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Agent-Based Modeling of Pollen Competition

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I. Abstract

Non-random mating in *Arabidopsis Thaliana* is due to intense competition between pollen grains to fertilize the limited number of ovules. Using competition traits identified in past studies, we are building an Agent-Based Model (ABM) with NetLogo that simulates the competition between two accessions of *Arabidopsis Thaliana* pollen. This model will allow for the user to adjust pollen traits and competition strategies for each of the two competing pollen accessions. Some of the factors being considered include pollen viability, pollen tube growth rate, nutrients provided by the female, pollen tube attrition and the means of locating unfertilized ovules. To assess the competitiveness of the selected pollen traits, this model will track the number of fertilized ovules and maximum pollen tube length for each accession. This ABM will allow further study into the traits that make pollen most competitive as well as the strategies used by pollen to fertilize ovules. This model has the potential to quickly test a wide variety of competition traits and strategies without the need for in lab experiments.

II. Introduction

Research Question

Which competition traits and movement strategies allow an *Arabidopsis Thaliana* pollen accession to fertilize more ovules?

Pollen Competition

- Angiosperms sexually reproduce when sperm in a pollen grain fertilize an ovule.
- When pollen grains first reach the stigma, they begin to form pollen tubes which grow down the transmitting tract of the style.
- Pollen tubes create a path for the pollen's sperm to reach an ovule.
- There are far more pollen grains on a style than available ovules in the ovary creating intense competition between pollen grains that leads to non-random mating.

Pollen Competition Traits

- **Pollen viability:** the proportion of pollen from each accession that have the ability to germinate.
- **Pollen germination rate:** the rate at which a pollen grain will attach itself to the stigma; faster germination rates lead to more competitive pollen.
- **Pollen tube growth rate:** the rate at which the tip of the pollen tube moves down the transmitting tract; faster growth rates lead to more competitive pollen.
- **Interference competition:** the difference in germination and growth rates that occurs when comparing single-accession pollination with double-accession pollination.

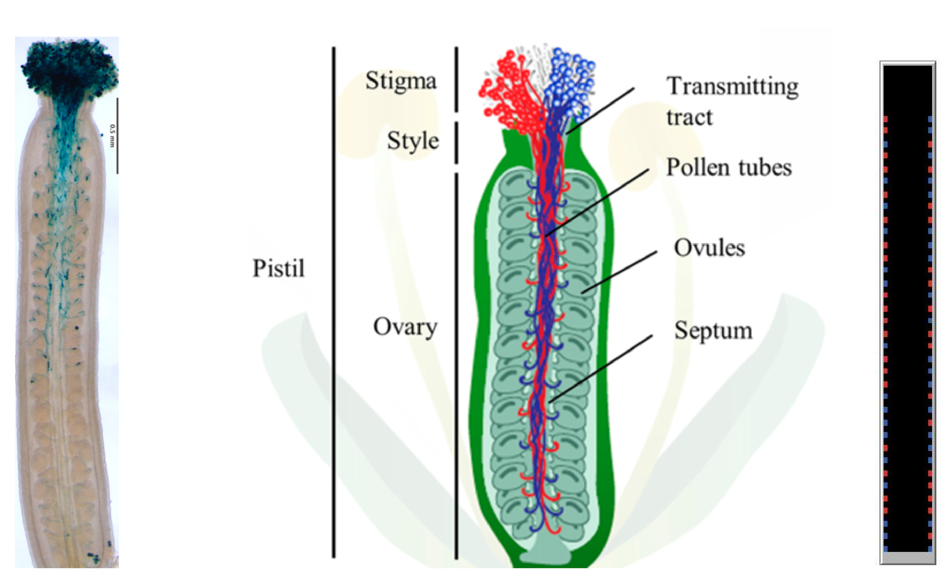

Figure 1: *Arabidopsis Thaliana* carpel represented in a photo, diagram and Netlogo Interface.

III. Model Description

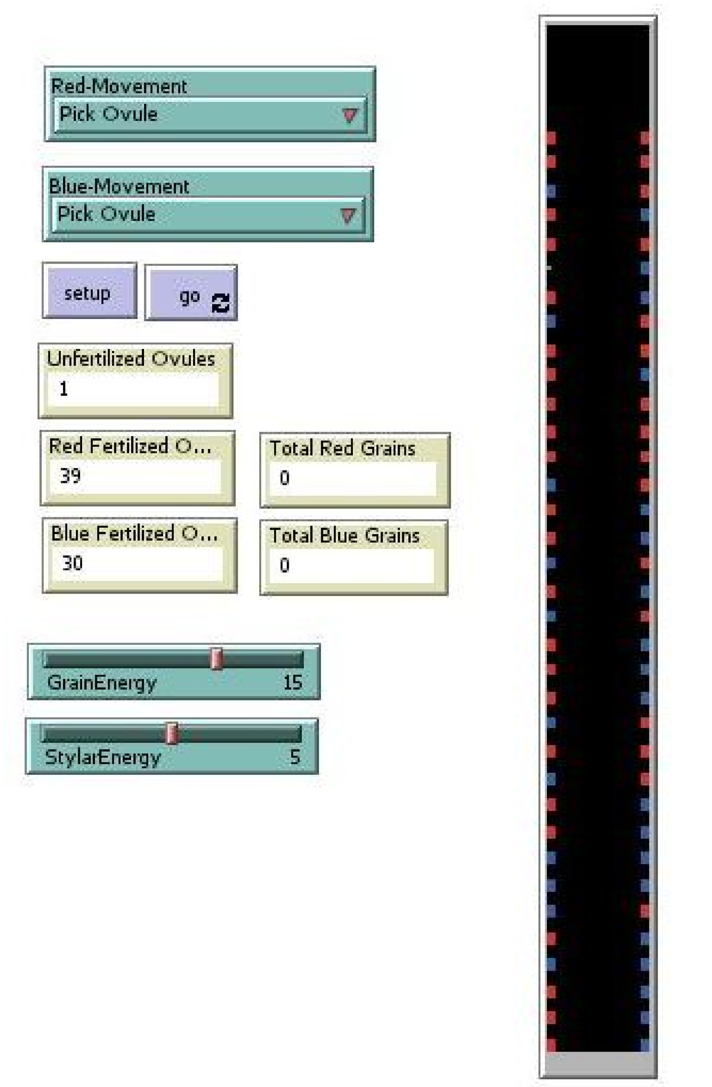

Figure 2: An image of a pollen competition simulation in progress on the Netlogo interface.

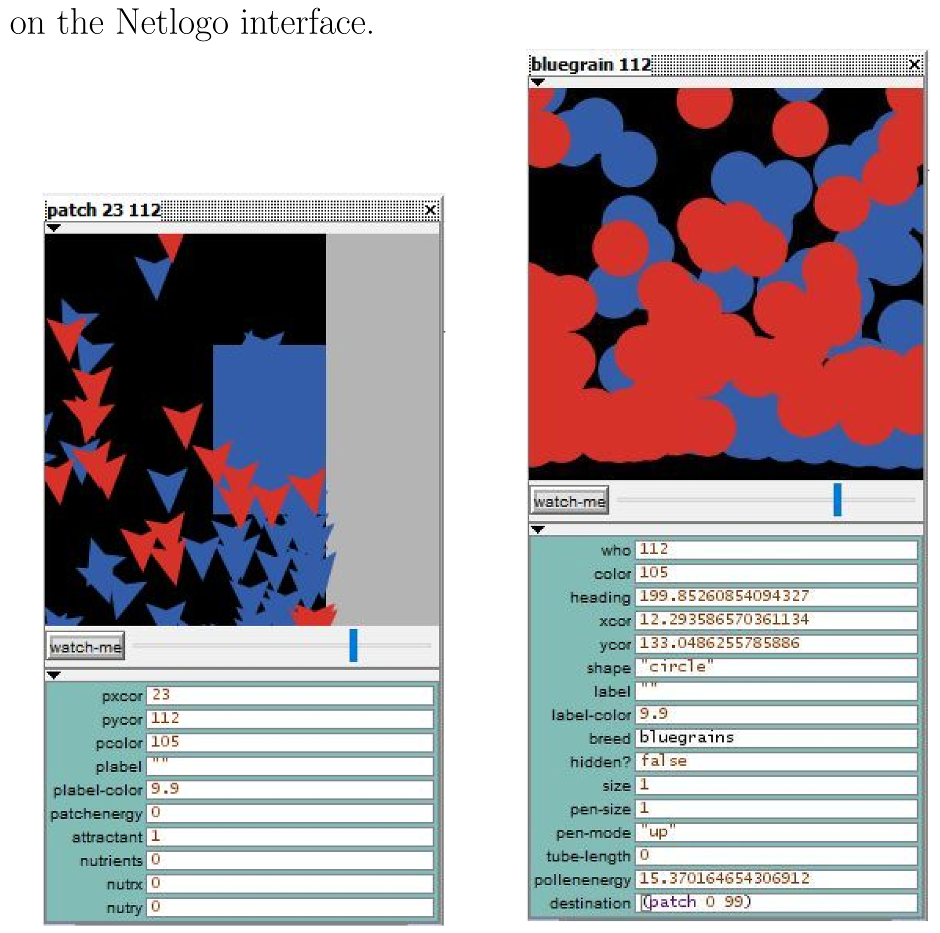

Figure 3: Traits of the patches and pollen grains can be analyzed through out the simulation.

Model vs. Reality

- Two-dimensional model for a three-dimensional system:
  - Multiple grains can occupy one space in the model.
  - Physical size constraints not included in the two-dimensional model.
- Pollen grains moving down the transmitting tract represent the location of the tip of pollen tubes in real-world pollen competition.
- Ovule patches represent the opening to the real-world ovules rather than the ovule as a whole as the opening is the target for pollen tubes.

Agent-Based Model (ABM)

- Models simplify real-world systems so conclusions can be drawn about the system's patterns and functions.
- Agents represent interacting components such as pollen grains and the surrounding environment.
- Each agent can be assigned specific traits such as energy levels and movement patterns.
- Agent traits can change over the course of the simulation through the progression of time and interactions with other agents.
- Changes to agent traits can be made through the user interface.

Patches

- The grid is made of 24×250 patches, this represents the entire *Arabidopsis Thaliana* pistil.
- The top row of the patches represents the stigma and is the starting location for the pollen.
- The following 21 rows of patches represents the style.
- All following rows of patches represents the ovary which contains 70 total ovules, 35 on each side.
- Ovules are green when unfertilized and change to blue or red when fertilized.
- The center columns of the grid represent the transmitting tract.

Agents

- The two competing accessions of pollen are represented by blue and red agents.
- Each accession of pollen can be assigned a different movement strategy by the user, this determines how the pollen moves and interacts with the patches.
- Once the model has been started, the pollen move down the transmitting tract toward the ovules.
- When a pollen grain comes into contact with an unfertilized ovule, the pollen fertilizes the ovule represented by turning it to its accession color.

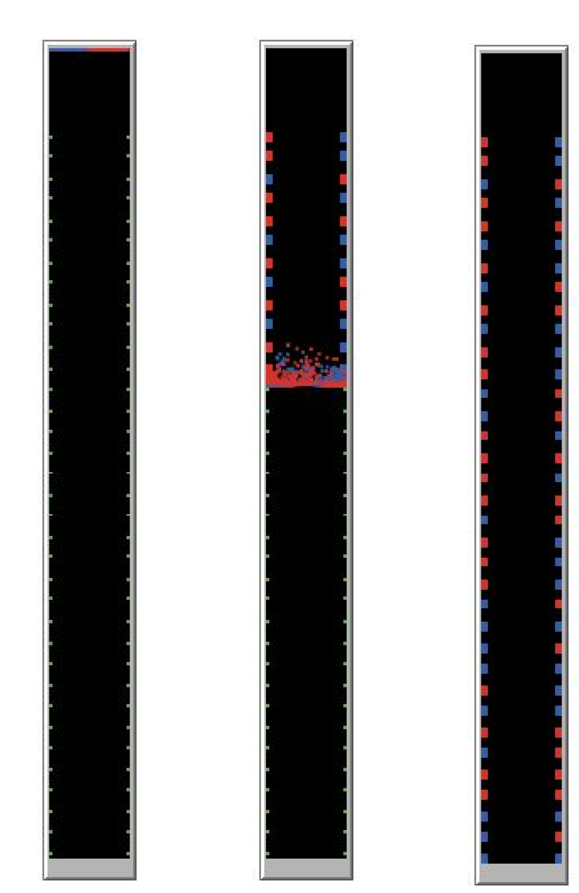

Figure 4: Three different stages of a model simulation.

IV. Movement Patterns

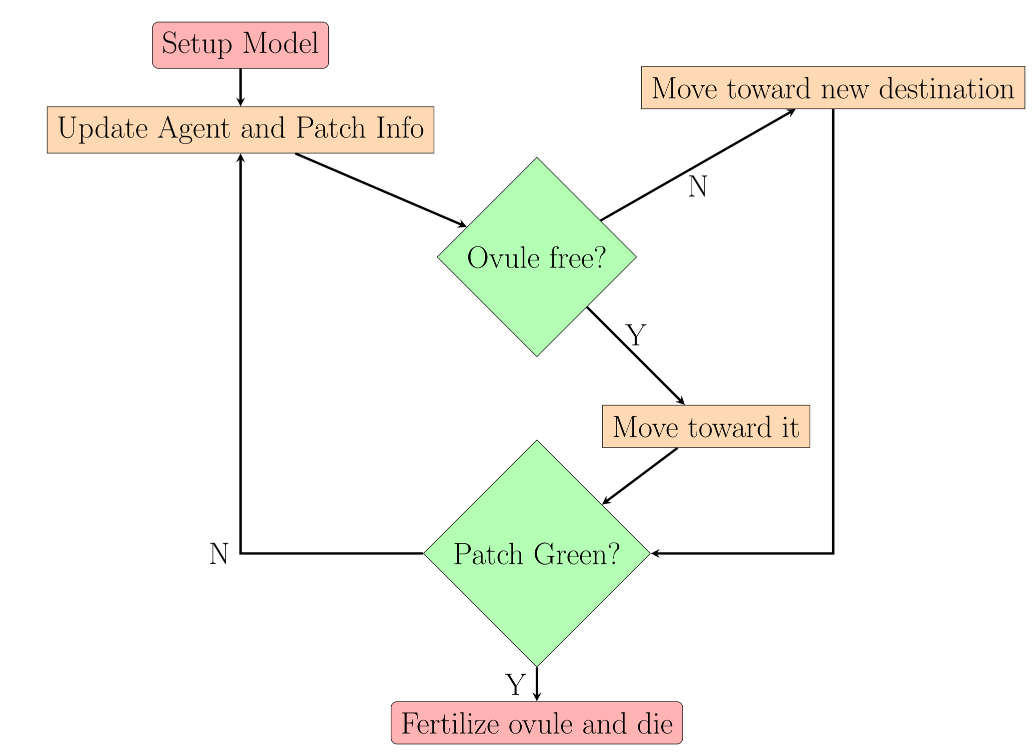

Figure 5: This decision tree is for a pollen movement pattern that selects an ovule to move toward until that ovule has been fertilized.

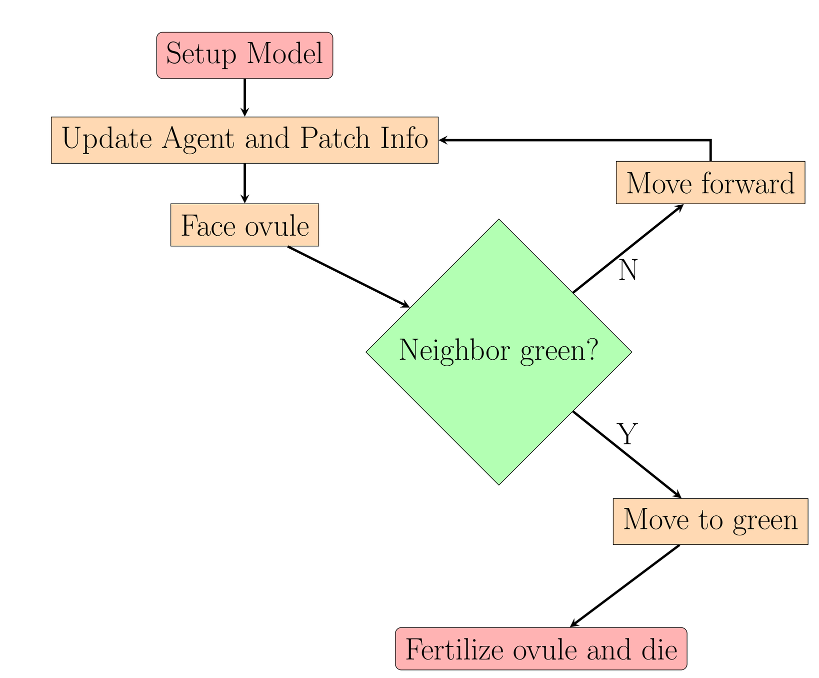

Figure 6: This decision tree is for a pollen movement pattern that can only detect them directly in a small radius.

These are two examples of foundational pollen movement patterns. These simple movement strategies will later be complicated with the addition of other factors, such as pollen energy and pollen attraction levels to ovules. These factors will help the model better match the real-world system.

V. Future Goals

- Devise different movement strategies to compare to real-world pollen grain movement strategies.
- Implement pollen energy that can be lost when moved and gained from surroundings.
- Implement a chemo-attractant into the model that directs the growth of the pollen tubes.
- Allow pollen to weigh the benefits of moving to a high energy vs. high chemo-attractant patch.

Acknowledgments

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