Modelling mite populations

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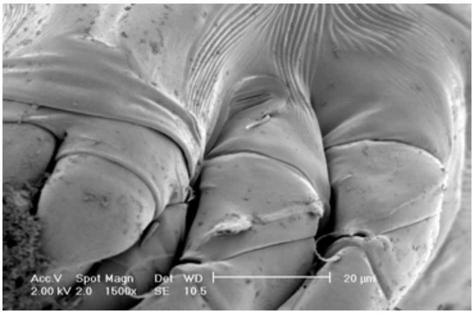

Outline

Considering two aspects:

- The effects of environmental conditions on mite growth from a population modelling point of view: how to quantify the link
- The obstacles to model development and some of the approaches that have been adopted, including our own

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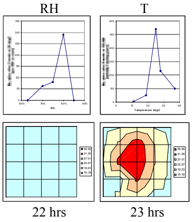
Environmental conditions and mites

As seen from previous presentations:

- Both humidity **and temperature** are important for modelling mite population growth
- Both are constantly changing: through the day, from month to month and from house to house



In addition, to complicate things further:

- Each life cycle stage is affected differently by the same environmental conditions

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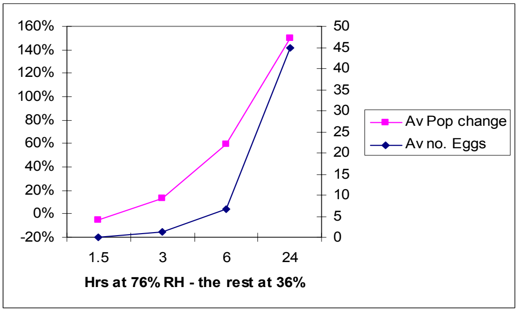
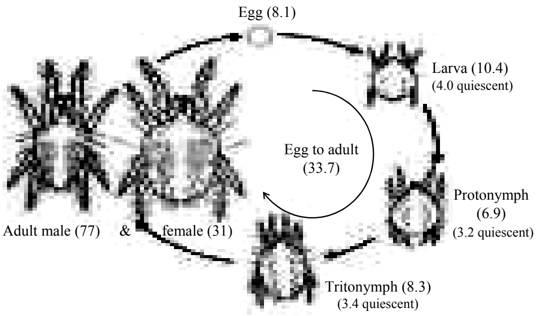
De Boer's experiment (1998)

showing the effect of transient conditions

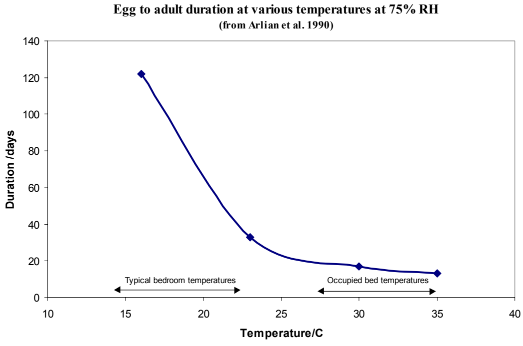


The 5 stages of the mite life cycle

(duration in days at 23°C and 75% from Arlian et al 1990)



Effect of temperature on egg-to-adult development



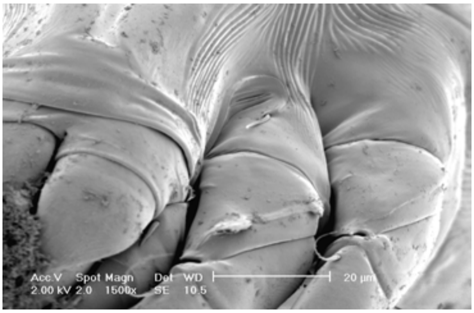
This strongly suggests that ….

In order to develop a population model, one needs to take account of:

- The effect of both RH and temperature
- The effect of transient conditions, not only steady state
- The effects of the above on different life cycle stages

However, before discussing modelling approaches, we need to consider more closely what role, if any, is played by the supracoxal gland and the **Critical Equilibrium Humidity**

The supracoxal gland



Critical Equilibrium Humidity (CEH$_T$)

In relation to a specified temperature (T), is defined as:

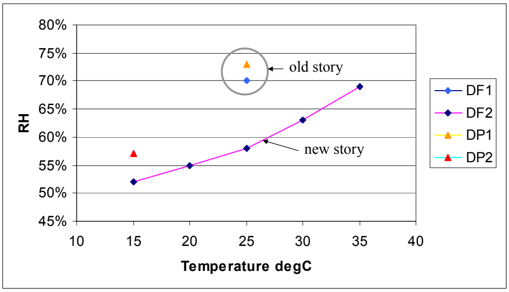
- The minimum RH required to maintain water balance, (ie. the RH below which a mite starts to lose more water than it can gain or above which it starts to gain more water than it needs)

This is normally considered to be the RH at which the active water pump (the supracoxal gland) stops (if RH is falling towards CEH) or starts (if RH is rising up to CEH). There is a great deal of discussion about CEH in the literature, but

Q: What role does CEH **actually** play in determining mite response to environmental conditions?

CEH values vs. temperature:

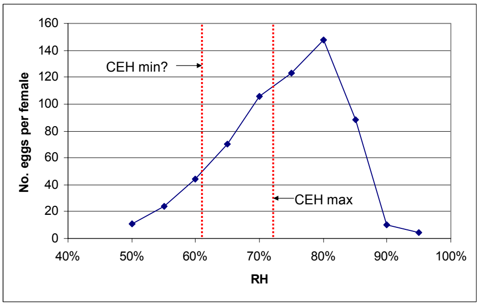
an unresolved mystery



Sources: DF1 = Larson 1969
DF2 = Arlian & Veselica 1981
DP1 = Arlian 1975
DP2 = de Boer et al 1998

DP egg production at 25 °C & varying RH

From Gamal Eddin 1983



is CEH a red herring?

Obstacles to developing a population model

- The paucity of data

  Ideally we need data specifying all aspects of mite physiology and behaviour for all relevant combinations of RH and T for each of the three main species DP, DF and EM

- Most available data relates to steady state conditions
- Most available data relates to lab raised HDM cultures

  These cultures, some of which are decades old, are kept in near ideal steady state conditions ("Royal" mites). It is known that "wild" mites living in real conditions behave differently, although there is very little data.

- The role of CEH is unresolved

The simplest model: Average room RH

a useful proxy/indicator of mite risk?

Problem:

- A single spot measurement (as is often the case) takes no account of the considerable variations in RH during 24 hrs

A logger provides accurate averages (per day or month) but the use of simple averages ignores:

- variations in RH and transient effects
- the important effect of temperature
- differences between room and habitat conditions

Can we do better?

The degree-day concept?

As used by heating engineers, Total heating load =

Σ hours of (18^{o}C - $T_{outside}$) over heating season /24

We (and others) have tried something similar using a combination of:

Σ hours of (CEH - RH) and Σ hours of (24^{o}C - T)

However, we have found that the two terms tend to cancel each other out.

Other approaches have been more fruitful……..

The Cunningham Model (1997)

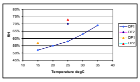
Malcolm Cunningham, Building Research Association of New Zealand

Assumed:

- mite populations decline below CEH and grow above it

Step 1) Curve fitted CEH vs. temperature data (for DF):

- CEH = 56.75 - 0.9917 T + 0.05 T^2 - 0.0003 T^3

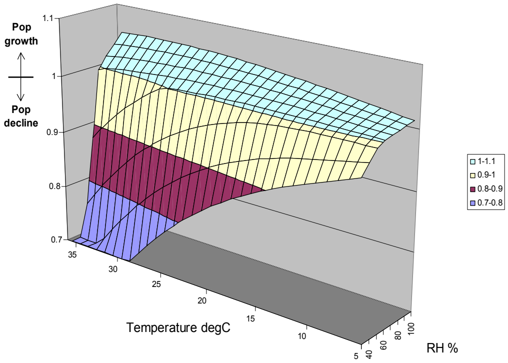


Step 2) Curve fitted population halving/doubling data:

- If RH is above CEH: Growth = 1 + 4.9 x 10^{-5} T (RH - CEH)
- If RH is below CEH: Decline = 1 - 3.38 x 10^{-4} T (CEH - RH)

Step 3) Applied to known RH and T values in mite habitats

Cunningham's model: 3-D chart



Cunningham model: pros & cons

Pros:

- Can model transient effects, by running it hour by hour
- Can be used to look at spatial differences (this needs a 3D hygrothermal model)

Cons:

- Although the effects of temperature are considered, the results are curious
- There are no constraints to growth at high temperatures (e.g. >30^{o}C) or humidities (e.g. >85% RH)

Unvalidated, but an excellent reference point for us ……

Our population models

We have two:

- A simple model
  This simulates the effect of RH and T on overall mite populations, very like Cunningham's in principle, but based on a fuller range of data
- A more complex model. *This considers:*
  - each life cycle stage separately
    The overall population predicted by the model is thus the net result of simulating the effects on each stage
  - the mite habitat (eg. bed) as a 3D grid of zones
    Allows us to take full account of spatial differences in conditions within habitats, but this in turn means we need to take account of:
    - mite movement, if any, between zones
    - density constraints, or Carrying Capacity, of habitat zones …….