Selection criteria for improving honey production in Africanized honey bees

Fabiana Costa-Maia

Daniela Lourenco, Shogo Tsuruta, Elias Nunes Martins

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Why honey bees?

Table 1. Ranking of the fifteen countries, which shipped over three-quarters (76.5%) off all world’s natural honey exported during 2017, in million dollars (US$) and percentage (%)

<table>
<thead>
<tr>
<th>Country</th>
<th>Ranking</th>
<th>US$</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1°</td>
<td>270.7</td>
<td>11.44</td>
</tr>
<tr>
<td>New Zealand</td>
<td>2°</td>
<td>269.2</td>
<td>11.38</td>
</tr>
<tr>
<td>Argentina</td>
<td>3°</td>
<td>183.2</td>
<td>7.7</td>
</tr>
<tr>
<td>Germany</td>
<td>4°</td>
<td>145.6</td>
<td>6.2</td>
</tr>
<tr>
<td>Ukraine</td>
<td>5°</td>
<td>133.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Brazil</td>
<td>6°</td>
<td>121.3</td>
<td>5.1</td>
</tr>
<tr>
<td>Spain</td>
<td>7°</td>
<td>110.3</td>
<td>4.7</td>
</tr>
<tr>
<td>Mexico</td>
<td>8°</td>
<td>104.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Hungary</td>
<td>9°</td>
<td>89.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Belgium</td>
<td>10°</td>
<td>77.3</td>
<td>3.3</td>
</tr>
<tr>
<td>India</td>
<td>11°</td>
<td>73.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Vietnam</td>
<td>12°</td>
<td>70.6</td>
<td>3</td>
</tr>
<tr>
<td>Canada</td>
<td>13°</td>
<td>60.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Romania</td>
<td>14°</td>
<td>52.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>15°</td>
<td>48.1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>1811.0</td>
<td>76.5</td>
</tr>
</tbody>
</table>

Introduction

Why honey bees?

http://www.worldstopexports.com
https://www.trademap.org/Index.aspx
Introduction

Honey production = complex interplay

Queen + Workers + Environment

Mechanisms behind honey production are not fully understood

Genes + Eggs + Nectar + Pheromones + Pollen
Introduction

Background – queen’s & colony traits

Queen’s size & honey production

Queen’s size & reproduction potential

Heritability
Genetic Correlation

Behaviour

Behavior BLUP

Heritabilities
Genetic Correlations
Methodology
Introduction

Criteria to improve honey production
Aim

To investigate the feasibility of using emergence weight measured in the queen as criteria for improving honey production
Material and Methods

First Study

Genetic variation for emergence weight and honey production

Estimate: $h^2$ and $r_{g1,2}$

High quality phenotypes

Second Study

Selection for emergence weight to improve honey production

Selected and unselected queens for honey production
Material and Methods

**First study: Maringa State University**

The base population
↓
Daughter queens rearing
↓
Emergence weight
↓
Queen identification
↓
Fecundation
↓
Honey production

Doolittle (1889)

Regular Mating Flight (Winston (1987))
Material and Methods

First study:

The base population

Daughter queens rearing

Emergence weight

Queen identification

Fecundation

Honey production

Data set → Variance components estimation

Gibbs1f90

Miształ et al. (2002)

Two-trait analysis

- Pedigree – Great granddaughters
- 45 queens reared/generation
- 180 animals with records
- Missing information - Drone

\[ y_{1ij} = l a_i + a_{1i} + e_{1ij} \]

\[ y_{2ij} = c g_i + a_{2i} + e_{2ij} \]
First study:

Table 2. Posterior means and standard errors, in parentheses, of heritability, genetic and phenotypic correlations for queen’s emergence weight and honey production, in Africanized honey bees.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heritability</th>
<th>Genetic correlation</th>
<th>Phenotypic correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence weight</td>
<td>0.49 (0.27)</td>
<td>0.46 (0.35)</td>
<td>0.52 (0.15)</td>
</tr>
<tr>
<td>Honey production</td>
<td>0.32 (0.15)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Emergence weight would speed up the process to improve honey production!
Projection

First study:

**Annual Genetic Gain**

**Indirect selection**

\[
\Delta G_{\text{Honey,Weight}} = \frac{h_{\text{Honey}} \cdot h_{\text{Weight}} \cdot r_{g1,2} \cdot i \cdot \sigma_{y \text{Honey}}}{GI}
\]

\[
\Delta G_{\text{Honey,Weight}} = 5.30 \text{ kg/year}
\]

**Direct selection**

\[
\Delta G_{\text{Honey}} = \frac{h_{\text{Honey}} \cdot i \cdot \sigma_{a \text{Honey}}}{GI}
\]

\[
\Delta G_{\text{Honey}} = 1.86 \text{ kg/year}
\]

2.8 times greater
Material and Methods

Second study:

- The base population (60)
  - Daughter queens rearing (200)
  - Emergence weight
    - Genetic Evaluation
      - Daughter queens – highest EBV (60)
      - Queen identification
      - Fecundation
      - Daughter queens rearing (200)

(...)

5 Generations
Material and Methods

Second study: Federal Technological University of Paraná

Field test

Selected (Generation 5)

- 60 Daughter queens
- Regular mating flights
- Same apiary
- 60 days after

Unselected

- 60 Daughter queens

Honey production

60 days after
Results

Second study:

Phenotypic and Genetic trends for queen’s emergence weight

![Graph showing Phenotypic and Genetic trends for queen’s emergence weight](image-url)
Results

Second study:

Honey production (kg) – Selected and Unselected colonies

Potential of selecting queens based on emergence weight

Honey production, kg

30.23
22.36

26%
Adopting the *in vitro* production of queens and selecting for emergence weight is feasible for breeding programs aiming to increase honey production.
Our objective, in a near future, is to provide improved queens to beekeepers, to help them improve honey production in Brazil.
Questions
Extra Slides
Studies currently under investigation

Genetic correlation between emergence weight and queen reproductive system
Studies currently under investigation

Instrumental Insemination for complete pedigree
Studies currently under investigation

Drone rearing by virgin queen’s CO$_2$ stimulation
Studies currently under investigation

Genetic correlation between emergence weight and MORPHOMETRICS TRAITS
Material and Methods

First study:

Honey production
Material and Methods

First study:

The base population

11 honey bee farmers

Brazil

Maringá
Material and Methods

First study:

Queen rearing

Queen rearing Doolittle (1889)
Material and Methods

First study:

Emergence weight measurements
Material and Methods

First study:

Honey production

Regular Mating Flight
17 to 20 drones

Winston (1987)
Material and Methods

2009: the first study

11 honey bee farmers

Brazil

<table>
<thead>
<tr>
<th>Queen rearing, measurements and fecundation</th>
<th>Honey production (one year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 29</td>
<td>29 29 17 7</td>
</tr>
<tr>
<td>63 55</td>
<td>36</td>
</tr>
</tbody>
</table>

\[
y_{1ij} = \lambda_i + a_{1i} + e_{1ij}
\]

\[
y_{2ij} = c_{gi} + a_{2i} + e_{2ij}
\]

Gibbs1f90
Misztal et al. (2002)
Material and Methods

Second study:

- **G0**: 60 Mother queens → 60 ≠ families
  - 218 Daughter queens  
  - Genetic evaluation
  - Queen’s emergence weight
  - Regular mating flight

- **G1**: 60 Mother queens → 45 ≠ families
  - 235 Daughter queens  
  - Genetic evaluation
  - Queen’s emergence weight
  - Regular mating flight

- **G2**: 60 Mother queens → 24 ≠ families
  - (…)
  - Genetic evaluation
  - Regular mating flight

- **G5**: 60 Mother queens → 5 ≠ families
  - 60 Daughter queens - highest EBV  
  - Genetic evaluation
  - Regular mating flight
First study:

**Annual Genetic Gain**

**Direct selection**

\[
\Delta G_{\text{Honey}} = \frac{h_{\text{Honey}} \cdot i \cdot \sigma_{a_{\text{Honey}}}}{G_l}
\]

\[
\Delta G_{\text{Honey}} = \frac{(0.57) \cdot (1.14) \cdot (5.73)}{1}
\]

(\( \Delta G_{\text{Honey}} = 3.72 \text{ kg/year} \) )/2

\[
\Delta G_{\text{Honey}} = 1.86 \text{ kg/year}
\]

**Indirect selection**

\[
\Delta G_{\text{Honey,Weight}} = \frac{h_{\text{Honey}} \cdot h_{\text{Weight}} \cdot r_{g1,2} \cdot i \cdot \sigma_{y_{\text{Honey}}}}{G_l}
\]

\[
\Delta G_{\text{Honey,Weight}} = \frac{(0.57) \cdot (0.70) \cdot (0.46) \cdot (1.14) \cdot (10.13)}{0.20}
\]

(\( \Delta G_{\text{Honey,Weight}} = 10.60 \text{ kg/year} \) )/2

\[
\Delta G_{\text{Honey,Weight}} = 5.30 \text{ kg/year}
\]

Return an annual gain 2.8 times greater than honey production
Selection intensity \( (i) = 1.14 \Rightarrow b = 30.85\% \)

Generation interval \((GI) \Rightarrow \) Direct Selection by honey = 1 year

Generation interval \((GI) \Rightarrow \) Indirect Selection by emergence weight = 0.20 year

365 days/70 days (each generation) = 4.8 generations/year; 1 year/4.8 generations = 0.20 year

<table>
<thead>
<tr>
<th>Honey</th>
<th>Emergence weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma_a^2 = 32.83 \text{ kg}^2 )</td>
<td>( h^2 = 0.49 )</td>
</tr>
<tr>
<td>( \sigma_a = \sqrt{\sigma_a^2} = \sqrt{32.83} = 5.73 \text{ kg} )</td>
<td>( h = \sqrt{h^2} = \sqrt{0.49} = 0.70 )</td>
</tr>
<tr>
<td>( h^2 = 0.32 )</td>
<td></td>
</tr>
<tr>
<td>( h = \sqrt{h^2} = \sqrt{0.32} = 0.57 )</td>
<td></td>
</tr>
<tr>
<td>( \sigma_y^2 = 102.59 \text{ kg}^2 )</td>
<td></td>
</tr>
<tr>
<td>( \sigma_y = \sqrt{\sigma_y^2} = \sqrt{102.59} = 10.13 \text{ kg} )</td>
<td></td>
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