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Optimised refugia in BT sugarcane

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Introduction

There are many methods of pest control in use today

- Sprayed pesticides
- Biological control (natural predators)

Crops with built-in pest resistance, using genetic modification

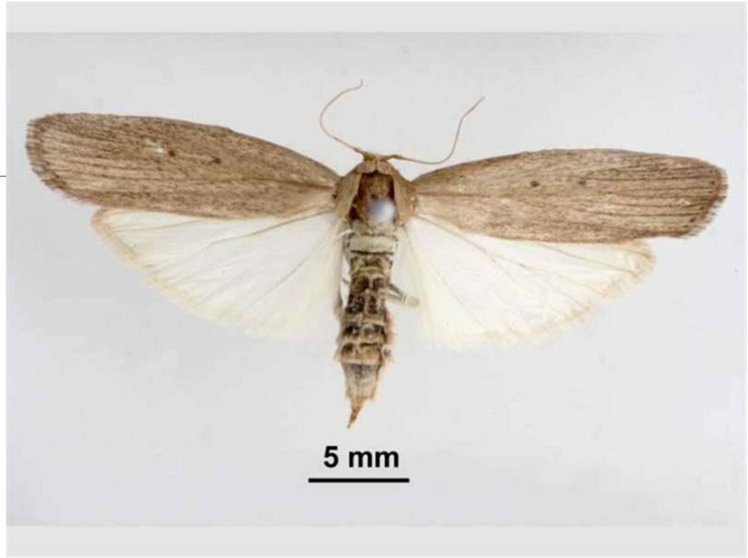
Bt crops, containing genes from a ground-dwelling bacteria, kill *Lepidoptera* species

Proven to be effective, but with caveats

Due to its effectiveness, one has to limit the rate of resistance development in target pest

Use refuge areas to maintain pockets of none-resistant pests to curb development

Problem Statement



Common pest in sugarcane – *Eldana Saccharina* Walker

Stalk borer moth that causes significant losses in revenue

In the process of developing Bt sugarcane

Require a recommendation of how to plan refuge areas (refugia)

MK Butterfield used population and genetic models to predict how much

Painted a bleak picture, stating between 40 and 75% of the land must be refugia

His model had certain weaknesses and blind spots which we want to address

Research Drivers

Although a study was done on refuge areas, there were aspects that needed exploring

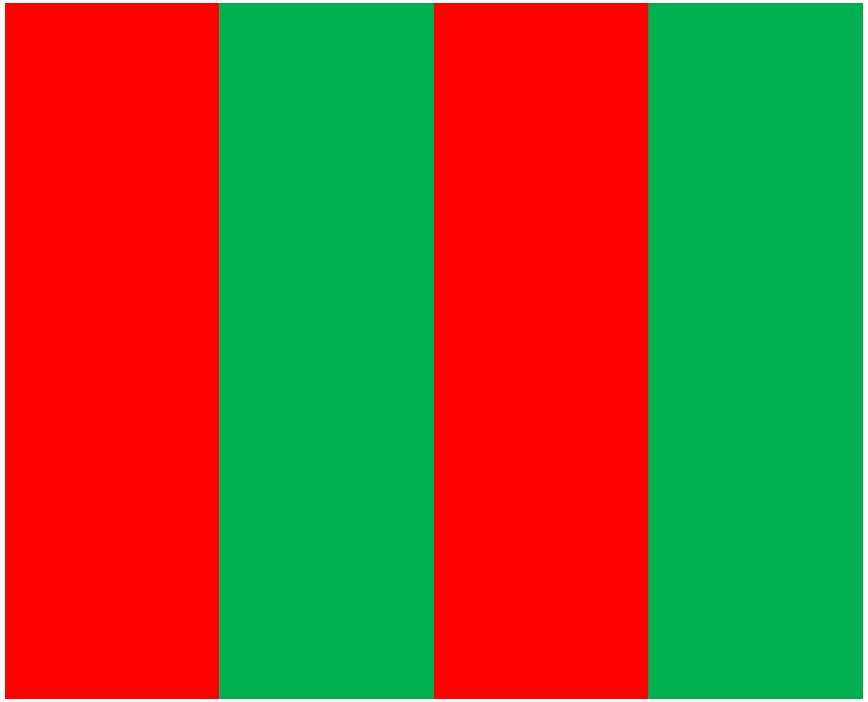
- How should refuge be planted (layout)
- Does *Eldana's* behavior impact how resistance might develop
  - Low dispersal rate
  - "Lek" mating

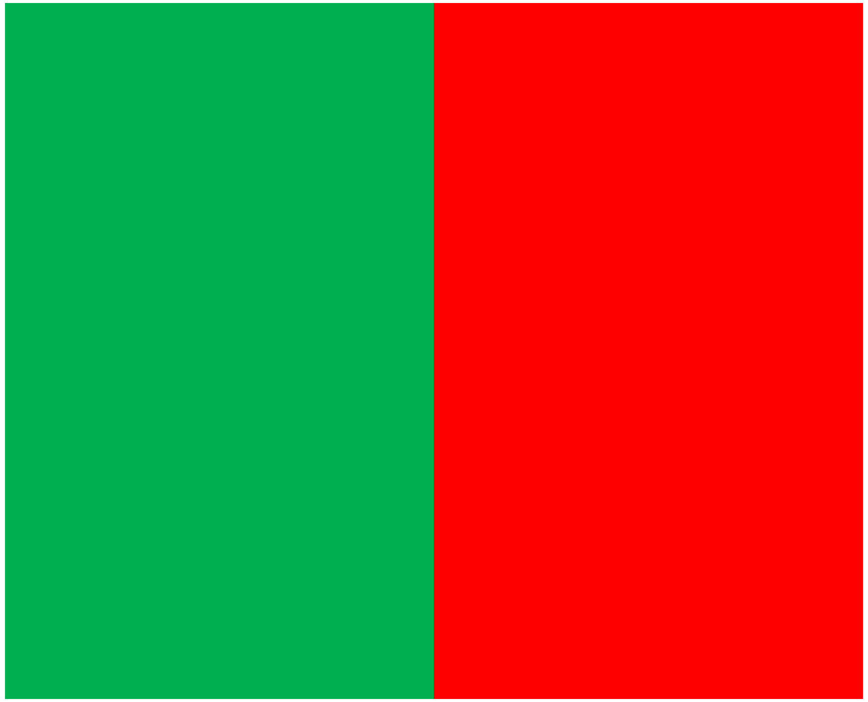
For these questions a more complex approach is necessary

Using spatial models can give insight into how and where resistance starts to develop

Using agent-based simulation allows us to add behavioral aspects

Research Drivers





Research Drivers

Proposed Model

Dr BJ van Vuuren developed a very detailed simulation model of the moth’s lifecycle

It attempted to accommodate for nearly every aspect of its behavior

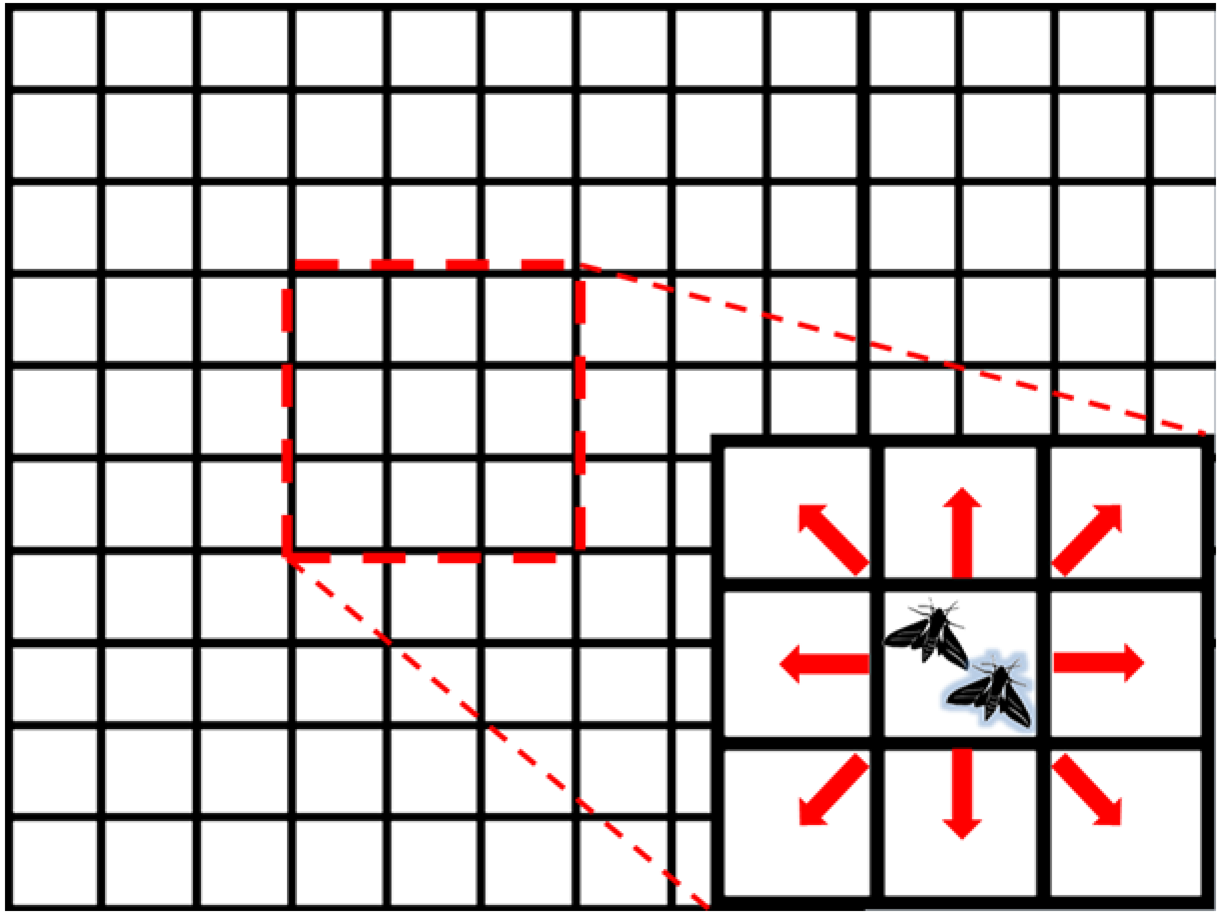
Very complex and very slow when handling large numbers or areas

We wanted a simplified model that could run over extended periods for very large spaces

Did plenty of research and received feedback at conferences of how to approach this

Developed a novel hybrid approach, combining agent-based simulation with cells

- Use many, smaller areas (cells) in a grid instead of one large one
- Delegate lots of the neighborhood searching to the cell
- Don’t worry about the actual location of each agent



Proposed Model

Develop a “plug-and-play” model

- Core simulation environment containing all the agents and underlying field
- Modules that drive behaviour plug into the model
  - Movement drivers
  - Genetics
  - Life stages

Simplifies adding new behaviours to existing models

Reduce “stationary” life stages (eggs, larvae, pupae) to clusters

Limit an agent’s “scope” to its current cell

- No neighbourhood searches for other agents, simply iterate through the other agents in cell

Preliminary Results

The core model for the project has been developed throughout 2017

Some assumptions need to be finalized

Some small scale results are already available

- 1 hectare
- Resistance gene is recessive or dominant
- Sugarcane is on a two year harvest cycle
- 1% resistant initial population
- Fitness of resistant and non-resistant are identical
- Toxin is 90% effective (lower dose)
- Heterozygote (carrier) gets no advantage
- Temperature is constant over entire area

Preliminary Results

For dominant genes:

- 60%+ refuge areas in a striped pattern curb resistance in 90% of runs
- Resistance gene takes over immediately if no refuge is planted

For recessive genes:

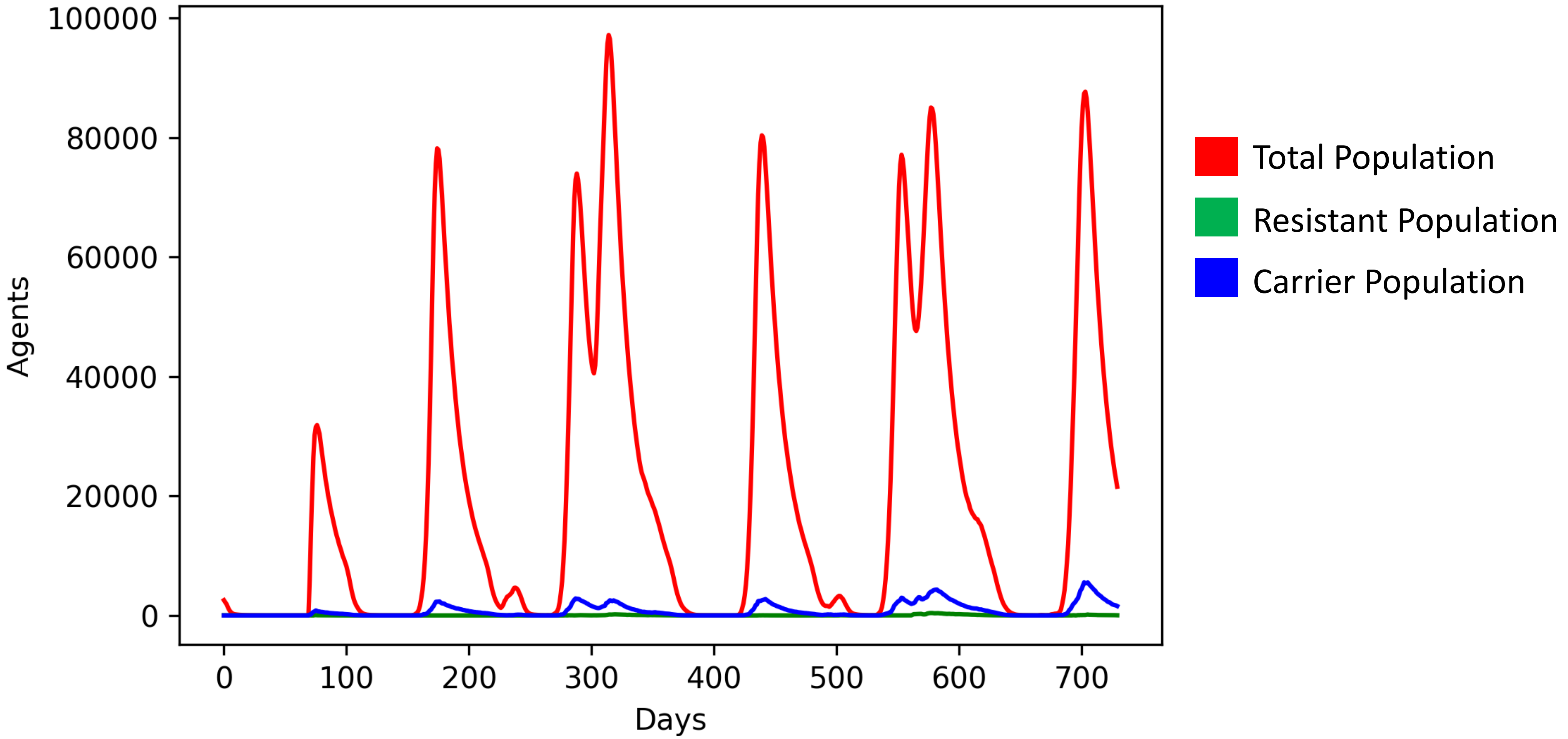
- 40% refuge areas in a striped pattern curb resistance in 95% of runs
- 20% refuge areas in a striped pattern curb resistance in 10% of runs
- Unless initial resistant populations were in close contact, they die out quickly

In both cases striped layouts worked better than block layouts

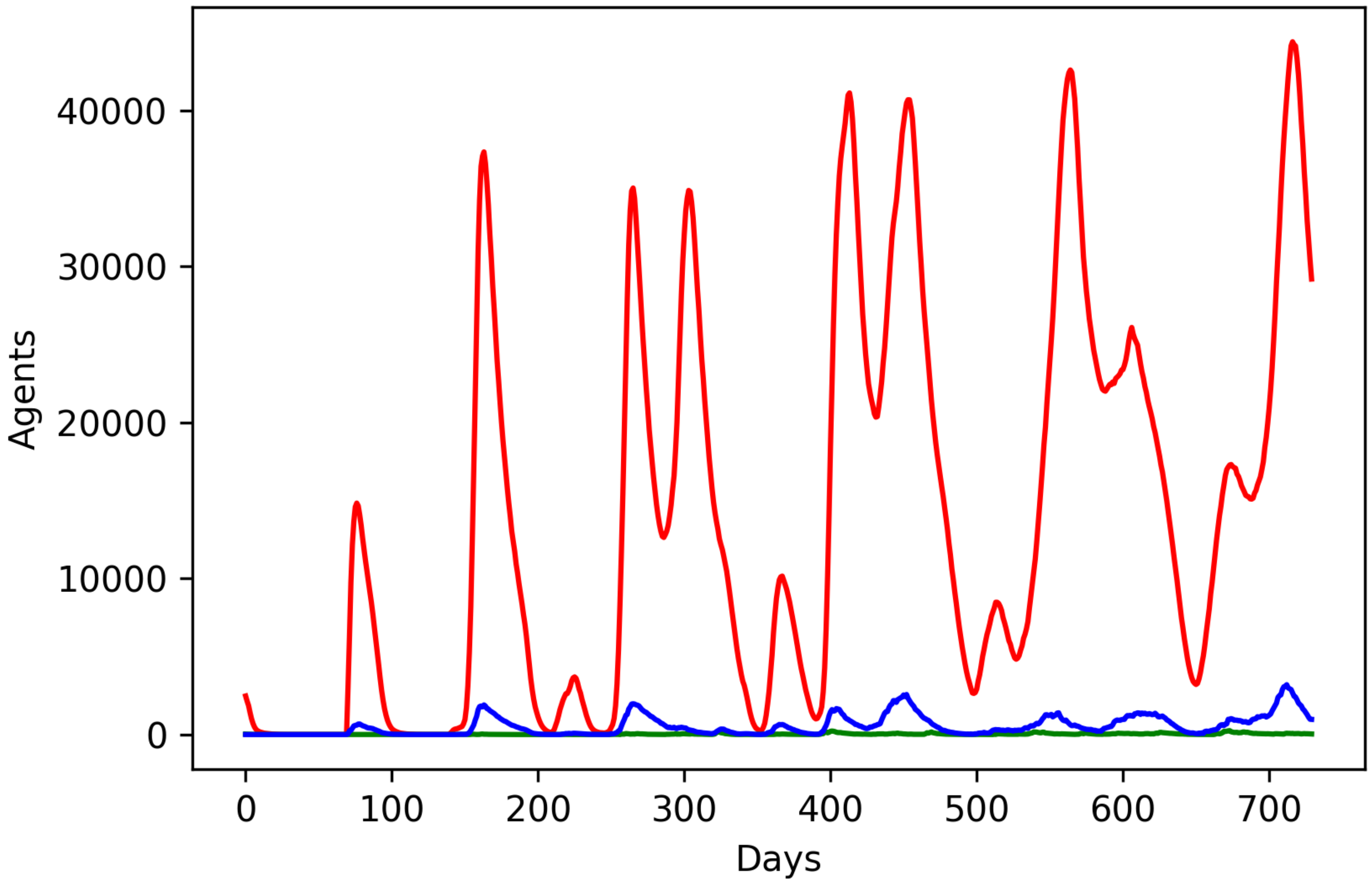
Suggests that distance to refuge as important as overall size

- Low dispersal rate leads to reduced gene flow

100% Refuge (Control)

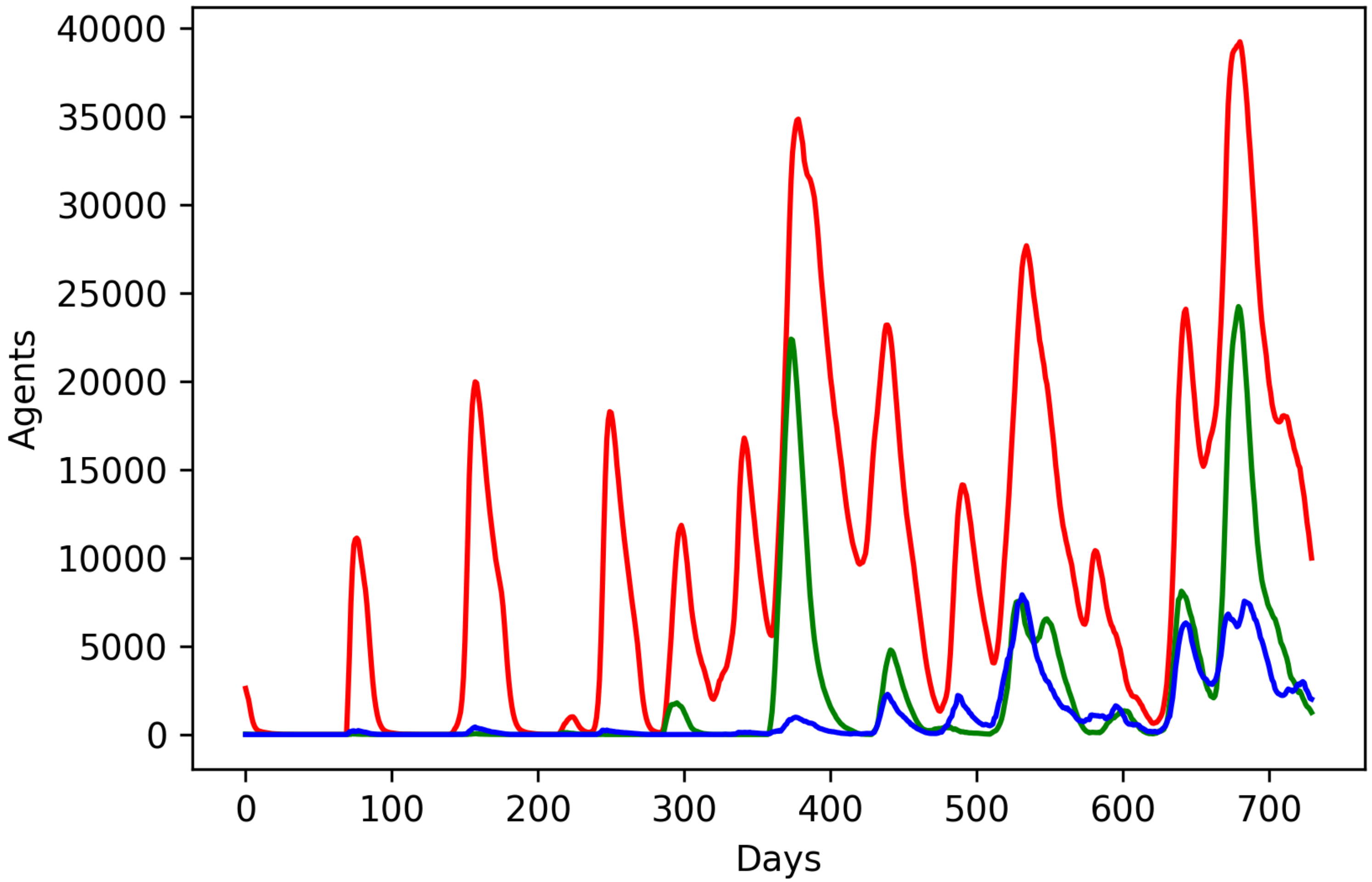


50% Refuge



40000
30000
20000
10000
0
Agents
0
100
200
300
400
500
600
700
Days

30% Refuge


40000
35000
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Agents
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200
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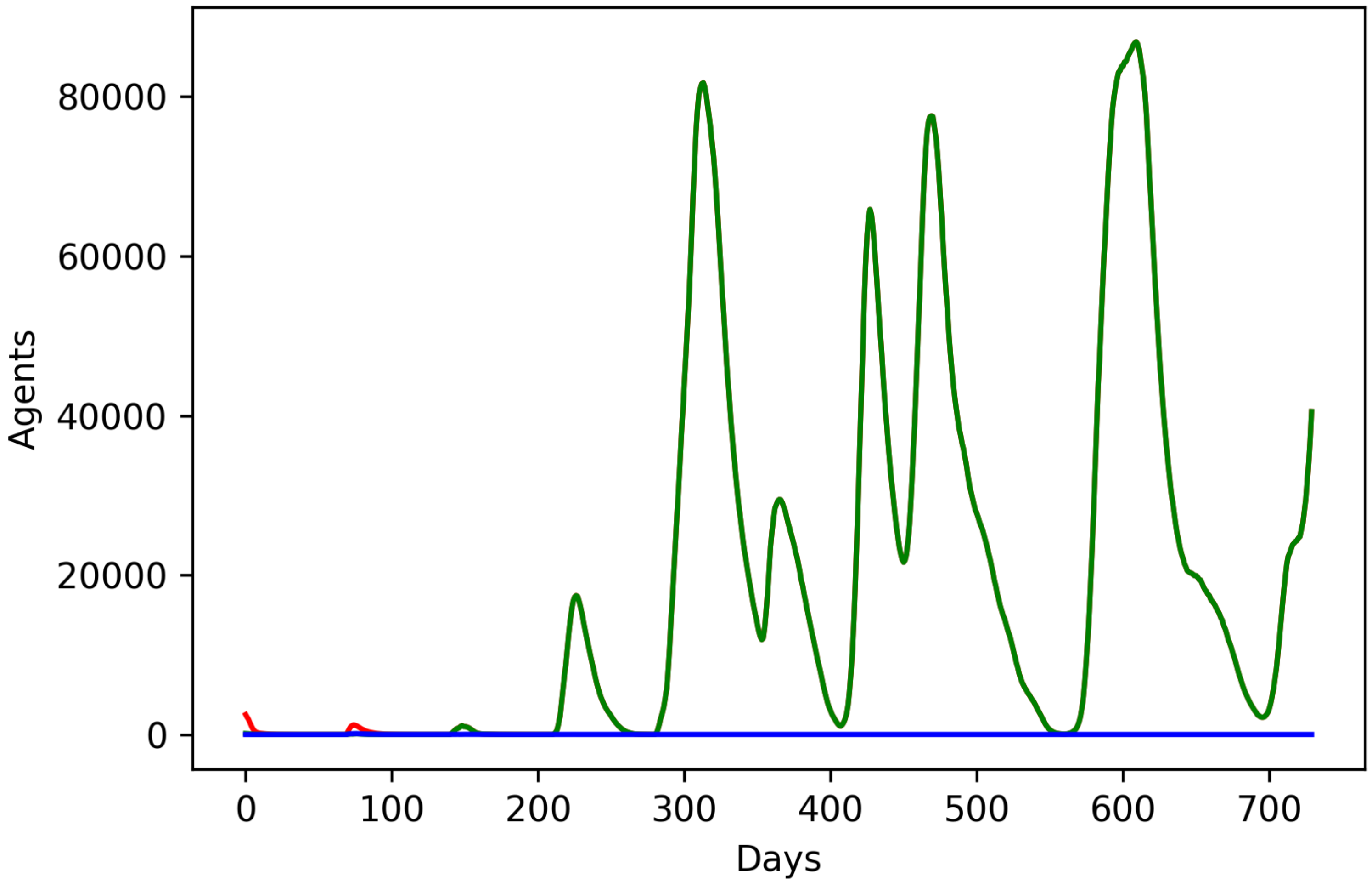
400
500
600
700
Days

0% Refuge (Only Bt)



Early Observations

Sensitive to many initial inputs, and size of initial resistant population

Efficacy of toxin has an interesting, but eventually intuitive result

- A less effective toxin curbs resistance development while effectively reducing numbers
- Could be the "Hydra effect"

90% effective could mean many things in the model:

- Case A: 90% of crop is 100% effective, 10% is 0% effective (fitness remains constant)
- Case B: 100% of crop is 90% effective (fitness varies)

Case A opens up debate whether or not "Refuge in a bag" would be sufficient

Many results might be nullified with assumptions that need to be added still

Thank you