

A Guide to the TACF
Recurrent Genomic
Selection (RGS)
Research Program



Restoration is a Process, Not a Product

Historic Blight Control Attempts



Immediate Response

Removing healthy trees to control spread
(Lunsford 1999)



Early 1900s

Search for an ecological replacement in China, breeding, irradiating chestnuts



1920s - Today

Breeding,
Biotechnology and
Diversity

Our central challenge

Capture enough disease resistance from Chinese chestnut for long term survival

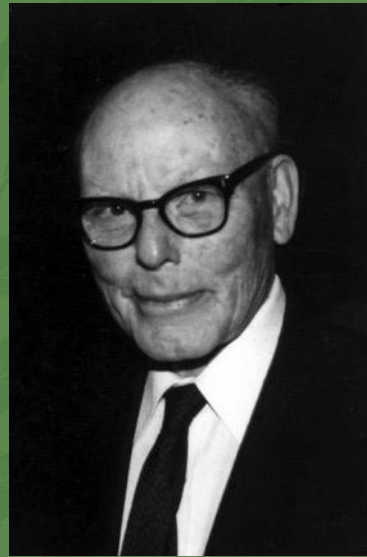


50 foot tall
90 year old Chinese chestnut

Retain forest competitiveness of American chestnut

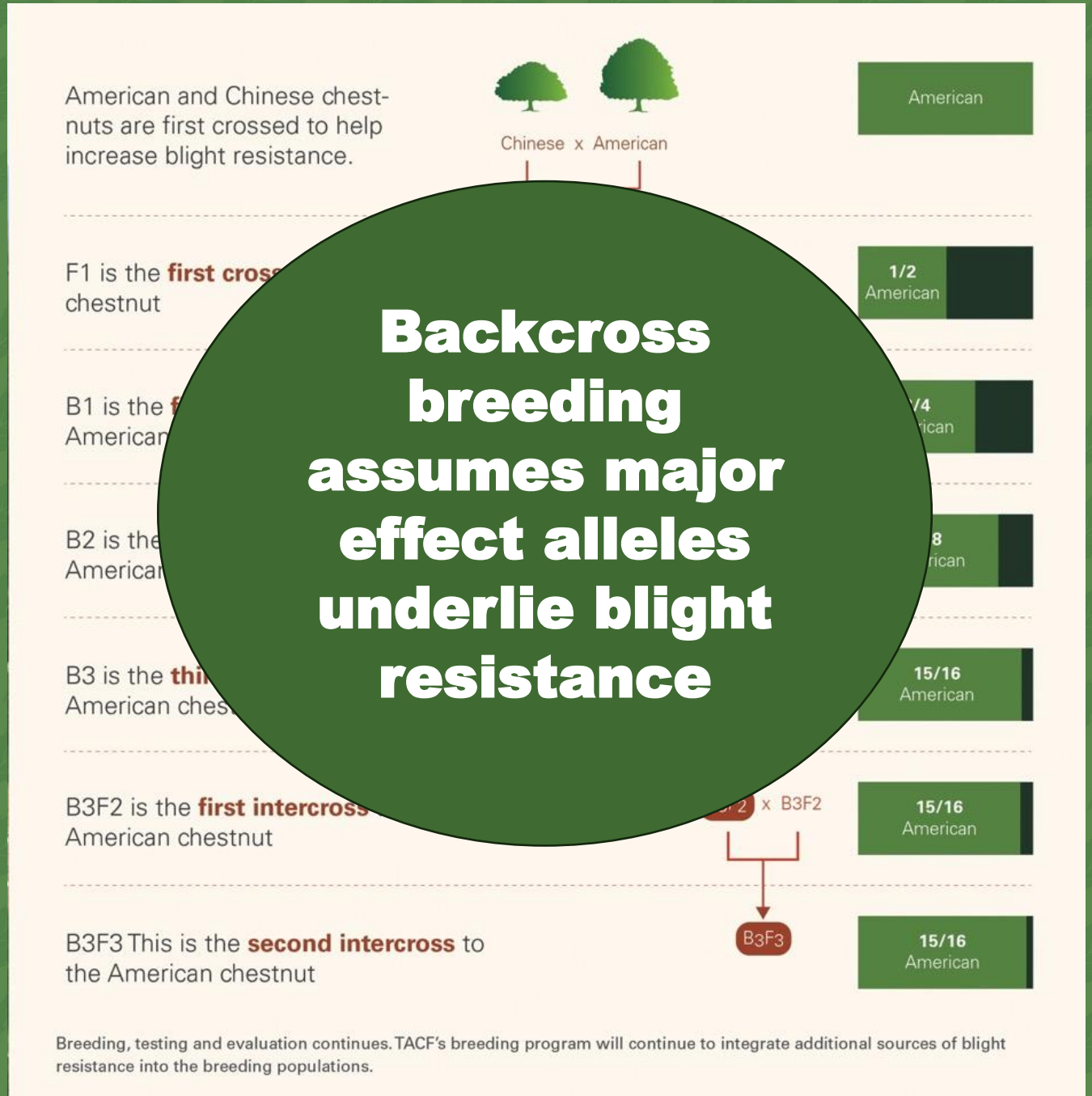


>120 foot tall
120 year old American chestnut
Photo: Anna Spoul-Lattimer (Teurven Arboretum)



Charles Burnham

Backcross Breeding Chart



Moving Forward: Learning and Adapting

Recurrent Genomic Selection (RGS)

A breeding approach that continually selects individuals with superior genetic traits using genomic data to improve populations.



Biotechnology: Genomics

- Study the genetic diversity of American chestnut populations
- Identify regions of the Chinese and American chestnut genomes that are associated with disease resistance or susceptibility
- Predict disease resistance from DNA sequence



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RESEARCH ARTICLE | TREE BREEDING f X Twitter in Reddit WhatsApp Telegram Envelope

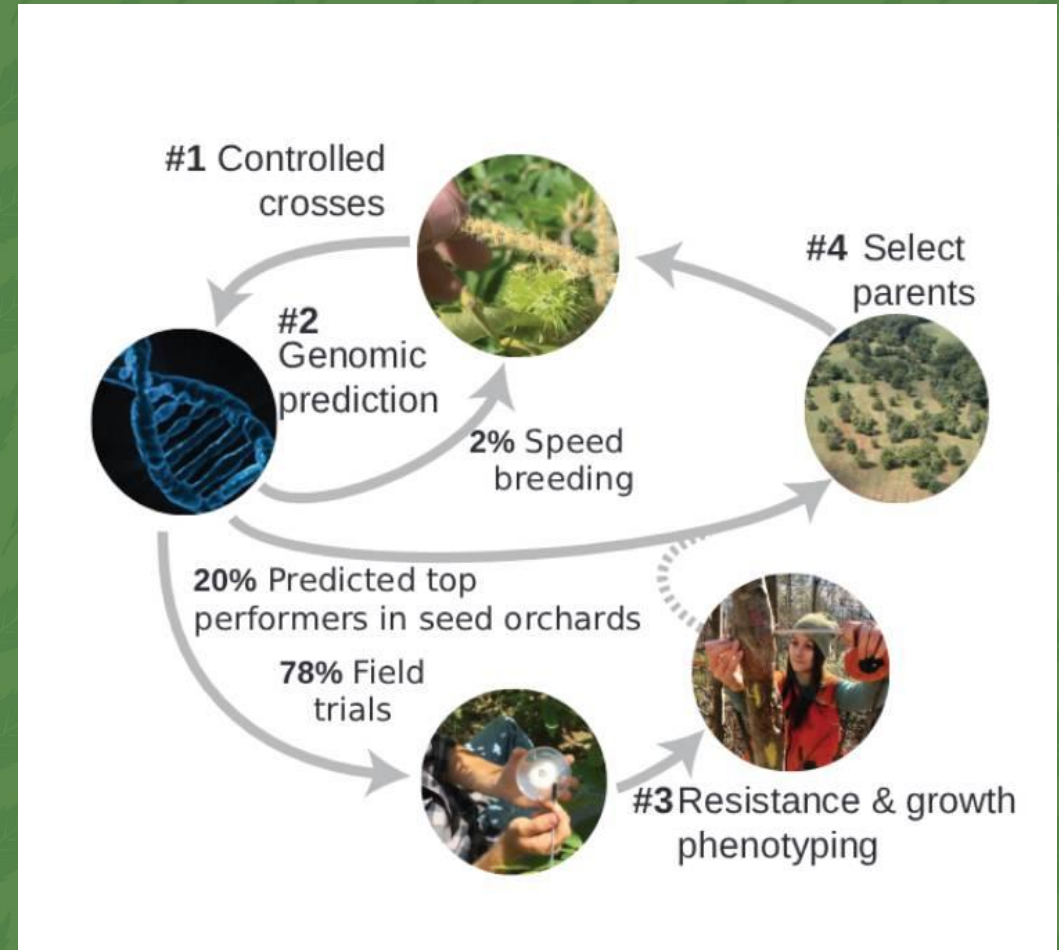
Genomic approaches to accelerate American chestnut restoration

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Recurrent Genomic Selection (RGS)

- Accelerated Genetic Gains: Enables rapid accumulation of favorable traits.
- Increased Selection Accuracy: Uses genome-wide markers to predict breeding values more precisely than conventional methods.



What does success look like?

Blight resistance



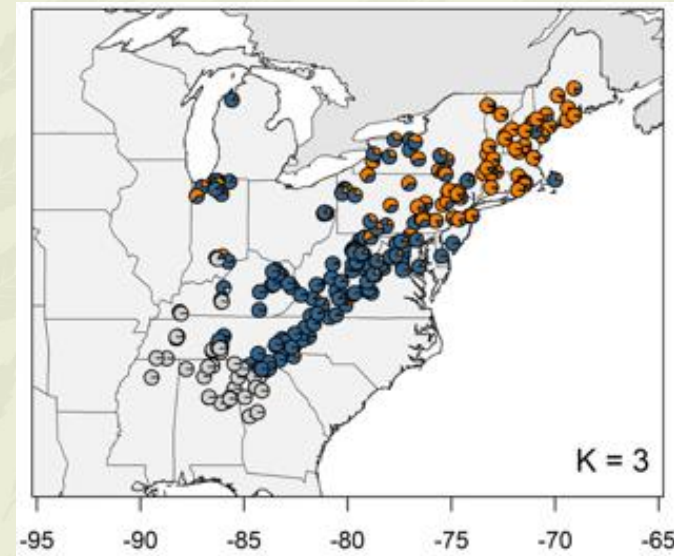
Phytophthora root rot resistance



Forest competitiveness



Genetic diversity/climate resilience



<https://onlinelibrary.wiley.com/doi/epdf/10.1111/mec.16629>

Selection for improved blight resistance & majority American chestnut ancestry



Main stem alive?



Cankers > 15 cm?



Cankers sunken?



% canopy dead



Exposed wood?



Sporulation?

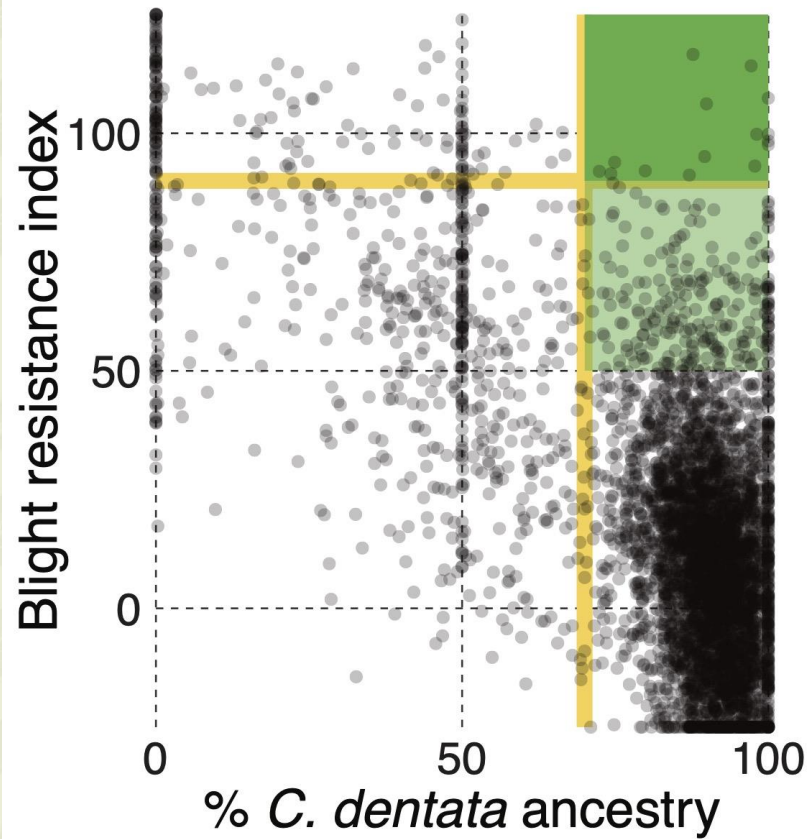


Stump sprouts?



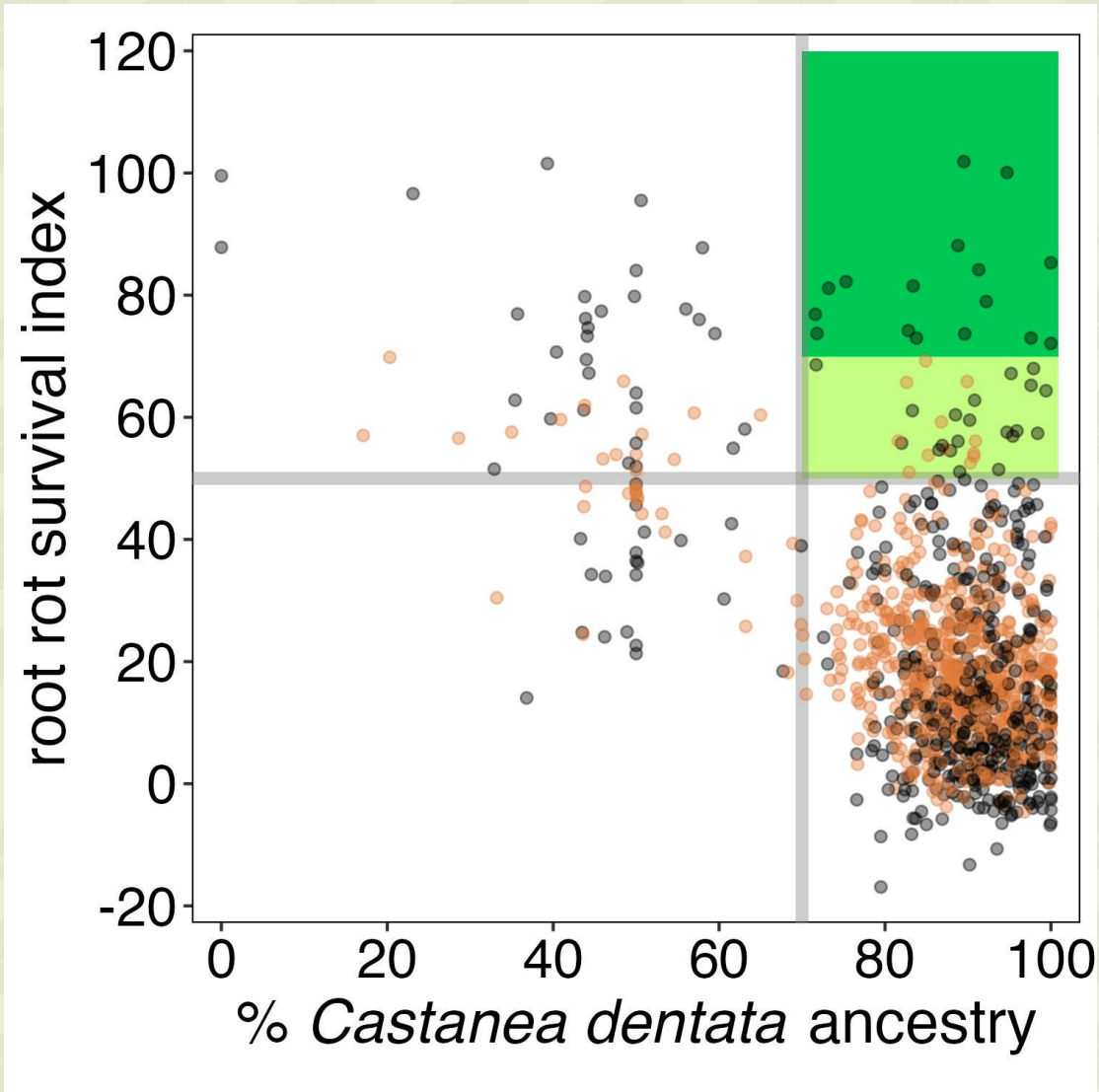
Blight resistance traits

C Disease Resistance



Trees with blight resistance > 50 and American chestnut ancestry 70% - 100%

Selection for *Phytophthora* root rot resistance

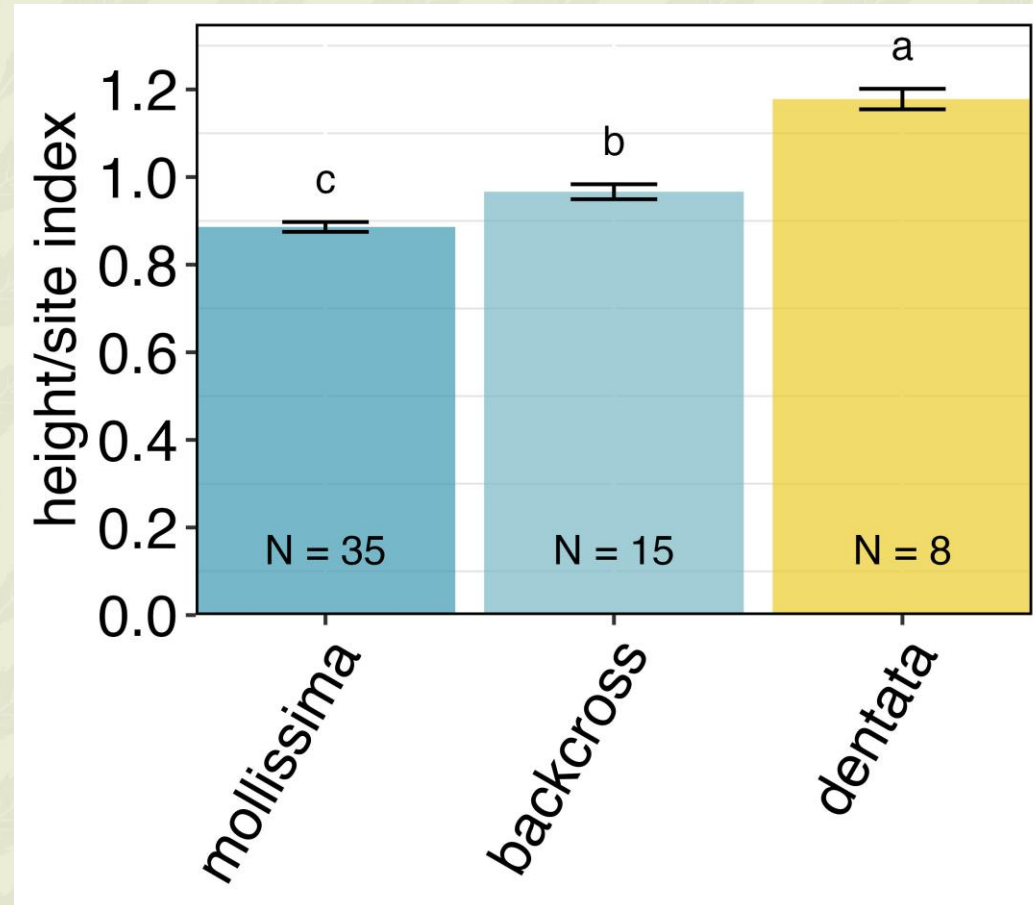


Genetic values estimated for parents based on progeny 6 month **survival** & **root lesion severity ratings**



923 open pollinated families evaluated for PRR resistance (2005 – 2023)

Selection for competitive growth: An important additional objective for American chestnut hybrids



The recurrent genomic selection cycle

Step 1. Controlled pollinations between selected parents



Average for parents:

- blight resistance > 70
- American chestnut ancestry > 70%

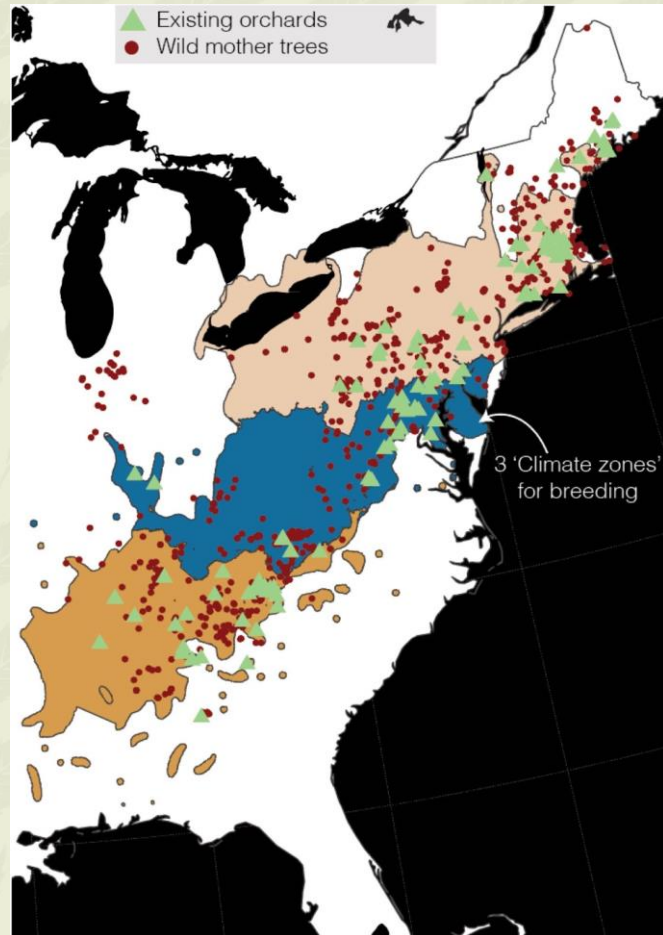
20 – 30 crosses x 3 regions

50 - 100 seeds per cross

~7000 seeds per year

Regionalization of TACF breeding programs

Collaborate across chapters for crosses to conserve > 95% of the adaptive diversity from *C. dentata*



Adaptive diversity target:

Conserve enough *C. dentata* individuals each seed zone to match adaptive allele frequencies at $R^2 = 0.99$

Seed zone	$R^2 = 99\%$	$R^2 = 95\%$	N BC lines
North	92	18	159
Central	87	17	291
South	30	6	44
Total	209	41	421*

*Some BC families split between two seed zones

Analyses by Alex Sandercock

The recurrent genomic selection cycle

Step 2. Predict & screen progeny for resistance

5000 – 6000 genotyped seedlings/yr



Seed orchards (N~800/yr)
Purpose: Select 10-20% with the highest predicted resistance. Produce large quantities of open-pollinated seed with improved blight resistance



Progeny tests (N~3800/yr)
Purpose: evaluate growth and resistance across sites, retrain genomic prediction models, select parent for next generation



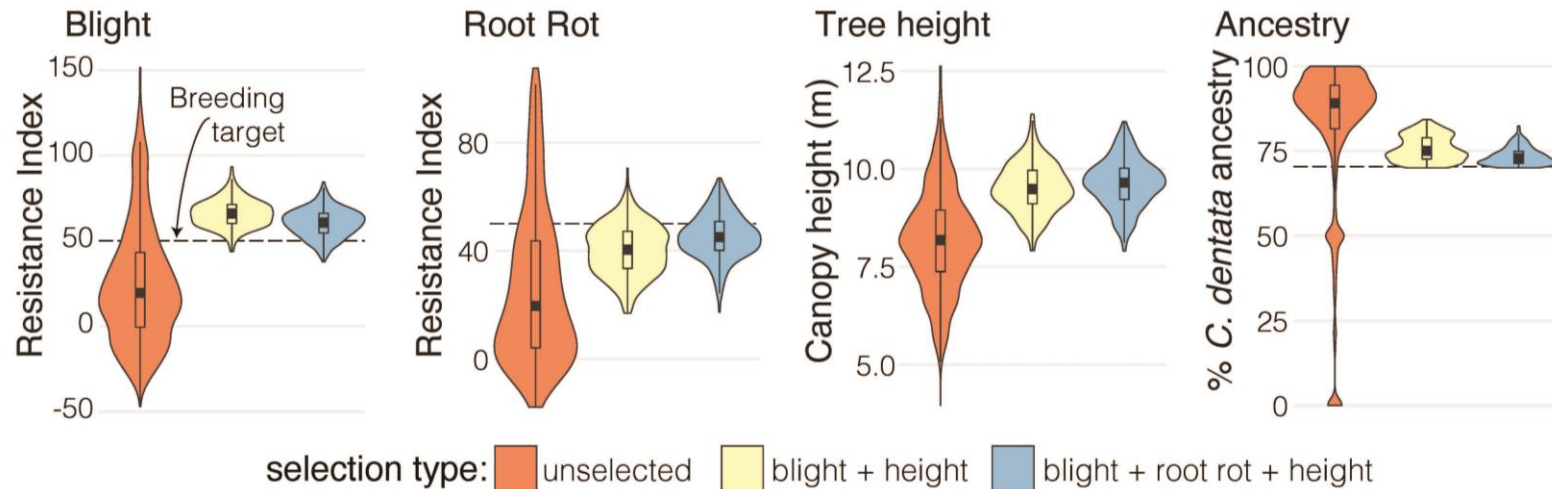
SSAs (N~1500/yr)
Purpose: obtain early estimates of family average resistance, select most resistant families for planting in seed orchards



PRR trials (N~1000/yr)
Purpose: Evaluate PRR resistance in greenhouse trials. Improve genomic prediction models.

We aim to double population-average resistance and increase forest competitiveness in the next decade

B Predicted gains in the first RGS cycle

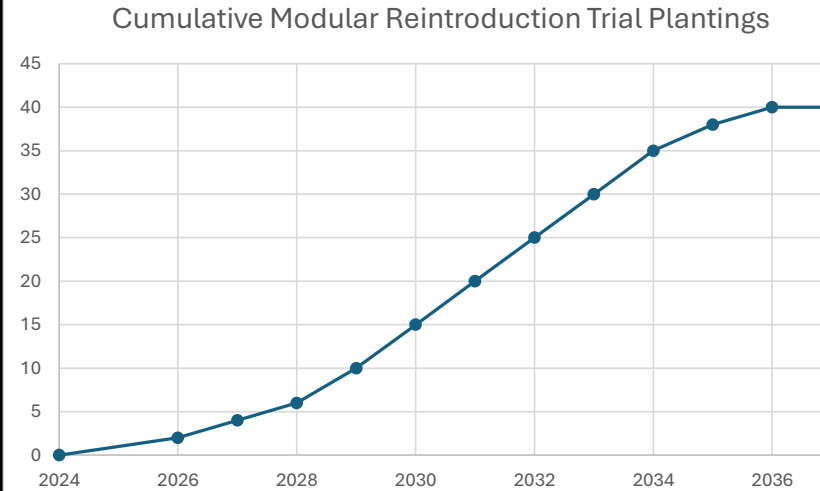
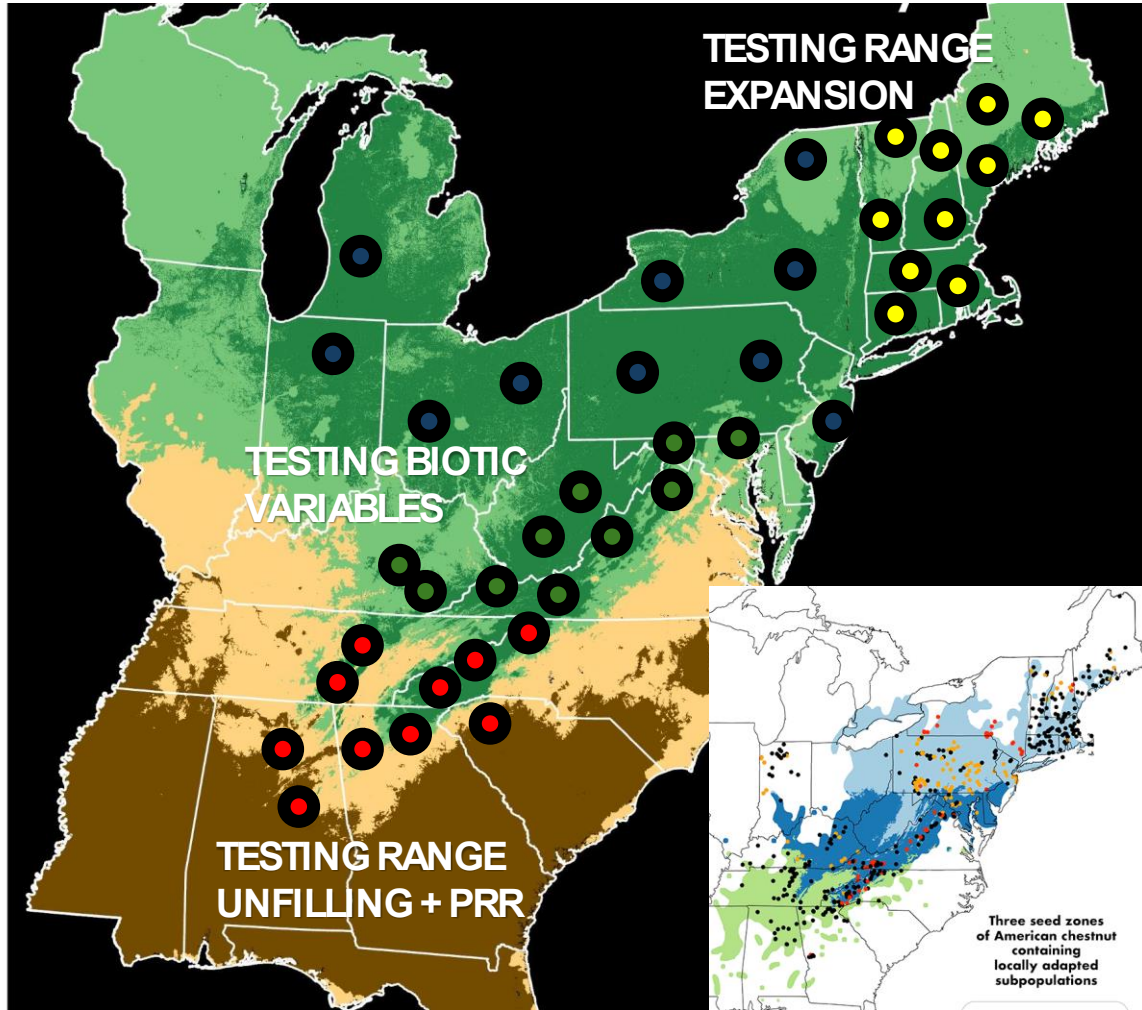


Predicted increases in population average blight, root rot, and tree height from one generation of controlled crosses followed by genomic selection of 20% of the highest performing progeny

Role of chapters: Decentralized progeny tests

The Footprint: Chapter-Driven and Decentralized

AMERICAN CHESTNUT RESTORATION



Slide by
Vasiliy Lakoba

Typical Planting lifespan:

- | | |
|------------|------------------------|
| Year 0 | Planning |
| Year 1 | Seed generated |
| Year 2 | Nursery Growth |
| Year 3 | Field planting |
| Years 4-13 | Yearly data collection |

2026 Selected Mother Trees

Shieling State Forest

- VT-SF08-140
- VT-SF08-247
- VT-SF08-448
- VT-SF08-531
- VT-SF08-610
- VT-SF08-637
- VT-SF08-835

Valley View

- VT-VV05-R9T19
- VT-VV07-R1T3
- VT-VV07-R4T20
- VT-VV08-R2T5
- VT-VV08-R3T20

Future Work Ahead

	A	B	C	D	E	F	G	H	I	J
1	Orchard	Plot	Cross	Recommended Management	SG Inoculation	SG Selection	EP/Weekly Inoculation	EP/Weekly Selection	Genotyped	Phenotyped
2	ValleyView	ValleyView Lower	VT-BE001 x DV189 (2006)		2014	2015	2014	2015 Y		2020
3			VT-CC001 x AL50 (2006)		2014	2015	2014	2015 Y		2020
4	ValleyView	ValleyView Upper	VT-WD001 x AB419 (2004)		2014	2015	2014	2015 Y		2020
5			VT-SB001 x AB247 (2004)		2014	2015	2014	2015 Y		2020
6			VT-WD001 x BG531 (2005)		2014	2015	2014	2015 Y		2020
7	ValleyView	ValleyView Pine	VT-CC001 x SC531 (2007)		2019	2020	2019	2020 Y		2022
8			VT-BE002 x MA349 (2007)		2019	2020	2019	2020 Y		2022
9			VT-WD001 x BG531 (2007)		2019	2020	2019	2020 Y		2022
10			RHR4T5 x open (2007)		2019	2020	2019	2020 Y		2022
11			VT-CC002 x open (2007)		2019	2020	2019	2020 Y		2022
12			CT-WS001a x open (2007)		2019	2020	2019	2020 Y		2022
13	Shieling Forest	Shieling Forest	NH-FT001 x SC444 (2007)		2017	2020	2018	2020 Y		2022
14	Shieling Forest	Shieling Forest	CT-WS001c x open (2007)		2017	2020	2018	2020 Y		2022
15	Shieling Forest	Shieling Forest	RHR4T5 x open (2007)		2017	2020	2018	2020 Y		2022
16	Shieling Forest	Shieling Forest	HHR3T1 x RHR1T7 (2007)		2017	2020	2018	2020 Y		2022
17	Shieling Forest	Shieling Forest	NH-FT001 x SC444 (2007)		2017	2020	2018	2020 Y		2022
18	Shieling Forest	Shieling Forest	VT-CC002 x open (2008)		2017	2020	2018	2020 Y		2022
19	Shieling Forest	Shieling Forest	VT-EX001 x open (2008)		2017	2020	2018	2020 Y		2022
20	Shieling Forest	Shieling Forest	KY106 x MB190 (2008)		2017	2020	2018	2020 Y		2022
21	Shieling Forest	Shieling Forest	NH-DY017 x MA49 (2008)		2017	2020	2018	2020 Y		2022
22	Shieling Forest	Shieling Forest	NH-NB001 x MA9 (2009)		2017	2020	2018	2020 Y		2022
23	Shieling Forest	Shieling Forest	NH-NS001 x VT-BT001 (2009)		2017	2020	2018	2020 Y		2022
24	Shieling Forest	Shieling Forest	NH-DY001 x BG413-98 (2009)		2017	2020	2018	2020 Y		2022
25	Shieling Forest	Shieling Forest	PA-hu97-01-013 x PA-PCSo (2009)		2017	2020	2018	2020 Y		2022

Future Work Ahead

A	B	C	D	E	F	G	H	I	J
Name	Office address	Publicly Viewabl	Planting types	Actions Needed	Expected Costs	Timing	Priority	Who?	Future Possibilities?
Valley View Farm	614 Farm Barn Lane Shelburne, VT	no	Breeding Orchard	Update data on remaining trees; RGS pollination/harvest	none	Data - 2026; pollination July/harvest Oct	High	Deni and Gary H	No - landowners have been ready to move on from this project once we have enough material from their trees
High Shelter Farm	328 Gravelin Road Perkinsville, VT	no	Breeding Orchard	Ensure seed captured from all unique B3/B4 lines and planted in Fox Forest BCO - possible harvest or get seeds from Randy Knight	none	Oct pollination July/harvest Oct; signage convo spring 2026	Medium	Deni or someone in chapter to connect with Randy re: priorities to harvest	No - landowners seem ready to move on from project
Shieling State Forest	395 Old Street Rd Peterborough, NH	yes	Breeding Orchard	Possible RGS pollination or pollen collection; new sign desired - consider demo planting to make worthwhile? Attempt to capture seed from unique B3/B4 lines for Fox Forest BCO - Chris Leask can harvest - get list of flowering trees from him to determine which trees to prioritize harvesting	1200 for sign	early july for flower inventory; harvest oct site visit with Mike in spring to broach inoculation convo - could inoc in June (or even June '27) OR see about fall harvest	High	Deni coordinate pollination, Chris L can help but needs good support; will to work with AJ re: signage and possible demo planting	Uncertain but unlikely - ask AJ
Otter Brook Farm	81 Crosby Rd Peterborough, NH	no	Breeding Orchard		none		Medium	Someone from chapter a/o Deni coordinate with Chris Leask	No - orchard owners have been unresponsive - can walk away from orchard once germplasm is captured (and this activity isn't critical but worth a try)
Pikes Peak Farm	769 Pikes Peak Road Perkinsville, VT	no	Breeding Orchard	Could inoculate this BC orchard if Mike is willing OR just capture seed from unique B3/B4 lines for Fox BCO. Inoc/selection process would be better but Mike not thrilled about that so a bit of a balance on how hard to push	none		Medium	Deni and chapter leader - Kendra happy to make introduction to Mike over email	No - landowner happy with his orchard, not looking for more
Beaver Brook	Beaver Brook Association 117 Ridge Rd Hollis, NH 03	yes	Progeny Test	Connect with Kim Colson a/o others at BBA re: future desires for the orchard; determine any next steps	none	field season 2026 - a visit would be nice for this discussion	High	chapter leadership, Deni could join or provide recommendations but not required	Hopefully! Nice fence and site, need clear management plan expectations re: who does what for any future planting. Could be a nice reintroduction trial site. Field between 2 forested parcels but fence in place and this was original plan for the progeny test planting
Old Gurdy Farm	Schaefer Rd Bristol, NH	no	Breeding Orchard	Inoculate and start selection process for these B3/B4 trees	\$50 for water/snacks for field crew	June 2026	High	Deni to lead field crew; connect with Hans (Kendra happy to make intro)	Aside from following existing trees for possible RGS use, could be a nice site for a reintroduction trial - recommend asking Hans about this
Lake St. Catherine	Lake St. Catherine State Park 3034 - South Vermont	yes	Breeding Orchard	Inoculate and start selection process for these B3/B4 trees	\$50 for water/snacks for field crew	June 2026	Medium	Deni to lead field crew; someone needs to find out current contact with state park to coordinate	No - landowner has struggled with maintenance. Could walk away from this site if run into issues around inoc but Evan put a lot into getting it cleaned up and would be good to try to follow the trees through selection process as intended
Camp Endo	Trager Rd Jamaica, VT	no	Breeding Orchard	Rate the inoculated trees	none	Field season 2026	High	Deni - could have company if anyone interested but won't likely need help per se	Not likely - nice and well-funded site but landowner has been quietly looking to sell - uncertain what future access might look like
GMNF - Fags Meadow	Fag Rd Forest Dale, VT	yes	Progeny Test	Possible field season work day if requested by USFS; Paula Murakami best contact (Gary and Deni know her well)	none	Field season 2026	Low/unlikely	Field crew	Uncertain ATM - USFS in a weird spot w/RT research
UVM Horticulture Research Center	Horticultural Research Center access road.	yes	American GCO	Connect with Terry Bradshaw re: maintenance and upkeep	possible stipend for paid mowing?	winter/spring 2026	High	chapter leadership	Not likely - but would be good to maintain this well-established GCO as long as UVM willing to have it on-site
Merck Forest and Farmland Center	3270 Route 315, Rupert, VT 05768	yes	Breeding Orchard	Connect with leadership for site visit; possible inoc in 2026 or 2027 or harvest B3/B4 lines for Fox Forest BCO	none	Field season 2026	Medium	chapter leadership, Deni could join or provide recommendations but not required	No - host org hasn't been very engaged but would be good to salvage material that is there if possible
Vincent State Forest	Reservoir Drive Weare, NH	yes	Reintroduction Trial	Could connect with Will Guinn for a tour; Deni to get updated data	none	Anytime	Low	chapter leadership/Deni	In general NH DFL has been great partner and will Guinn best contact if looking for forest sites.
Fox State Forest	309 Center Road Hillsboro, NH 03244	yes	Seed Orchard	Don't think there is any spring planting this year - connect with Inge re: any needs for a work day	\$100 for supplies? Ask Inge	Field season 2026	High	chapter leadership	Might be a lengthy planning process so bring what we're looking for to him sooner than later if we need forested planting sites
Burlington College City Park (yet to be named)	351 North Ave Burlington, VT 05401	yes	Demonstration	Connect with Bill Keeton at UVM or just visit site to update status	none	Anytime	Low	local volunteer or Gary	Not likely at this site, but as above - NH DFL good host
The Harris Center for Conservation Education	83 King's Highway Hancock, NH 03449	yes	Demonstration	Nothing specific - could connect for a status update	none	Anytime	Low	chapter leadership	No
									Could be nice partner for larger forest planting - worth inquiring as need arises



Thank you!

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