Improving Resiliency for Pitch Canker in Southern Pine

Andrew Sims

Aug. 30, 2023

FFA Annual Meeting

UF|IFAS
UNIVERSITY of FLORIDA

COOPERATIVE
FOREST GENETICS
RESEARCH PROGRAM

What is Tree Improvement

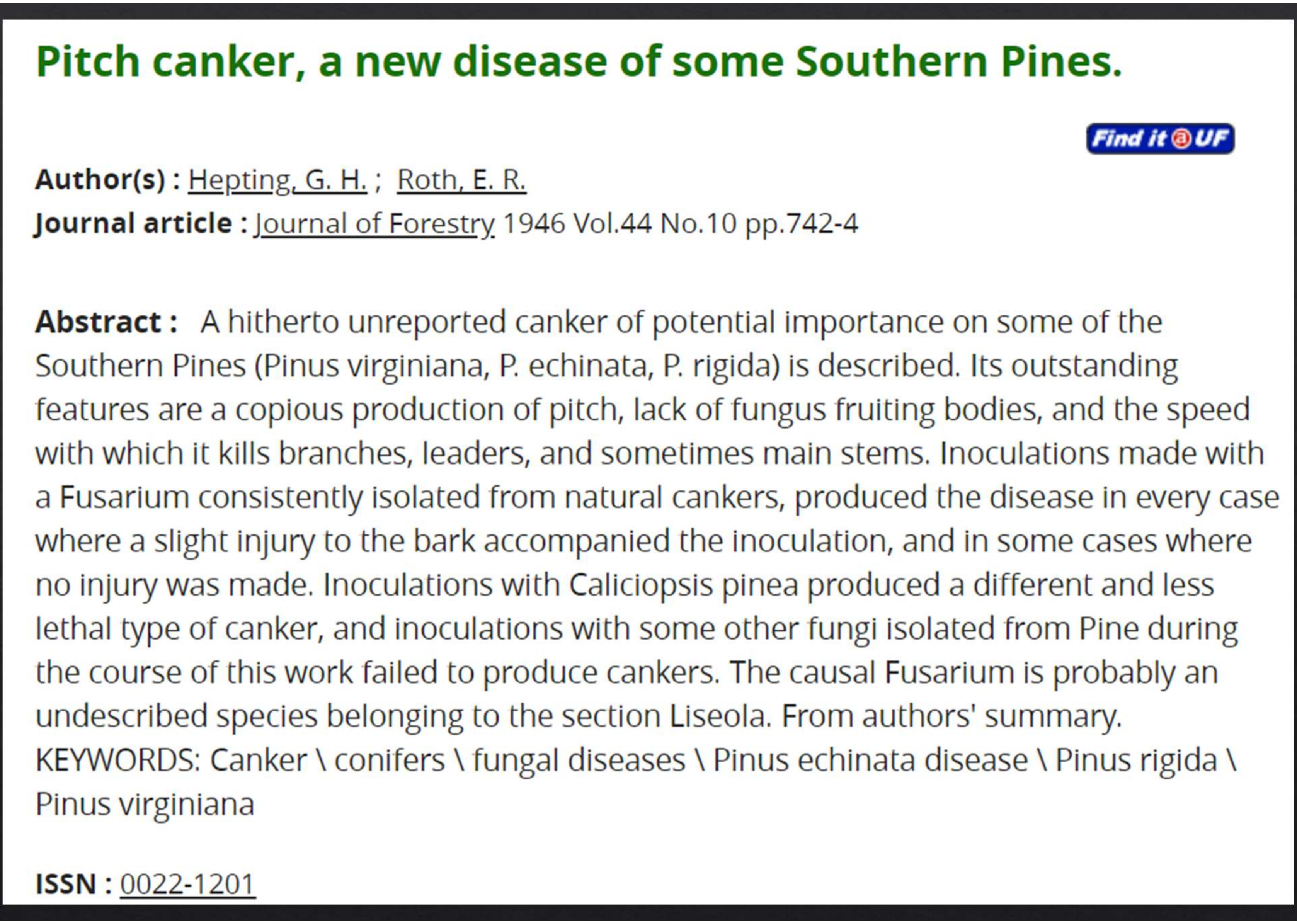
- >99% of southern pine explants are grown from seeds
- This means that the genes a tree's parents pass on to it may influence its health, form, and productivity
- We test families of trees side-by-side so we can:
  - Determine how much of the difference in trees is related to genetics **(heritability)**
  - Predict how families of trees will perform compared to others **(genetic gain)**
  - Pick new individuals to add to the list of possible parents and improve the population average for a trait **(selection)**

From Our Research to Your Land

- Virtually all loblolly and slash pine deployed in plantations today come from a tree improvement program
- Three programs in the US South:
  - UF|IFAS Cooperative Forest Genetics Research Program (loblolly and slash pine)
  - Western Gulf Forest Tree Improvement Program (Texas A&M, loblolly and slash pine)
  - NC State Cooperative Tree Improvement Program (loblolly pine)
- Only these programs have the backing of a land-grant university

What is Pitch Canker?

- Pitch canker is a disease complex caused by infection of the necrotrophic fungal pathogen *Fusarium circinatum*
- It causes trees to have resinous lesions, crown dieback, loss of vigor, mechanical weakness, stem defect, and mortality
- It can affect loblolly, longleaf, sand, slash, shortleaf, etc.… functionally every pine commercially relevant to the US South
- *F. circinatum* likely emerged from Central America and spread widely in the Southeastern US during the 20th century



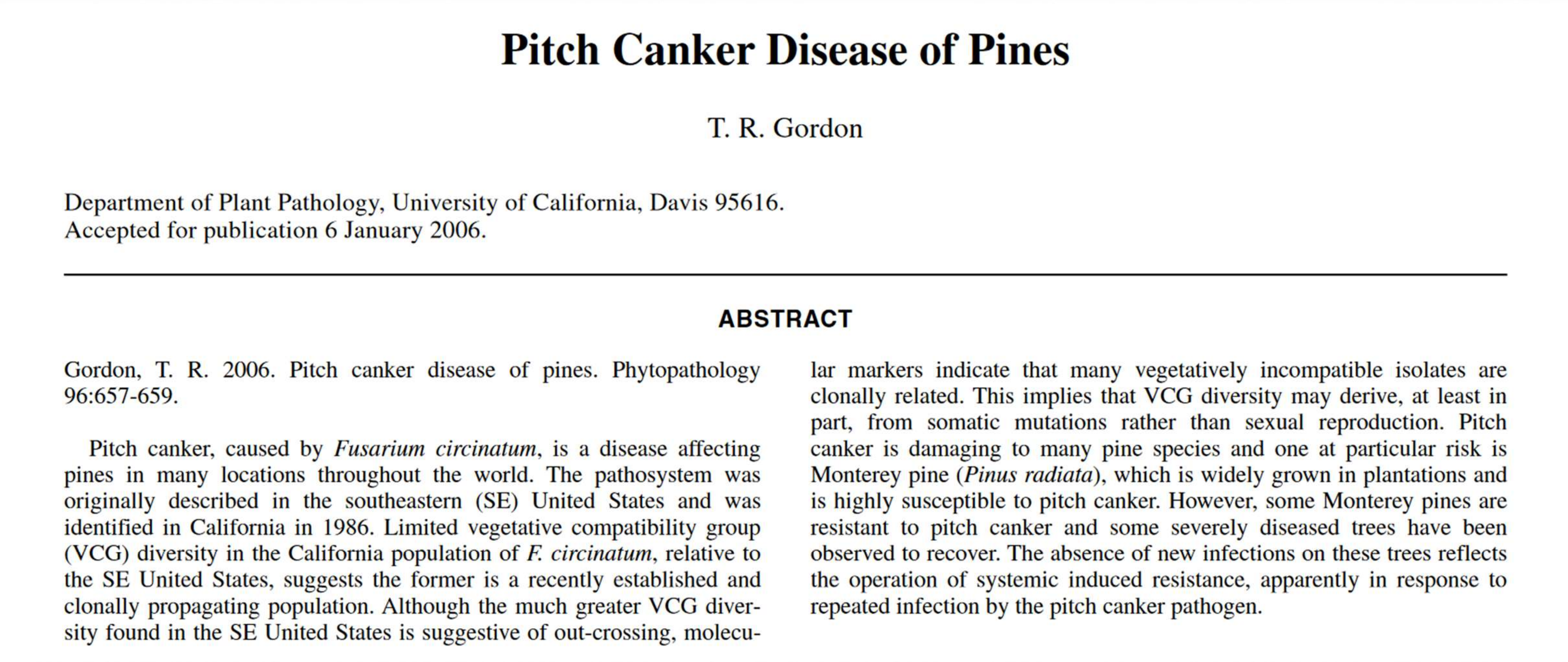
Pitch canker, a new disease of some Southern Pines.

Author(s) : Hepting, G. H. ; Roth, E. R.

Journal article : Journal of Forestry 1946 Vol.44 No.10 pp.742-4

Abstract : A hitherto unreported canker of potential importance on some of the Southern Pines (Pinus virginiana, P. echinata, P. rigida) is described. Its outstanding features are a copious production of pitch, lack of fungus fruiting bodies, and the speed with which it kills branches, leaders, and sometimes main stems. Inoculations made with a Fusarium consistently isolated from natural cankers, produced the disease in every case where a slight injury to the bark accompanied the inoculation, and in some cases where no injury was made. Inoculations with Caliciopsis pinea produced a different and less lethal type of canker, and inoculations with some other fungi isolated from Pine during the course of this work failed to produce cankers. The causal Fusarium is probably an undescribed species belonging to the section Liseola. From authors' summary.
KEYWORDS: Canker \ conifers \ fungal diseases \ Pinus echinata disease \ Pinus rigida \ Pinus virginiana

ISSN : 0022-1201



Pitch Canker Disease of Pines

T. R. Gordon

Department of Plant Pathology, University of California, Davis 95616.

Accepted for publication 6 January 2006.

ABSTRACT

Gordon, T. R. 2006. Pitch canker disease of pines. Phytopathology 96:657-659.

Pitch canker, caused by *Fusarium circinatum*, is a disease affecting pines in many locations throughout the world. The pathosystem was originally described in the southeastern (SE) United States and was identified in California in 1986. Limited vegetative compatibility group (VCG) diversity in the California population of *F. circinatum*, relative to the SE United States, suggests the former is a recently established and clonally propagating population. Although the much greater VCG diversity found in the SE United States is suggestive of out-crossing, molecular markers indicate that many vegetatively incompatible isolates are clonally related. This implies that VCG diversity may derive, at least in part, from somatic mutations rather than sexual reproduction. Pitch canker is damaging to many pine species and one at particular risk is Monterey pine (*Pinus radiata*), which is widely grown in plantations and is highly susceptible to pitch canker. However, some Monterey pines are resistant to pitch canker and some severely diseased trees have been observed to recover. The absence of new infections on these trees reflects the operation of systemic induced resistance, apparently in response to repeated infection by the pitch canker pathogen.

How Does PPC Infect and Affect Trees?

- It’s spread from tree to tree by wind, insects, or water
- It doesn’t require a dual life cycle like endemic fusiform rust (*Cronartium quercuum* f. sp. *fusiforme*)
- PPC infection can happen at any point in the rotation or life cycle
- Outbreaks – groups of trees with PPC symptoms - are most often observed in locations prone to high wind events in stands with high nutrition
- Outbreaks are episodic, but single tree infections are not uncommon

- **Stating the obvious: the lower US Southeast has a lot of wind, water, insects, and high-silviculture plantations**

Source: https://site.extension.uga.edu/wilcoxcoag/2018/05/pitch-canker/

Accounting for PPC in Deployment

- Susceptibility is not the same for every species of pine – Central American pines like *Pinus caribaea* are among the most tolerant
- PPC has spread to the Atlantic and Pacific coasts of the US, to Europe, to South America, and even to South Africa
- Among commercial species in the US Southeast, loblolly is relatively tolerant and slash pine is relatively susceptible
- There is evidence for genetic inheritance of pitch canker response in many pine species

Deployment and Management Implications

- Land managers are often reticent to push stand nutrition in slash pine since high nitrogen is associated with PPC risk
- Slash pine is generally more appropriate for zones known to be at high risk for cyclonic wind impacts
- These and other factors have convinced many land managers to deploy loblolly onto sites more appropriate for slash
- Even if slash could be similar in productivity with superior wood quality traits, it can be risky to choose over loblolly

Deployment and Management Implications

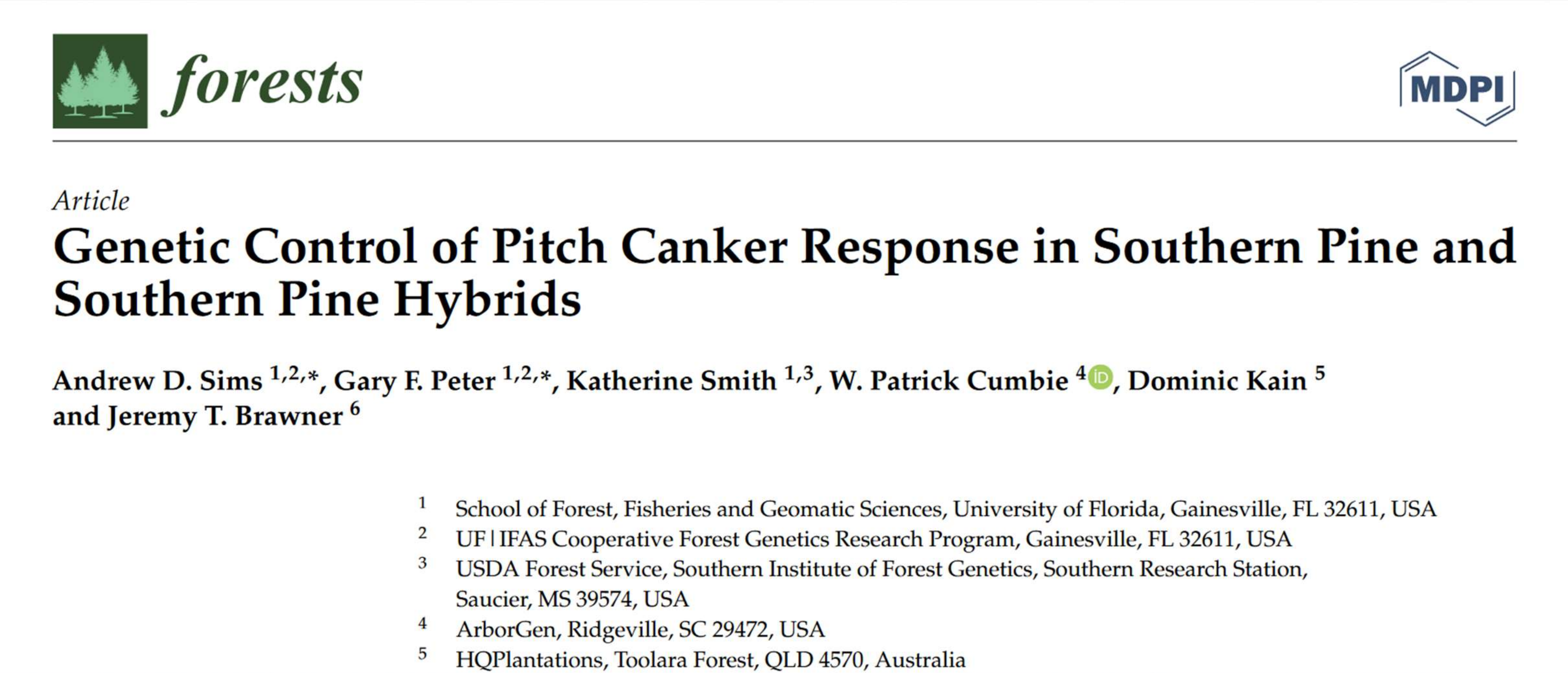
- Hypothesis: slash pine families have a spectrum of response to PPC challenge, just as they have a spectrum of growth potential, straightness, fusiform rust resistance, etc.
- Questions:
  - How much genetic control is exhibited from gene inheritance -> ***heritability***
  - Which families will be the most tolerant -> ***genetic gain***
  - Can we identify excellent individuals to carry forward the best genes -> ***selection***

Implementation of Study

- 103 families from three taxa were screened against isolates from three locations in Florida and Georgia
- Screening of seedlings executed at USDA Forest Service Screening Center in Asheville, NC
- Slash pine from CFGRP and WGFTIP, slash x *caribaea* hybrid from HQ Plantations in Qld., Australia, and loblolly from ArborGen

Results of Study

- Significant evidence for large degree of genetic control of response - ~25-40% heritability
- Agreement with previous literature that *caribaea* and loblolly are considerably more resilient than slash
- Many slash pine families have excellent resilience, but some have very little
- No meaningful correlation with other traits (i.e., growth is not related to PPC tolerance)
- Some PPC isolates are more virulent than others



forests

MDPI

Article

Genetic Control of Pitch Canker Response in Southern Pine and Southern Pine Hybrids

Andrew D. Sims [1,2,*], Gary F. Peter [1,2,*], Katherine Smith [1,3], W. Patrick Cumbie [4], Dominic Kain [5] and Jeremy T. Brawner [6]

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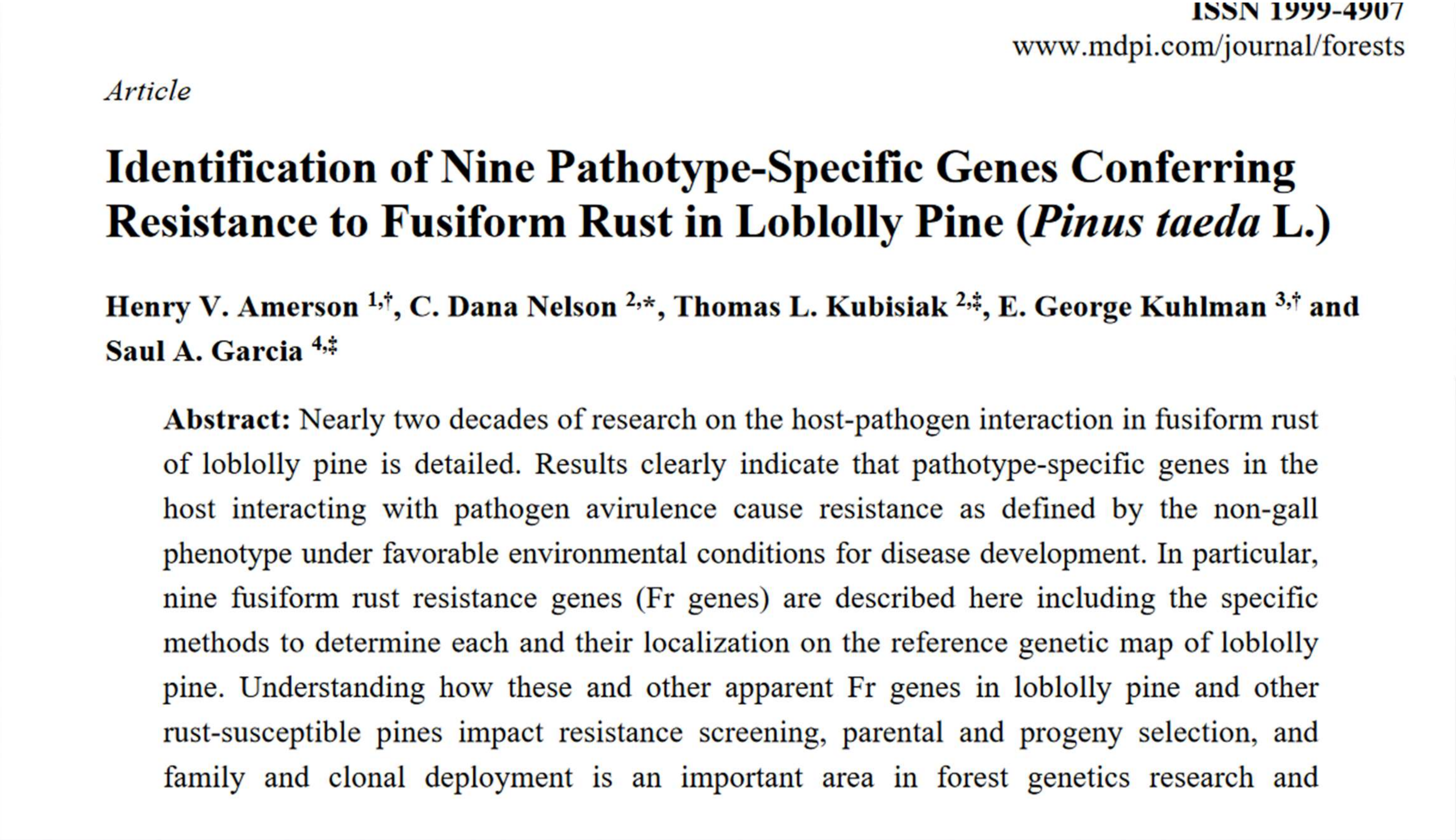
[4] ArborGen, Ridgeville, SC 29472, USA
[5] HQPlantations, Toolara Forest, QLD 4570, Australia

So, what else do we need to know?



ISSN 1999-4907
www.mdpi.com/journal/forests

Article

Identification of Nine Pathotype-Specific Genes Conferring Resistance to Fusiform Rust in Loblolly Pine (*Pinus taeda* L.)

Henry V. Amerson [1,†], C. Dana Nelson [2,*], Thomas L. Kubisiak [2,‡], E. George Kuhlman [3,†] and Saul A. Garcia [4,‡]

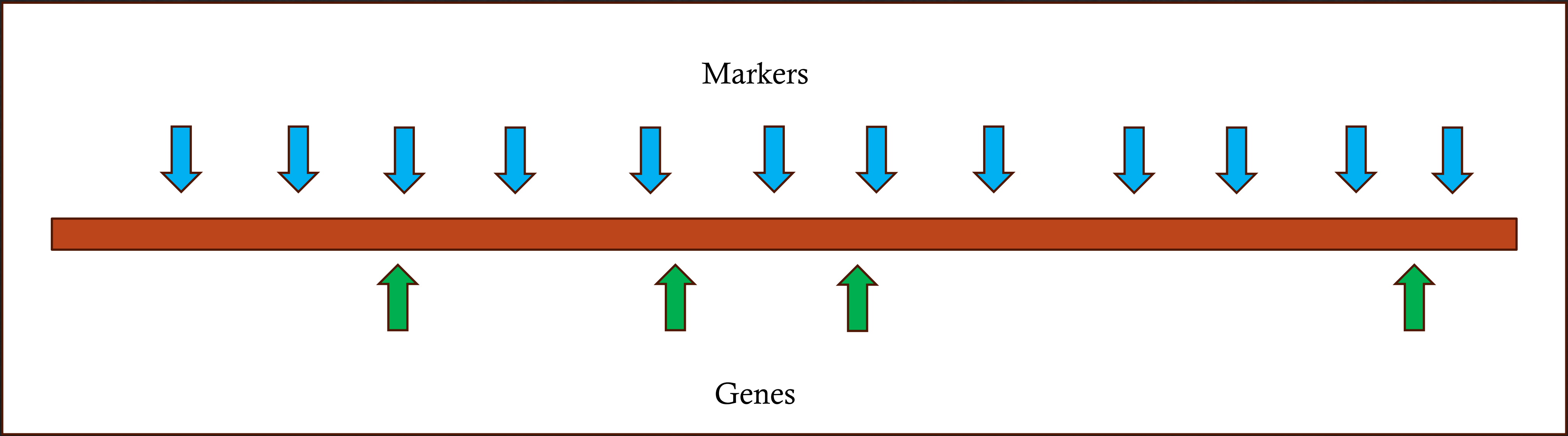
Abstract: Nearly two decades of research on the host-pathogen interaction in fusiform rust of loblolly pine is detailed. Results clearly indicate that pathotype-specific genes in the host interacting with pathogen avirulence cause resistance as defined by the non-gall phenotype under favorable environmental conditions for disease development. In particular, nine fusiform rust resistance genes (Fr genes) are described here including the specific methods to determine each and their localization on the reference genetic map of loblolly pine. Understanding how these and other apparent Fr genes in loblolly pine and other rust-susceptible pines impact resistance screening, parental and progeny selection, and family and clonal deployment is an important area in forest genetics research and

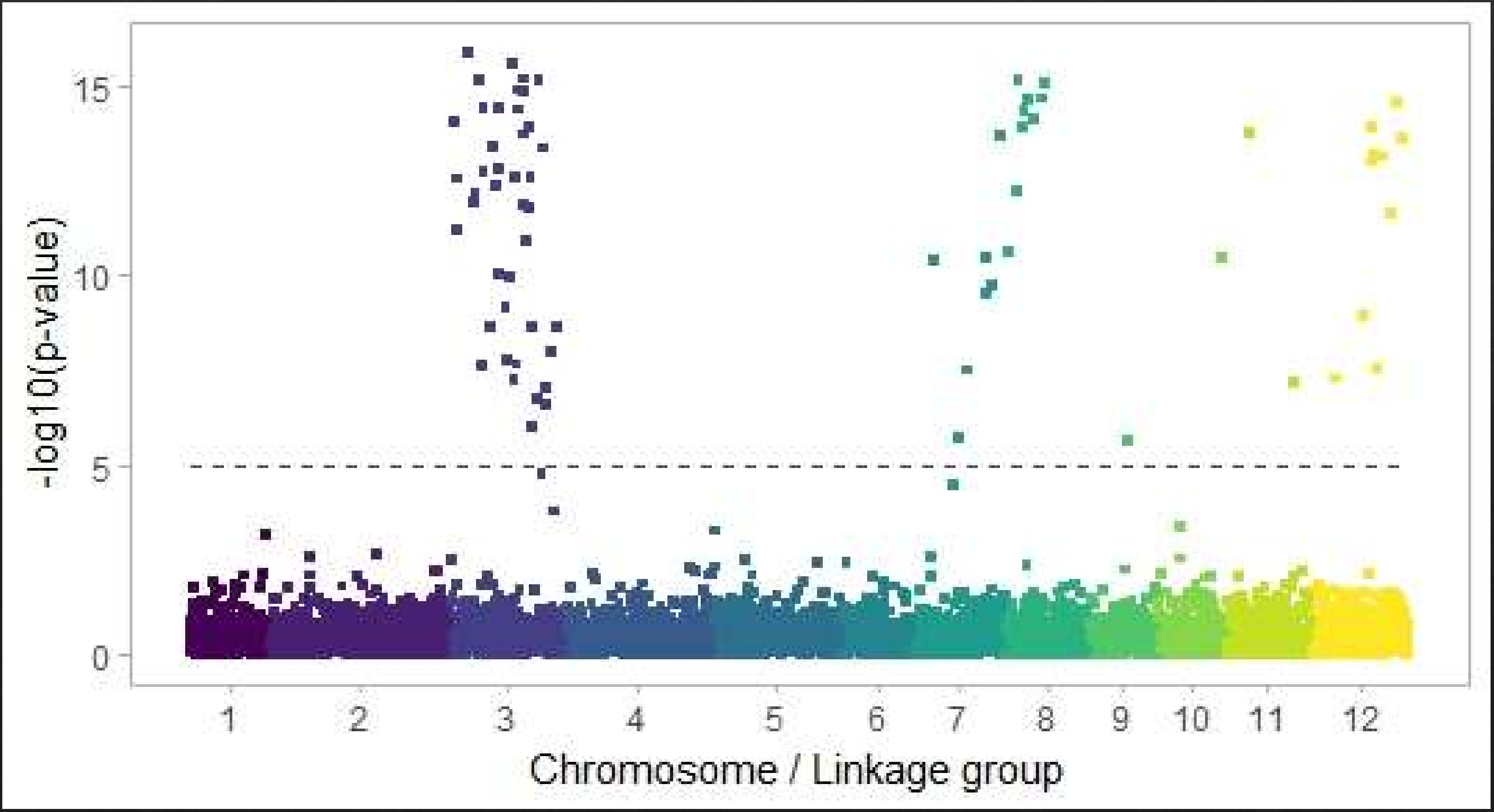
PPC Response Mechanism

- PPC response is a complex trait
- There are some traits that are polygenic – how much resin can a tree produce, its baseline vigor, etc.
- There are some traits that may be controlled by a few genes – does the tree get infected or stave off infection entirely?
- Study method: genome-wide association study
  - Strong evidence for a few genes controlling if a tree does or does not become infected
  - Strong evidence that there is genetic control of how badly a tree is affected if it does become infected

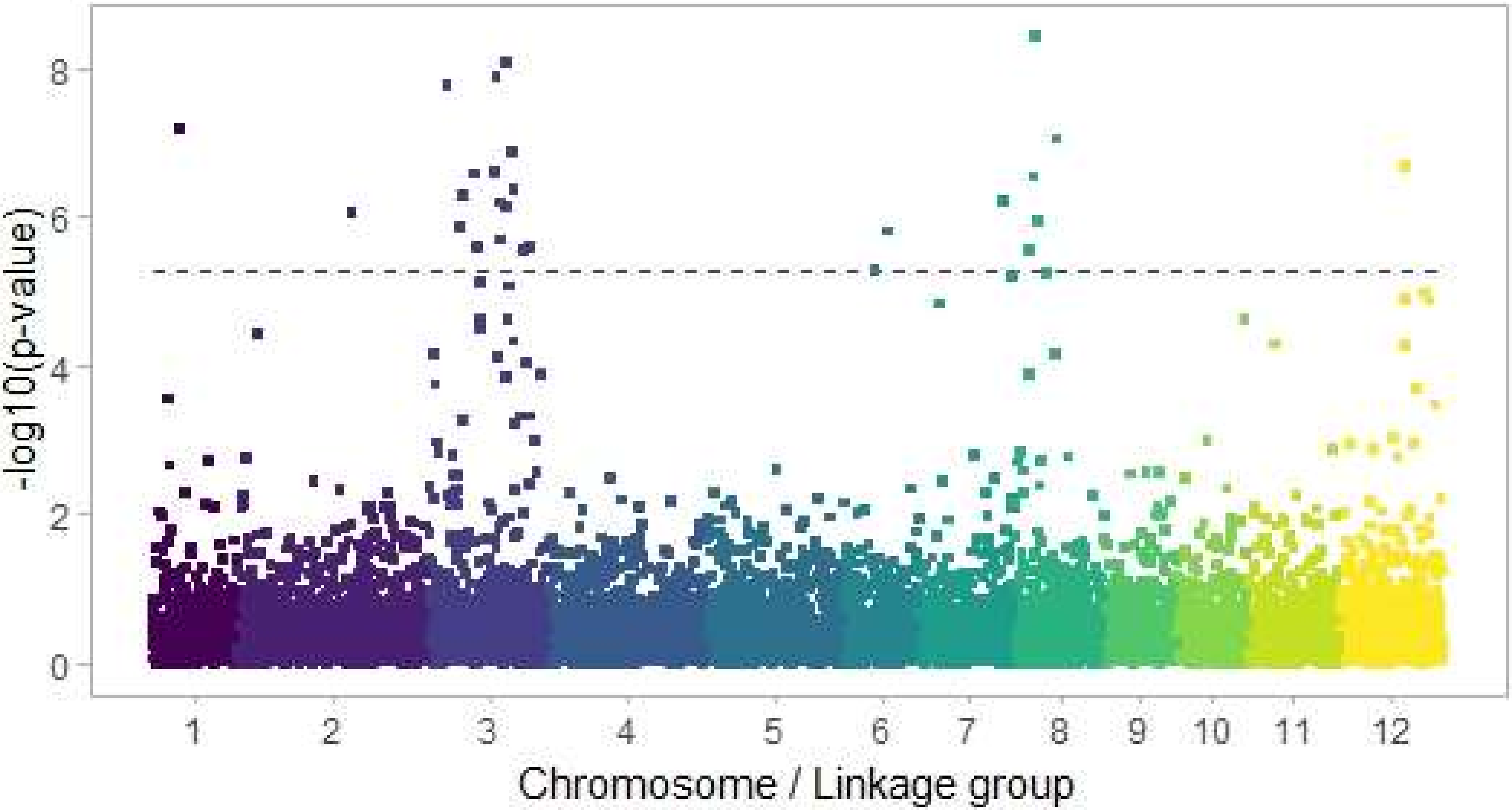
What is GWAS?

- Find different markers across the whole genome
- See if they segregate with a trait
- Predict the effect size of each marker





15
10
5
0
-log10(p-value)
1
2
3
4
5
6
7
8
9
10
11
12
Chromosome / Linkage group



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0
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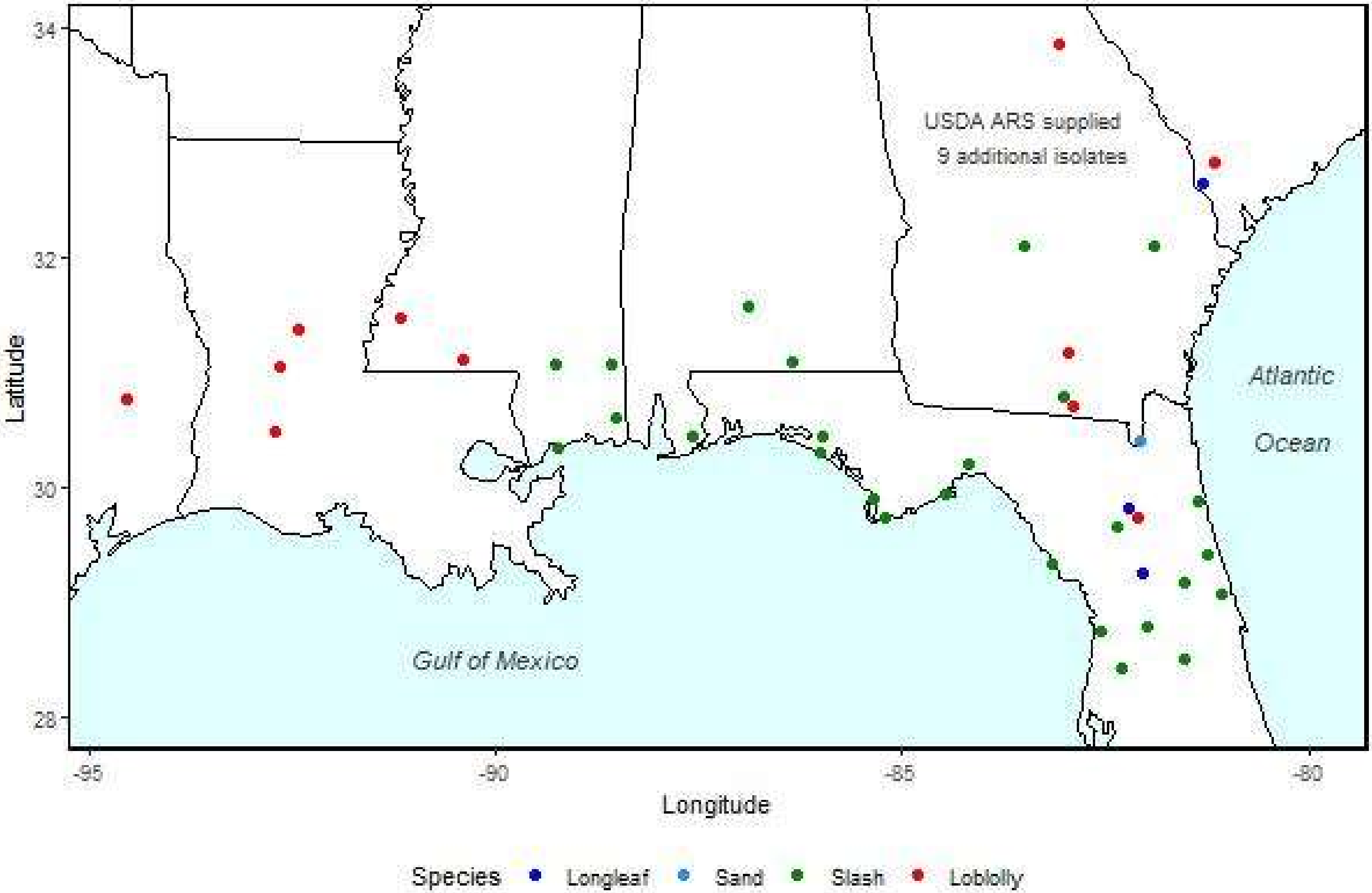
Chromosome / Linkage group

What We Think… So Far

- There is strong evidence that perhaps a small number of genes could control ***resistance*** to PPC, while there are probably a lot that control ***tolerance***, or how badly a tree is affected once infected
- We know some isolates are more virulent than others, but we need to know more about the whole South, isolates behaving differently among host species, etc.

What We Think… So Far

- We don't actually know where these genes are on the genome… there is no genome assembly for slash pine!
- These results need to be validated in a different testing population
- Further research being conducted with CFGRP, Jeremy Brawner lab at UF


USDA ARS supplied
9 additional isolates
Atlantic
Ocean
Gulf of Mexico
Latitude
34
32
30
28
Longitude
-95
-90
-85
-80
Species
● Longleaf
● Sand
● Slash
● Loblolly

What Do We Need To Learn?

- How do trees respond: qualitative resistance, quantitative tolerance, or both?
- How is PPC response inherited? Are there many genes or few genes?
- Is there a spectrum of virulence among isolate sources?

Further Research

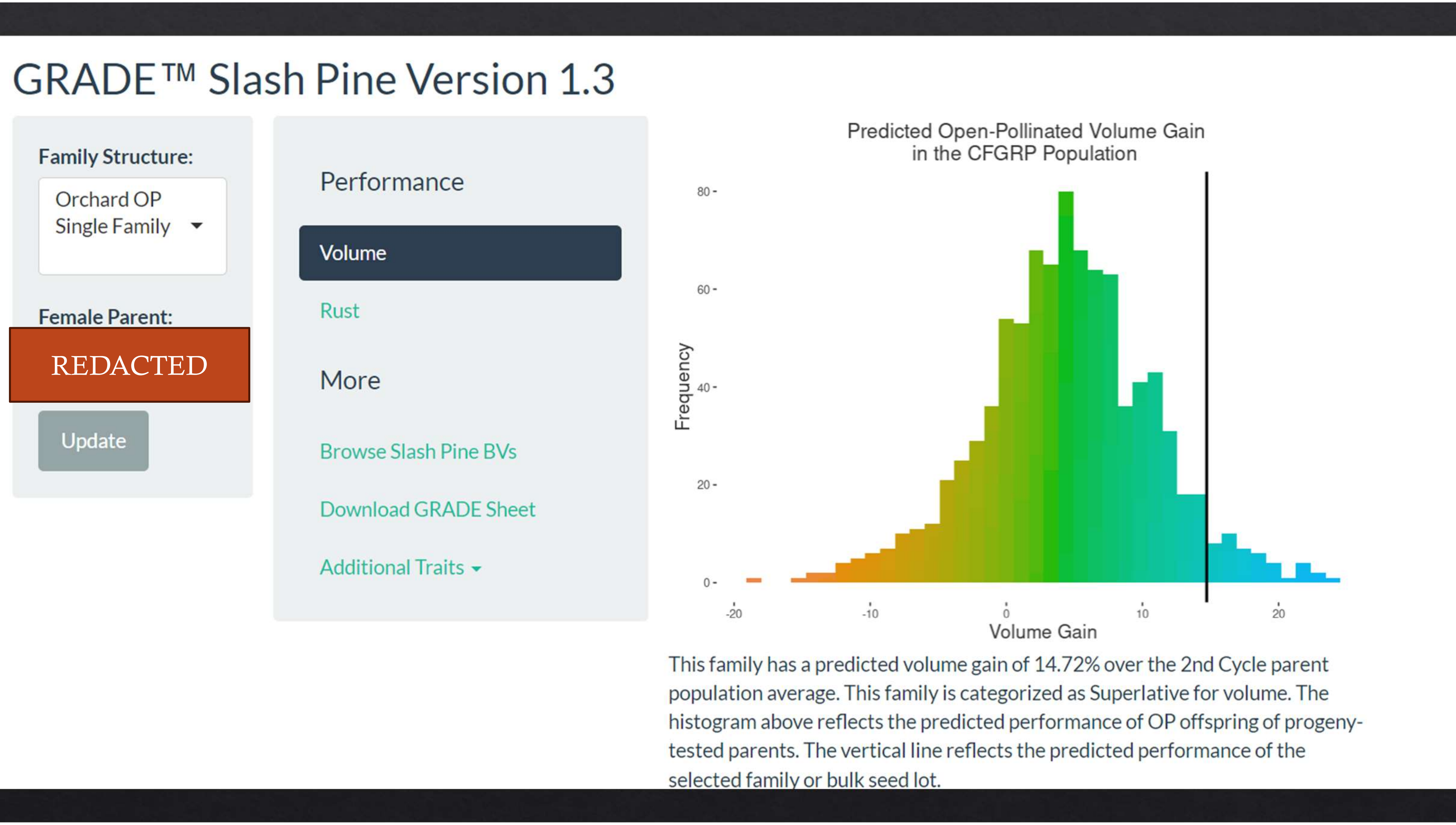
- Screening of new development populations for PPC resistance against isolates from across the entire US Southeast
- Building and validating model for PPC response selection to integrate into breeding program
- Working with partners to validate greenhouse study against field deployment
    - Takes a long time! PPC can happen at any point in rotation/life cycle!
    - Literature suggests that there is a correspondence in slash and longleaf pine (Blakeslee and Rockwood, Carey et al., etc.) Defining extent and impacts of PPC damage in mid-rotation stands – we need to know if you're seeing pitch canker damage!

Collaboration Opportunity

- Do you know of any stands badly affected by pitch canker?
- We want to know if our results correspond to the field
- Very little data available for field deployments
  - Slash pine has only been sold as limited genetic families for <5 years
  - Pitch canker infections can occur any time during rotation!

Translating Research to Deployment

- All CFGRP members have breeding values (genetic predictions) for most commercially relevant slash pine families
- These predictions are recorded in GRADE™ sheets along with predictions for other traits
- All slash pine sold east of the Mississippi river should have an associated GRADE™ sheet for it to be backed by 3rd party land-grant institution data
- Most loblolly is likely to be reasonably resistant, but not fully resistant

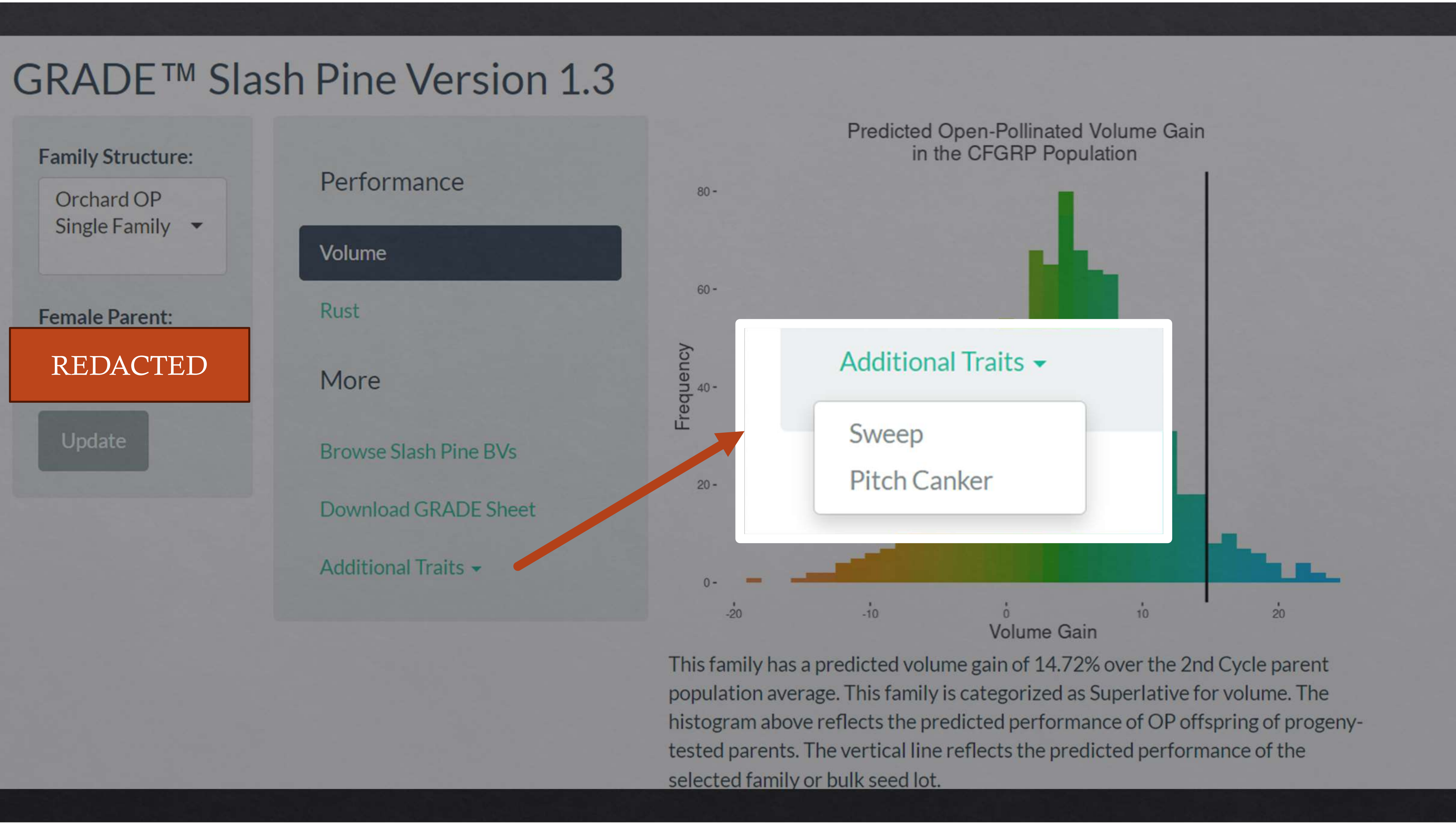


GRADE™ Slash Pine Version 1.3

Family Structure: Orchard OP Single Family

Female Parent: REDACTED

This family has a predicted volume gain of 14.72% over the 2nd Cycle parent population average. This family is categorized as Superlative for volume. The histogram above reflects the predicted performance of OP offspring of progeny-tested parents. The vertical line reflects the predicted performance of the selected family or bulk seed lot.



This family has a predicted volume gain of 14.72% over the 2nd Cycle parent population average. This family is categorized as Superlative for volume. The histogram above reflects the predicted performance of OP offspring of progeny-tested parents. The vertical line reflects the predicted performance of the selected family or bulk seed lot.

Questions You Might Ask

What do I need to know about accounting for PPC on my lands?

- Improved genetic material is available
- Loblolly is probably not a huge risk
- We haven’t tested longleaf
    - There is no such thing as improved longleaf
    - We still need to know how it stacks up against other species!

What is the value of improved pine genetics regarding PPC?

- Like rust resistance, better survival, resilience, quality, and value
- If PPC can be accounted for, possibly viable to push nutrition (and production) in slash
    - Slash may be a better option than is currently thought on borderline slash/lob sites
    - This is subject of study with UF|IFAS Forest Biology Research Cooperative

If I get the best genetics, will I never see PPC?

- In short, you can still see PPC
- Just like rust resistance, it's probably a matter of relative risk and impact
- PPC cannot be "cured" or "prevented" with any treatment on the deployment level – only genetic resistance can provide insulation

Take-Aways

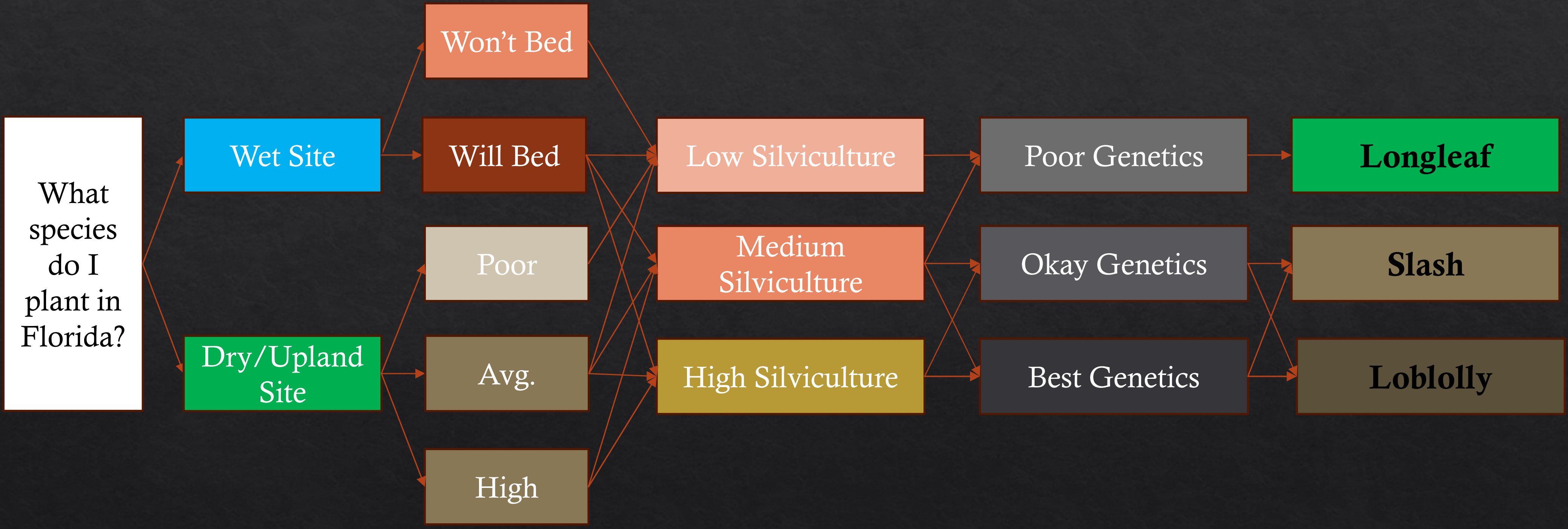
- Pitch canker outbreaks appear to be increasing in importance as a threat to forest health ad productivity
- The UF|IFAS CFGRP has conducted screenings to
    - Describe how genetic resilience is controlled
    - Predicted ratings for PPC resilience in slash pine families
    - Select new individuals to improve population-wide resilience
- Landowners can ask their seedling vendor about PPC response in seedlings
- Your seedling vendor should be backed by one of the three Southern cooperatives

Further Questions

Thank you!

Contact: adsims@ufl.edu

Abbreviated Thought Process for Speciation



What species do I plant in Florida?

Wet Site

Dry/Upland Site

Won't Bed

Will Bed

Poor

Avg.

High

Low Silviculture

Medium Silviculture

High Silviculture

Poor Genetics

Okay Genetics

Best Genetics

Longleaf

Slash

Loblolly