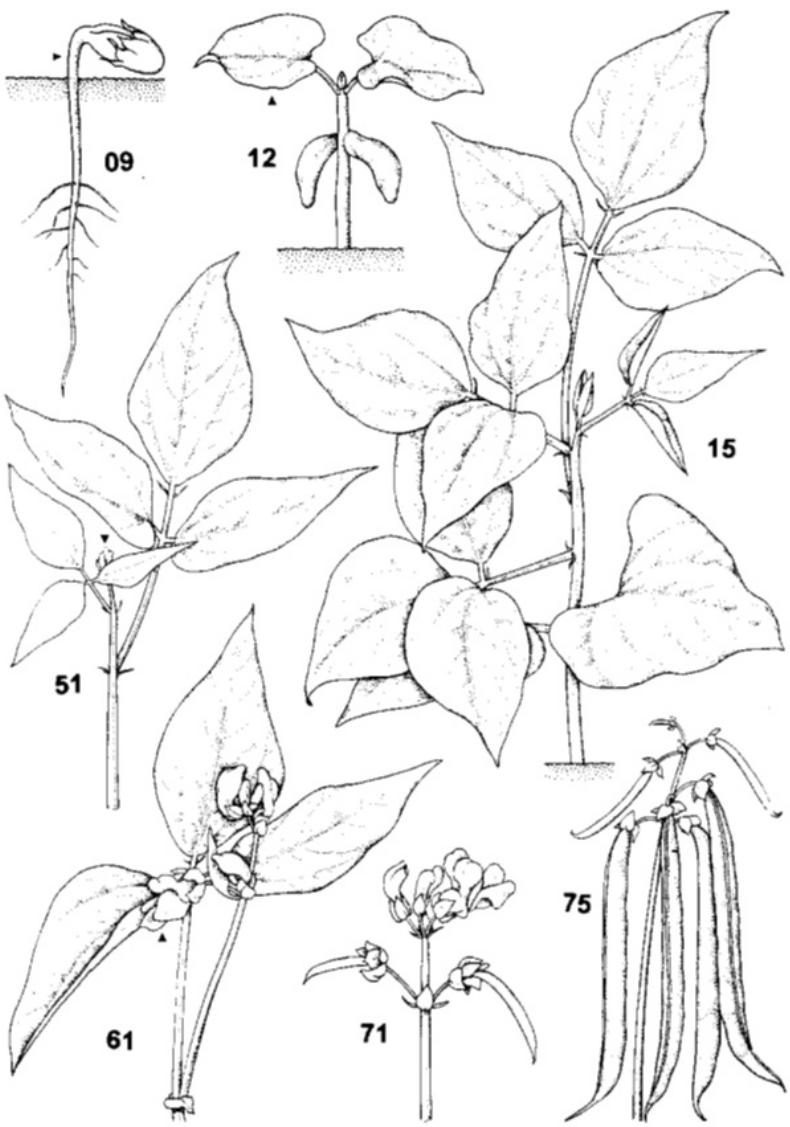
Bioclimatic models can be used to establish links between biological processes and meteorological phenomena. They provide agricultural decision makers with guidance on cultivation practices, such as the cultivars to use in a given area, sowing dates and harvesting dates. For bean production, temperature is the main climate factor influencing crop yield and quality. Seeds are highly sensitive to cold and germination is optimal at 25°C. Also, to avoid physiological disorders (seed rot), germination temperature should be above 10°C and during the reproductive phase, high temperatures induce bud and flower abscission and decline of productivity. The accumulation of degree days is therefore important after the first flowering. This is an important datum for predicting crop yield and quality.

Phenological growth stages and BBCH-identification keys of Bean (Meier, 2001)
(*Phaseolus vulgaris* var. nanus L.)

Code	Description
Principal growth stage 0: Germination	
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
08	Hypocotyl reaches the soil surface; hypocotyl arch visible
09	Emergence: hypocotyl with cotyledons break through soil surface (“cracking stage”)
Principal growth stage 1: Leaf development	
10	Cotyledons completely unfolded
12	2 full leaves (first leaf pair unfolded)
13	3rd true leaf (first trifoliate leaf) unfolded
1 .	Stages continuous till . . .
19	9 or more leaves (2 full leaves, 7 or more trifoliate) unfolded
Principal growth stage 2: Formation of side shoots	
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
Principal growth stage 5: Inflorescence emergence	
51	First flower buds visible
55	First flower buds enlarged
59	First petals visible, flowers still closed
Principal growth stage 6: Flowering	
60	First flowers open (sporadically within the population)
61	Beginning of flowering
62	20% of flowers open
63	30% of flowers open
64	40% of flowers open
65	Full flowering: 50% of flowers open1 Main flowering period
67	Flowering finishing: majority of petals fallen or dry
69	End of flowering: first pods visible

Principal growth stage 7: Development of fruit

71 10% of pods have reached typical length
72 20% of pods have reached typical length
73 30% of pods have reached typical length
74 40% of pods have reached typical length
75 50% of pods have reached typical length, beans beginning to fill out, main pod development period
76 60% of pods have reached typical length
77 70% of pods have reached typical length, pods still break cleanly
78 80% of pods have reached typical length
79 Pods: individual beans easily visible



REFERENCE FOR THE MODEL

Bean Phenology

Jenni, S., Bourgeois, G., Laurence H., Roy, G. et N. Tremblay. 2000. Improving the Prediction of Processing Bean Maturity Based on the Growing-degree Day Approach. HortScience 35(7):1234-1237.

Models were developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu based on data from reports on cultivar trials of processing vegetables (pea, bean, corn) from 1998 to 2013.
Data compiled by Stéphanie Lavergne in the summer of 2015.

Cumulative degree days for each threshold development

Base temperature = 5°C
Optimal temperature = 30°C
Method = single sine
Date for starting calculations = sowing date

Common bean - early cultivars [1] (BBCH)	**Degree Days (°C)**
Beginning of flowering (61)	587
Harvest (79)	885

[1] Cultivars used to develop the early model: Dart, Goldmine, Goldrush, Impact, Labrador

Common bean - intermediate cultivars [2] (BBCH)	**Degree Days (°C)**
Beginning of flowering (61)	606
Harvest (79)	932

[2] Cultivars used to develop the intermediate model: Matador, Minuette, Sonesta, Teseo

Common bean - late cultivars [3] (BBCH)	**Degree Days (°C)**
Beginning of flowering (61)	605
Harvest (79)	995

[3] Cultivars used to develop the late model: Angers, Bowie, Caprice, Huntington

Bean

Blueberry

Highbush Blueberry Phenology
Lowbush Blueberry Phenology

Highbush Blueberry Phenology

DESCRIPTION OF PHENOLOGY

Bud swelling (BBCH = 51): Beginning of bud swelling; clear border on edges of bud scales.
Green tip (BBCH = 54): Leaf tips above the bud scales.

Separated buds (BBCH = 59): All flower buds separated from each other.
Flowering (BBCH = 65): Full flowering, at least 50% of flowers open, first petals falling.

Fruit setting (BBCH = 71): Beginning of fruit formation, first fruits visible at raceme base.
Green fruit (BBCH = 75): At least 50% of fruits formed; fruits are green.

Veraison (BBCH = 81) : Beginning of ripening, first fruits are turning blue.
Mature fruit-harvest (BBCH = 87): Fruit ripe for picking; most fruits are ripe and blue; they have reached the maturity necessary for harvest. Photos source: Gaétan Racette, AAC

REFERENCE FOR THE MODEL

Highbush Blueberry Phenology

Meier, U., H. Bleiholder, *et al.* 2001. Growth stages of mono-and dicotyledonous plants, BBCH Monograph. 60-62.

Bleuet en corymbe. Guide de protection. CRAAQ 2012. 27 p.

Results were based on the warnings issued by the MAPAQ “Réseau d'avertissements phytosanitaires" (Phytosanitary warning network) from 2005 to 2016 and data collected by the Bioclimatology and Modelling research team at Agriculture and Agri-Food Canada’s Research and Development Centre in Saint-Jean-sur-Richelieu during 2014 to 2016 growing seasons. The model was developed by the Bioclimatology and Modelling research team. Data compiled by Antoine Hénault in winter 2017.

Cumulative degree days for each threshold development

Cutivar: Patriot
Base temperature = 0°C
Optimal temperature = 30°C
Method = single sine
Date for starting calculations = 1st March

Highbush Blueberry (BBCH)	Degree Days (°C)
Bud swelling (51)	173
Green tip (54)	267
Separated buds (59)	462
Flowering (65)	576
Fruit setting (71)	765
Green fruit (75)	929
Veraison (81)	1275
Mature fruit-harvest (87)	1598

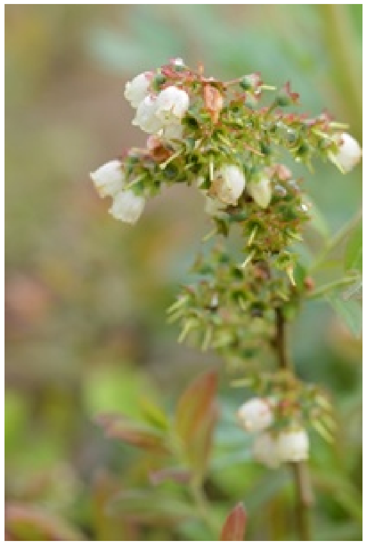
Blueberry

Lowbush Blueberry Phenology

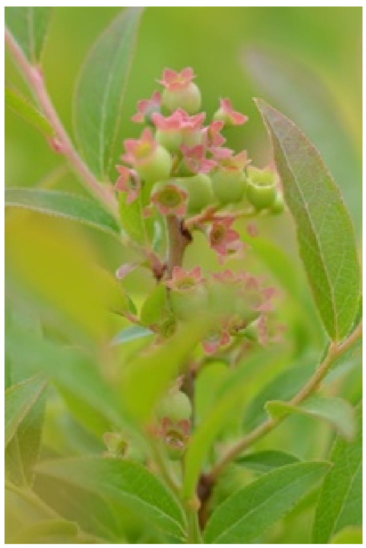
DESCRIPTION OF PHENOLOGY

Bud swelling (BBCH = 51): Inflorescence buds and leaf buds swelling, buds closed, light brown scales visible.
Bud burst (BBCH = 53): Scales separated, light green spots visible on buds.

Flower buds emergence (BBCH = 55): First flower buds (compact raceme) visible beside unfolded leaves.
Flower buds (BBCH = 59): All flower buds are fully developed (separated).

Flower buds emergence (BBCH = 55): First flower buds (compact raceme) visible beside unfolded leaves.
Flower buds (BBCH = 59): All flower buds are fully developed (separated).

Fruit setting (BBCH = 71): Beginning of fruit formation, first fruits visible at raceme base.
Green fruit (BBCH = 75): At least 50% of fruits formed; fruits are green. Growth is slowed.

Veraison (BBCH = 81) : Beginning of ripening, first fruits are turning blue.
Mature fruit-harvest (BBCH = 87): Fruit ripe for picking; most fruits are ripe and blue; they have reached the maturity necessary for harvest.

Photos source: Raphaël Porlier-Fournier, MAPAQ

REFERENCE FOR THE MODEL

Lowbush Blueberry Phenology

Meier, U., H. Bleiholder, *et al.* 2001. Growth stages of mono-and dicotyledonous plants, BBCH Monograph. 60-62.

AAC. 2011. Profil de la culture du bleuet nain au Canada. 61 p.

CRAAQ. 2013. Guide d'identification - Alliés et ennemis du bleuet nain. 33 p.

The model was developed by the Bioclimatology and Modelling research team at Agriculture and Agri-Food Canada's Research and Development Centre in Saint-Jean-sur-Richelieu. Results were based on the warnings issued by the MAPAQ "Réseau d'avertissements phytosanitaires" (Phytosanitary warning network) from 2005 to 2016. Data compiled by Stéphanie Lavergne in winter 2017.

Cumulative degree days for each threshold development

Model 1
Base temperature = 0°C
Optimal temperature = 28°C
Method = single sine
Date for starting calculations = 1st March

Lowbush Blueberry (BBCH)	Degree Days (°C)
Bud swelling (51)	236
Bud burst (53)	262
Flower buds emergence (55)	307
Flower buds (59)	320
Full bloom (65)	458
End of flowering (67)	553
Fruit setting (71)	650
Green fruit (75)	760
Veraison (81)	1044
Mature fruit - harvest (87)	1195

Model 2: with snow cover
Base temperature = 0 °C
Optimal temperature = 28 °C
Method = single sine
Date for starting calculations = last day when the snow cover is less than 10 cm[1]

Lowbush Blueberry (BBCH)	Degree Days (°C)
Bud swelling (51)	230
Bud burst (53)	244
Flower buds emergence (55)	278
Flower buds (59)	328
Full bloom (65)	396
End of flowering (67)	487
Fruit setting (71)	582
Green fruit (75)	691
Veraison (81)	973
Mature fruit - harvest (87)	1125

[1] Date determined by the user or estimated by the snow depth model implemented in CIPRA.

Blueberry

Carrot

Carrot Phenology

Insects
Carrot rust fly
Carrot weevil

Diseases
Alternaria blight
Cercospora blight

Carrot Phenology

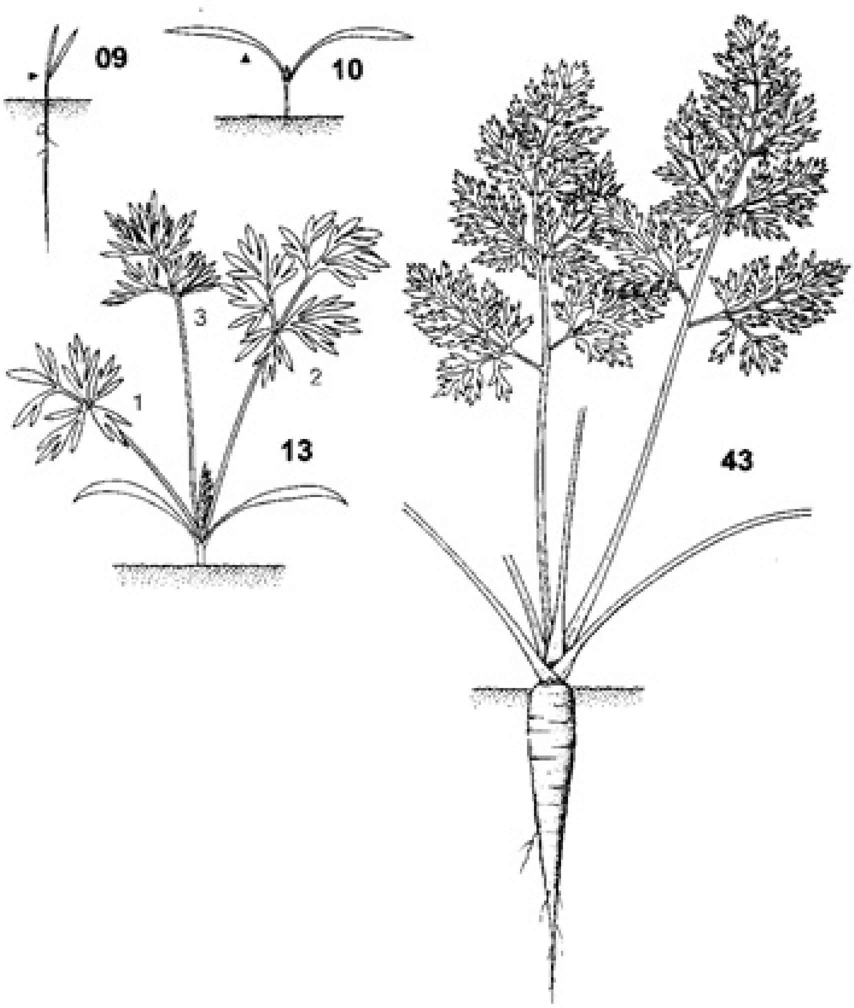
DESCRIPTION OF PHENOLOGY

For a carrot producer, the ability to predict phenology is key to ensuring an optimal harvest and meeting market needs during the growing season. In addition, simultaneous modelling of the phenology of carrot and its biological threats (carrot weevil, Alternaria blight, Cercospora blight) can help farmers plan phytosanitary treatments by synchronizing the treatments with the phases when carrots are vulnerable to the presence of pests/diseases.

The BBCH-scale used for the carrot phenology model is a two-digit code that provides a precise description of the principal and secondary growth stages of the crop. The model presents a foliar stage followed by a commercial stage.

Phenological growth stages and BBCH-identification keys of root and stem vegetables (Meier, 2001)
(Carrot = Daucus carota L. ssp. sativus)

Code	Description
Principal growth stage 0: Germination	
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
Principal growth stage 1: Leaf development (Main shoot)	
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
Principal growth stage 4: Development of harvestable vegetative plant parts	
41	Roots beginning to expand (diameter > 0,5 cm)
42	20% of the expected root diameter reached
43	30% of the expected root diameter reached
44	40% of the expected root diameter reached
45	50% of the expected root diameter reached
46	60% of the expected root diameter reached
47	70% of the expected root diameter reached
48	80% of the expected root diameter reached
49	Expansion complete; typical form and size of roots reached



REFERENCE FOR THE MODEL

Carrot Phenology: Model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu using data collected from 2005 and 2006 at the experimental farm in Sainte-Clotilde (QC).

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

Carrot

Insects

Carrot rust fly (*Psila rosae* (Fabricius))

PEST DESCRIPTION

MAPAQ.

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 Research and Development Centre 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 = 1st March

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

INTERPRETATION OF THE CURVE[1],[2]

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.

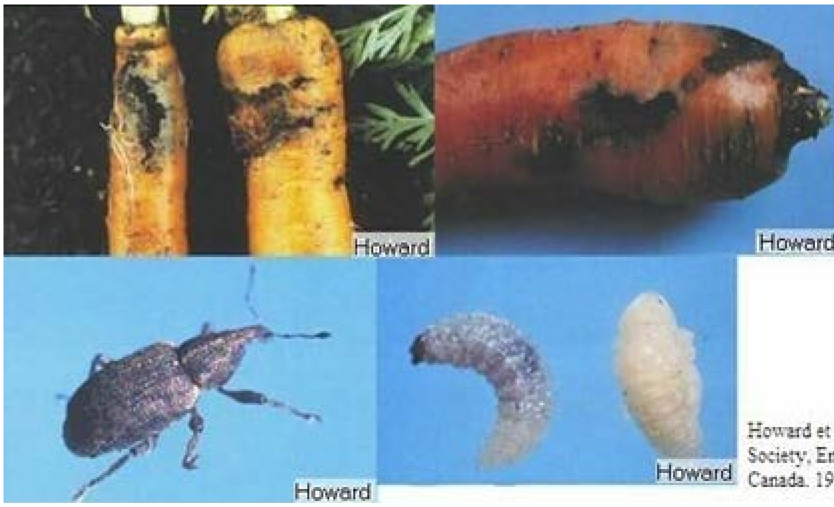
The latest edition of this text was made on March 1998.

Carrot

[1] Text written in collaboration with Pierre Sauriol, agrologist, Productions en régie intégrée du Sud de Montréal, enr. (PRISME), Sherrington, Québec.
[2] 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 (*Listronotus oregonensis* (LeConte))

PEST DESCRIPTION



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

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 Research and Development Centre 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 = 1st adults capture

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

INTERPRETATION OF THE CURVE[1]

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 indicate 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

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

Diseases

Alternaria blight (*Alternaria dauci* (Kühn) Groves & Skolko)

PEST DESCRIPTION

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

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 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 = 1st April

Host: carrot	Infection index
Low	1
Intermediate	2
High	3

INTERPRETATION OF THE CURVE

The system calculates an infection risk index on a scale of 1 to 3, where 1 is a low infection risk, 2 is the treatment threshold (moderate infection), and 3 is a major infection risk. The model uses the following criteria:

1) No fungicide spraying until symptoms appear on 1% to 2% of leaves.
2) Fungicide spraying if the 36-hour forecast predicts weather conditions favourable to Alternaria infection of carrot leaves. Treatments should therefore be applied once the prediction curve exceeds the threshold of 2.
3) Intervals of 7 to 10 days between treatments.

This text was last revised in July 1999.

Carrot

Cercospora blight (*Cercospora carotae* (Pass.) Solheim)

PEST DESCRIPTION

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

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 weatness 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[1]

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.” (available in French only). See bibliography.

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

Carrot

[1] Agrologist, Productions en régie intégrée du Sud de Montréal, enr. (PRISME), Sherrington, Québec.

Cranberry

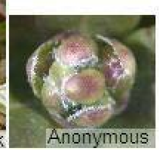
Cranberry Phenology

Insects
Blackheaded fireworm
Cranberry tipworm
Cranberry fruitworm

Cranberry Phenology

DESCRIPTION OF PHENOLOGY (Guérin, 2009a)

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:



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.

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.

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.

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.

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

Photos source: Mark Longstroth, Steven Gordon, Ben Lear from Michigan State University.

REFERENCE FOR THE MODEL

Cranberry phenology: model developed by the Bioclimatology and Modelling research team of the 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 = 1st 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

Blackheaded fireworm (*Rhopobota naevana* (Hübner))

PEST DESCRIPTION

Adult

Mature larva

Damage on cranberry

Images from: ©Laboratoire d’expertise et de diagnostic en phytoprotection – MAPAQ
From: IRIIS phytoprotection (http:// www.iriisphytoprotection.qc.ca/), 11/07/2018

The blackhead fireworm adult is a grey or olive brown moth, with a coppery tinge and gray transverse bands more or less dark. At rest, its wings give it a tent shape. It has a wingspan of 9 to 11 mm. The oval eggs, that measure approximatively 0.7 mm, are pale yellow or whitish and turn red during overwintering. The caterpillar has 5 pairs of prolegs. Its body is greenish-yellow or beige-brown and is dotted with small tubercles. Its head, thorax and legs are black. At maturity, it measures 10 mm long and when disturbed, the caterpillar wriggles vigorously.

The blackhead fireworm produces two generations per year. It overwinters in the egg stage, and the eggs hatch in May. The adults of the first generation emerge in June and the females lay their eggs singly under the leaves of new shoots. The second-generation caterpillars can be seen in July. In August, the second-generation adults emerge and are active until mid-September. Eggs laid at this period go into diapause in the fall. The adults are not very mobile; they are active during the day, except during hot, overcast days. Their peak of activity is at dusk.

In the spring, the newly hatched larvae feed on the leaves from which they have just emerged. They burrow into the old foliage and then weave a silk web joining several leaves at the tip of a stem. There they eat the terminal buds and leaves, leaving only the veins. As they eat, they add stems to their web. During a severe infestation, the foliage turns brownish and looks as though it has been scorched by fire. In summer, the second-generation caterpillars devour the new shoots, flowers and fruits. They weave a silk web joining several berries, into which they may bore holes or nibble furrows. Eventually, the leaves they have devoured fall off, leaving the stem bare and giving the plant this scorched appearance. The fruits that are eaten affect the current production, while the damaged buds have an effect on the following year's production (Le Duc 2004; IRIIS Phytoprotection).

REFERENCE FOR THE MODEL

Blackheaded fireworm: model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at Saint-Jean-sur-Richelieu, in collaboration with the research team of Annabelle Firlej of the Institut de recherche et de développement en agroenvironnement (IRDA) at Saint-Bruno-de-Montarville, using data collected by the "Club environnemental et technique Atocas Québec" (CETAQ) from 2004 to 2015 in the Centre-du-Québec region. Results were compiled by Marie-Pier Lepage during the 2017 fall.

Cumulative degree days for each threshold development

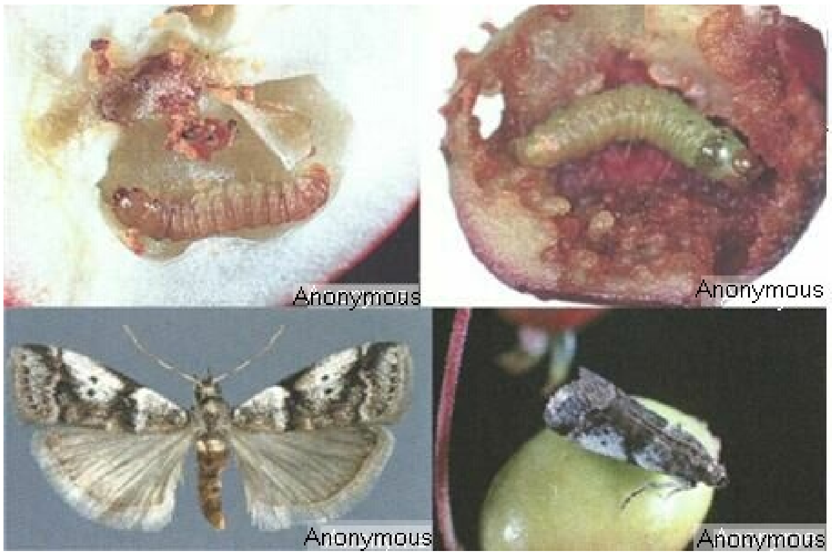
Base temperature = 10°C
Optimal temperature = 30°C
Method = single sine
Date for starting calculations = 1st March

Host: cranberry	**Degree Days (°C)**
1st generation, 5% larvae	103
1st generation, 50% larvae	142
1st generation, 95% larvae	192
1st generation, 5% adults	295
1st generation, 50% adults	390
2nd generation, 5% larvae	471
1st generation, 95% adults	495
2nd generation, 50% larvae	558
2nd generation, 95% larvae	653
2nd generation, 50% adults	806

Cranberry

Cranberry fruitworm (*Acrobasis vaccinii* (Riley))

PEST DESCRIPTION



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 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

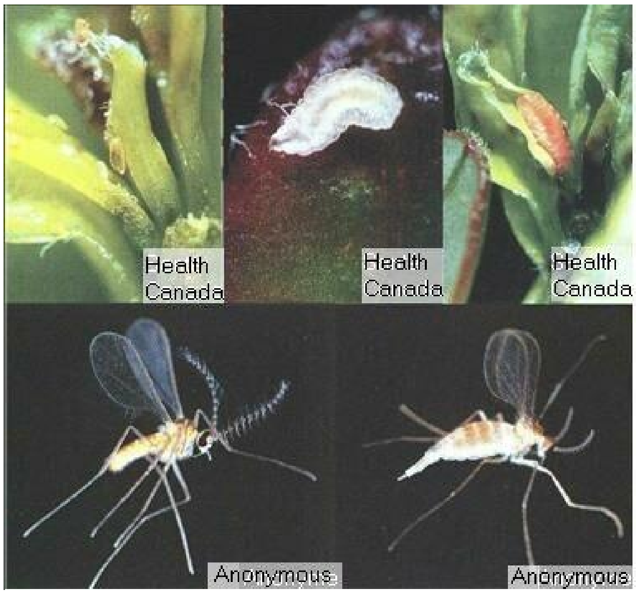
Base temperature = 10°C
Optimal temperature = 40°C
Method = single sine
Date for starting calculations = 1st March

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

Cranberry

Cranberry tipworm (*Dasineura oxycoccana* (Johnson))

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 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 = 1st March

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

Cranberry

Crucifers (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

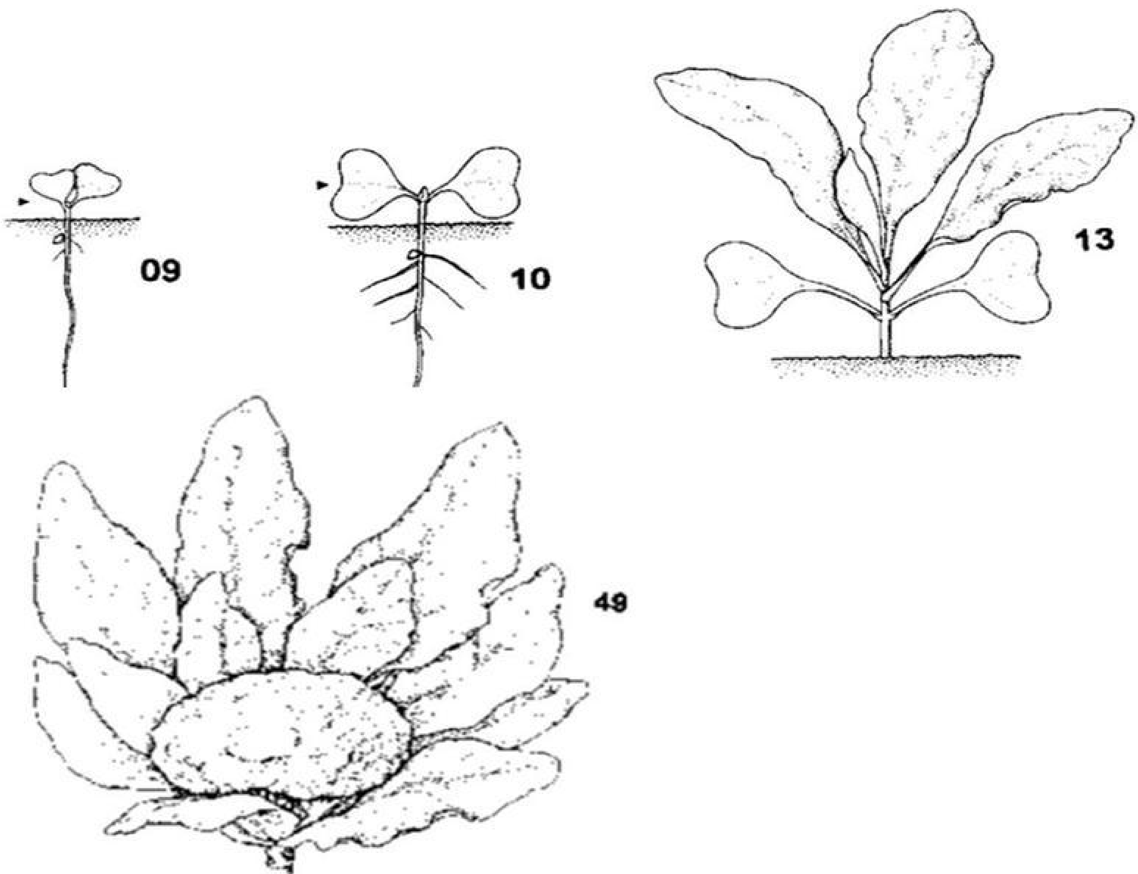
Broccoli Phenology

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)

Code	Description
Principal growth stage 0: Germination	
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
Principal growth stage 1: Leaf development (Main shoot)	
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
Principal growth stage 2: Formation of side shoots	
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
Principal growth stage 4: Development of harvestable vegetative plant parts	
41	Cauliflower heads begin to form;width of growing tip > 1 cm3
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



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

REFERENCE FOR THE MODEL

Broccoli phenology: model developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's Research and Development Centre 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
Start of calculations = variable (date of sowing, transplantation or observation)

Broccoli

Insects

Diamondback moth (*Plutella xylostella* (L.))

PEST DESCRIPTION

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

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 occurence 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 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 = 1st April

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

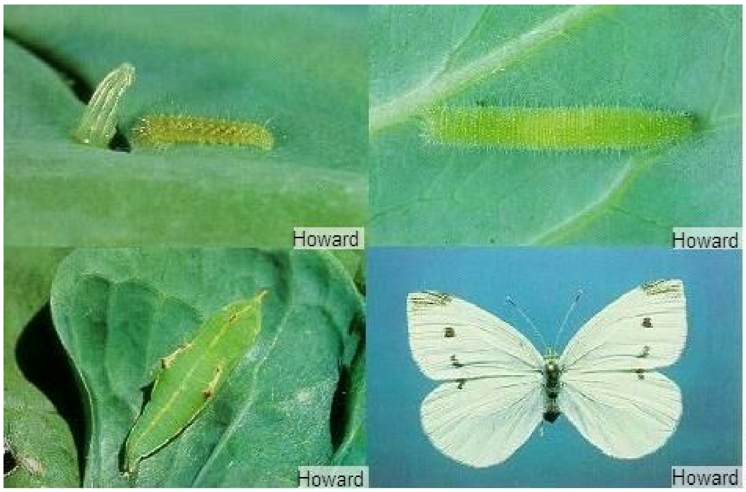
Larva
Base temperature = 7.5°C
Optimal temperature =40°C
Method = single sine
Date for starting calculations = 1st April

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

Broccoli
Cabbage
Brussels sprouts

Imported cabbageworm (*Pieris rapae* (L.) (syn. *Artogeia rapae* (L.)))

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 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 = 1st April

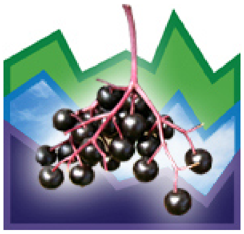
Hosts: cabbage / Brussels Sprouts / broccoli	Degree Days (°C)
1st generation, 10% egg-laying	189
1st generation, 50% egg-laying	208
2nd generation, 10% egg-laying	597
2nd generation, 50% egg-laying	668
3rd generation, 10% egg-laying	964
3rd generation, 50% egg-laying	1054
4th generation, 10% egg-laying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

Larva
Base temperature = 10°C
Optimal temperature =40°C
Method = single sine
Date for starting calculations = 1st April

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

Broccoli
Cabbage
Brussels sprouts

Elderberry



Elderberry Phenology

Elderberry Phenology

DESCRIPTION OF PHENOLOGY


Bloom: 50% or more of the inflorescence flower buds are in bloom.
Green berries: 50% or more of the cluster berries are no longer ovoid, but have taken a more spherical shape. They have increased volume by turgidity and their green color is more pronounced.


Red berries: 50% or more of the cluster berries have a reddish hue.
Black berries: berries have a black purple color. They have entirely lost their reddish hue.

REFERENCE FOR THE MODEL

Elderberry Phenology: model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu using data collected between 2006 and 2010 at the experimental farm at L'Acadie (QC) by Dr Denis Charlebois research team.

Results were compiled by Julie Ladouceur during the 2012 spring.

Cumulative degree days for each threshold development

Base temperature = 5°C
Optimal temperature = 30°C
Method = single sine
Date for starting calculations = 1st March

Elderberry - native cultivars	Degree Days (°C)
5% bloom	695
50% bloom	758
95% bloom	838
50% green berries	877
5% red berries	1305
50% red berries	1416
5% black berries	1491
95 % red berries	1530
50 % black berries	1603
95 % black berries	1699

Elderberry - early flowering cultivars	Degree Days (°C)
5% bloom	629
50% bloom	680
95% bloom	747
50% green berries	802
5% red berries	1236
50% red berries	1330
5% black berries	1402
95 % red berries	1405
50 % black berries	1489
95 % black berries	1585

Elderberry - early midseason flowering	**Degree Days (°C)**
5% bloom	662
50% bloom	713
95% bloom	777
50% green berries	810
5% red berries	1257
50% red berries	1378
5% black berries	1448
95 % red berries	1466
50 % black berries	1544
95 % black berries	1638

Elderberry

Field Crops

Barley

Barley Phenology

Disease

Fusarium

Grain maize

Insects

Brown marmorated stink bug (see Apple)

European corn borer (see Sweet corn)

Southern green stink bug

Soya

Insects

Brown marmorated stink bug (see Apple)

Southern green stink bug

Wheat

Spring Wheat Phenology

Insects

Brown marmorated stink bug (see Apple)

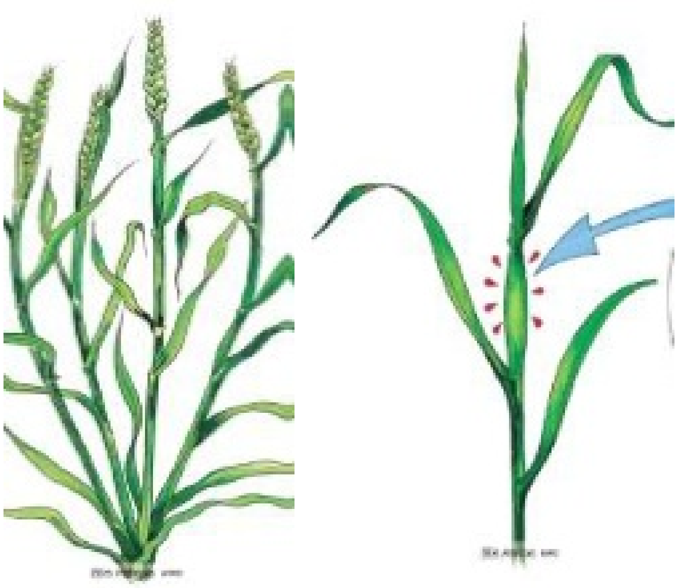
Southern green stink bug

Disease

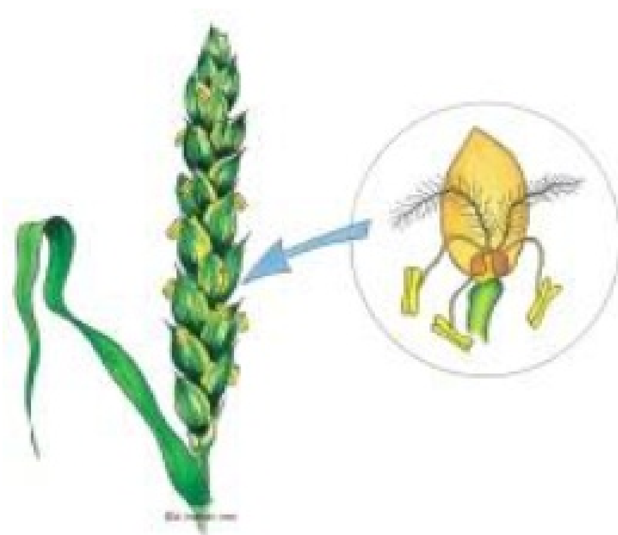
Fusarium

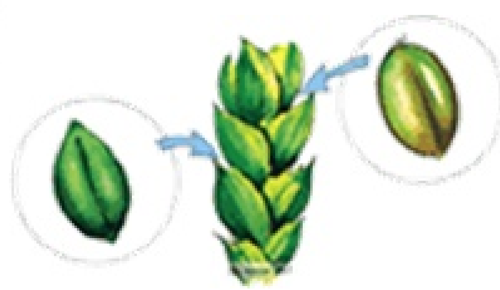
Barley and Spring Wheat Phenology

DESCRIPTION OF PHENOLOGY



Booting: flag leaf sheath extending.
Heading: the tip of the head has almost completely emerged.





Anthesis: full flowering.
Milk stage: the grains pass from the aqueous to milky stage.

Photos: Blés Hybride HYNO

Heading
The heading occurs when the exploded sheath allows to see the ear that will emerge (known as swelling). For bearded varieties such as durum wheat, the ends of barbs appear at the base of the last leaf ligule. Before the ear appearance, a swelling of the sheath is visible. At this stage, the total number of ears is defined, as is the total number of flowers per ear. Each flower can potentially give a grain (eg 25 grains per ear), but it is possible that some flowers never give ear, because of fertilization deficit, for example.

Milky Stage
When the light green grain, of milky content, reaches its definitive size.

REFERENCE FOR THE MODEL

Barley Phenology: Model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu. Data used to calibrate the model was collected at different CRAAQ trial sites and producers fields from 2000 and 2001. The selected cultivars were Beluga, Grant, Myriam and Nadia.

Results compiled by Geneviève Gay in spring 2003.

Cumulative degree days for each threshold development
Base temperature = 0°C
Optimal temperature = 30°C
Method = sinus simple
Date for starting calculations = variable (sowing date)

Barley (Zadoks)	Degree Days (°C)
Booting (40)	723
Heading (58)	834
Anthesis (65)	856
Milk stage (70)	906

Field Crops

Insect

Southern green stink bug (*Nezara viridula* (L.))

PEST DESCRIPTION

1- eggs
2- nymph stage 1
3- nymph stage 2
4- nymph stage 3
5- nymph stage 4
6- nymph stage 5
7- adult

Photos 1 to 6: Herb Pilcher, USDA-ARS
Photo 7: J. Caster, University of Florida

The adult southern green stink bug is 1.2 to 1.6 cm long and approximately 0.8 cm wide. It is green in spring and summer, becoming purplish brown in fall and winter. It has the typical shield-shaped body of the family Pentatomidae. There are three to five pale dots on the front of the pronotum. In addition, it has alternating light and dark antennal segments and black dots along the sides of its body. The barrel-shaped eggs stand approximately 1 mm high and are light yellow, turning light orange prior to hatching. Before reaching the adult stage, the southern green stink bug goes through five different larval stages. The coloration of the first three instars is relatively dark, ranging from dark red to black, while the last two instars are light-coloured, in shades of green and yellow with white spots. During the different larval stages, this stink bug grows from between 1 and 2 mm to approximately 1 cm long.

The southern green stink bug is a polyphagous species that feeds on roughly 150 crop species around the world. Wheat, corn and soybean fields would be the most susceptible to infestation if this insect reached Quebec. Stink bugs tend to move from one host plant to another based on which phenological phase is the most attractive. They may feed on all plant parts, but developing fruit and growing shoots are preferred. The southern green stink bug is a piercing-sucking insect that feeds on the sap of plants. When it pierces a fruit, necrotic areas form at the feeding sites, resulting in hard brownish or black spots. Young fruit growth is retarded, and the fruit withers and drops from the plant. Furthermore, seed quality and yield in certain crops, such as soybean, can be significantly affected by this insect pest.

No sightings of the southern green stink bug have been reported in Quebec. In 2016, the only observations in North America came from the southern United States, primarily Florida and Louisiana. In the regions where this insect is present, there can be three to five generations per year, rising to as many as six in the most tropical areas. The observations have demonstrated that stink bugs are capable of travelling long distances. They have high dispersal potential, thanks to their ability to exploit climate conditions and various modes of road transport.

REFERENCE FOR THE MODEL

Southern green stink bug

Cividanes F, Parra J. 1994. Biology of soyabean pests with different temperatures and thermal requirements. I. Nezara viridula (L.)(Heteroptera: Pentatomidae). Anais da Sociedade Entomológica do Brasil 23(2): 243-250.

Harris VE, Todd JW. 1980. Duration of immature stages of the southern green stink bug, Nezara viridula (L.), with a comparative review of previous studies. Journal of the Georgia Entomological Society 15(2): 114-124.

Cumulative degree days for each threshold development

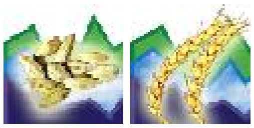
Base temperature = 15°C
Optimal temperature = 25°C
Method = single sine
Date for starting calculations = 1st March

Hosts: grain maize, soya, wheat	**Degree Days (°C)**
1st generation, 1% egg-laying	192
1st generation, 1% nymph stage 1-3	247
1st generation, 50% egg-laying	267
1st generation, 99% egg-laying	342
1st generation, 50% nymph stage 1-3	372
1st generation, 1% nymph stage 4-5	402
1st generation, 50% nymph stage 4-5	555
1st generation, 1% adults	613
1st generation, 50% adults	756
1st generation, 99% adults	899

Field Crops

Disease

Fusarium (*Fusarium graminearum*)



DISEASE DESCRIPTION

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

Fusarium head blight is mostly caused by *Gibberella zeae,* an ascomycete of Pyrenomycetes subclass, in Spheriales 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

Fusariose head blight

De Wolf, E. D., Madden, L. V., and Lipps, P. E. 2003. Risk assessment models for wheat Fusarium head blight epidemics based on within-season weather data. Phytopathology 93:428-435.

Giroux, M.-E., Bourgeois, G., Dion, Y., Rioux, S., Pageau, D., Zoghlami, S., Parent, C., Vachon, E. and Vanasse, A. 2016. Evaluation og forecasting models for Fusarium head blight of wheat under growing conditions of Quebec, Canada. Plant disease 100:1192-1201.

The models were modified by Giroux (2016), and the data used for these modifications came from field trials carried out in 2011 and 2012. The study sites were located in Quebec, specifically at Agriculture and Agri-Food Canada's L'Acadie and Normandin experimental farms, at the grain research centre (CÉROM) in Saint-Mathieu-de-Beloeil, and at the experimental farm in Saint-Augustin-de-Desmaures (Laval University) (QC).

Infection risk tables

De Wolf A modified

Date for starting calculations = sowing date

Host: barley, wheat	Risk index (%)
Intermediate risk	27
High risk	37

De Wolf B modified

Date for starting calculations = sowing date

Host: barley, wheat	Risk index (%)
Intermediate risk	26
High risk	36

INTERPRETATION OF THE CURVE

To predict the risk of infection, the two selected models (De Wolf, 2003) use the number of hours in the 7 days before flowering when the temperature was between 10 °C and 30 °C (model B) and the number of hours in the 10 days after flowering when the temperature was between 10 °C and 30 °C and the relative humidity was at or above 90% (models A and B).

The yellow band on the chart corresponds to anthesis (61 to 69 on the Zadoks scale) and represents the period with the highest risk of disease development. During this period, the risk of infection becomes high when the blue curve is between the moderate and high thresholds (red and orange lines).

Field Crops

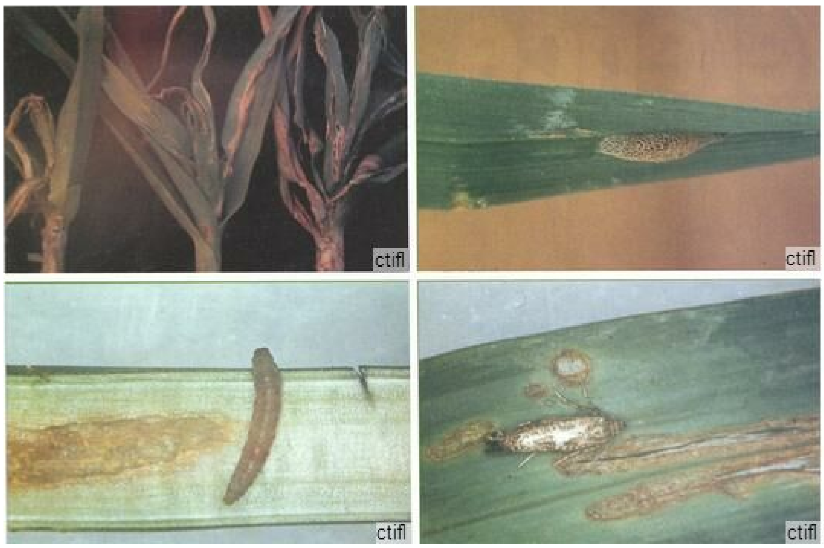
Leek

Insect
Leek moth

Insect

Leek moth (*Acrolepiopsis assectella* (Zeller))

PEST DESCRIPTION



Le poireau guide pratique, ctifl, 1994.

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[1]

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).

[1]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 Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu, using data compiled by Mario Leblanc (MAPAQ) 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 = 1st March

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

Leek

Lettuce

Disease
Downy mildew

Disease

Downy mildew (*Bremia lactucae* Regel)

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
Downy mildew of onion

Insect
Onion maggot

Insect

Onion maggot (*Delia antiqua* (Meigen))

PEST DESCRIPTION

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

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 = 1st April

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

INTERPRETATION OF THE CURVE[1,2]

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

1 Text written in collaboration with Pierre Sauriol, retired agrologist, Ministère de l'Agriculture des Pêcheries et de l'Alimentation of Québec, Saint-Rémi, Québec.
2 Text written in collaboration with Mario Asselin, agrologist, Productions en régie intégrée du Sud de Montréal, enr. (PRISME), Sherrington, Québec.

Disease

Botrytis leaf blight (*Botrytis squamosa* J.C. Walker)

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.

BOTCAST model

Sutton, J.C., T.D.W. James, P.M. Rowell. 1986. Botcast: A forecasting system to time the initial fungicide spray for managing botrytis leaf blight of onions. Agric. Ecosyst. Environ. 18 (2):123-143.

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

BOTCAST

Date for starting calculations = onion emergence

Host: onion	Sporulation index
Risk warning	20
First treatment	30
Second treatment	40

INTERPRETATION OF THE CURVE[1,2]

The Botrytis leaf blight models Lacy and Lacy modified have two sporulation indices, namely an intermediate risk index (50%) and a high risk index (80%). They are 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

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

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

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.

BOTCAST model provides daily cumulative indices of disease severity, beginning when the onions emerged and continuing until values of two spray thresholds have accumulated. Threshold 1 (20%) is a warning threshold, and no spray is required unless rain is predicted or overhead irrigation is applied. Threshold 1 usually occurs 2–3 weeks before leaf blight progresses rapidly and it is important at that time to monitor BOTCAST frequently. At threshold 2, the risk of rapid disease progress is high and a spray must be considered as soon as possible. Threshold 2 precedes rapid disease increase by a few days in epidemics with a logarithmic phase.

The latest edition of this text was made on June 2018.

Onion

Downy mildew of onion (*Peronospora destructor* (Berk.) Casp. in Berk)

DISEASE DESCRIPTION

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

Onion downy mildew occurs sporadically in the onion-producing areas of British Columbia, Ontario and Québec. Epidemics in onion fields are potentially explosive and destructive, given favorable weather. In some instances, the disease destroys all of the foliage in just four or five weeks. Severe downy mildew reduces bulb size and can result in bulbs being downgraded for market. Necks of diseased onions often remain succulent and difficult to cure at harvest.

The first sign of downy mildew is velvet-like growth of the pathogen on the otherwise green leaves. Early in the morning, the fungal growth appears purplish due to pigment in the fungal spores (sporangia), which form overnight just above the leaf surface. Later, most of the spores are dispersed in the air and a whitish fungal growth remains on the leaf. During the next two to four days, the diseased leaves turn pale green, then yellow, and finally collapse and die. Blackish growth of other fungi, especially *Stemphylium botryosum* Wallr., is common on the dead leaves. Small green leaves often emerge from the cluster of dead top growth within a week or two. Necks of affected plants remain succulent. Affected areas on seed stems tend to remain yellow, but may bend over and break when the seed head enlarges. The downy mildew fungus may also invade flowers and seeds (Howard *et al.*, 1994).

REFERENCE FOR THE MODEL

Mildiou (DOWNCAST)

C.L.M. de Visser. 1998. Development of a downy mildew advisory model based on downcast. European Journal of Plant Pathology 104: 933–943

Infection risk table

Date for starting calculations: onions emergence

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

INTERPRETATION OF THE CURVE[1]

The downy mildew forecast (DOWNCAST) was developed by Dr. P.D. Hildebrand and Dr. J. C. Sutton from the University of Guelph (Ontario, Canada). DOWNCAST predicts sporulation of *Peronospora destructor*, the fungus that causes downy mildew, by indicating whether the weather was favorable or unfavorable for sporulation. Occasional favorable days (low risk) in areas where downy mildew has not been reported are not cause for concern or special fungicide applications. If long periods of favorable weather have occurred (high risk), a good coverage with protectant fungicides must be maintained and fields must be scouted carefully. If downy mildew is present in a field or the immediate vicinity, it may be necessary to apply specific fungicides targeting that fungus.

Onion

[1] Network for Environment and Weather Applications (NEWA), Cornell University. http://newa.cornell.edu/index.php?page=Using-Onion-Disease-Forecasts-Effectively

Pea

Pea Phenology

Pea Phenology

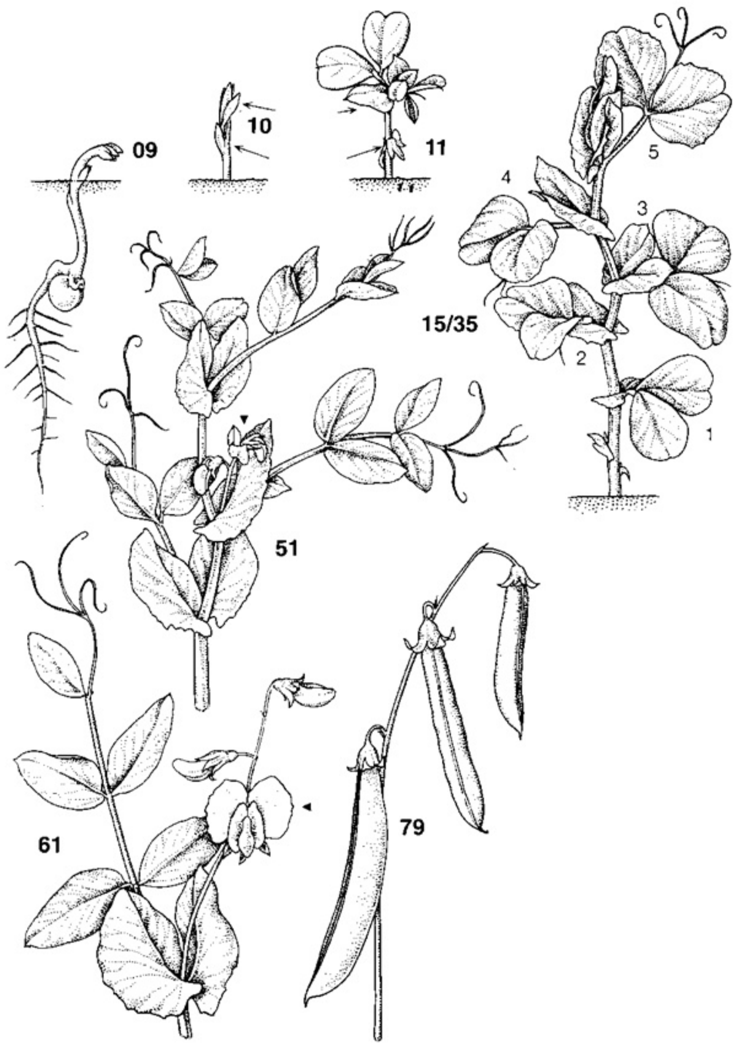
DESCRIPTION OF PHENOLOGY

Bioclimatic models can be used to establish links between biological processes and meteorological phenomena. They provide agricultural decision makers with guidance on cultivation practices, such as the cultivars to use in a given area, sowing dates and harvesting dates. For pea production, the reproductive phase is strongly influenced by temperature and photoperiod. Yield apparently increases with the accumulation of degree days, but temperatures above 27°C inhibit growth and crop yield.

Phenological growth stages and BBCH-identification keysof pea (Meier, 2001)
(*Pisum sativum* L.)

Code	Description
Principal growth stage 0: Germination	
00	Dry seed
01	Beginning of seed imbibition
03	Seed imbibition complete
05	Radicle emerged from seed
07	Shoot breaking through seed coat
08	Shoot growing towards soil surface; hypocotyl arch visible
09	Emergence: shoot breaks through soil surface (“cracking stage”)
Principal growth stage 1: Leaf development	
10	Pair of scale leaves visible
11	First true leaf (with stipules) unfolded or first tendril developed
12	2 leaves (with stipules) unfolded or 2 tendrils developed
13	3 leaves (with stipules) unfolded or 3 tendrils developed
1 .	Stages continuous till . . .
19	9 or more leaves (with stipules) unfolded or 9 or moretendrils developed
Principal growth stage 3: Stem elongation (Main shoot)	
30	Beginning of stem elongation
31	1 visibly extended internode1
32	2 visibly extended internodes1
33	3 visibly extended internodes1
3 .	Stages continuous till . . .
39	9 or more visibly extended internodes1
Principal growth stage 5: Inflorescence emergence	
51	First flower buds visible outside leaves
55	First separated flower buds visible outside leaves but still closed
59	First petals visible, flowers still closed
Principal growth stage 6: Flowering	
60	First flowers open (sporadically within the population)
61	Beginning of flowering: 10% of flowers open
62	20% of flowers open
63	30% of flowers open
64	40% of flowers open
65	Full flowering: 50% of flowers open
67	Flowering declining
69	End of flowering
Principal growth stage 7: Development of fruit	
71	10% of pods have reached typical length; juice exudes if pressed
72	20% of pods have reached typical length; juice exudes if pressed

73	30% of pods have reached typical length; juice exudes if pressed.Tenderometer value: 80 TE
74	40% of pods have reached typical length; juice exudes if pressed.Tenderometer value: 95 TE
75	50% of pods have reached typical length; juice exudes if pressed.Tenderometer value: 105 TE
76	60% of pods have reached typical length; juice exudes if pressed.Tenderometer value: 115 TE
77	70% of pods have reached typical length. Tenderometer value: 130 TE
79	Pods have reached typical size (green ripe); peas fully formed



REFERENCE FOR THE MODEL

Pea Phenology

Bourgeois, G., Jenni, S., Laurence H. et N. Tremblay. 2000. Improving the Prediction of Processing Pea Maturity Based on the Growing-degree Day Approach. HortScience 35(4):611-614.

Models were developed by the Bioclimatology and Modelling reseach team of the Research and Development Centre of Agriculture and Agri-Food Canada at Saint-Jean-sur-Richelieu based on data from reports on cultivar trials of processing vegetables (pea, bean, corn) from 1998 to 2013.
Data compiled by Stéphanie Lavergne in the summer of 2015.

Cumulative degree days for each threshold development

Base temperature = 5°C
Optimal temperature = 25°C
Method = sinus simple
Date for starting calculations = sowing date

Pea - early cultivars [1] (BBCH)	**Degree Days (°C)**
Beginning of flowering (61)	445
Harvest (79)	725

[1] Cultivars used to develop the early model: Flair, Kriter, Lil'mo, Rally

Pea - intermediate cultivars [2] (BBCH)	**Degree Days (°C)**
Beginning of flowering (61)	513
Harvest (79)	782

[2] Cultivars used to develop the intermediate model: Bolero, Estancia, Nitro, Sancho

Pea- late cultivars [3] (BBCH)	**Degree Days (°C)**
Beginning of flowering (61)	529
Harvest (79)	807

[3] Cultivars used to develop the late model: Gallant, Geisha, Starlight

Pea

Potato

Insect
Colorado potato beetle

Disease
Late blight

Insect

Colorado potato beetle (*Leptinotarsa decemlineata* (Say))

PEST DESCRIPTION

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

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 Research and Development Centre of Agriculture and Agri-Food Canada 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, 1st and 2nd instar	275
5% larvae, 3rd and 4th instar	321
85% larvae, 1st and 2nd instar	339

Potato

Disease

Late blight (*Phytophthora infestans* (Mont.) de Bary)

DISEASE DESCRIPTION

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

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 veination 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[1]

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

[1] 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.

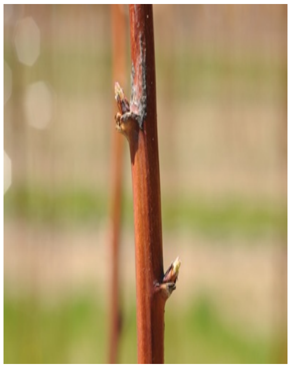
Raspberry

Raspberry Phenology

Insect
Spotted wing drosophila
Japanese beetle (see vineyard)

Raspberry phenology

DESCRIPTION OF PHENOLOGY

Bud swelling (BBCH = 51): beginning of bud swelling; bud scales elongated.
Green tip (BBCH = 54): leaf tips extended beyond scales and first leaves separate.


Green buds tight: flower buds are not yet visible, they are hidden inside the new leaves.
Green buds grouped (BBCH = 55): flower buds are visible but are grouped.


Green buds separated (BBCH = 59): flower buds are well separated from each other and are clearly visible.
Flowering (BBCH = 65): full bloom, at least 50% of flowers open.


Beginning of green fruit (BBCH = 71): beginning of fruit growth; first green fruits visible, there are still some flowers.
Green fruit (BBCH = 75): at least 50% of fruits formed; they have a green color.


Beginning of ripening (BBCH = 81): beginning of fruit ripening, first fruits begin to turn red.
Mature fruit-harvest (BBCH = 87): fruit ripe for picking; most fruits are ripe and red; they have reached the maturity necessary for harvest.

Photos source: Gaétan Racette, AAC

REFERENCE FOR THE MODEL

Raspberry Phenology

Meier, U. 2001. Growth stages of mono-and dicotyledonous plants, BBCH Monograph. 60-62.
Framboisier. Guide de protection. CRAAQ 2008. 28 p.

Results were based on the warnings issued by the MAPAQ "Réseau d'avertissements phytosanitaires" (Phytosanitary warning network) from 2005 to 2016 and data collected by the Bioclimatology and Modelling research team at Agriculture and Agri-Food Canada's Research and Development Centre in Saint-Jean-sur-Richelieu during 2014 to 2016 growing seasons. The model was developed by the Bioclimatology and Modelling research team. Data compiled by Antoine Hénault in winter 2017.

Cumulative degree days for each threshold development

Cultivar: Killarney
Base temperature = 1,7 °C
Optimal temperature = 30 °C
Method = sinus simple
Date for starting calculations = 1st March

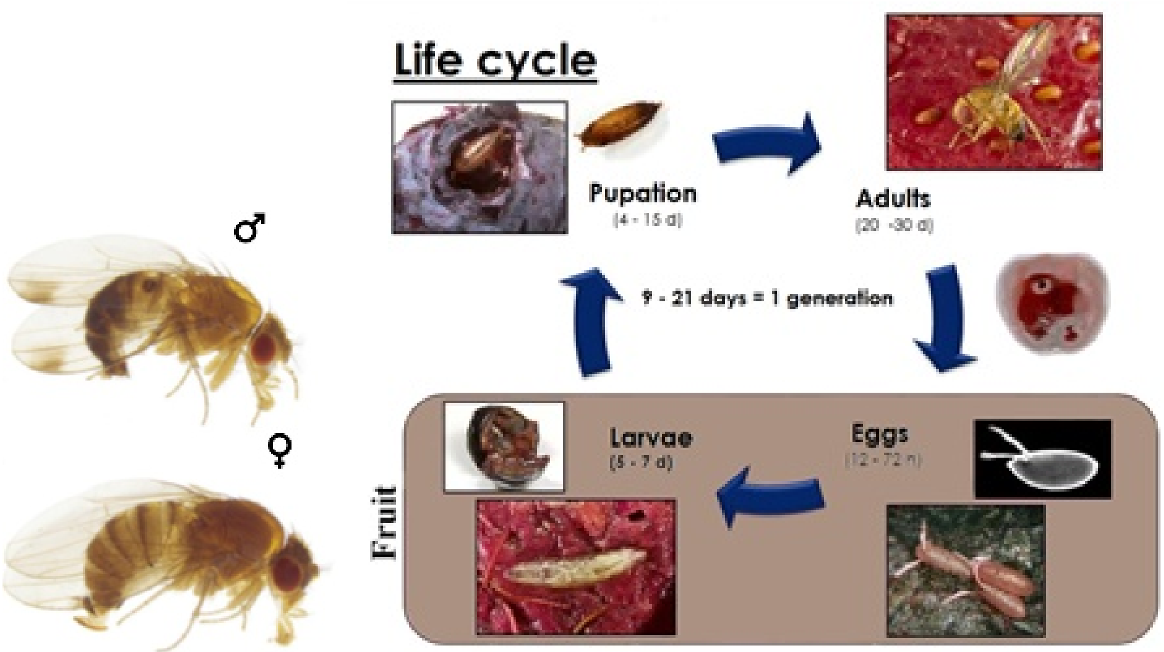
Raspberry: Killarney (BBCH)	**Degree Days (°C)**
Bud swelling (51)	130
Green tip (54)	189
Green buds tight	300
Green buds grouped (55)	430
Green buds separated (59)	513
Flowering (65)	686
Beginning of green fruit (71)	764
Green fruit (75)	858
Beginning of ripening (81)	1115
Mature fruit-harvest (87)	1303

Raspberry

Insect

Spotted wing drosophila (*Drosophila suzukii*)

PEST DESCRIPTION



Source of figures: laboratoire de diagnostic en phytoprotection, MAPAQ

The adult size of the spotted wing drosophila (SWD) is 3.2 to 3.4 mm for females and 2.6 to 2.8 mm for males. The SWD has red eyes and a yellowish-brown body. The male has spotted wings and the female has saw-like ovipositor, used to cut the skin of the fruits before inserting the eggs. The eggs, larvae and part of the pupae then develop inside the fruits causing their rapid degradation. SWD is the only fruit fly in Quebec to lay its eggs in healthy fruits at the beginning of maturation. This insect can cause damage to a range of small fruits including raspberry, strawberry, blackberry and blueberry. Fruit damage is first caused by the female during oviposition (egg-laying) while the female perforates the fruit's peel to deposit its eggs. Then, the main damage is made by the larvae causing sagging around its feeding site. There may be up to 60 larvae per fruit and secondary damage is frequently associated with the presence of larvae in the fruit. In fact, the egg scars will favor the development of fungal, yeast or bacterial infections. In addition, some secondary pests are attracted to damaged fruit and take advantage of openings caused by SWD to reach the flesh of the latter. In spring, SWD activate when the temperature reaches 10 ° C. The fertilized female can lay up to 3 eggs on a healthy fruit and lay 7 to 16 eggs per day.

REFERENCE FOR THE MODEL

Spotted wing drosophila
Len Coop and Amy Dreves. Spotted Wing Drosophila Degree-Day Model. Initial model analysis 10/14/11, revised 4/24/15 vers. 3. Integrated Plant Protection Center, Oregon State University

Cumulative degree days for each threshold development

Base temperature = 10°C
Optimal temperature = 31 °C
Method = single average
Date for starting calculations = 1st March

Host: raspberry	**Degree Days (°C)**
Overwintering generation, 5% egg-laying	145
Overwintering generation, 50% egg-laying	278
1st generation, 50% adults	419
1st generation, 50% egg-laying	553
2nd generation, 50% adults	694
2nd generation, 50% egg-laying	827
3rd generation, 50% adults	968
3rd generation, 50% egg-laying	1102
4th generation, 50% adults	1243
4th generation, 50% egg-laying	1376

INTERPRETATION OF THE CURVE

The model presents the cumulative degree days to reach different stages. It is under evaluation in Quebec (summer 2017).

Raspberry

Strawberry

Strawberry Phenology

Insect
Bud weevil
Japanese beetle (see vineyard)

Disease
Strawberry leaf spot

Strawberry Phenology

DESCRIPTION OF PHENOLOGY

Beginning leaf development (BBCH = 10): first leaves emerging.
Beginning green bud (BBCH = 55): first set flowers at the bottom of the rosette

Advanced green bud (BBCH = 58): first flowers with petals forming a hollow ball.
Flowering (BBCH = 65): full flowering; secondary and tertiary flowers open, first petals falling.

Source : https://pixabay.com

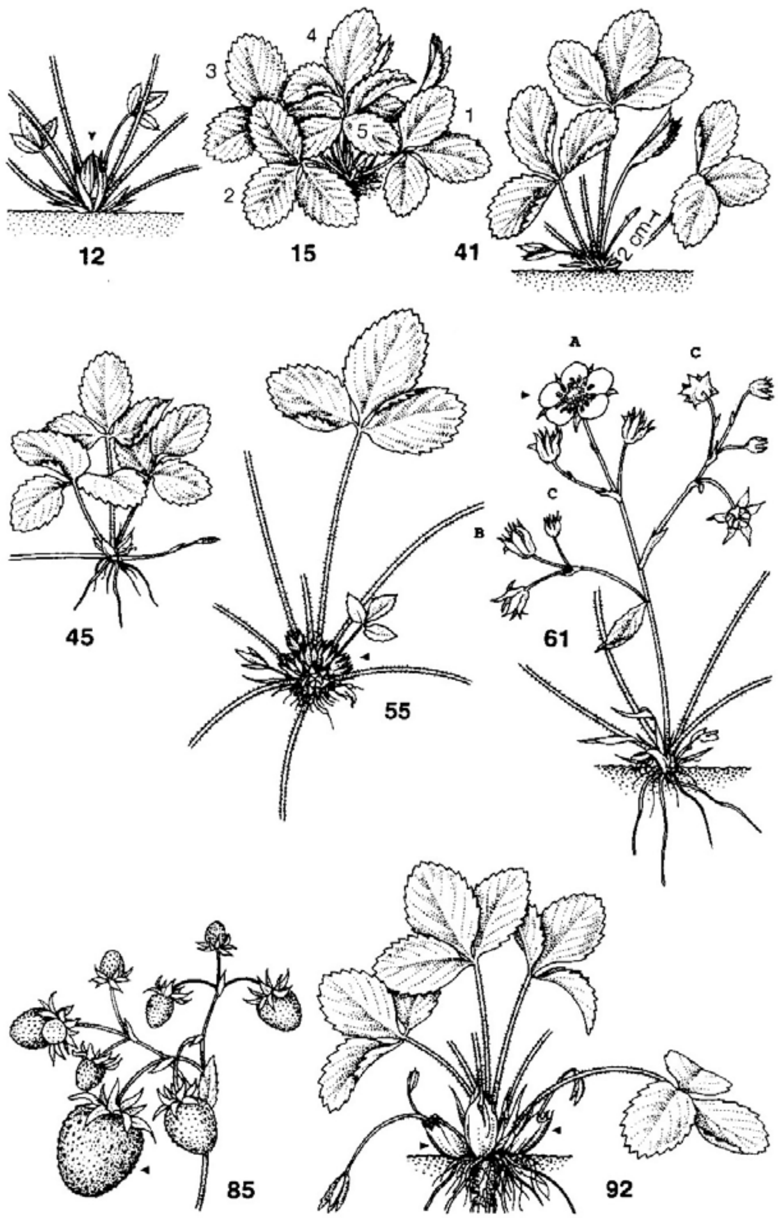
Green fruit (BBCH = 73): seeds are clearly visible on receptacle tissue and have a distinctly green color.
White fruit (BBCH = 81): beginning of ripening, most fruits white in color.

Ripe fruit-harvest (BBCH=87): most fruit have reached their specific red color. They have reached the maturity necessary to produce a first harvest.

Photos source: Fraisier, guide de protection 2010. CRAAQ. Luc Urbain, MAPAQ

Phenological growth stages of strawberry (Meier, 2001)
(Fragaria ananassa Duch.)

Code	Description
Principal growth stage 0: Sprouting/Bud development	
00	Dormancy: Leaves prostrate and partly dead
03	Main bud swelling
Principal growth stage 1: Leaf development	
10	First leaf emerging
11	First leaf unfolded
12	2nd leaf unfolded
13	3rd leaf unfolded (normally after the three leaf stage the bud development occurs in principal growth stage 5)
1 .	Stages continuous till . . .
19	9 or more leaves unfolded
Principal growth stage 5: Inflorescence emergence	
55	First set flowers at the bottom of the rosette
56	Inflorescence elongating
57	First flower buds emerged (still closed)
58	Early balloon stage: first flowers with petals forming a hollow ball
59	Most flowers with petals forming a hollow ball
Principal growth stage 6: Flowering	
60	First flowers open (primary or A-flower)
61	Beginning of flowering: about 10% of flowers open
65	Full flowering: secondary (B) and tertiary (C) flowers open, first petals falling
67	Flowers fading: majority of petals fallen
Principal growth stage 7: Development of fruit	
71	Receptacle protruding from sepal whorl
73	Seeds clearly visible on receptacle tissue
Principal growth stage 8: Maturity of fruit	
81	Beginning of ripening: most fruits white in color
85	First fruits have cultivar-specific color
87	Main harvest: more fruits colored
89	Second harvest: more fruits colored



REFERENCE FOR THE MODEL

Strawberry Phenology (BBCH model - Jewel)
Meier, U. 2001. Growth stages of mono-and dicotyledonous plants. BBCH Monograph. 62-63.

BBCH-Jewel model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at Saint-Jean-sur-Richelieu, using data collected between 2008 and 2010 at the experimental farms of L'Acadie and Frelighsburg (QC). Results compiled by Dominique Plouffe in spring 2011.

Results for the *degree-days-Jewel* model were based on the warnings issued by the MAPAQ "Réseau d'avertissements phytosanitaires" (Phytosanitary warning network) from 2005 to 2016 and the model was developed by the Bioclimatology and Modelling research team. Data compiled by Antoine Hénault in winter 2017.

Cumulative Degree days for each threshold development

Cultivar: Jewel
Base temperature = 0 °C
Optimal temperature = 30 °C
Method = single average
Date for starting calculations = 1st March

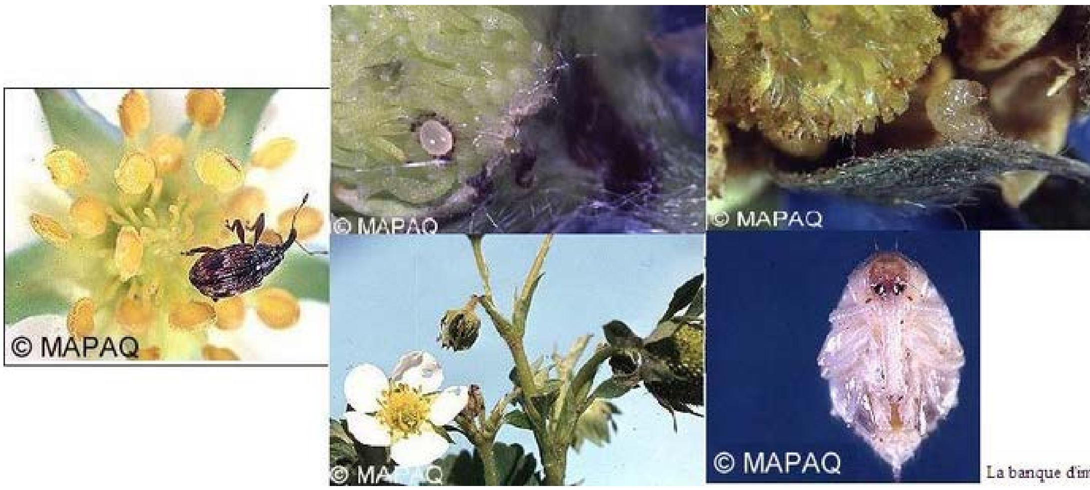
Strawberry: Jewel (BBCH)	Degree Days (°C)
Beginning leaf development (10)	241
Beginning green bud (55)	395
Advanced green bud (58)	451
Flowering (65)	607
Green fruit (73)	739
White fruit (81)	910
Ripe fruit-harvest (87)	1029

Strawberry

Insect

Bud weevil (*Anthonomus signatus* Say)

PEST DESCRIPTION



La banque d'images, MAPAQ.

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 = 1st April

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

Strawberry

Disease

Leaf spot (*Mycosphaerella fragariae* (Tul.) Lindau)

DISEASE DESCRIPTION

La banque d'images, Ministère de l'Agriculture, Pêcheries et Alimentation du Québec.

Compendium of plant diseases. Rohm & Haas company, Philadelphia, PA.

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 = 1st April

Host: strawberry	Infection index
Intermediate	1.5
High	3

Strawberry

Sweet corn

Sweet corn phenology

Insect
European corn borer

Sweet corn phenology

DESCRIPTION OF PHENOLOGY

Bioclimatic models can be used to establish links between biological processes and meteorological phenomena. They provide agricultural decision makers with guidance on cultivation practices, such as the cultivars to use in a given area, sowing dates and harvesting dates. For sweet corn production, plant development is influenced by temperature and photoperiod. The beginning of the reproductive phase, which is characterized by the emergence of the male inflorescence, is largely determined by temperature, with a linear relationship at a base temperature of 7°C. This relationship is also observed upon the emergence of the stigmata at a base temperature of 8°C.

Phenological growth stages and BBCH-identification keys of maize (Meier, 2001)
(*Zea mays* L.)

Code	Description
Principal growth stage 0: Germination	
00	Dry seed (caryopsis)
01	Beginning of seed imbibition
03	Seed imbibition complete
05	Radicle emerged from caryopsis
06	Radicle elongated, root hairs and/or side roots visible
07	Coleptile emerged from caryopsis
09	Emergence: coleoptile penetrates soil surface (cracking stage)
Principal growth stage 1: Leaf development1, 2	
10	First leaf through coleoptile
11	First leaf unfolded
12	2 leaves unfolded
13	3 leaves unfolded
1 .	Stages continuous till . . .
19	9 or more leaves unfolded
Principal growth stage 3: Stem elongation	
30	Beginning of stem elongation
31	First node detectable
32	2 nodes detectable
33	3 nodes detectable
3 .	Stages continuous till . . .
39	9 or more nodes detectable3
Principal growth stage 5: Inflorescence emergence, heading	
51	Beginning of tassel emergence: tassel detectable at top of stem
53	Tip of tassel visible
55	Middle of tassel emergence: middle of tassel begins to separate
59	End of tassel emergence: tassel fully emerged and separated
Principal growth stage 6: Flowering, anthesis	
61	M: stamens in middle of tassel visible F: tip of ear emerging from leaf sheath
63	M: beginning of pollen shedding F: tips of stigmata (silks) visible
65	M: upper and lower parts of tassel in flower F: stigmata (silks) fully emerged
67	M: flowering completed

F: stigmata (silks) drying

69 End of flowering: stigmata (silks) completely dry

Principal growth stage 7: Development of fruit

71 Beginning of grain development: kernels at blister stage, about 16% dry matter

73 Early milk

75 Kernels in middle of cob yellowish-white (variety-dependent), content milky, about 40% dry matter

79 Nearly all kernels have reached final size

Principal growth stage 8: Ripening

83 Early dough: kernel content soft, about 45% dry matter

85 Dough stage: kernels yellowish to yellow (variety dependent), about 55% dry matter

87 Physiological maturity: black dot/layer visible at base of kernels, about 60% dry matter

89 Fully ripe: kernels hard and shiny, about 65% dry matter

REFERENCE FOR THE MODEL

Sweet corn Phenology: models were developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada at St-Jean-sur-Richelieu based on data from reports on cultivar trials of processing vegetables (pea, bean, corn) from 1998 to 2013.
Data compiled by Stéphanie Lavergne in the summer of 2015.

Cumulative degree days for each threshold development

Base temperature = 8°C
Optimal temperature = 30°C
Method = sinus simple
Date for starting calculations = sowing date

Sweet corn - early cultivars [1] (BBCH)	Degree Days (°C)
50% sylking (63)	740
Harvest (73)	1023

[1] Cultivars used to develop the early model: C-83 (Sh2), Code-60 (Su), Dugan (Se), GSS 9299 (Sh2)

Sweet corn - intermediate cultivars [2] (BBCH)	Degree Days (°C)
50% silking (63)	793
Harvest (73)	1081

[2] Cultivars used to develop the intermediate model: C-702 (Sh2), GH 6462 (Su), Legacy (Su), SS Jubilee (Sh2)

Sweet corn - late cultivars [3] (BBCH)	Degree Days (°C)
50% silking (63)	841
Harvest (73)	1161

[3] Cultivars used to develop the late model: C-741 (Sh2), Overland (Sh2)

Sweet corn

Insect

European corn borer (*Ostrinia nubilalis* (Hübner))

PEST DESCRIPTION

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

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, univotine race: model developed by the Bioclimatology and Modelling research team of the 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 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 = 1st 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 = 1st April

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

INTERPRETATION OF THE CURVE[1]

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 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

[1] 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 egglaying 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

Tomato

Disease
TOM-CAST

Disease

TOM-CAST: Early blight, Septoria leaf spot & Anthracnose (*Alternaria solani* Sorauer, *septoria lycopersici* Speg. and *Colletotrichum coccodes* Wallr. (syn. *Colletotrichum atramentarium* Berk. & Broome))

DISEASE DESCRIPTION

Early blight

Septoria leaf spot

Anthracnose

Photos source: Richard and Boivin (1994)

REFERENCE FOR THE MODEL

Pitblado, R. 1992. The Development and Implementation of TOM-CAST. Ontario Ministry of Agriculture, Food and Rural Affairs. 25 pp.

Infection risk table

Date for starting calculations = 1st May

Host: tomato	**Cumulative severity values**
Threshold for first treatment	35

Tomato

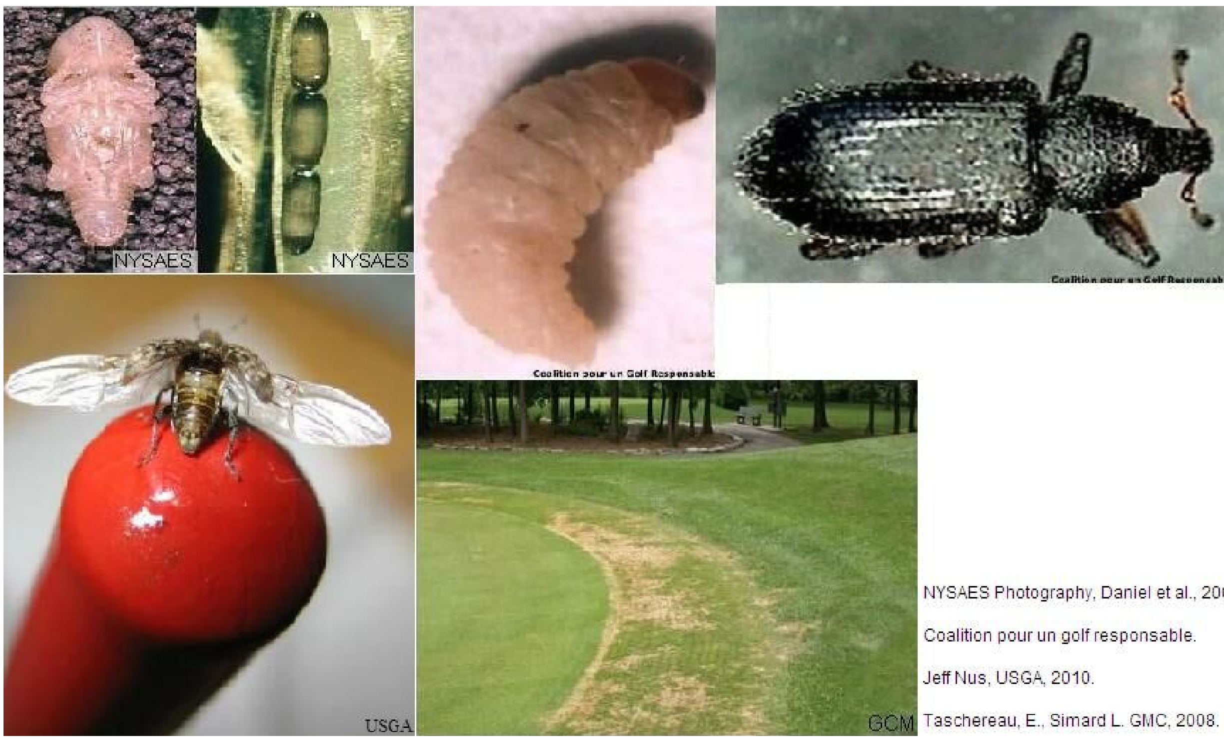
Turfgrass

Insects
Annual bluegrass weevil
Aphodius
Black cutworm
Black turfgrass ataenius

Insects

Annual bluegrass weevil (*Listronotus maculicollis* Kirby)

PEST DESCRIPTION



NYSAES Photography, Daniel et al., 2007.

Coalition pour un golf responsable.

Jeff Nus, USGA, 2010.

Taschereau, E., Simard L. GMC, 2008.

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 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

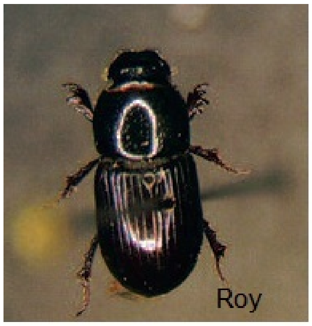
Base temperature = 10°C
Optimal temperature = 35°C
Method = single sine
Date for starting calculations = 1st March

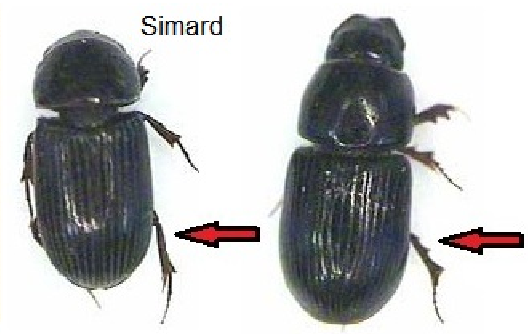
Host: turfgrass	Degree Days (°C)
Overwintering generation, 5% adults	36
Overwintering generation, 50% adults	104
Overwintering generation, 95% adults	233
1st generation, 5% larvae	298
1st generation, 5% adults	393
1st generation, 50% larvae	399
1st generation, 50% adults	501
2nd generation, 5% adults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

Turfgrass

Aphodius (*Aphodius granarius*)

PEST DESCRIPTION





Simard et al. 2006 Québec Vert. Jonathan Roy 2009

Black turfgrass Ataenius

Aphodius

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 ataenius. The length of *A. granarius* tends to be slightly smaller (3-5 mm) compared to black turfgrass ataenius (4 to 5.6 mm). *Aphodius granarius* beetle and black turfgrass ataenius 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 ataenius (Simard, 2006).

Life cycle

The life cycle of *A. granarius,* like the black turfgrass ataenius, 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 ataenius. 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 ataenius. 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 ataenius 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 ataenius 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 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 = 1st 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 (*Agrotis ipsilon* Hufnagel)

PEST DESCRIPTION

Simard et al. . 2006.
Coalition pour un golf responsable.

Life cycle
Black cutworm, *Agrotis ipsilon* Hufnagel, is a lepidopteran jn 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 places 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 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 = 1st adults capture

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

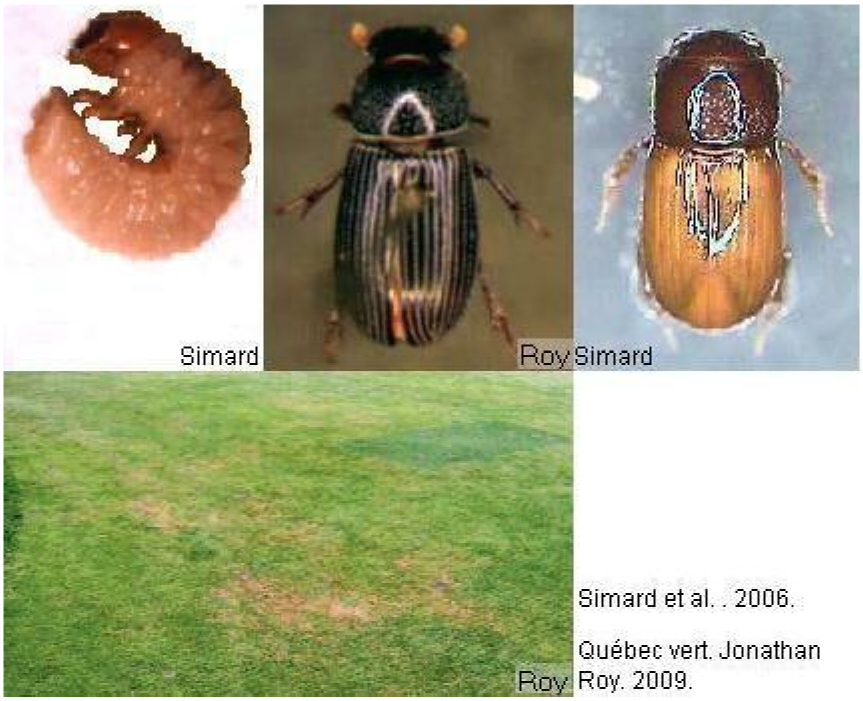
Damages
Base temperature = 4.4°C
Optimal temperature = 40°C
Method = single sine
Date for starting calculations = date of beginning of damages

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 (*Ataenius spretulus* Haldeman)

PEST DESCRIPTION



Simard et al. . 2006.
Québec vert. Jonathan Roy. 2009.

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^2 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 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 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 = 1st 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

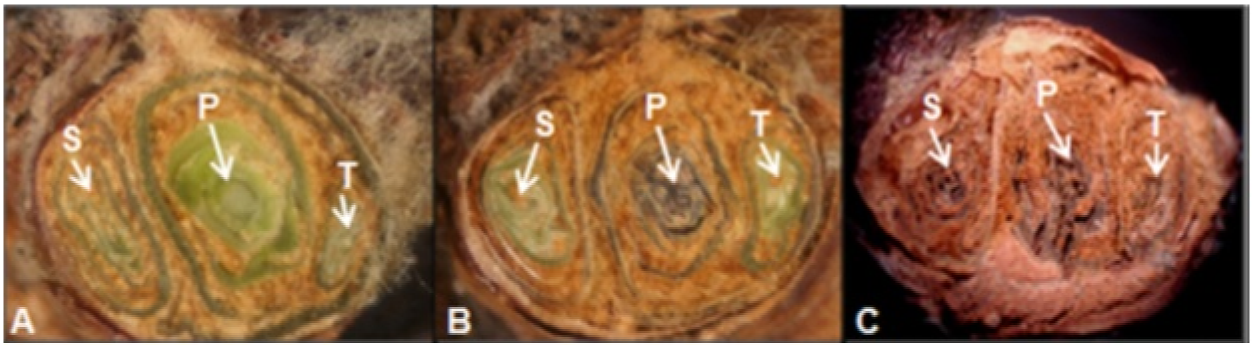
Cold hardiness
Vineyard Phenology

Insect
Grape berry moth
Grape Phylloxera
Japanese beetle
Leafhoppers
Tarnished plantbug

Disease
Grape powdery mildew

Cold hardiness

DESCRIPTION



Cross sections of grapevine compound buds showing the location of primary (P), secondary (S), and tertiary (T) buds. A) All three buds are alive; B) P bud is dead, while S and T buds are alive; C) All three buds are dead.

Photos source:
Moyer M, L. Mills, Keller M. and Hoheisel G. 2011. Assessing and Managing Cold Damage in Washington Vineyards. Washington State University extension.

Canadian winters can be tough on wine grape vines. A single extreme cold snap can damage vines and reduce crop yields by 50%. Before the season begins, growers must evaluate the damage in order to adapt the pruning and adjust their vineyard practices to ensure the quality of the next harvest, the viability of the vines and the economic stability of their business. Predicting the cold hardiness of the vines allows the use of direct protection methods in very cold conditions (candles, heaters, water sprinkling, air stirring) in order to decrease risks of bud damages. The resistance to frost varies during hardening, dormancy and bud break. The cooler the temperatures during the hardening, the more the vine buds will be resistant to the cold. De-hardening occurs more quickly than acclimation and depends on the increase in hot temperatures. Temperature fluctuations (freezing/thawing) can also lead to de-hardening. Climatic factors that influence damage are the duration of exposure to cold temperatures, drastic decreases in temperature and rise in temperatures before frost periods.

REFERENCE FOR THE MODEL

Cold hardiness

Ferguson J.C., J.M. Tarara, L.J. Mills, G.G. Grove, and M. Keller. 2011. Dynamic thermal time model of cold hardiness for dormant grapevine buds. Annals of Botany 107:389-396.

Ferguson J.C., M.M. Moyer, L.J. Mills, G. Hoogenboom, and M. Keller. 2014. Modelling dormant bud cold hardiness and budbreak in twenty-three *Vitis* genotypes reveals variation by region of origin. Am. J. of Vitic. 65(1):59-71.

The model comes from Ferguson 2011, updated in 2014. Varieties chosen are Cabernet Sauvignon, Chardonnay, Concord, Pinot gris and Riesling.

INTERPRETATION OF THE CURVE

From October 1 to bud break, the model (blue curve) predicts the lethal temperature at which 50% of buds will die (LT50). The pink curve represents the observed minimum hourly temperatures as well as the 7-day forecast.

Vineyard

Vineyard Phenology

DESCRIPTION OF PHENOLOGY

Wool stage (BBCH = 05): brown wool clearly visible.
Green shoot (BBCH = 09): green shoot tips clearly visible.

1st leaf unfolded (BBCH = 11): first leaf unfolded and spread away from shoot.
3 leaves unfolded (BBCH = 13)

Flowers closely pressed together (BBCH = 55): grape clusters increase in size.
Flowers separating (BBCH = 57): grape clusters well developed; flowers separating.

End of flowering (BBCH = 68): 80% of flowerhoods fallen
Closure of grape cluster (BBCH = 77): grape cluster beginning to close, berries starting to touch.

Photos source: Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA 2005)

BBCH scale VS Eichhorm-Lorenz stages (EL)		
BBCH	**Description**	**EL**
05	**Wool stage**: brown wool clearly visible	03
09	**Green shoot**: green shoot tips clearly visible	05
11	**1st leaf unfolded** and spread away from shoot	07
13	**3 leaves unfolded**	09
55	**Flowers closely pressed together**: grape clusters increase in size	15
57	**Flowers separating**: grape clusters well developed; flowers separating.	17
68	**End of flowering**: 80% of flowerhoods fallen	25
77	**Closure of grape cluster**: grape cluster beginning to close, berries starting to touch.	33

REFERENCE FOR THE MODEL

Phenology of grapevine: models developed by the bioclimatology and modelling team at Agriculture and Agri-Food Canada's 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 = 1st March

Seyval blanc (BBCH)	Degree Days (°C)
Wool stage (05)	74
Green shoot (09)	95
1st leaf unfolded (11)	121
3 leaves unfolded (13)	146
Flowers closely pressed together (55)	237
Flowers separating (57)	288
End of flowering (68)	416
Closure of grape cluster (77)	656

Early bud burst vine varieties [1] (BBCH)	Degree Days (°C)
Wool stage (05)	52
Green shoot (09)	75
1st leaf unfolded (11)	102
3 leaves unfolded (13)	130
Flowers closely pressed together (55)	218
Flowers separating (57)	257
End of flowering (68)	359
Closure of grape cluster (77)	659

[1] Varieties used to develop the early bud burst model: Marquette, La Crescent, Baltica, E.S. 4-23-60, DM 8521-1, Osceola Muscat

Semi-late bud burst vine varieties [2] (BBCH)	Degree Days (°C)
Wool stage (05)	63
Green shoot (09)	88
1st leaf unfolded (11)	111
3 leaves unfolded (13)	140
Flowers closely pressed together (55)	224
Flowers separating (57)	262
End of flowering (68)	371
Closure of grape cluster (77)	690

[2] Varieties used to develop the semi-late bud burst model: Adalmiina, E.S. 10-18-30, Frontenac blanc, Frontenac gris, Frontenac rouge, Louise Swenson, Radisson, St. Croix

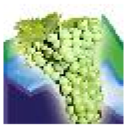
INTERPRETATION OF THE CURVE

Selected stages correspond to the following activities in the vineyard:
Wool stage: early visits to the field and scouting for grape flea beetle
Green shoot: scouting and intervention against dead-arm disease of grapevine caused by *Phomopsis*
1st leaf unfolded: scouting and intervention against anthracnose
3 leaves unfolded: scouting and intervention against the following diseases: black rot, red fire (Brenner) and downy mildew
Flowers closely pressed together: scouting and intervention against powdery mildew
Flowers separating: scouting and intervention against powdery mildew
End of flowering: scouting and intervention against gray mold
Closure of grape cluster: scouting and intervention against gray-mold rot

Vineyard

Insect

Grape berry moth (*Endopiza viteana*)



PEST DESCRIPTION

Laboratoire de diagnostic en phytoprotection. IRIIS phytoprotection.

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 = 1st March

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

Vineyard

Grape Phylloxera (*Daktulosphaira vitifoliae* (Fitch))

PEST DESCRIPTION

Leaf lightly affected: few galls

Leaf moderately affected: several galls

When severely affected, leaves close

Source: Réseau d'avertissements phytosanitaires – Bulletin d'information No 02 – vigne – 6 mai 2010. https://www.agrireseau.net/Rap/documents/b02vig10.pdf

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

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. 5th 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 1st leaf unfolded

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

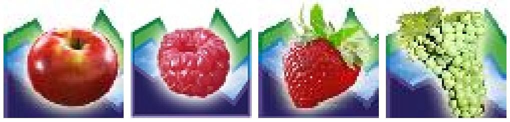
INTERPRÉTATION OF THE CURVE (Bergeron, 2010)

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 crawlwers 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

Japanese beetle (*Popillia Japonica* Newman)



PEST DESCRIPTION

Adult

Young larva on soil

Adults and damage on vine leaf

Images from: ©Laboratoire d'expertise et de diagnostic en phytoprotection – MAPAQ
From: IRIIS phytoprotection (http:// www.iriisphytoprotection.qc.ca/), 06/07/2018

The adult Japanese beetle measures almost 10 mm long and 6 mm wide. Its abdomen, thorax and head are metallic green and its wings are copper brown. It has white tufts of hair along the sides and rear of the abdomen. Its white elliptical eggs of about 1.5 mm long are laid beneath the soil surface. The larva is a typical C-shaped creamy white or translucent grub with a yellowish-brown head. The pupa is about the same size as the adult and somewhat resembling the adult except that the legs, antennae and wings are closely folded to the body. The pupae are found about 5-8 cm beneath the soil surface.

The Japanese beetle has only one generation per year and its normal life span is from 30 to 45 days. Typically, it emerges in July and starts to fly when temperature reaches 21°C. Feeding is most extensive on clear summer days when the temperature is between 21°C and 35°C, and the relative humidity is above 60%. There is little feeding on cloudy and windy days and no feeding on rainy days.

Beetles prefer to feed on plants exposed to the direct rays of the sun and they feed on the tissue between the veins, leaving a lace-like skeleton. The larvae attack the grass, but also the roots of other plants. Adults feed on the foliage and fruit of more than 250 plants including grape vine, apple, corn, blueberry and raspberry (CFIA 2017; IRIIS Phytoprotection).

REFERENCE FOR THE MODEL

Japanese beetle: model developed by the Bioclimatology and Modelling research team at Agriculture and Agri-Food Canada's Research and Development Centre in Saint-Jean-sur-Richelieu, in collaboration with the research team of Annabelle Firlej of the Institut de recherche et de développement en agroenvironnement (IRDA) at Saint-Bruno-de-Montarville. The model was based both from the literature and trap data observed from 2010 to 2016 from 27 sites in Quebec. Data compiled by Marie-Pier Ricard during fall of 2017.

Cumulative degree days for each threshold development

Base temperature = 10°C
Optimal temperature = 35°C
Method = single sine
Date for starting calculations = 1er March

Host: vineyard	**Degree Days (°C)**
Beginning of adults flight	575
Beginning of egg laying	635
Peak of adults	970
End of egg laying	1210
End of adults	1535

INTERPRETATION OF THE CURVE

The model is useful for targeting the date of first adults captures. It is in under evaluation and should be improved with the results of the coming years.

This text was last revised in July 2018.

Leafhoppers (*Empoasca fabae* (Harris), *Erythroneura comes* (Say), *Erythroneura vitis* (Harris), *Erythroneura tricincta* Fitch)

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.

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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.

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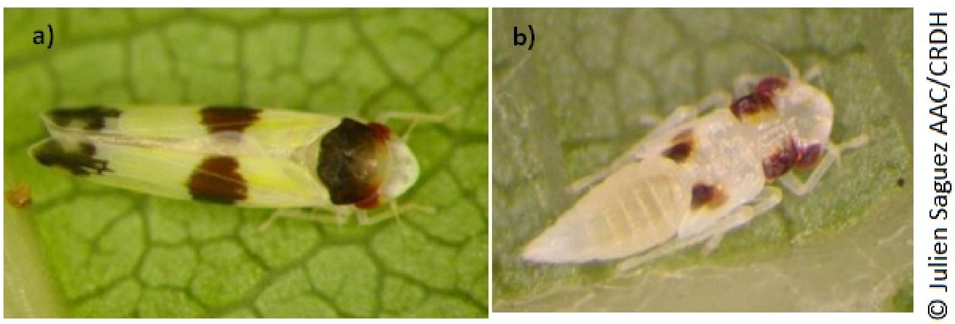
Eastern grape leafhopper

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 grapheving leafhopper, *Erythroneura vitis*. *E. trincincta* 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 = 1st March

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

Vineyard

Tarnished plantbug (*Lygus lineolaris* (P. de B.))

PEST DESCRIPTION

A) Tarnished plantbug nymph (Art Agnello, Ph.D., Cornell University). B) Tarnished plantbug adult (Agriculture and Agri-Food Canada, Saskatoon Research Centre)

Tarnished plantbug nymphs are greenish with black spots and wing pads are present on older nymphs. They are distinguished from aphids by their lack of cornicles and rapid movement when disturbed. Adult tarnished plant bugs are oval, 5-6 mm long, with a brown-yellow mottled appearance. A diagnostic feature is the buff or yellow Y on the triangular area between the wings (scutellum). Adults from the overwintering generation tend to be much darker than the summer generation.

Adult tarnished plantbugs overwinter under leaf debris, bark, logs and under broadleaf weed litter. They become active on warm days in early spring and attack apple buds before green tissue is even present. In late spring (late May and early June), the insects migrate to herbaceous weeds, flowers and vegetables where they insert eggs into stems and stalks. Nymphs progress through five instars before moulting to adults. The final three instars have wing pads. There are two generations per year.

The tarnished plantbug has a very broad host range, feeding on more than 300 plant species including weeds, vegetables, fruit, flowers, shrubs and trees. They prefer feeding on meristematic tissues, floral buds and immature fruit. Adults are mobile and move from one crop to another as the season progresses, in search of alternate hosts. Damage symptoms are as variable as the host list, and occur as a result of both feeding and egg-laying activities.

Reference: http://www.omafra.gov.on.ca/english/crops/facts/tarbug.htm

REFERENCE FOR THE MODEL

Tarnished plantbyg, nymphs

Bostanian N.J., G. Bourgeois, D.Plouffe and C.Vincent. 2014. Modeling phytophagous mirid nymphs in cool-climate vineyards. Phytoparasita 42:13-22.

Model developed by the Bioclimatology and Modelling research team of the Research and Development Centre of Agriculture and Agri-Food Canada in Saint-Jean-sur-Richelieu. Data was collected from 2000 to 2003 from 3 sites in Québec.

Cumulative degree days for each threshold development

Base temperature = 10°C
Optimal temperature = 32°C
Method = single sine
Date for starting calculations = 1er March

Host: vineyard	**Degree Days (°C)**
1st generation, 5% nymphs	228
1st generation, 50% nymphs	327
1st generation, 95% nymphs	468
2nd generation, 5% nymphs	630
2nd generation, 50% nymphs	806
2nd generation, 95% nymphs	1000

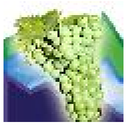
INTERPRETATION OF THE CURVE

Model predicts plantbug nymphs development in vineyard.

Vineyard

Disease

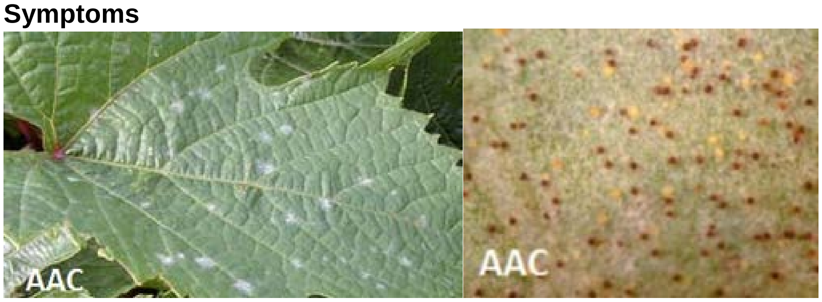
Grape powdery mildew (*Uncinula necator* (syn. *Erysiphe necator*))



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

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