1st model example.

Phenology model of insect (carrot Weevil).

Description and practical work with R

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IPM CC, October 2016
carrot Weevil

Biology and protection solutions

François Brun (ACTA)
IPM CC, October 2016
carrot

- *aucus carota subsp. sativus*
- one of the ten most economically important vegetable crops in the world

### Production of carrots and turnips – 2013

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (millions of tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>16.8</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>1.6</td>
</tr>
<tr>
<td>Russia</td>
<td>1.6</td>
</tr>
<tr>
<td>United States</td>
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<td>Ukraine</td>
<td>0.9</td>
</tr>
<tr>
<td>World</td>
<td>37.2</td>
</tr>
</tbody>
</table>

Source: [FAOSTAT](http://www.faostat.org) of the [United Nations](http://www.un.org)[43]
Carrot Weevil - *Listronotus oregonensis*

- **Region:** This weevil can be found throughout eastern and central North America (other country?).
- **Physical Description:**
  - 0.5 cm long
  - dark brown to coppery
  - with a hard shell.
- **This pest attacks:**
  - carrot, celery, dill, parsley, and parsnip plants
  - by boring into the tops of the carrot roots or directly into the carrot heart.
  - destroy most of the plant's tissue with a zigzag pattern.
Carrot weevil damage

- damaged
- no damage

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life cycle

- two generations each year
- overwinters as an adult in grass or garden debris immediately adjacent to carrot fields.
Life cycle

- Adult
- Egg: 130°C.day
- Prepupa: 114°C.day
- Larva: 256°C.day
- Pupa: 130°C.day

Generation time (egg to adult): 630 °C.day
Chemical control

• Fungicides available: several families
• Effectiveness in prevention (before infection)
• Curatively on infected culture, may also stop the disease for 3 to 5 weeks depending on the fungicide, the dose and conditions

⇒ Importance of treatment positioning to maximize efficiency
Biological control

Based on nematodes
cultural practices

clean up, rotation and soil preparation

- If debris, high grass, weedy areas next to crops or gardens are clean up, the weevil won't be able to find a cozy place to overwinter.
- Crop rotation is helpful in the prevention of this insect.
- In the spring, destroy any grubs in the soil by a deep cultivation in the area where you will be planting.
Phenology model of insect (carrot Weevil).
Objectives

• Understand the formalism.
• Write the simulator for this model in R.
• Use the model for different objectives.
Description of the model

• thermal time: a very common variable used in agronomy and in crop protection.

• Phenology models predict timing of events base on thermal time.

• For crop protection, it’s often used for calculate the development of pests such as insects, whose development depends on temperature of their environment.
definition of thermal time

• A simple definition of thermal time (TT) is the sum each day of daily mean temperature (Tmean) minus Tbase.

• If the difference is negative (if daily mean temperature is below Tbase) then the temperature sum that day is 0.

• The units of thermal time are °C.day
Equation of the model

\[ TT = \sum_{day=1}^{duration} \max(Tmean_{day} - Tbase; 0) \times 1 \]
Application to Carrot Weevil

- Carrot Weevil (*Listronotus oregonensis*) develops only when temperature is above 7.0°C
- 7.0°C is the Lower Developmental threshold, usually noted Tbase or base temperature.
Lets start in R

a) Write an R function taking as argument a vector of temperatures and returning the TT on the last day of the input.

Use a loop (for … ) and a condition (if… else…) for it. Write a main program that executes the function.

R needs to be installed (an older version is Ok !)
https://cran.r-project.org/bin/windows/base

If not too much familiar with R, I propose to use Rstudio : https://www.rstudio.com/products/rstudio/download
b) Modify the previous function to store the TT values at each time step in a vector called TT. Before storing the TT values, you must define the TT vector. You can create a vector TT where the using the instruction TT <- rep(NA, duration). Also, modify the function so that Tbase is also an argument.

Bravo! You have written your first dynamic model with R!
• **Supplementary questions**

• c) We have information on thermal time accumulation required for each stage of development (Eggs: 130.0 °C.day; Larvae: 256.0 °C.day; Prepupae: 114.0 °C.day; Pupae: 130.0 °C.day; Generation time - egg to adult : 630.0 °C.day). Use this information to propose a complete phenology model for Carrot Weevil.

• d) Propose a simpler function that does not have a loop and does not have a condition.
Run the code on weather data

- Use the European JRC data extracted for Toscana:

File:

test_toscane_ver2015-1_0_6325_247018277.csv

<table>
<thead>
<tr>
<th>GRID_NO</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>ALTITUDE</th>
<th>DAY</th>
<th>TEMPERATURE</th>
<th>PRECIPITATION</th>
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</tbody>
</table>
How to structure the code of the function?

• creation of state variable as vector
• initialization of state variable
• Simulation loop
  – Calculate rates of change of state variables (dTT)
  – Update state variables *
• End simulation loop
• Return results