UMBC

Chemical Biochemical and Environmental Engineering

Optimization of Anti-Aphrodisiacs in *P. Brassicae* Under Strong Selective Pressure

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Problem 3
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Prompt

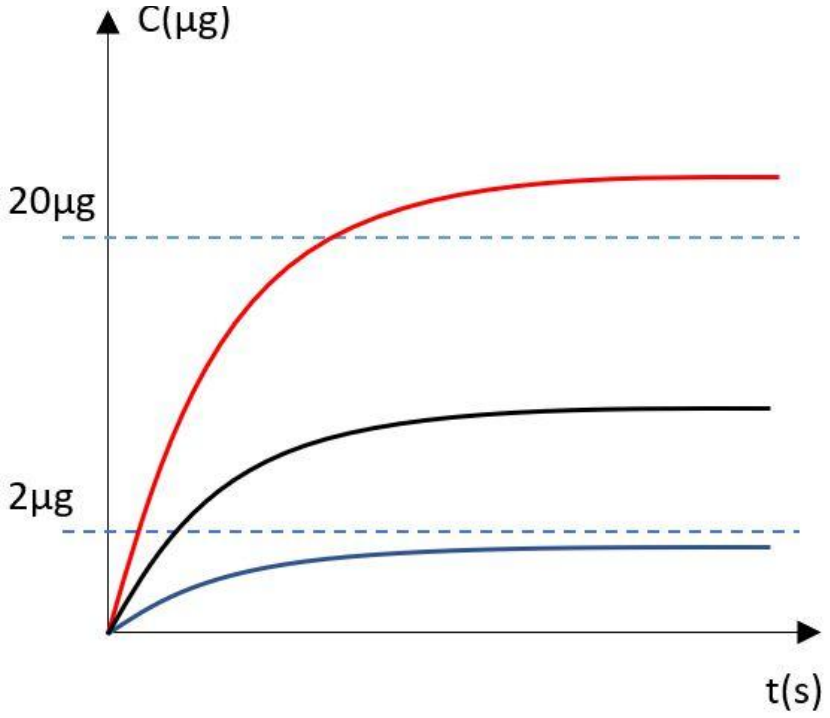
Model the interactions between the male and female *P. Brassicae* butterflies and the *T. Evanescens* and *T. Brassicae* wasps.

Overall Interactions

Mathematical Approach

$$Wasp\ Threshold - C_{max} = C_{BC,net}$$

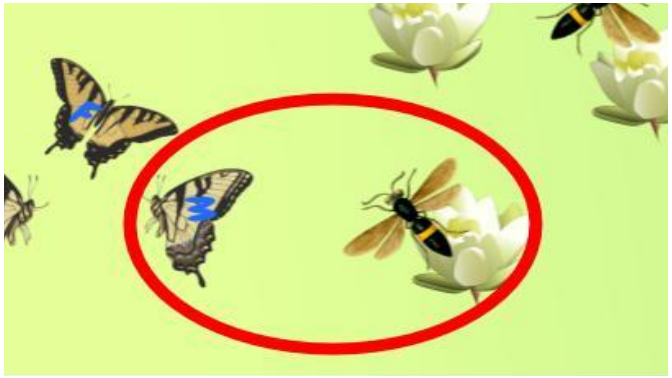
- Optimize **male** anti-aphrodisiac levels (Benzyl Cyanide)
  - Maximize concentration for sexual selection
  - Stay under wasp detection barrier
- Use diffusive mass transfer to model anti-aphrodisiac levels



Indirect Wasp-Male Interactions

$$Wasp\ Threshold - C_{max} = C_{BC,net}$$

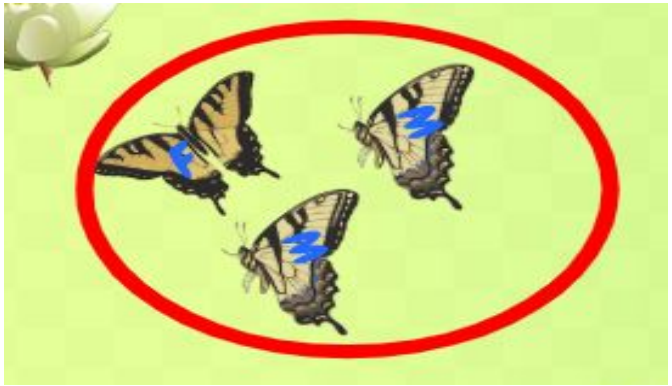
- *T. Evanescens* **(25%)** vs. *T. Brassicae* **(100%)**

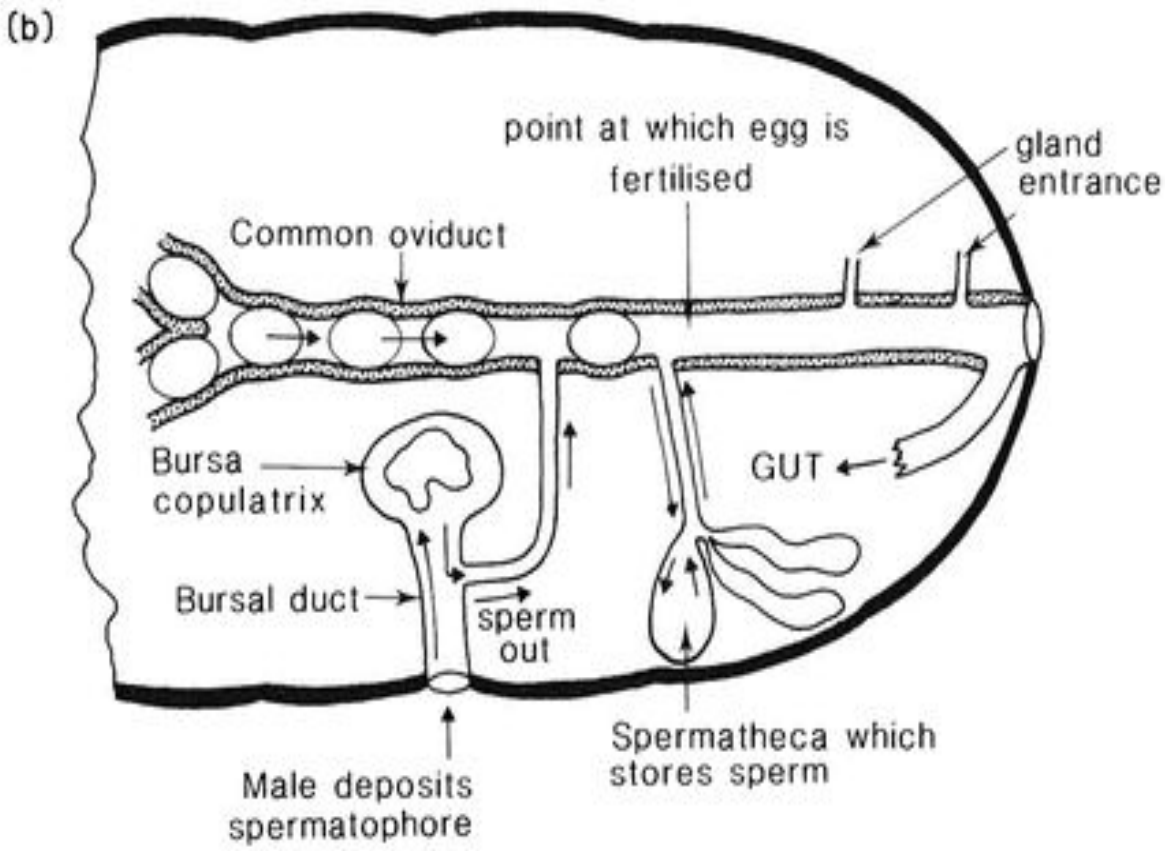


Direct Male-Male Interaction

$$Wasp\ Threshold - C_{max} = C_{BC,net}$$

- Strongest male
- Enzyme degradation → sperm degradation





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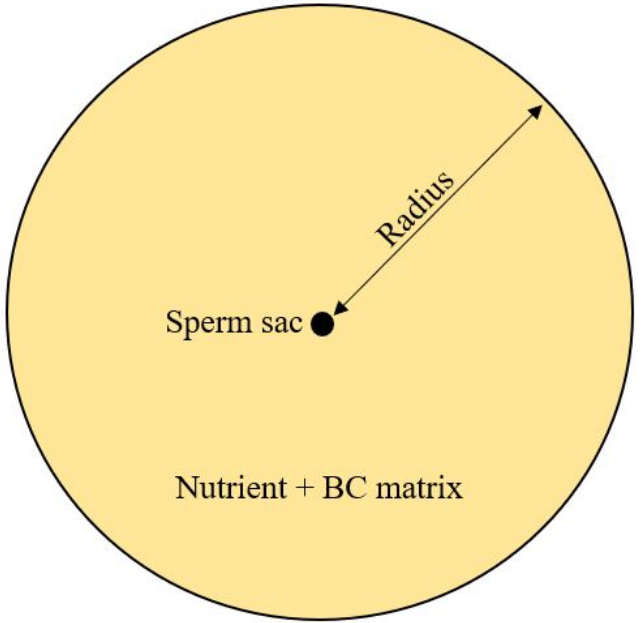
Direct Female-Male Interaction

$$\frac{\partial C_{Bc}}{\partial t} = D_{AB}\nabla^2 C_{AB}$$

- BC directly proportional to spermatophore nutrients
- Spherical Assumption
- The size of sperm sac is negligible compared to the spermatophore



Fick's Second Law of Diffusion

$$\frac{\partial C_{Bc}}{\partial t} = D_{AB}\nabla^2 C_{AB}$$

$$\frac{\partial C_{Bc}}{\partial t} = D_{AB}\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial C_{BC}}{\partial r}\right) + \frac{1}{r^2 sin\theta}\frac{\partial}{\partial \theta}\left(sin\theta\frac{\partial C_{BC}}{\partial \theta}\right) + \frac{1}{r^2 sin^2\theta}\left(\frac{\partial^2 C_{BC}}{\partial \emptyset^2}\right)\right]$$

$$\frac{\partial C_{Bc}}{\partial t} = D_{AB}\left(\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial C_{BC}}{\partial r}\right)\right)$$

Fick's Second Law of Diffusion

$$\frac{\partial C_{Bc}}{\partial t} = D_{AB}\left(\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial C_{BC}}{\partial r}\right)\right)$$

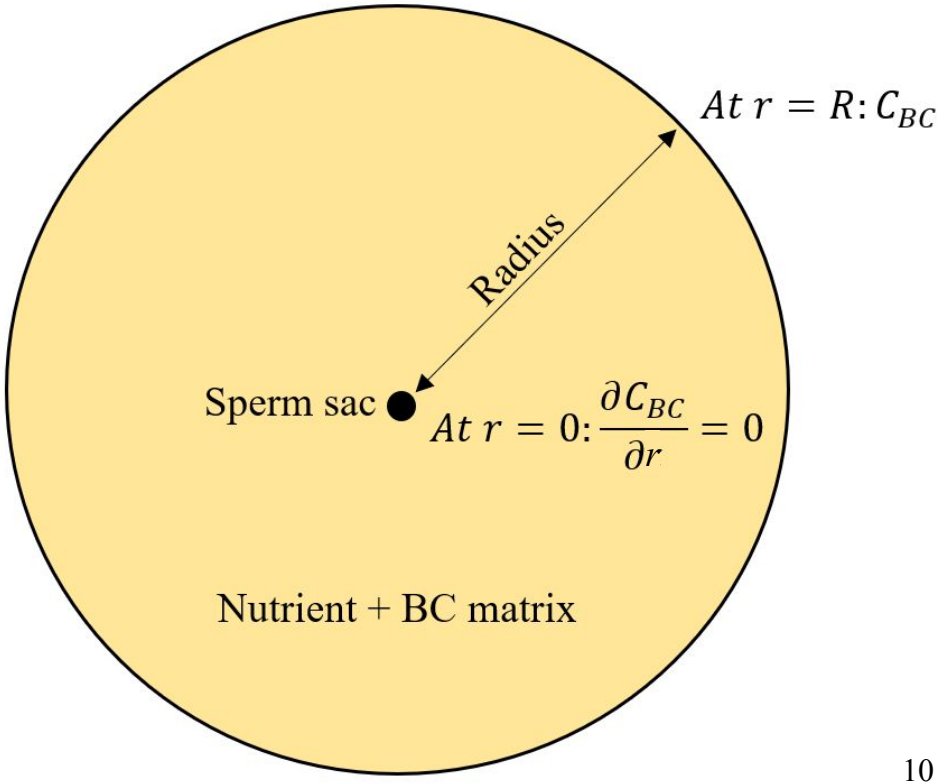
Boundary Conditions:

At $r = 0$, $\frac{\partial C_{BC}}{\partial r} = 0$ for t ≥ 0

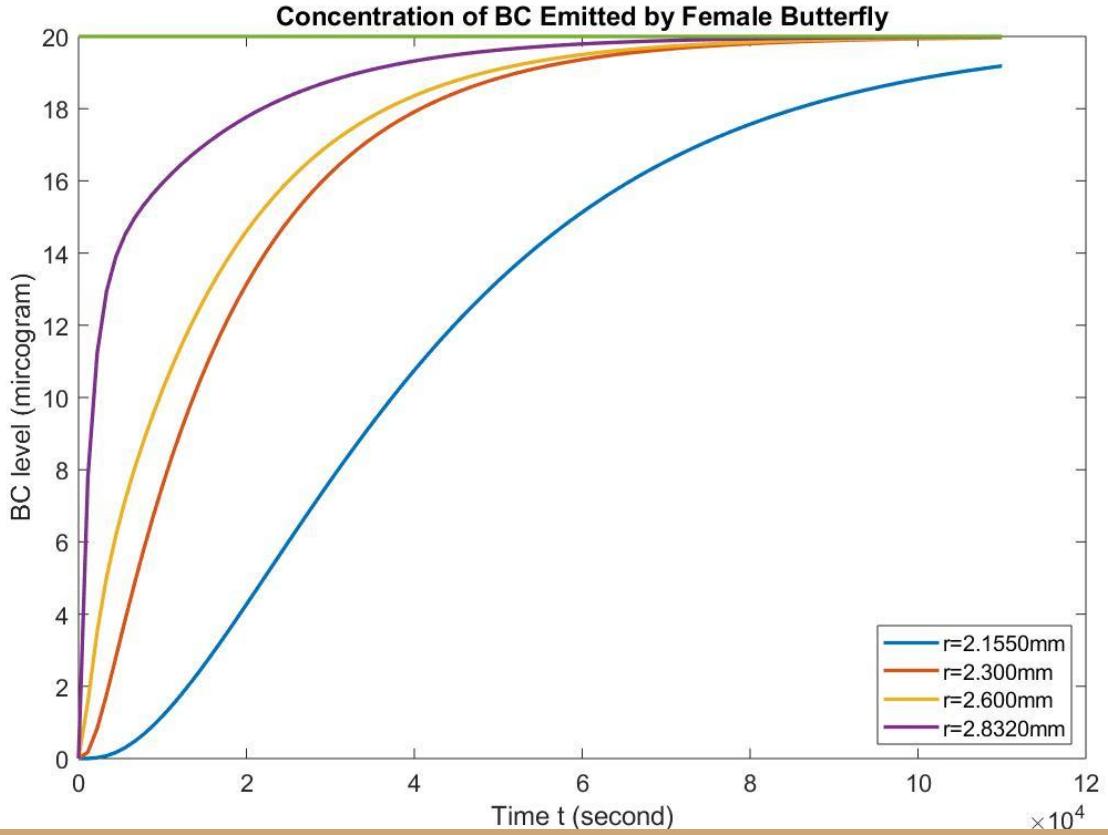
At $r = R$, C_{BC} = 0 for t > 0

Initial Conditions:

At t= 0 , C_{BC} = 0 for 0 ≤ r ≤ R



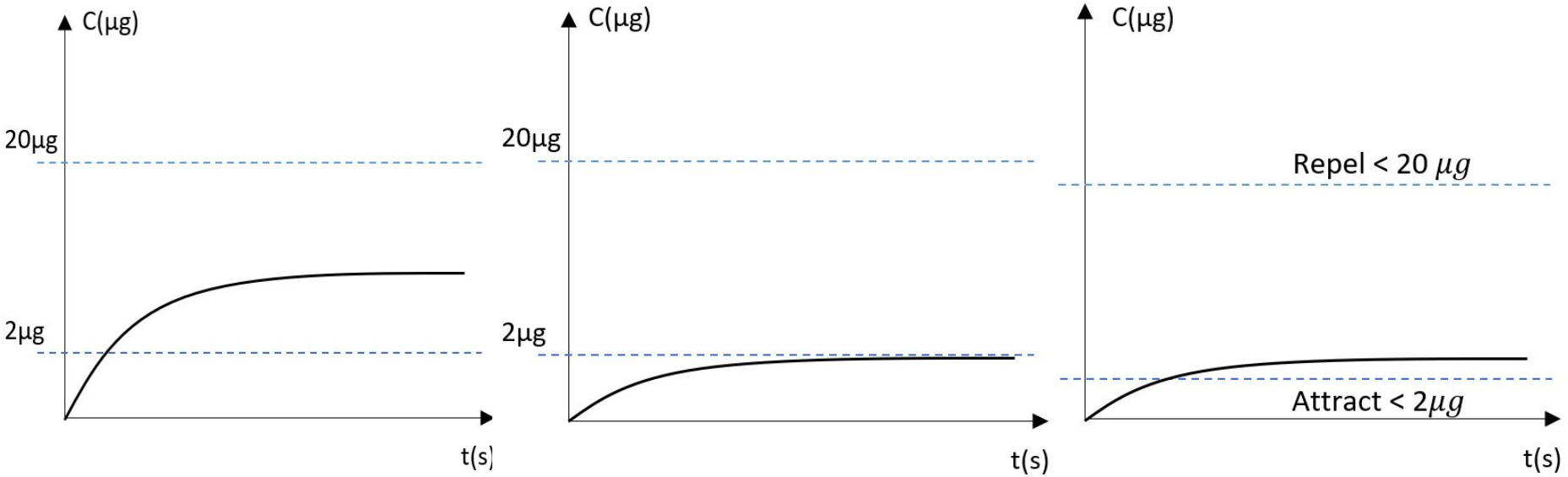
Differential Model Result



- Female butterfly emitted max concentration of BC at tf = 30 hrs.
- Assuming 20 μL of BC
- $D_{AB} = 3 * 10^{-5}$
  - Iterative process

Multi-Generational Effects:

$$Wasp\ Threshold - C_{max} = C_{BC,net}$$



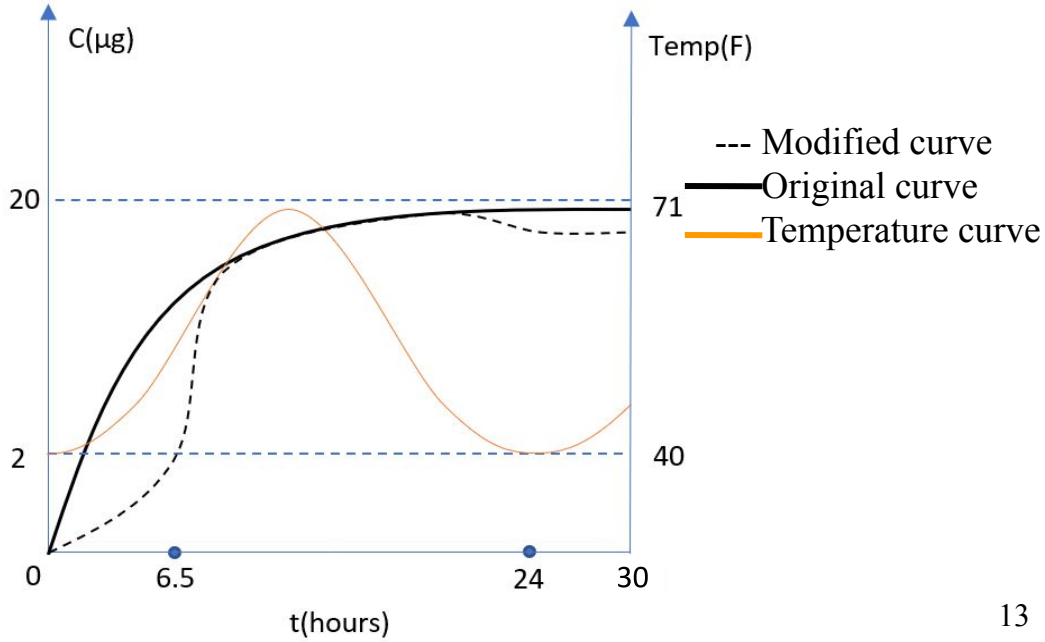
Generation 1 Generation 2 Generation 3

Additional Issue #3:

$$C_{BC,net} = Wasp\ Threshold - C_{BC,max}[1 - \eta(T(t))]$$

Assumptions:

- Low temperature → decreases radius of dispersal
- Sunny all day
- Temp interval: dawn to dusk



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- Our mentor: Dr. Neha Raikar
- Our UMBC contact: Dr. Douglas Frey
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- SIMIODE for hosting the competition.

Questions?

References

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