

COMPUTER MODELLING FOR EXTREME ENVIRONMENTS – HOW BEEHAVE MODEL CAN BE USED FOR EXTRATERRESTRIAL APPLICATIONS AND ESTABLISHING DIRECTIONS OF FUTURE STUDIES

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MOTIVATION

Extraterrestrial settlement

The food production system is one of the most important parts enabling long-term extraterrestrial settlement. A well-balanced, highly nutritious diet is crucial for astronauts' health and good cognitive functions. However, many plants providing fresh fruits and vegetables require pollination. For this purpose, using bees in extraterrestrial greenhouses should be considered, as being low-energy and low-resources consuming. An additional advantage is the possible positive impact of beekeeping on human mental health and the ability to cope with prolonged isolation and high-stress environment.

History of bees in space

The record of space and extraterrestrial settlement-related experiments is very scarce. Only a few experiments on space conditions and space travel impact on bees were done in the history, focusing on:

- microgravity impact on specimens mobility (1,2),
- greenhouse air pressure requirements (4)
- space travel impact on survivability and reproductive traits (3,5,6).

Bee colony modeling

Establishing the impact of specific conditions on honey bee colony development requires perennial observation to collect sufficient data for concluding. Using modeling tools for the long-term effects assessment might help to fill the existing knowledge gaps while simultaneously saving time. Simulating the required life period of a bee colony under the considered stressor and later comparing obtained results with the healthy, Earth-based colonies may significantly support the process.

BEEHAVE

BEEHAVE is a computer model of a bee colony simulating its development while considering both in-hive dynamics and external activities. The model considers factors such as: foraging activity, queen's egg-laying rate, diseases presence, beekeeping activities, weather. It is based on free, open-source software, the NetLogo, easily understandable for non-specialists.

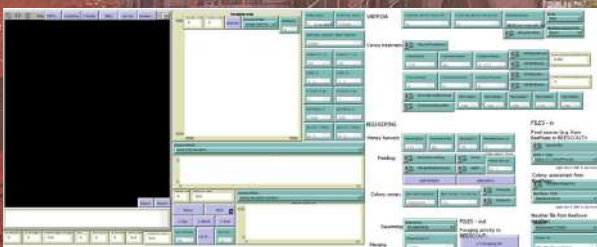


Fig. 1 Model's interface

Model expansion

Three modules were added to the model to enable simulation of development of colonies with queen bee given to the launching rocket acceleration pattern:

I. Queen bee assets module



II. Real-life input data

Modification of data format used by the model, to enable usage of data collected in the experimental apiary with Liebefeld method.

III. Hive type modification

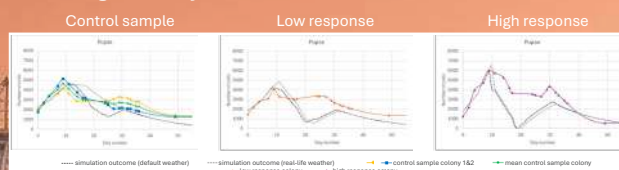


Input data

An experiment was performed to gather the data necessary for creation of a model considering space travel impact on bee colony development. Collected data showed that honey bee queen given to the acceleration pattern of launching rocket reacts twofold:

- 1) High response scenario: queen maximizes the number of eggs laid, with the increase in drone to worker ratio
- 2) Low response scenario: queen minimizes the number of eggs laid, following pattern similar to overwintering preparation

Modelling accuracy



Stability analysis

Stability analysis shows which parameters the model is most sensitive to. It enables to support the decision on future real-life studies direction.

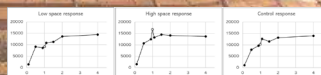


Fig. 2 Amount of pollen collected during single successful trip

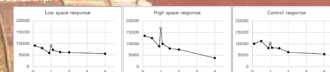


Fig. 3 Time to fill honey stomach with nectar

CONCLUSIONS

Space exploration & future studies directions

Based on the obtained results and existing knowledge gaps, future studies on space conditions impact on honey bee shall include altered gravity impact on foraging activities, emerging from overwintering state after space travel, and extraterrestrial crops nutritional composition.

Extreme environments

The presented example proves that computer modeling tools, such as BEEHAVE, can successfully be used to simulate bee colony development in extreme environment conditions. Such application requires initial collection of the input data for validation of the model and critical analysis of the obtained results. However, such an approach can significantly shorten the time of the research, limit the number of required deepening experiments and therefore, reduce the expenses necessary to conduct comprehensive research.

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Background image created with OpenAI

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Bee colony models are a popular and useful tool for their development dynamics prediction, enabling to analyze combination of various factors on bee colony in short time. Due to increasing interest in human settling on other celestial bodies, there is a need to verify the possibility of using natural pollinators, such as bees, for extraterrestrial crops pollination. To achieve this goal, the impact of space travel and conditions on pollinators should be thoroughly investigated.

However, a traditional way of anticipating long-term effects requires perennial observation. From the close perspective of setting up a lunar or Martian base, the time is very limited. This scarcity of time can be filled by computer model usage, such as BEEHAVE, which good capabilities of projection of a real-life colony dynamic was proven by many researchers already

Data on rocket-launch-related hypergravity impact on honey bee queen effects on colony development was used to expand the simulation capabilities of the model and dedicated "space travel" modules were developed. Created expansion enabled to acquire developmental effects observed in the experimental apiary. Model's analysis enabled to determine directions for further research on honey bees in context of their extraterrestrial usage with the most crucial areas being defined.

Identified issues should be addressed in the upcoming field studies to be able to conclusively answer the question of whether beekeepers will someday be needed on Mars. Additionally, the discussed application proved modelling tools versatility, being possible to be used for extreme environments as well and which are limited mainly by available data.