

Gene Drives in Pathogenic Fungi

Top 10 Pathogenic Fungi



M.oryzae



B.cinerea



P.graminis



F.graminearum



F.oxysporum



B.graminis



M.graminicola



C.glocosporiodes



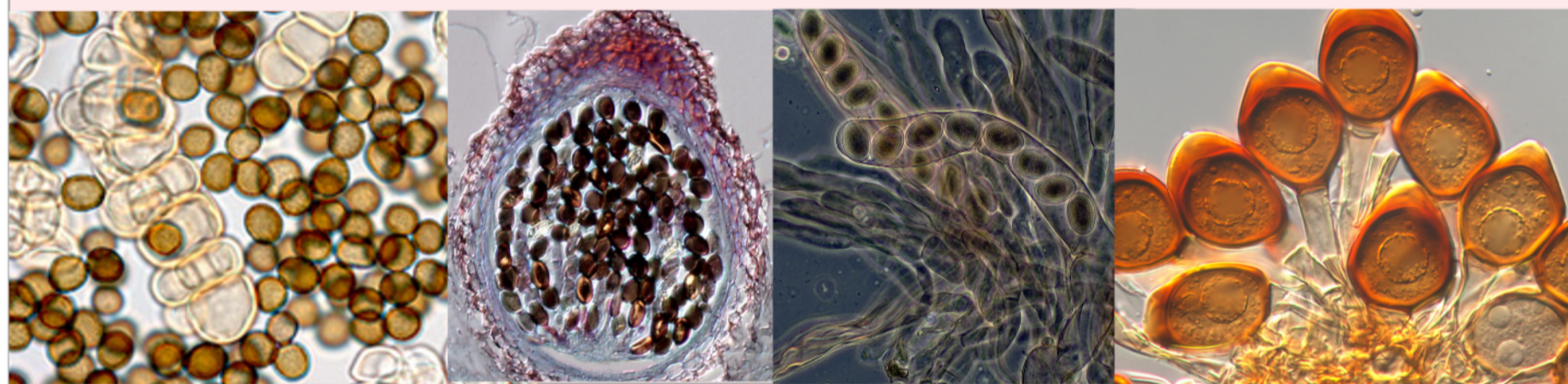
U.maydis



M.lini

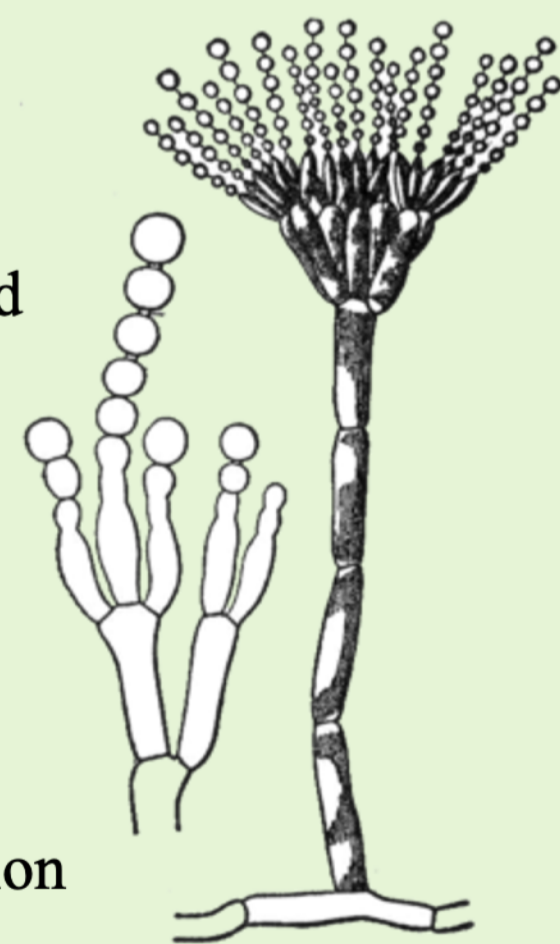
Abstract:

Here, we explore a distinct route to combat fungal outbreaks in crop communities. Since it is clear that sexual reproduction provides numerous advantages to fungi, what if we could halt this process?



Sexual reproduction

- Fungi are often facultative sexuals, with species specific environmental conditions governing their sexual life stages.
- Sexual reproduction provides practical and ecological benefits. Including increased virulence, fungicide resistance and the formation of resistant spores.
- There are two sexual systems; Homothallism where individual fungi can reproduce sexually via selfing and Heterothallism in which sexual reproduction requires two individuals of compatible mating type (MT) (Ni *et al.*, 2011).



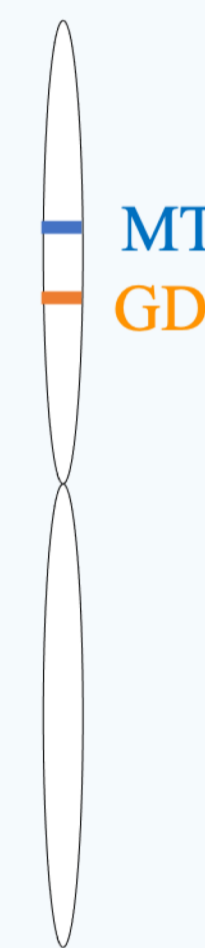
Bipolar Heterothallic Fungi

In bipolar heterothallic fungi sexual reproduction requires two individuals of compatible MT, in which compatibility is determined by a single MAT locus, with two or more alleles



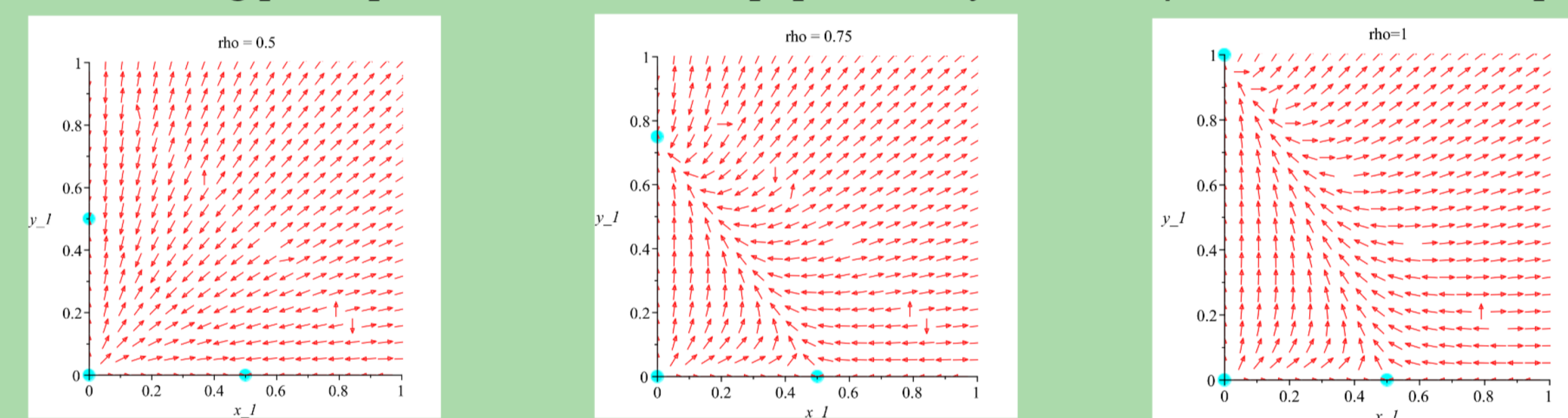
Gene Drives

- Gene drives (GD) are genetic elements that manipulate gametogenesis and reproduction to increase their own transmission into the next generation (Wedell *et al.*, 2019).
- Constructing synthetic fungal GD linked to MT locus could potentially drive target bipolar heterothallic fungal populations to obligate asexuals.



Phase analysis

The following phase portraits illustrate the population dynamics at $\rho = 0.5, 0.75$ and 1 respectively.



The series of plots illustrates the decline in MT – with increasing ρ . The third plot shows the eventual complete eradication of x_2 individuals and the resulting population composed purely of MT +.

ODEs

Let x_1 , x_2 and y_1 denote the frequency of MT +, - and + linked to GD respectively. Inheritance of MT in a reproduction event between x_1 and x_2 follows mendelian laws. However, in a reproduction event between y_1 and x_2 the probability the progeny will inherit MT with GD linked is ρ .

The OEDs describing the system are as follows:

$$\frac{dx_1}{dt} = \frac{1}{2}x_1(x_1 + y_1 - 1)(2x_1 + 2y_1 - \rho)$$

$$\frac{dy_1}{dt} = y_1(x_1 + y_1 - 1)(y_1 + x_1 - \rho)$$

Solving the coupled system of equations reveals stationary points at (x_1, y_1) at $(x_1, 1 - x_1)$, $(0, \rho)$, $(0.5, \rho)$ and $(0, 0)$.

Conclusions

Here we have shown GD linked to MT has the potential to drive target fungal populations to obligate asexuals. Not only will this allow for the cessation of over-winter transmission for species in which sexual reproduction is associated with a resistant form, but it would also have the potential to place a "speed break" on their evolution, decreasing population stability.

Future Directions

In order to fully understand the affects of gene drive on pathogenic fungi, multiple factors need to be incorporated into the model; these include recombination, space and stochasticity

Acknowledgements

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References

- Ni, M., Feretzaki, M., Sun, S., Wang, X., & Heitman, J. (2011). Sex in fungi. *Annual review of genetics*, 45, 405-430.
- Wedell, N., Price, T. A. R., & Lindholm, A. K. (2019). Gene drive: progress and prospects.