Using Resistant Trees to Mitigate Impacts from Pests & Pathogens

Paul Woodcock[1], Joan Cottrell[2], Richard Buggs[3], Chris Quine[2]

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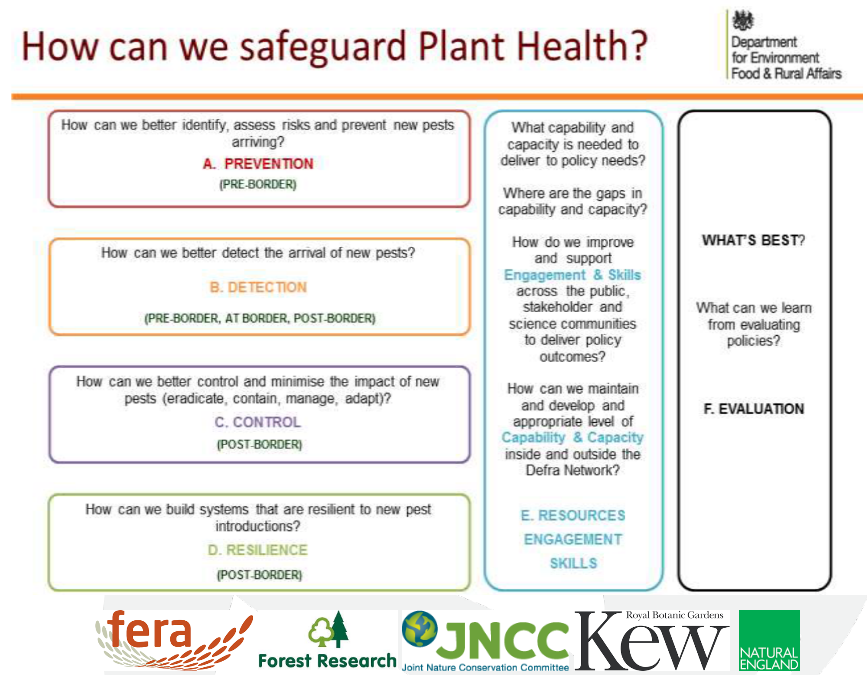
Future-Proofing Plant Health

- 5-year Defra-funded project to provide evidence for Tree Health Biosecurity Strategy
- Resilience Work Package (JNCC, FR, Kew, NE)



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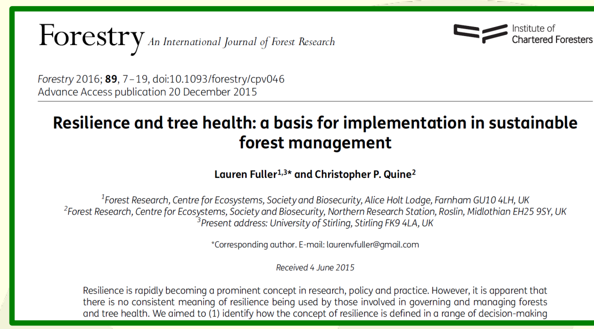
Future-Proofing Plant Health

- 5-year Defra-funded project to provide evidence for Tree Health Biosecurity Strategy
- Resilience Work Package (JNCC, FR, Kew, NE)
  - Defining and implementing resilience (Fuller & Quine 2016, Forestry)
  - **Developing and using resistant trees**

Resilience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Resilience and tree health: a basis for implementation in sustainable forest management

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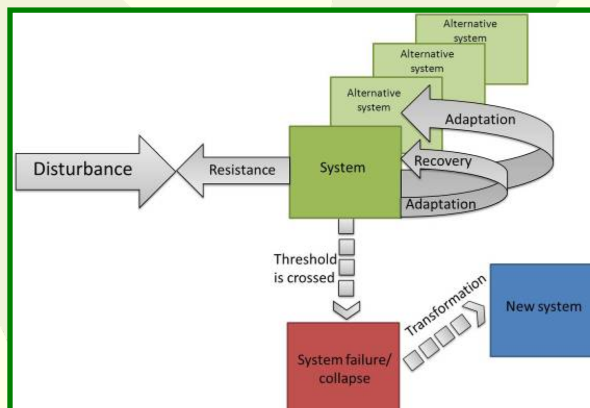
Resilience is rapidly becoming a prominent concept in research, policy and practice. However, it is apparent that there is no consistent meaning of resilience being used by those involved in governing and managing forests and tree health. We aimed to (1) identify how the concept of resilience is defined in a range of decision-making



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What is resistance?

- Qualitative resistance
  - Complete resistance, controlled by a single gene – e.g. some forms of rust resistance in white pine (Sniezko et al. 2014)
- Quantitative resistance
  - Partial resistance, usually multiple genes – e.g. *Dothistroma* resistance in Scots pine (Perry et al. 2016)
- Tolerance
  - Reduce the impacts of a given amount of damage – e.g. pitch canker in pine (Elvira-Recuenco et al. 2014)?

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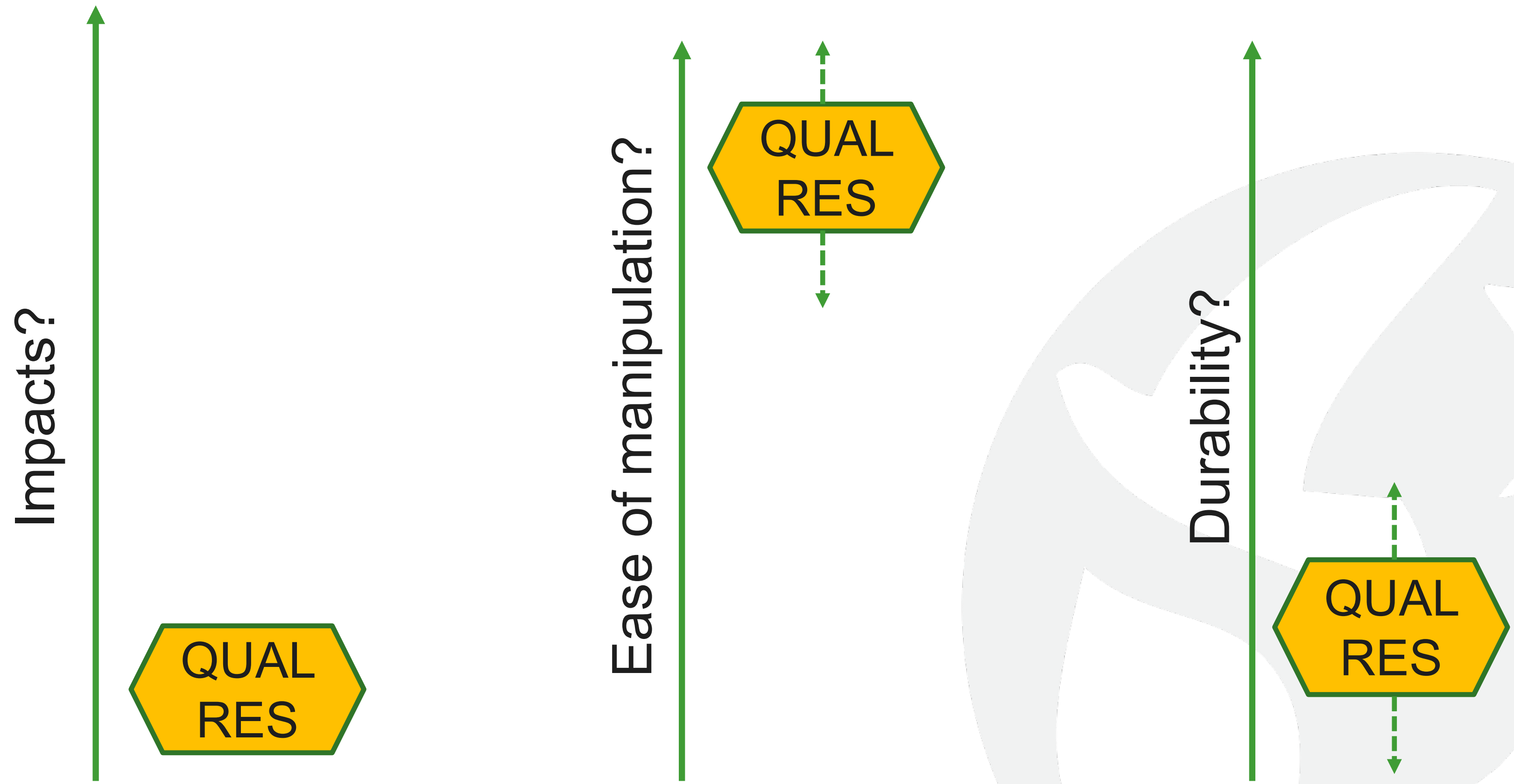
Resistance definitions matter



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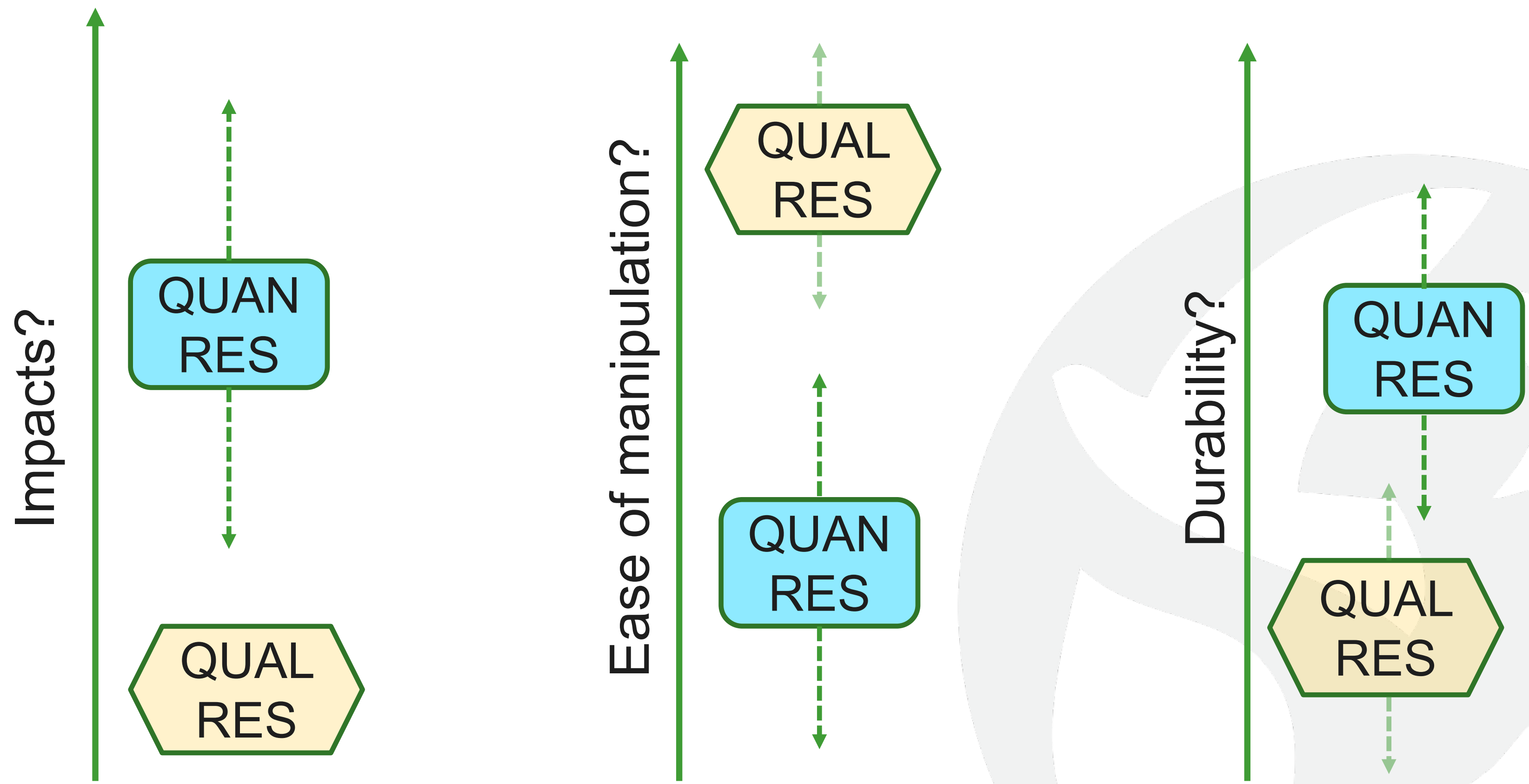

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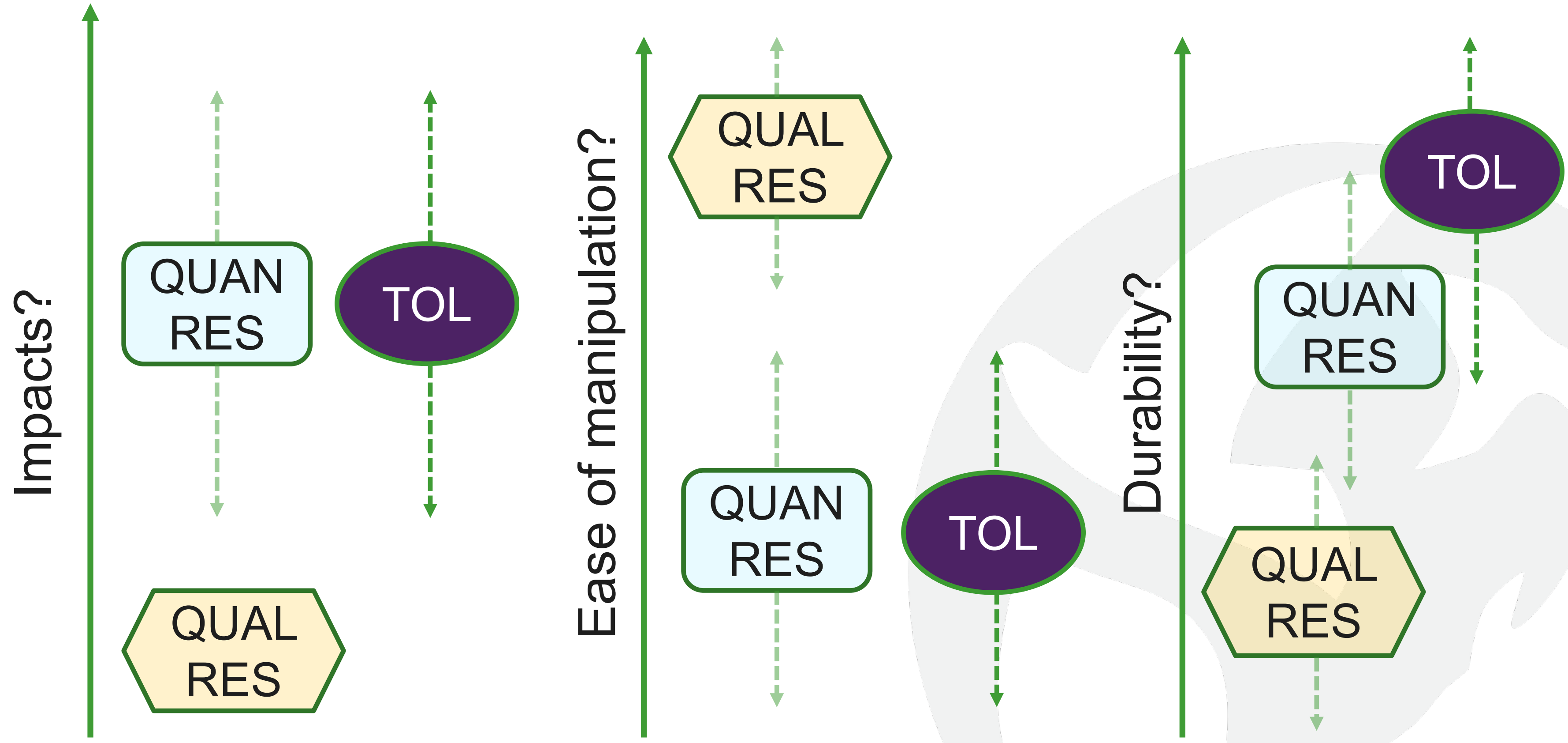

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Resistance definitions matter

- Practitioners and policymakers may also interpret terms differently

Need to be clear on how terms such as 'resistance' and 'tolerance' are being used

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Resistant tree programmes

- Programmes date back to (at least) early 1900s
- FAO (2011): 274 activities on breeding for resistance

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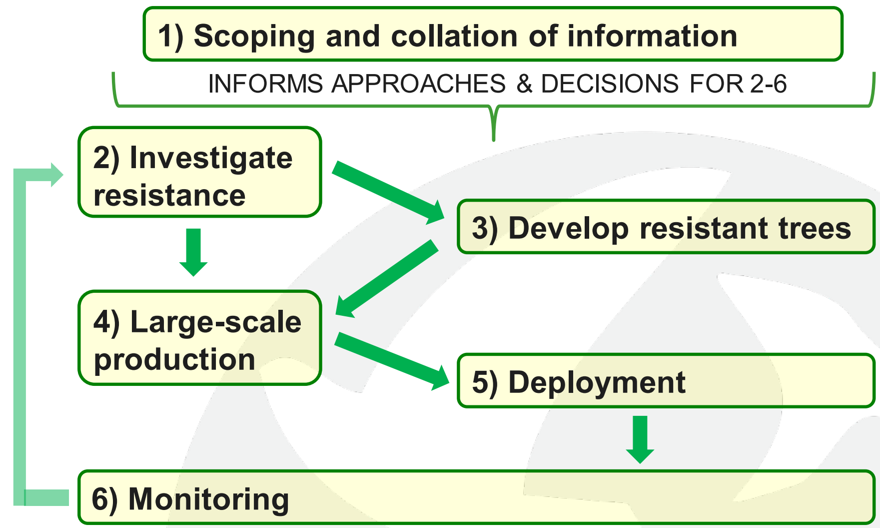
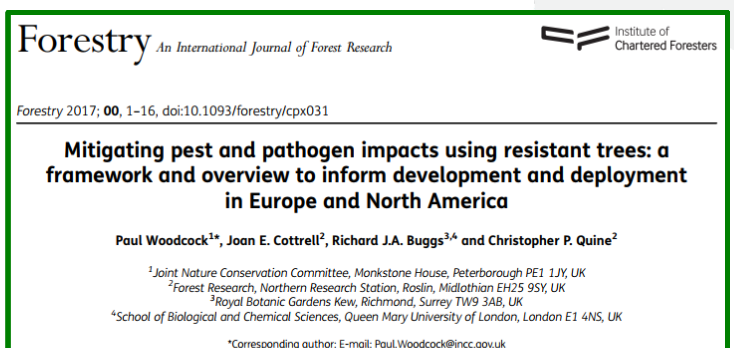
Developing and using resistant trees

- Substantial investment
  - What are the stages?
  - What are the options for each stage?
  - What are the risks and considerations?
  - What about alternative strategies?





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Mitigating pest and pathogen impacts using resistant trees: a framework and overview to inform development and deployment in Europe and North America

Paul Woodcock[1]*, Joan E. Cottrell[2], Richard J.A. Buggs[3,4] and Christopher P. Quine[2]

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1) Scoping

➢ TREE SPECIES

- Biology
- Ecological, economic, cultural importance

➢ PEST/PATHOGEN

- Spread rate, damage
- Outbreak stage
- Genetic variation

➢ OBJECTIVES AND CONSTRAINTS

- Economic? Ecological? Cultural?
- What resources are available?

2) Investigate resistance

FIELD SURVEYS

- Survey heavily affected areas
- Combine with other approaches – e.g. aerial imagery, citizen science

PLANTING TRIALS

- Plant a range of genotypes
- Use in areas containing the pest or pathogen
- Sometimes actively inoculate with pest or pathogen

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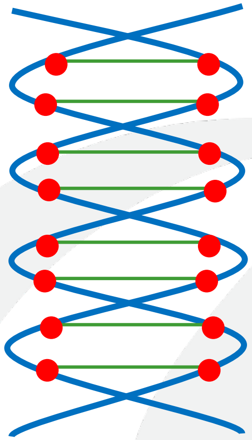
2) Investigate resistance

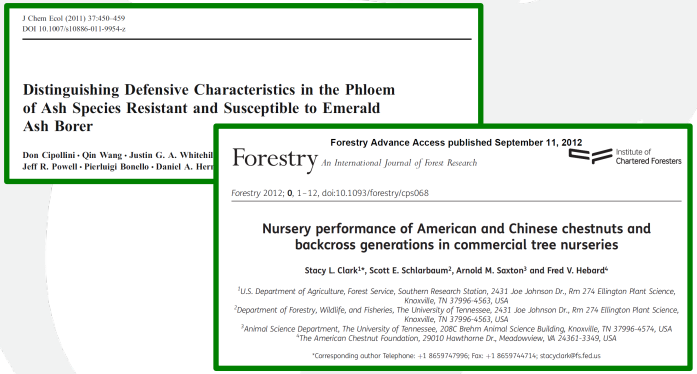
GENETIC SCREENING

- Identify genetic markers associated with resistance
- Increasingly used as DNA sequencing technology improves (e.g. Harper et al. 2016, *Scientific Reports*)



SCREENING OTHER SPECIES

- Understand options for developing resistant trees



J Chem Ecol (2011) 37:450–459
DOI 10.1007/s10886-011-9954-z

Distinguishing Defensive Characteristics in the Phloem of Ash Species Resistant and Susceptible to Emerald Ash Borer

Don Cipollini · Qin Wang · Justin G. A. Whitehil
Jeff R. Powell · Pierluigi Bonello · Daniel A. Herr

Forestry Advance Access published September 11, 2012
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Forestry 2012; **0**, 1–12, doi:10.1093/forestry/cps068

Nursery performance of American and Chinese chestnuts and backcross generations in commercial tree nurseries

Stacy L. Clark[1]*, Scott E. Schlarbaum[2], Arnold M. Saxton[3] and Fred V. Hebard[4]

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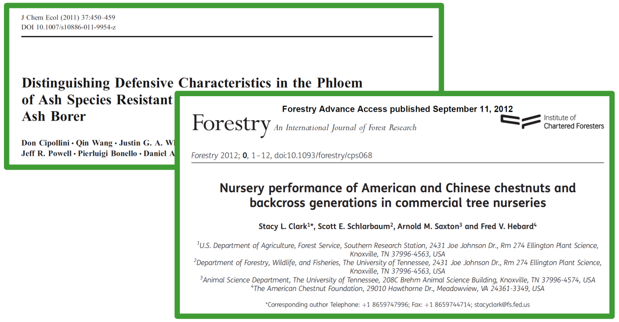
Which approach to use?

- Depends on objectives, resources, time, technology

FIELD SURVEYS

PLANTING TRIALS

RELATED TREE SPECIES



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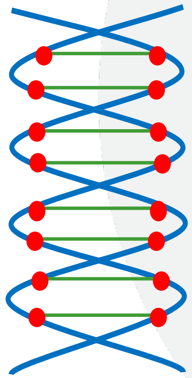
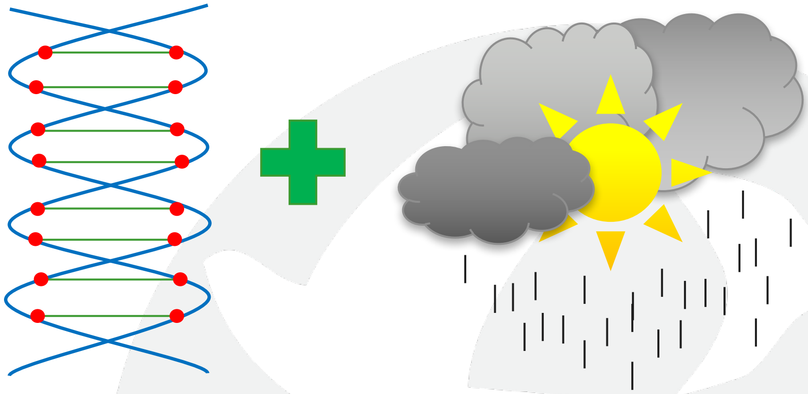
GENETIC SCREENING



The heritability of resistance

- Resistant tree programmes require heritable resistance
- Resistance depends on genetic + environmental effects, and expression can be influenced by e.g.
  - Stress
  - Climate and phenology



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3) Developing resistant trees

- **Natural processes** with *in situ* management
- **Conventional tree breeding**
  - Cycles of selecting and crossing phenotypically resistant trees
- **Molecular tree breeding**
  - Selection and crossing using genetic markers

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3) Developing resistant trees

- **Natural processes** with *in situ* management
- **Conventional tree breeding**
  - Cycles of selecting and crossing phenotypically resistant trees
- **Molecular tree breeding**
  - Selection and crossing using genetic markers
- **Hybridisation**
  - Introduce resistance by crossing with resistant species. Use backcrossing to recover traits of susceptible species
- **Genetic engineering**
  - Insert gene(s) from related species (cisgenics) or unrelated species (transgenics)

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3) Developing resistant trees

	+		−
NATURAL PROCESSES	Avoids large-scale planting	BUT	Relies on regeneration and heritable resistance
INTRASPECIFIC TREE BREEDING	Maintains affected species	BUT	Costly, time-consuming, needs heritable resistance
HYBRIDISATION	More flexible	BUT	Time-consuming, complex, controversial?
GENETIC ENGINEERING	Potentially very flexible	BUT	Complex and controversial

3) Developing resistant trees

- Valuable to consider…
  - Heritability and extent of resistance
  - Time and resources available
  - Acceptability for intended planting location
- Potential to combine approaches
  - e.g. Natural processes + conventional tree breeding

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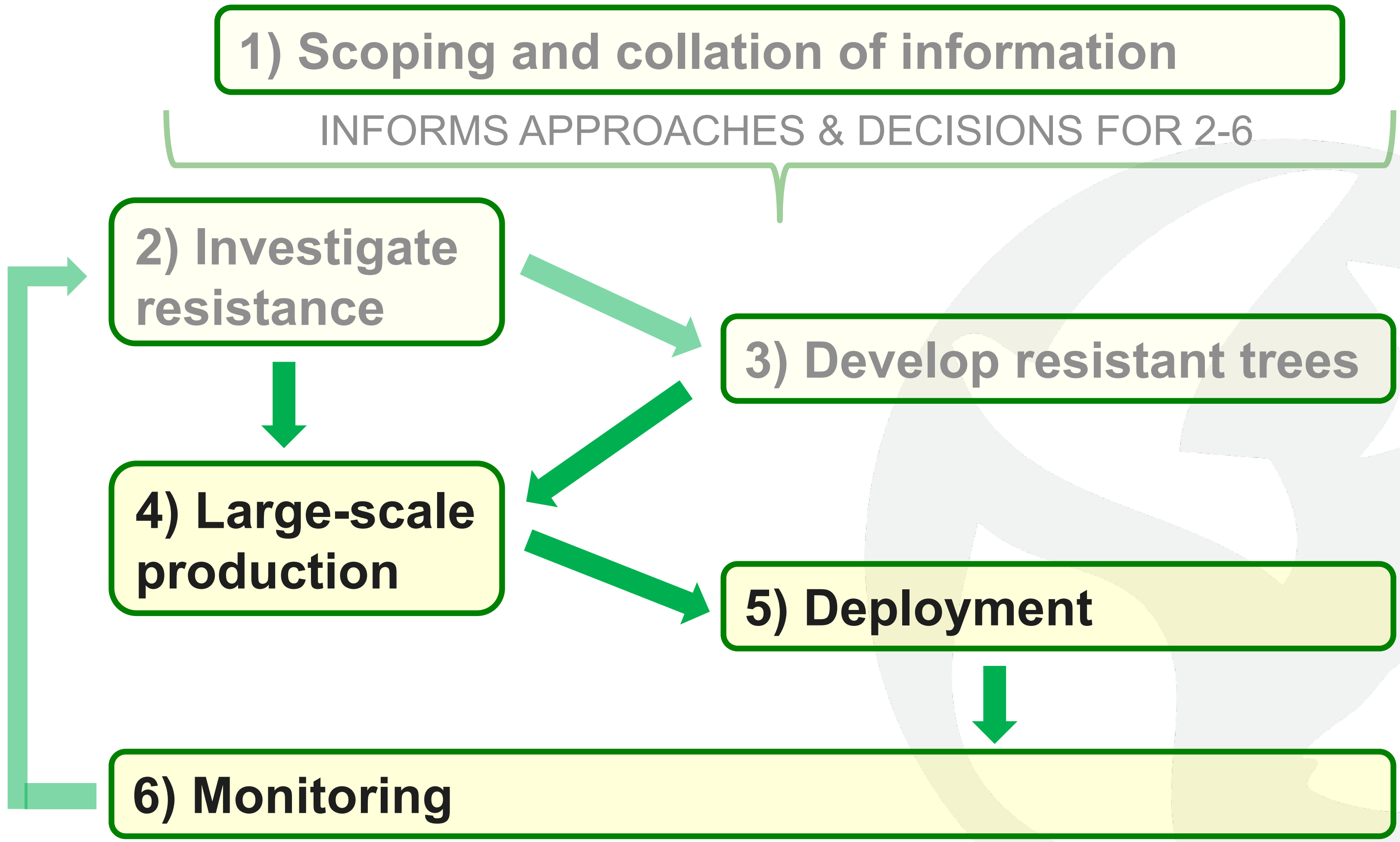
Overview


1) Scoping and collation of information
INFORMS APPROACHES & DECISIONS FOR 2-6
2) Investigate resistance
3) Develop resistant trees
4) Large-scale production
5) Deployment
6) Monitoring

4) Large-scale production

- Rely on natural processes
- Seed orchards to generate large amounts of material
  - **Seedling orchards** use offspring of selected parents from breeding programme or collected in the field
  - **Clonal orchards** use many individuals from selected genotypes (trade-off between using only the most resistant clones vs. retaining genetic variation).

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5) Deployment

- Natural processes, potentially with management

AND/OR

NON-TARGETED PLANTING
- Supply on request
- No formal planning of where to plant

AND/OR

TARGETED PLANTING
- Focus on particular locations
- Maximise benefits from resistant trees
- Environmental suitability

CONSIDERATIONS

5) Deployment

- Natural processes, potentially with management

AND/OR

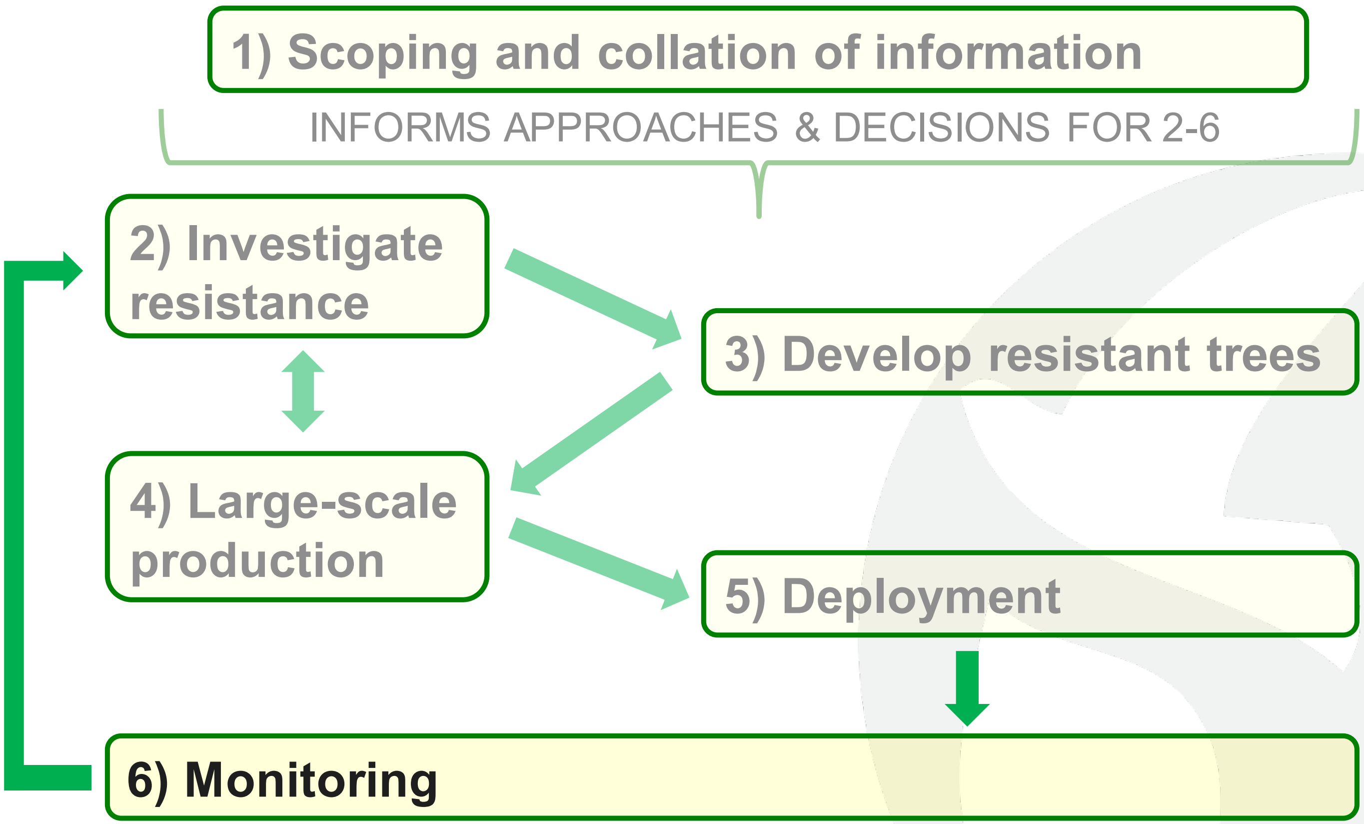
NON-TARGETED PLANTING
- Supply on request
- No formal planning of where to plant

AND/OR

TARGETED PLANTING
- Focus on particular locations
- Maximise benefits from resistant trees
- Environmental suitability

CONSIDERATIONS
- Genetic variation
- Population connectivity
- Costs of production and planting
- Availability of material
- Consequences of failure
- Incentives to support planting
- Silviculture

6) Monitoring resistant trees



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Risks of resistant tree programmes

BIOLOGICAL

- Impacts from other threats
- Loss of resistance
- Loss of genetic variation
- Other negative effects

SOCIAL

- Limited demand from growers
- Acceptability to public etc.
- Resources available
- Land availability

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Comparison of resistant tree programmes

- AMERICAN CHESTNUT-CHESTNUT BLIGHT
- SITKA SPRUCE-PINE WEEVIL
- ELM-DUTCH ELM DISEASE
- PINE-BLISTER RUST

OBJECTIVES

- Restore culturally important species (chestnut)
- Economic and ecological (White pine-blister rust)
- Economic value (Sitka spruce-pine weevil)

Comparison of resistant tree programmes

- AMERICAN CHESTNUT-CHESTNUT BLIGHT
- SITKA SPRUCE-PINE WEEVIL
- ELM-DUTCH ELM DISEASE
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INVESTIGATING RESISTANCE

- Planting trials and field surveys
- Some artificial inoculation or augmentation
- Very little natural resistance (chestnut, elm)
- Evidence for heritable resistance (spruce, pine)

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Comparison of resistant tree programmes

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- SITKA SPRUCE-PINE WEEVIL
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- PINE-BLISTER RUST

DEVELOPING RESISTANCE

- Direct use of field-collected material (spruce)
- Conventional tree breeding (spruce, pine, chestnut)
- Hybridisation (elm, chestnut)

Comparison of resistant tree programmes

AMERICAN CHESTNUT-CHESTNUT BLIGHT

SITKA SPRUCE-PINE WEEVIL

ELM-DUTCH ELM DISEASE

PINE-BLISTER RUST

DEPLOYMENT

- Use less resistant material as an interim measure (spruce)
- Limit in areas with high hazard (spruce, pine)
- Work with volunteers (chestnut)

Comparison of resistant tree programmes

- AMERICAN CHESTNUT-CHESTNUT BLIGHT
- SITKA SPRUCE-PINE WEEVIL
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- PINE-BLISTER RUST

PROBLEMS

- Developing resistance (chestnut, elm)
- Loss of resistance (some pine)
- Other pressures (chestnut, elm)
- Loss of confidence (elm)
- Land availability (pine, chestnut)

Summary of resistant tree programmes

- Timescales have been substantial (10-20 years+) and have involved sustained investment
- Successful programmes tend to have some central co-ordination
- Volunteer outreach and engagement can give substantial benefits

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Other strategies

- Using alternative native tree species to increase diversity
- Supporting populations of natural enemies
- Clearance of affected areas to restrict spread
- Use of insecticides/fungicides
- Better control/detection at borders

NEED TO CONSIDER IF AND HOW RESISTANT TREES COMPLEMENT OTHER APPROACHES

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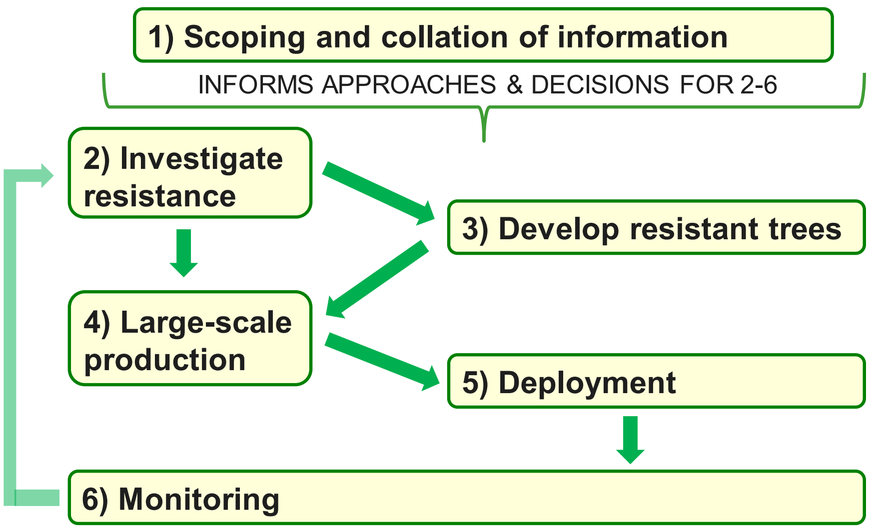
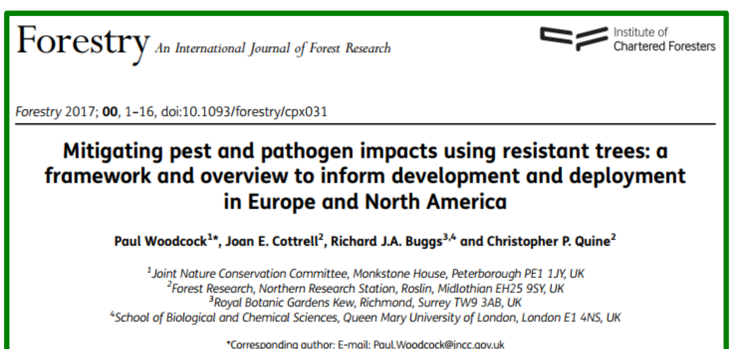
Conclusions



- Several options for each stage
- Approach should match the objectives and resources
- Resistant trees can be successful, **but** have needed substantial resources
- Stack resistant traits to increase durability?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Some literature I found useful...

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