MECHANISMS OF RESISTANCE TO PESTS AND PATHOGENS

Moderator: Kimberly Wallin

Tree Breeding for Pest Resistance for the Next 50 years:

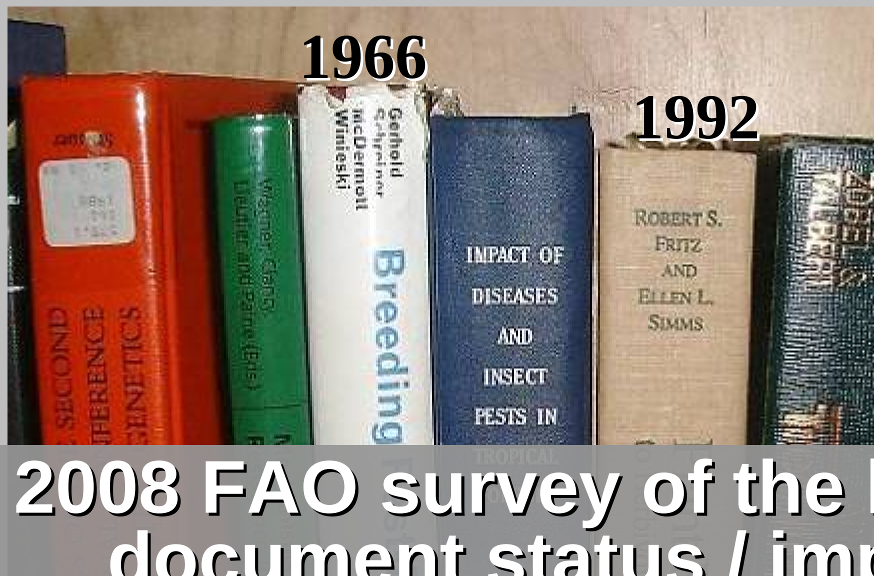
the search for cross resistance?

Alvin Yanchuk

SCION Next generation biomaterials

FOREST SERVICE BRITISH COLUMBIA

A long history pest and disease resistance research in forestry….



CANADA
Department of Northern Affairs and National Resources
FORESTRY BRANCH

AN OBSERVATION OF WEEVIL DAMAGE IN NORWAY SPRUCE

by
M. J. Holst

1955

2008 FAO survey of the literature to document status / impact of tree improvement programmes addressing disease and pest resistance

Journal of Forestry
Official Organ of the Society of American Foresters

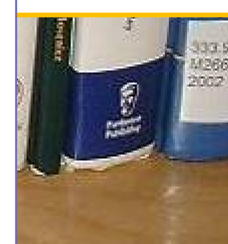
Breeding Blister-Rust-Resistant Western White Pine

R. T. Bingham, A. E. Squillace, and J. W. Duffield

Respectively Office of Blister Rust Control, Spokane, Wash., Northern Rocky Mountain Forest and Range Experiment Station, Missoula, Mont., and California Forest and Range Experiment Station, Institute of Forest Genetics, Placerville, Calif.

The selection and breeding of white pines resistant to blister rust have been of continuing interest to pathologists, geneticists, and foresters for many years. Work on rust resistance in western white pine was started in the Inland Empire region in 1949. This article is a progress report covering work accomplished thus for and plans for future work.

1953



Food and Agriculture Organization of the United Nations
for a world without hunger
Google Custom Search
FAO home
Forestry home
Breeding for resistance
Global status of research and applications
Review information
Methodology
Results and analysis
Current applications
Conclusions

Selection and breeding for insect and disease resistance

send by email | printer-friendly version

Selection and breeding for insect and disease resistance

Pest and disease resistance has been an essential part of crop breeding for many years, but has only had marginal impact in tree breeding to date. Crop varieties are domesticated and their continued cultivation depends on continuous breeding programmes for insect, disease and virus resistance, since large-scale monocultures are generally more susceptible to variable pathogens. Forest trees are mainly wild, undomesticated, outbred organisms and their natural populations retain a wide genetic diversity that helps them resist insect pests and pathogens. In addition, the genetic control of insect pest and disease resistance is sophisticated and probably more complex than for annual crops. Moreover, conventional tree selection and breeding for insect and disease resistance requires complex and lengthy laboratory and field tests, especially since resistance patterns may change from young to adult trees.

Over the past 20 years, tree breeding programmes have been reduced worldwide and now focus on a limited number of species and traits. However, since the risk of introducing new pests is likely to increase in the future, insect and disease resistant breeding programmes may be particularly important for several large-scale or valuable commercial plantations.

Pest resistance breeding may be a technical option in large-scale or valuable commercial plantations if there:

- are few silvicultural options to mitigate losses to insect pests and diseases;

See also

- Forest health
- Biosecurity in forestry
- Invasive species: impacts on forests & forestry

Comments and feedback

Comments and feedback are welcome. For further information or if you are interested in providing information on breeding for resistance activities, please contact:

Gillian Allard
Forestry Officer (Forest Protection and Health)
Forest Resources Development Service
Forest Management Division
Forestry Department
FAO
Viale delle Terme di

Selection and breeding for insect and disease resistance - Windows Internet Explorer

http://www.fao.org/forestry/26462/en/

File Edit View Favorites Tools Help

Favorites | Selection and breeding for insect and ...

Food and Agriculture Organization of the United Nations

for a world without hunger

FAO Home
Forestry
Breeding for resistance
Global status of research and applications
Review information
Methodology
Results and analysis
Current applications
Conclusions

Results and analysis

Results

The files below summarize what has been gathered to date. The activities or programmes recorded were classified into four categories that capture the current **status** of the work:

1. Breeding programmes with deployed resistant material;
2. Programmes breeding for resistance, no deployed material;
3. Resistance detected in genetic/provenance trials;
4. Evidence in genetic variation in resistance in seedling or clonal screens.

The information is also categorized under three broad **approaches**:

1. traditional plant breeding methods;
2. molecular biology approaches;
3. genetic engineering.

While some research initiatives that have not been documented as of yet, may have been overlooked or misclassified in terms of the three approach categories, it is hoped and expected that this information will be continuously updated as more people become aware of the resource and can provide feedback, updates or new information.

Documentation:

Resistance breeding programmes for diseases and insect pests of forest trees PDF
Resistance breeding programmes for diseases and insect pests of forest trees

Programmes by status PDF
Programmes by approach PDF
Programmes by country and status PDF

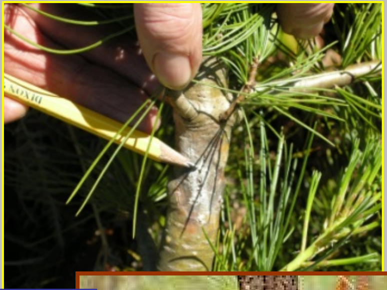
Breeding programmes that have led to deployment of trees with improved pest resistance PDF
References PDF

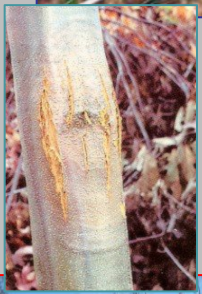
Local intranet | Protected Mode: Off | 100%

Start | Microsoft PowerPoint n... | Selection and breedin... | 84% | 5:10 PM

Disease resistance breeding

- western white and sugar pines
  - blister rust resistance
    - USDA For Serv (Moscow, ID; Doreena, OR; IFG, CA)
    - BC MoFR and Canadian Forest Service
- loblolly and slash pines
  - fusiform rust resistance
    - NCSU / U. Florida / WGTIP
- radiata pine
  - *Dothistroma* (RPBC-FRI (Scion))
- poplars
  - e.g., Greenwood / many European countries)
  - *Melampspora, Septoria, Venturia*
- chestnut





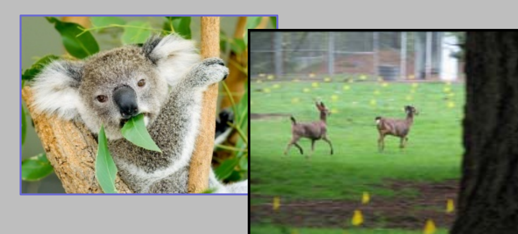
Insect resistance breeding

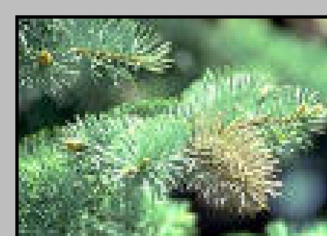
<u>Improvement Programs</u>

- spruces
  - white pine weevil (B.C.)
  - aphids (DK,UK)
- poplar
  - long-horned beetle, stem borers (China, US)
  - leaf beetles

<u>Research / Screening Programs</u>

- >> leaf beetles – poplars, ‘*Eucs*’
- >> mammals- ‘*Eucs*’, redcedar
- >> adelgids in spruce
- >> birch borer / ash borer
- >> bark beetles (lodgepole pine)
- >> many others!!





Tree Improvement and Breeding Programmes for Pest and Disease Resistance…..*summary*

- ~ 260 resistance 'research programmes' identified
- ~ 20 programmes are 'using' or have identified resistance materials
- only 4-5 major commercial forestry programmes have documented 'impacts' (~2%!?)
  - substantial investments have had to be made in these 4-5 large commercial programmes!
  - and decades in most cases to develop.
- 'transgenic resistance' – most are with poplars in China

‘Road blocks’ to application of resistance research:

- studies are developed that work on materials not related to a breeding (or with a significant planting) program
- adequate infection does not occur in a trial, or
- artificial inoculation techniques are too expensive (and a large enough population cannot be screened), and
- the genetic gain in resistance may not be ‘silviculturally’ important or effective *(and little confidence it will hold up, or is important in the long term)*

Interior spruce breeding program

- first generation orchards producing resistant seed
- ~20-40% reduction in attack /yr (lower in Sitka spruce)
- over 80 million trees planted per year

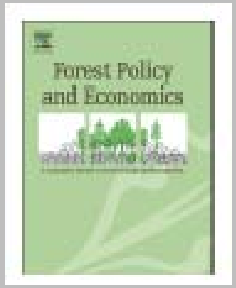
Modeling the timber supply impact of introducing weevil-resistant spruce in British Columbia with cellular automata

Olaf Schwab [a,*], Thomas Maness [a,1], Gary Bull [a], Clive Welham [b], Brad Seely [b], Juan Blanco [b]

Forest Policy and Economics (2010), doi:10.1016/j.forpol.2010.08.004

Table 4
Present value of avoided merchantable volume losses.

		Present value ($ million)		
Discount rate		1%	3%	5%
Increase in weevil resistance	25%	195.2	4.3	0.2
	50%	562.3	13.4	0.8
	75%	1 123.3	30.0	2.3



They value of this resistance may be greater for some future biotic challenge, than the current problem (terminal weevil).....now largely 'solved'!?

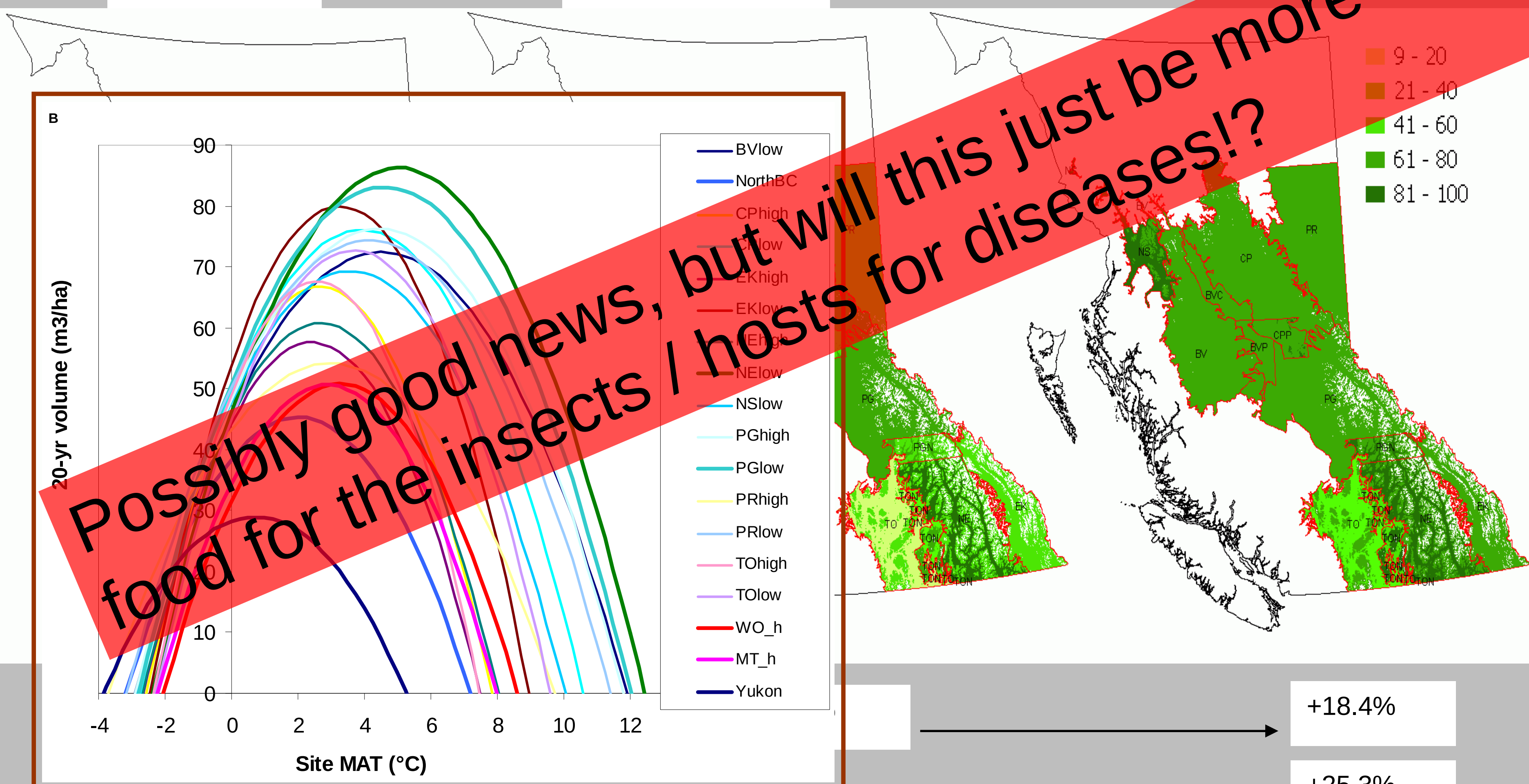
Predicted changes in productivity of lodgepole pine breeding zones in BC (~2040); and "facilitated migration"?

From: Wang et al. 2006, Global Change Biology 12:2404-2416

Local

Local + 2°C

Optimized at +2°C



+18.4%

+25.3%

Possibly good news, but will this just be more food for the insects / hosts for diseases!?

Climate and pest range shifts under future warming predictions; e.g., Gypsy moth

Fig. 7. Predicted distribution of Gypsy moth (*Lymantria dispar*) by CLIMEX in Europe using average global temperature increase of 3.6°C. Black circles indicate Ecoclimatic Indices (EI) at meteorological stations. Crosses indicate an EI of 0. Larger circles represent higher EI values and more favourable climatic conditions for *L. dispar*. Shaded area represents current distribution (For references: see Fig. 2).

Vanhanen, H., Veteli, T.O., Päivinen, S., Kellomäki, S. & Niemelä, P. 2007. Climate change and range shifts in two insect defoliators: gypsy moth and nun moth – a model study. Silva Fennica 41(4): 621–638.

REVIEW / SYNTHÈSE

Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict?[1]

Jeffrey S. Dukes, Jennifer Pontius, David Orwig, Jeffrey R. Garnas, Vikki L. Rodgers, Nicholas Brazee, Barry Cooke, Kathleen A. Theoharides, Erik E. Stange, Robin Harrington, Joan Ehrenfeld, Jessica Gurevitch, Manuel Lerdau, Kristina Stinson, Robert Wick, and Matthew Ayres

letters to nature

Poleward shifts in geographical ranges of butterfly species associated with regional warming

Camille Parmesan*†, Nils Ryrholm‡, Constantí Stefanescu§, Jane K. Hill‖, Chris D. Thomas¶, Henri Descimon#, Brian Huntley‖, Lauri Kaila☆, Jaakko Kullberg☆, Toomas Tammaru**, W. John Tennent††, Jeremy A. Thomas‡‡ & Martin Warren§§

USDA

United States Department of Agriculture

Forest Service

Pacific Southwest Research Station

General Technical Report PSW-GTR-225 October 2009

Review of Literature on Climate Change and Forest Diseases of Western North America

John T. Kliejunas, Brian W. Geils, Jessie Micales Glaeser, Ellen Michaels Goheen, Paul Hennon, Mee-Sook Kim, Harry Kope, Jeff Stone, Rona Sturrock, and Susan J. Frankel

Global Change Biology (2006) 12, 1545–1553, doi: 10.1111/j.1365-2486.2006.01180.x

Impacts of climate warming and habitat loss on extinctions at species' low-latitude range boundaries

ALDINA M. A. FRANCO*, JANE K. HILL*, CLAUDIA KITSCHKE*, YVONNE C. COLLINGHAM†, DAVID B. ROY‡, RICHARD FOX§, BRIAN HUNTLEY† and CHRIS D. THOMAS*

Ecology Letters, (2005) 8: 1138–1146 doi: 10.1111/j.1461-0248.2005.00824.x

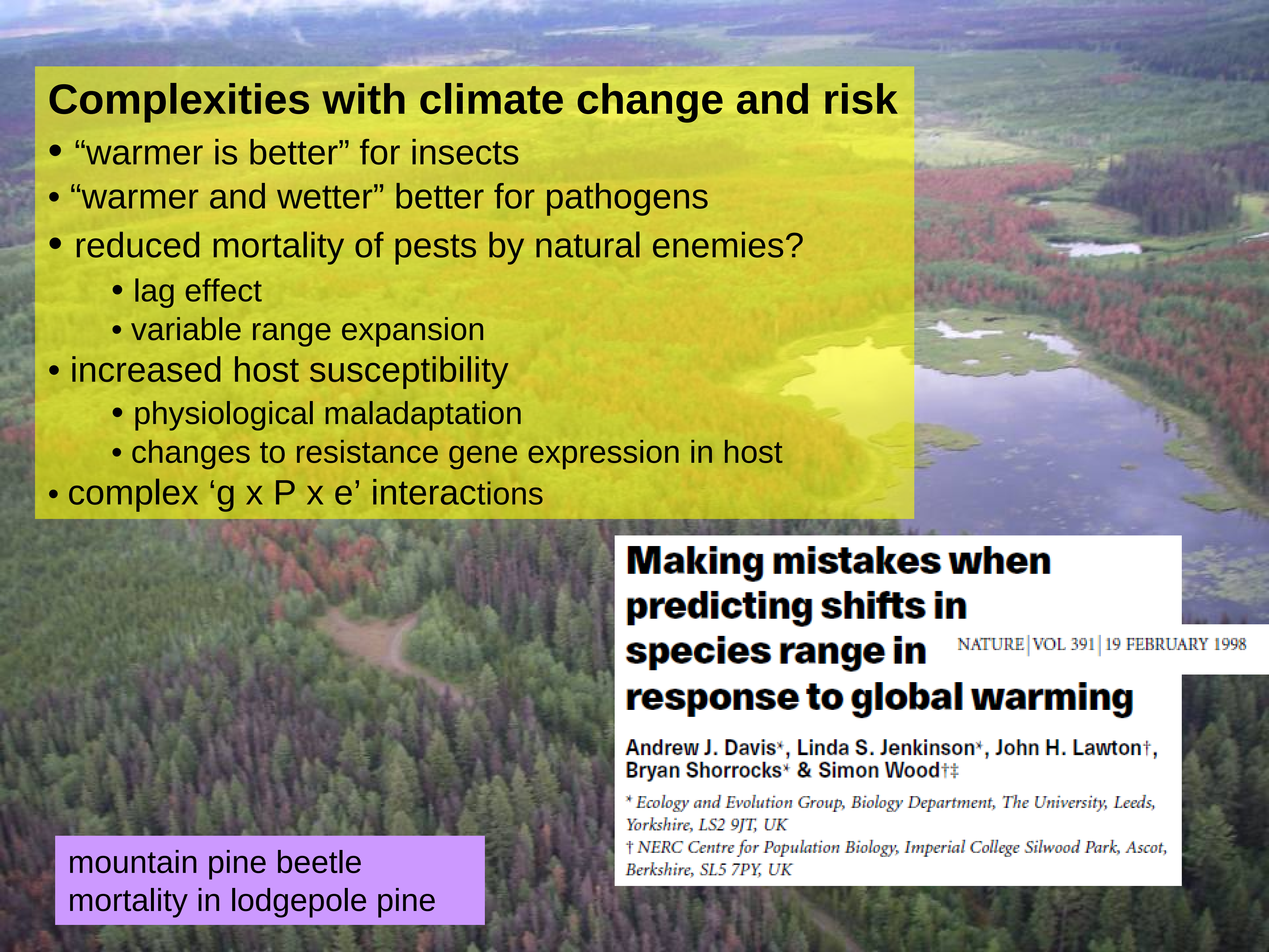
LETTER

Changes to the elevational limits and extent of species ranges associated with climate change

Robert J. Wilson,[1]* David Gutiérrez,[1] Javier Gutiérrez,[1] David Martínez,[1] Rosa Agudo[1] and Víctor J. Monserrat[2]

Complexities with climate change and risk

- “warmer is better” for insects
- “warmer and wetter” better for pathogens
- reduced mortality of pests by natural enemies?
    - lag effect
    - variable range expansion
- increased host susceptibility
    - physiological maladaptation
    - changes to resistance gene expression in host
- complex ‘g x P x e’ interactions



mountain pine beetle mortality in lodgepole pine

Making mistakes when predicting shifts in species range in response to global warming

NATURE | VOL 391 | 19 FEBRUARY 1998

Andrew J. Davis*, Linda S. Jenkinson*, John H. Lawton†, Bryan Shorrocks* & Simon Wood†‡

** Ecology and Evolution Group, Biology Department, The University, Leeds, Yorkshire, LS2 9JT, UK*

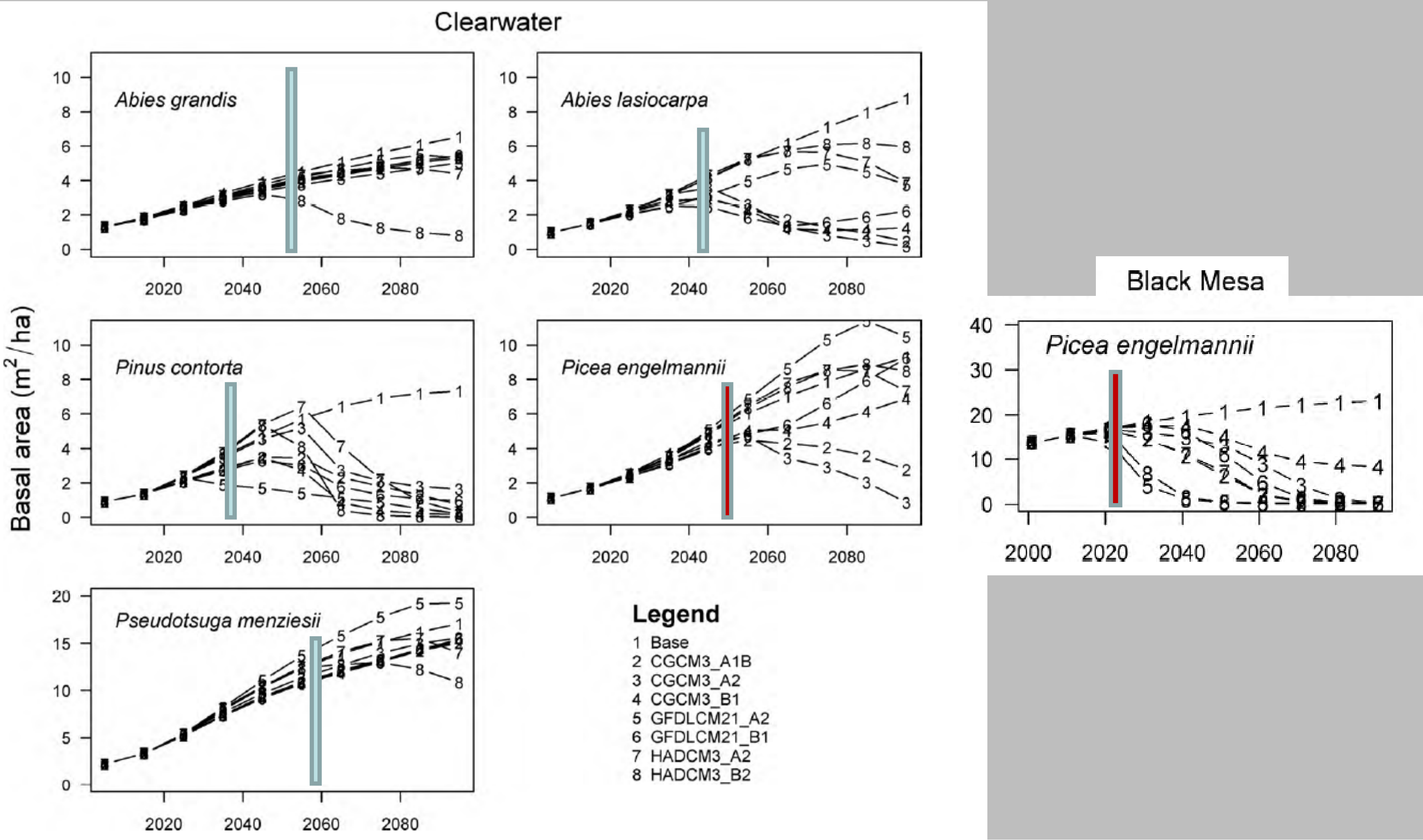
† NERC Centre for Population Biology, Imperial College Silwood Park, Ascot, Berkshire, SL5 7PY, UK

Addressing climate change in the forest vegetation simulator to assess impacts on landscape forest dynamics

Nicholas L. Crookston[a,*], Gerald E. Rehfeldt[a], Gary E. Dixon[b], Aaron R. Weiskittel[c]

[a] Forest and Woodland Ecosystems, Rocky Mountain Research Station, US Forest Service, 1221 South Main, Moscow, ID 83843, United States
[b] Forest Management Service Center, US Forest Service, Fort Collins, CO, United States
[c] School of Forest Resources, University of Maine, Orono, ME, United States

Forest Ecology and Management 260 (2010) 1198–1211



Will our traditional approach serve us well with uncertain future climates?

- Pests and diseases we will be facing?
  - Increased activity/damage in current distributions
  - Continuing exotic pest and disease introductions
  - Large uncertainty in our predictions past 2040-2050
- Can we afford to develop ‘specific’ resistances to pest ‘x’ (or disease ‘y’)?
  - 15-40 years per programme to develop and deploy resistant material...!!??
  - Relatively few high economic impacts to report
- Can we utilize current biotic challenges as surrogates against classes/guilds of potential pests?

The difficulty in ‘finding’ mechanisms

- **e.g., mountain birch herbivory... (Haukioja *et al*.)… after decades of research – resistance is complex!;**
  - Large spectrum of compounds that change over seasons
  - Resistance varies by herbivore
  - Changes in nutrients, water content and leaf toughness as important as any chemistry
- **Endophyte interactions**
  - Induced responses?
  - g x ‘E’ x e interactions

Courtesy:
R. Ganley, Scion

- **e.g., Hessian wheat fly**
  - >25+ genes segregating for resistance to Hessian fly
  - resistance genes coding for the proteins unknown

Hessian fly (*Mayetiola destructor*) on Wheat

Oecologia (2007) 153:891–901
DOI 10.1007/s00442-007-0784-1

PLANT ANIMAL INTERACTIONS

Heritable variation in the foliar secondary metabolite sideroxylonal in *Eucalyptus* confers cross-resistance to herbivores

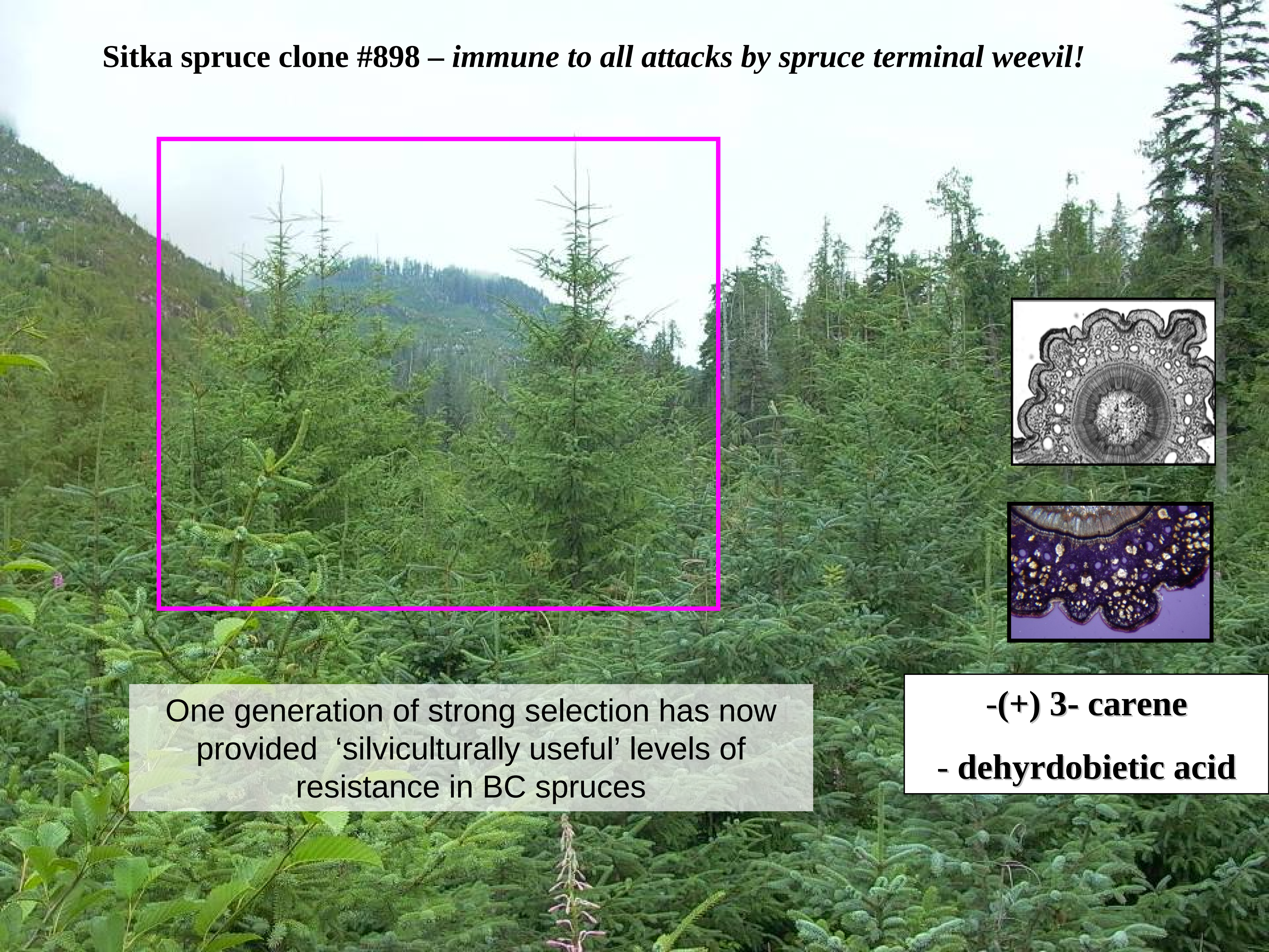
Rose L. Andrew · Ian R. Wallis · Chris E. Harwood · Michael Henson · William J. Foley

Table 4 Phenotypic (below diagonal) and additive genetic (above diagonal, with standard errors in parentheses) correlations for defense and growth traits in *E. tricarpa*. Average narrow-sense heritability (with standard errors in parentheses), estimated using the same provenances are shown italicized and on the diagonal. The genetic correlation of height and DBH was estimated using Fisher optimisation to obtain model convergence

Trait 1	Trait 2			
	Sideroxylonal	Damage	Height	DBH
Sideroxylonal	0.60* (0.13*)	–0.39 (0.21)	–0.07 (0.19)	0.00 (0.20)
Damage	–0.40*	0.34* (0.14*)	–0.30 (0.20)	–0.34 (0.22)
Height	0.05	–0.27*	0.53* (0.08*)	0.96* (0.03)
DBH	0.02	–0.19*	0.84*	0.34* (0.06*)

* Significantly different from zero ($P < 0.05$)

Sitka spruce clone #898 – *immune to all attacks by spruce terminal weevil!*



One generation of strong selection has now provided ‘silviculturally useful’ levels of resistance in BC spruces

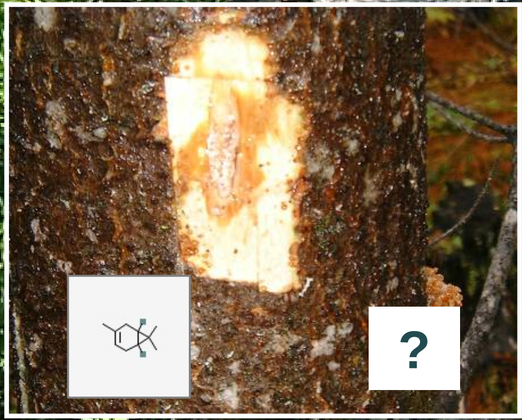
-(+) 3- carene

- dehyrdobietic acid

- Yanchuk, A.D., Murphy, J.C. and K.F. Wallin. 2008. Preliminary evaluation of genetic variation of attack and resistance in lodgepole pine to mountain pine beetle. Tree Genetics and Genomes 4:171-180.
- Ott, D. 2010. M.Sc. thesis, UNBC

h^2 @ 80% mortality =0.25

$r_{f\ (mortality,\ d\text{-}3\text{-}carene)}$ = - 0.35



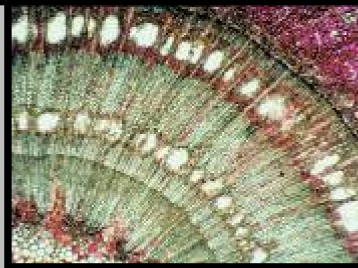
Indian Point (IP86) – lodgepole pine open-pollinated progeny test – age 20

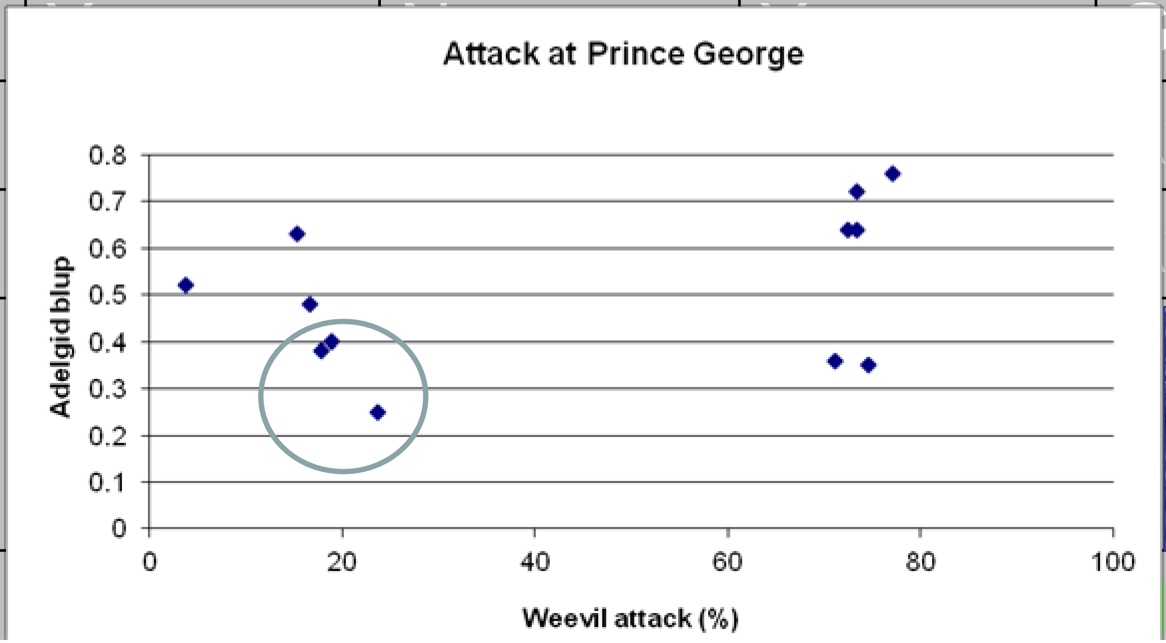
Findings from genomics research

- well known 'housekeeping' genes
  - TBS-LRRS
  - kinases
  - heat shock proteins
- marker assisted selection?
- genome wide (assisted) selection?

h^2 ~30%

Building resistance 'portfolios' to classes of diseases and pests?

Spruce Genotype				
1				ood
2				verage
3				verage
Pine Genotype				
A				o
C	Yes	No	No	Yes

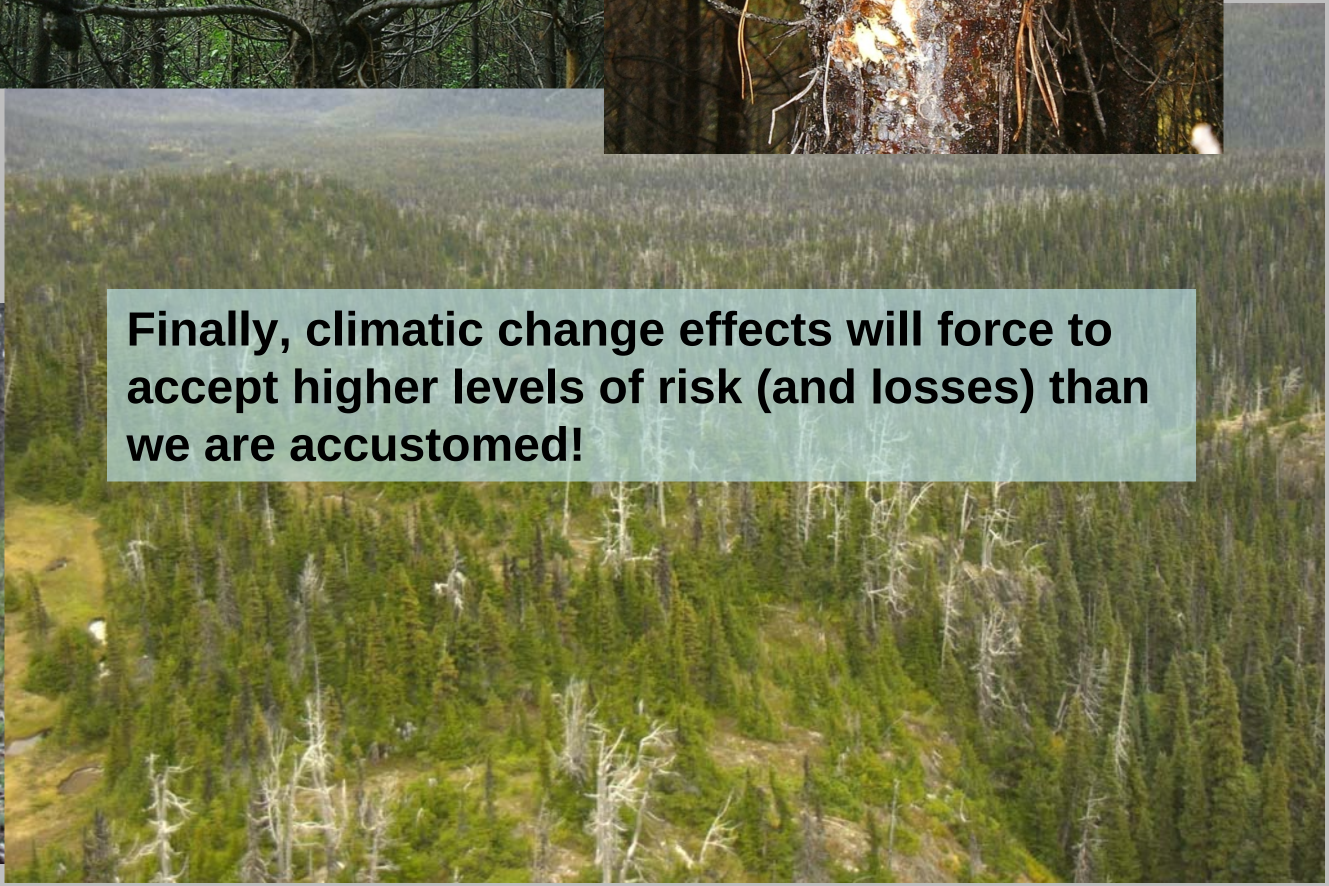


so, we can also build our own 'crosses resistance' (stacking)

Concluding Points

- **Traditional breeding approaches have been very successful in several places, but…**
  - limited to species have the tree improvement 'machinery' in place
  - not generally focused on problems where resistance can be delivered, and silvicultural management options are limited
  - expect a continuation of new pest introductions and outbreaks!?
  - resistance has taken decades to develop…???
- **New approaches necessary?**
  - can we develop 'general mechanisms' of resistance across classes of pests (i.e., cross resistance?)
    - *General resistance features*
    - *Multiple challenges from different pathogens / insects*
    - *Pyramiding or stacking*
    - *Focus on fewer species, and pool resources and expertise*

Thank you



Finally, climatic change effects will force to accept higher levels of risk (and losses) than we are accustomed!