Varroa Mite Honey Bee Coevolution Software

User's Guide

Important

Software requires Windows Vista or higher installed on your computer. It may not run on Windows Vista nor on Windows 7 if MS Framework 4.5 or higher is not installed.

Required MS Framevork can be downloaded for free at
https://www.microsoft.com/en-us/download/details.aspx?id=42643&desc=dotnet452.

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CHAPTER

ONE

POPULATION

1.1 Basic ideas

Population of honey bee colonies (aka apiary) is set in the model. Each colony has at the beginning a randomly generated genome, which governs colony traits. A population of Varroa destructor mites in each colony is generated similar way. Mites breed in a colony with breeding cycle $\triangle t$ =21 days while brood is present in the colony. Colonies may either swarm or splits may be created by a beekeeper. Colonies (swarms) die in case of overpopulation (by the lack of resources like empty hollows) or by mites (when population of mites in the colony reaches the lethal level). Honeybees as well as mites reproduce sexually and they are subject to "natural" selection.

1.2 Genome

Bees (i.e. queens and drones) and also mites are within the model represented by a simple genome, which consists just of few genes. Females are diploids, which means that each female (both honeybee queen and mite female) has two sets of genes in its genome. Males are haploids, each male has just one set of genes.

1.2.1 Genes

Gene is quantitative information, that determines phenotypic trait of honey bees and mites. The value of each gene in each colony is in the beginning randomly generated within interval $\langle A \cdot (1 - r) , A \cdot (1 + r) \rangle$, where A is average value of the trait and r is randomize value as stated in input formula.

1.2.2 The Queen

The honey bee queen is diploid, she has two genes for each phenotypic trait. She also has a mixture of sperm in her spermatheca, within the model we assume, that number of drones which mated the queen is always the same, equal to ten. The queen produces eggs:

- fertilised eggs – one set of genes originates from the queen's genome (each gen is randomly selected and a bit mutated), the other is equal to randomly selected sperm from spermatheca
- non-fertilised eggs – they have one set of genes randomly selected from queen's genome.

1.2.3 Males (drones and mite males)

Both drones and V. destructor males are haploids, they have just one copy of each gene. Males produce sperm, which is a copy of their genome (only little mutations are allowed).

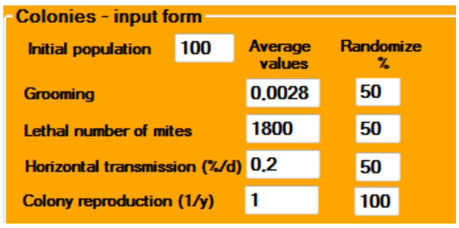
1.2.4 Mite female

Mite female is diploid, it has two genes for each phenotypic trait. It also has sperm in her spermatheca, within the model we assume, that it was mated by its brother. A female produces eggs:

- fertilised eggs – one set of genes originates from the female's genome (each gen is randomly selected and a bit mutated), the other is equal to genome of sperm from spermatheca
- non-fertilised eggs – they have one set of genes randomly selected from female's genome.

1.3 Phenotypic traits of honey bees

We suppose, that heritability of traits is 100 %, each individual exhibits phenotypic traits exactly expressing the genome. Traits of the colony are calculated taking into account the fact that the queen heading the colony was mated by multiple drones. Resulting trait is calculated as an average of genes of the queen and genes of the mating drones. Queen's genome is responsible for 50 % of the resulting value, the remaining 50 % is an average of all drone's genes.



1.3.1 Grooming g (%/d)

Grooming represents ability of a colony to get rid of mites. Relative number of mites removed during breeding cycle is described by the formula:

$$\frac{\triangle m}{m \triangle t} = g \ln m$$

This formula has been chosen quite arbitrarily, just to ensure somehow that equilibrium number of mites may exist in the colony. It means, that a colony is more active with removing of mites when higher number of mites is present. If it weren't so, any equilibrium wouldn't possible – the population of mites would grow indefinitely or it would disappear completely.

1.3.2 Lethal number of mites L (-)

Lethal number of mites is critical number of mites, at which colony collapses. More precisely, each mite in the sum is multiplied with it's *pathogenity* p which is a trait of a mite. Colony collapses when

$$\sum_{i=1}^{m} p_i \geq L \tag{1.1}$$

Lethal number of mites is use to define colony health as $H = 1 - \frac{\sum_{i=1}^{m} p_i}{L}$.

1.3.3 Horizontal transmission (%/d)

Horizontal transmission determines how many mites are transported from this hive to another ones and vice versa by drifting of workers and drones. It is expressed as proportion of mites in the colony transmitted per day. Horizontal transmission takes place only in summer.

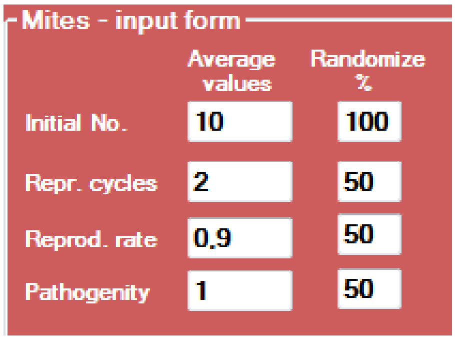
1.3.4 Colony reproduction (1/y)

Colony reproduction determines how many swarms are cast by the colony and year. Rational numbers are rounded randomly to integers (number 0.1 has ten times higher probability to be rounded to zero than to one).

1.4 Phenotypic traits of mites

1.4.1 Reproductive cycles (-)

Number of reproductive cycles a female can complete before it dies. Rational numbers are rounded randomly to integers.



1.4.2 Reproductive rate (-)

Number of fertile daughters per founder female in one reproductive cycle. Rational numbers are rounded randomly to integers.

1.4.3 Pathogenity p (-)

Pathogenity is a measure, how dangerous is a mite for the health of the colony. It's meaning is clear from Equation (1.1).

CHAPTER

TWO

RUN OF THE MODEL

2.1 Breeding the honey bee colonies

Breeding can take two basic form:

- swarming
- making splits

2.1.1 Swarming

Swarming imitates natural reproduction of honeybee colonies. In this case swarming is not controlled by a beekeeper.

Primary swarm has old queen, original colony as well as secondary swarms have a new queen, which mates naturally with ten drones if not required otherwise - see Section 2.1.3. Number of swarms cast by each colony is determined by *colony reproduction*. Each swarm normally caries 35 % of mites from original colony if not required otherwise.

2.1.2 Making splits

Making splits is an artificial way of reproduction, splits compensate colony loses. Splits are not made in case that apiary is at its original numbers. Just one split can be made from each colony. Splits have a new queen from artificial breeding. Certain rate of best colonies is chosen within apiary as breeders according to:

- the best health (health H is defined as $H = 1 - \frac{\sum_{i=1}^{m} p_i}{L}$)
- the lowest daily mite drop $\frac{\triangle m}{\triangle t}$ ($\triangle m$ is a sum of mites which died by age and due to grooming, excluding mites which died due to treatment)
- the lowest time elapsed since the last treatment (the higher the better)
- combination of two previous, colonies with the same values of the time elapsed since the last treatment are sorted by the daily mite drop

- the lowest daily mite-drop-grow-rate (the lower the better)
- randomly

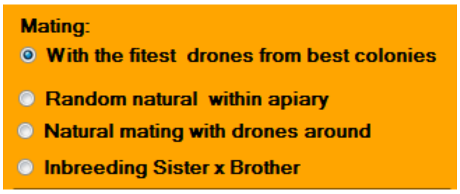
If any rate of worst queens for negative selection is specified, the worst queens are chosen according to the same criteria as for positive selection. These colonies are requeened.

Splits may contain:

- 35 % of population of mites from original colony
- a copy of mites of the originally colony
- no mites at all (all mites stay in original colony)

2.1.3 Queen mating

Queens are always mated by 10 drones. Mating can be:

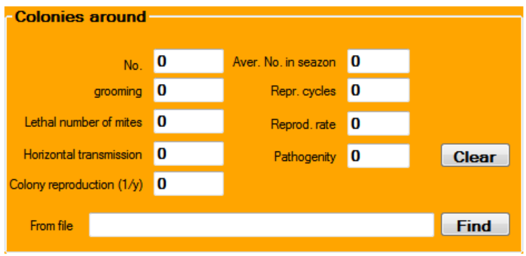


- with drones that are chosen from the same group of best colonies as new queens
- random (drones are chosen randomly from all colonies within apiary)
- with drones around (it simulates the situation, that apiary is not isolated from neighbours). Currently "drones around" are represented by one drone, whose genome is specified in the input box "Colonies around".
- inbreeding brother x sister (queen mates with her brothers)

This options can be applied also in case of swarming (selecting drones from some portion of fittest colonies make sense).

2.1.4 Colonies around apiary

Colonies around do "spoil" breeding within apiary. They are represented by one type of drone only (traits in the input form represent genome of the drone) and by one type of mite. Mites from colonies around may drift into colonies in the apiary and queens in the apiary can be mated by drones around. Probability of mating and drifting is governed by the ratio of colonies around to number of colonies in the apiary. Choosing values from file means, that final average values of colonies and mite population (at the end of calculation) are taken as drone and mites genome.



2.2 Mites breeding and spreading

Females enter a cell of brood where lay eggs. The first egg is always not fertilized – a male hatches from it. Daughters can mate with this male i.e. inbreeding sister x brother takes place. Sometimes two females (founders) are capped in one cell which may prevent inbreeding. Users of the software may choose whether probability of inbreeding is:

- 0 %

- 100 %
- governed by real statistics (which depends on mites to brood cells ratio).

Mites can spread into other colonies. Rate of spreading is governed by *horizontal transmission,* which is a trait of honey bee colonies. Mites can also propagate to other colonies after any colony died. *Rate of reinvasion* defines portion of mites distributed from the dead colony to the rest of apiary. In this case mites are distributed to other colonies by random. Spreading takes part only in month of the year, when colonies are active.

2.3 Natural selection

Both honey bee colonies and mites are subject to natural selection. The selection consist of two main parts - reproduction and dying.

2.3.1 Reproduction

Within the model rate of reproduction is fully "natural" only in case of swarming and is given by a trait *Colony reproduction*. In case of artificial splitting of colonies and artificial queen breading rate of reproduction depends on the way the queens and drones are selected as breeders (see 2.1.2).

Rate of reproduction on mites depend on their traits *reproductive cycles* and *reproductive rate* only.

2.3.2 Dying

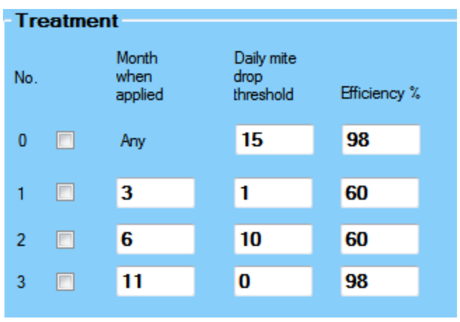
Mites in the honey bee colony die for age (after they perform all reproductive cycles) or by grooming or by treatment. The last two reasons are random. Contrary to honey bee colonies mites are not subject to natural selection of this kind within our model.

Colonies in the apiary may die due to two main natural reasons

- Lack of resources. This kind of selection takes place only in case that colonies swarm naturally. In this situation number of colonies (swarms + established ones) may be higher than the site can support, because nectar sources are limited as well as number of empty hollows. Redundant swarms die randomly in Autumn. This kind of control is called *chemostatic* according to [1, p. 184]
- Low health. Colonies die when health H is equal or lower then zero. It means that number and pathogenity of mites is higher than critical (lethal) number of mites. This kind of control is called *turbostatic* according to [1, p. 184]

2.4 The treatment

When the treatment is applied, intended portion of mites (according to efficiency of the treatment) is removed randomly from the colony. The treatment is applied only in colonies in which specified conditions are met.



CHAPTER

THREE

ABBREVIATIONS

	unit	description
g	%/d	grooming
H	-	health of the honeybee colony $H = 1 - \frac{\sum_{i=1}^{m} p_i}{L}$
L	-	lethal number of mites
m	-	number of mites in honey bee colony
p	-	pathogenity

BIBLIOGRAPHY

[1] Flegr J. 2006: Frozen Evolution, available online http://1url.cz/@Flegrbook