Phenotypic Analysis of Fire Blight in *Malus Species*

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Introduction

- Fire blight, caused by the Gram-negative bacteria *Erwinia amylovora*, impacts the cultivation of pome fruits worldwide.[1]
- Shoot blight is when an infected shoot and leaves turn brown, and the end of the shoot bends like a shepherd's crook **(Figure 1).**
- *Malus* (apple) species have different levels of inherent resistance to fire blight.[2]
- Some fire blight strains have been found to be resistant to streptomycin, which is true for the strain infecting the orchard during this study.
- The objective of this study was to collect and analyze phenotypic data about infection intensity of shoot blight in apples trees.

Figure 1. (A) Image of shoot blight. (B) Infected tree

Materials and Methods

Materials

- USDA National Plant Germplasm System Apple Collection blocks E7 and M7 at McCarthy Farm in Geneva, NY were investigated

Shoot counting

- Infected shoots and total number of shoots were counted for the east and the west of trees in E7 and M7
- More difficult to see individual shoots when they are healthy
- Not all trees were included because of the time-intensive nature of counting shoots and many of the trees were pruned before evaluation
- Had to differentiate between fire blight and spray damage

Cut scoring

- Seven-point rating for pruning due to fire blight, from zero visible cuts (0) to severe pruning of scaffolds and trunk (3) **(Figure 2)**
- This methods was significantly faster than shoot counting, so more trees were scored

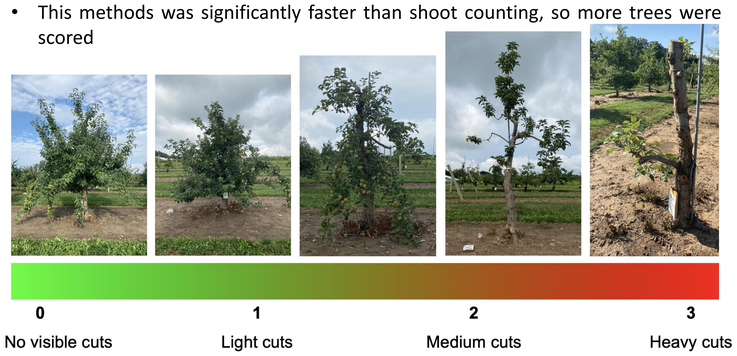

Figure 2. Zero to three rating scale used in cut scoring

References

1. Singh, J., J. Fabrizio, E. Desnoues, J.P. Silva, W. Busch, and A. Khan. Root system traits impact early fire blight susceptibility in apple (*Malus × domestica*). *BMC Plant Biol* 19, 579 (2019).
2. Peil, A., O.F. Emeriewen, A. Khan, S. Kostick, and M. Malnoy. Status of fire blight resistance breeding in *Malus*. *J Plant Pathol* (2020).
3. McCarthy Farm, *Google Maps* (2020)
4. Martin Hooker (2020)

Comparison of Species

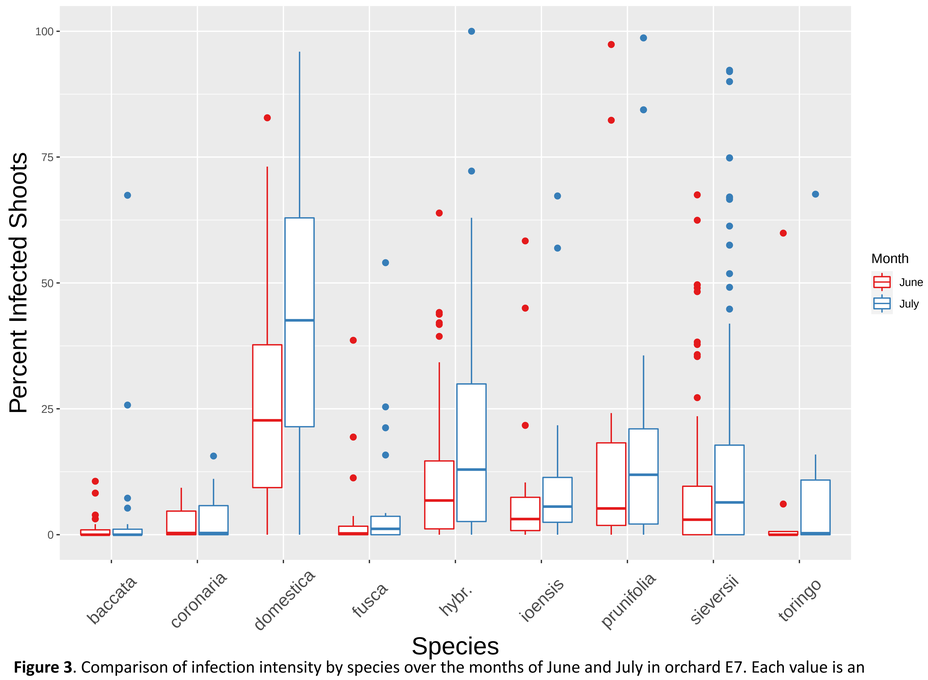

Figure 3. Comparison of infection intensity by species over the months of June and July in orchard E7. Each value is an average of the east and west percent of infected shoots. Letters signify a statistically significant difference in the percent of infected shoots. The number of trees in the sample for each species are as follows: *M. domestica* 796, *M. sieversii* 210, *Malus* hybrids 180, *M. baccata* 48, *M. coronaria* 44, *M. fusca* 40, *M. ioensis* 34, *M. prunifolia* 34, and *M. toringo* 20.

- These species were selected for analysis because each had more than 20 trees.
- The hybrid trees are crosses between domestica and *M. sieversii*.
- The species *M. baccata, M. coronaria, M. fusca, and M. toringo* had statistically equivalent low levels of infection as well as a statistically insignificant increase in infection intensity from June to July

Heat Map

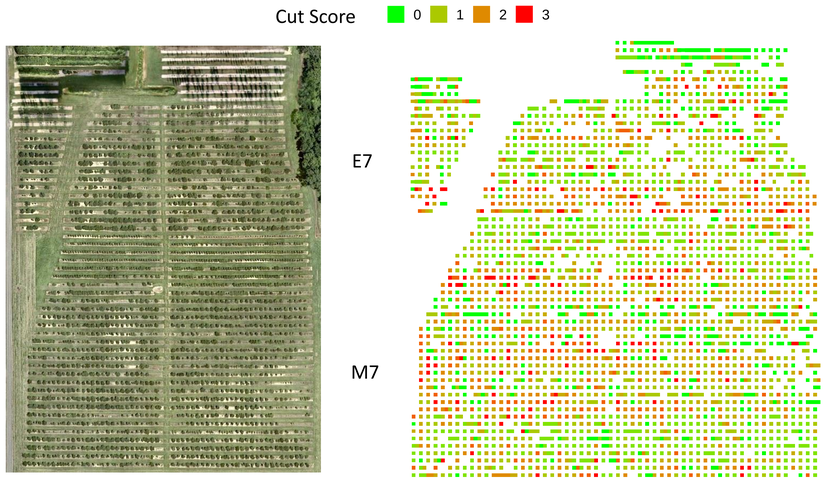

Figure 4. (A) Aerial image of orchards E7 and M7.[304] (B) Heat map of the intensity of cutting in E7 and M7. A gradient from green to red is used, with green indicating no visible cuts and red indicating heavy cuts.

Scoring Methods

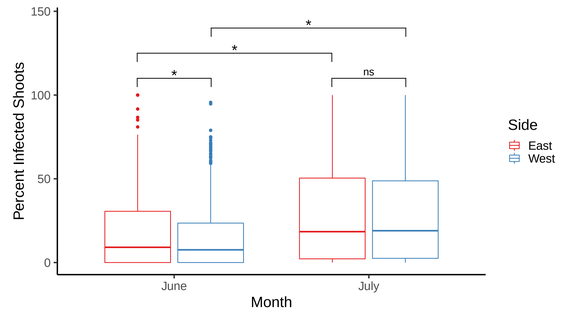

Figure 5. Comparison of fire blight on the east and west side of the tree in June and July. The * indicates a significant difference ($p < 0.05$) and ns indicates a non-significant difference ($p > 0.05$).

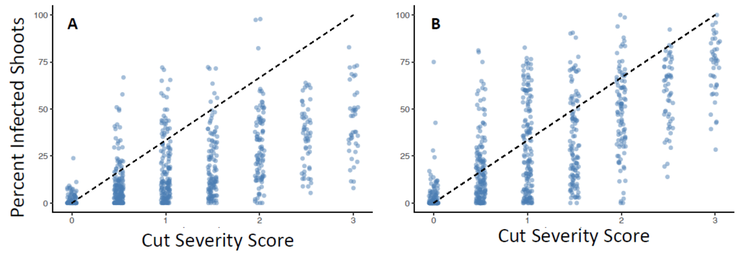

Figure 6. Comparison of cut score and shoot counting method in (A) June and (B) July in orchard E7. All cut severity scoring was done in August. The dashed line represents a correlation of r = 1.

Discussion & Conclusions

- The summer 2020 fire blight outbreak was unusually virulent throughout the whole orchard, so species with low levels of infection are promising as resistant species.
- The infection was widespread throughout the orchard, meaning that all trees were likely exposed to the pathogen.
- The difference in east versus west fire blight is likely due to scoring occurring at different times, so future studies do not need to include east versus west.
- Cut severity scoring aligns with scoring by counting shoots, and the relationship is closer to r = 1 in the July infection rates.
- Data suggests that the species *M. baccata, M. coronaria, M. fusca,* and *M. toringo* have resistance to fire blight.

Future Directions

- Genome wide association study (GWAS) to determine genetic controllers of fire blight response in apple
- Using computer vision to determine fire blight severity using images of trees (**Figure 7)**
- Scoring methods that include intensity by percent and spread through tree

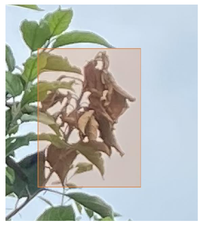

Figure 7. Example of image annotation for shoot blight

Acknowledgments

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