Instrument to Evaluate and Assess Tree Resistance Breeding for Insects and Diseases – Forest Service Guide

The introduction of invasive insects and diseases into the US continues to increase corresponding to the amount of trade and travel throughout the globe. Similarly, native insects and diseases can cause serious damage when they are at epidemic levels or spread to new environments. Breeding resistance to insect and disease pests in host tree species can be an effective tool to help restore and maintain desired species and ecosystems on the landscape, contributing to a healthy and sustainable forest. Ideally, resistance breeding should be considered along with other integrated pest management tools such as biological control, chemical control, and silvicultural treatment. These tools are may be most effective in combination. As with all management tools, resistance breeding can be a long-term effort with many uncertainties. In addition to a significant time commitment, resources are often limited and managers need to make choices with a number of possible options, frequently without information on the probability of long-term success. It is with this in mind that a small group of entomologists, plant pathologists and geneticists in the Forest Service came together in 2018 at Placerville, CA to develop an assessment tool to help evaluate the merits of resistance breeding for a specific host tree species to a new or eminent insect or disease (pest).

This assessment tool is designed to pose a series of questions across four broad areas to assess the likelihood of resistance breeding appropriateness and success for a specific pest/host: 1) Impacts (both biological and socioeconomic), 2) Demand and Necessity, 3) Feasibility, and 4) Costs. The assessment is not meant to be exhaustive but to take stock of the current status and state of knowledge of a particular host/pest. Additionally, expert opinion will be critical in many assessment areas due to limited information and high uncertainty.

Interacting with field staff and other collaborators, a National Technical Working Group under the guidance of Forest Service Directors for Forest Health Protection, Forest Management and Sustainable Forest Management Research will determine if an assessment should be undertaken. The Working Group will form a small team of appropriate experts (usually 3 to 5 people) to conduct the assessment. The team will include at least an entomologist or pathologist and a geneticist with breeding experience. Assessment team members should not necessarily have a specific interest in the host/pest being assessed to minimize unwanted bias. The duration of the assessment should not be longer than one year (normally 3-6 months) including documentation of findings and a short report identifying key findings, gaps, and suggested recommendations. The assessment and report is not meant to determine policy or funding in itself, but should be used by decision-makers as one factor in making such determinations.

Once the assessment is completed, the report should be shared with Forest Service Directors for consideration and appropriate action. The findings should also be shared with other working groups within the agency dealing with insect and disease pests (STDP, EM, response framework committees, etc.) to aid their project rankings and decision making.

Assessment Instrument to Evaluate Potential for Successful Resistance Breeding for Insects and Diseases

Assume there is a known threat to a host species from an insect(s) or disease(s)

1. Impacts
    a. Biological
        i. Pests
            1. Is pest risk assessment or other information available?
            2. Has pest been introduced, if not what is risk of introduction?
            3. Probability of establishment?
            4. Spread potential (and/or to other host)?
            5. Reproductive potential?
            6. Host specificity and range (current and projected)?
            7. What is known about pest impacts on native host?
            8. Any information on surrogates (closely related pest/host models)?
            9. Life history?
        ii. Hosts
            1. How much damage/mortality (current and projected) and how soon (i.e. 99 % in 6 years)?
            2. Age of mortality (pre-reproductive age?) across age groups or limited?
            3. Does mortality vary across environments (i.e. with stress?)?
            4. Host silvics/life history?
                a. Density, rarity, distribution, habit on landscape?
                b. Probability of natural regeneration?
            5. CAPTURE analysis risk?
            6. Endangered or threatened species IUCN, US FWS?
    b. Ecological/Environmental
        i. Role of host in ecosystem (e.g. Keystone species, foundational, services)?
        ii. Other species (plant and animal) affected (i.e. TES)?
        iii. Impacts on sensitive habitat?
        iv. Role of environmental stressors (climatic variability)?
    c. Social
        i. Impacts on recreational opportunities?
        ii. Degree of public/stakeholder concern (i.e. highly valued species)?
        iii. Aesthetic value? (landscape species and/or forest)
    d. Cultural
        i. Does host Species have cultural significance (e.g. black ash basketry)
        ii. Does pest species have cultural significance (e.g. mistletoe & Douglas fir)
    e. Economic
        i. Does the host have significant commercial value?
        ii. Does the host have significant value to Urban Forestry?

iii. Does the host have significant value to Native Forest & Recreation sites (e.gs. NTFP's, recreation and tourism industry)

2. Demand/Necessity
    a. Number and types of trees/sites in need of restoration with resistant materials?
        i. Who is interested in the material (e.g. documented in plans)?
    b. Are other management strategies available? Degree of success (demonstrated or potential)?
        i. Biocontrol
        ii. Pesticide treatments
        iii. Silviculture
        iv. Cultural
    c. Public awareness/concern
    d. Alternative non-host species available to replace needs?
    e. Industry awareness/concern (e.g. Baseball bats, guitars)
3. Feasibility of successful resistance breeding
    a. Is species impacted by more than one insect/pathogen of concern?
        i. Potential impact/severity of other pest species and/or interaction?
    b. Timeline for resistance development
        i. What is the objective of resistance breeding (timber production, conservation, site mitigation, other services)
        ii. Appropriate genetic material availability?
        iii. What is known about resistance?
            1. Evidence of resistance exist in host of concern?
            2. Evidence of resistance to pest groups of concern?
            3. Is there effective screen for resistance?
            4. What type(s) of resistance?
            5. Degree/level?
            6. Frequency?
            7. Heritability?
            8. Durability?
            9. Does resistant material still spread pest?
        iv. Host silvics related to ease of breeding & propagation?
            1. Ease of vegetation propagation?
            2. Self- pollination vs outcrossing?
            3. Monoecious v. dioecious?
            4. Seed production cycle?
            5. Age to seed production?
            6. Seed storage potential?
        v. Available seed transfer guidelines/seed zones?
        vi. Are genomic/biotechnology tools necessary?
            1. Are genomic/biotechnology tools that can assist breeding available?
        vii. Are there regulatory constraints that would limit studies?
    c. IPM strategies available to augment resistance and vice versa?
    d. Available pre-existing infrastructure & capacity (e.g. skilled personnel) for breeding?

    e. Available pre-existing capacity to deploy resistance?
4. Cost of Resistance Breeding
    a. Cost to fill necessary gaps in knowledge
    b. Need/cost of new infrastructure & capacity?
    c. Need/cost of new capacity to deploy resistance?
    d. Cost/Benefit Analysis:
        i. Cost of resistance breeding vs. cost of economic impacts
        ii. Cost of resistance breeding vs. cost of other management options?
5. Consequence of no action

Other Considerations

Definitions

Resistance: the ability of an individual host to limit pathogen (insect) growth

- When resistance increases, incidence and severity of pathogen/insect or abiotic problem decreases
- Is a measure of the impact of the host on the pathogen/insect or abiotic problem

(Schneider & Ayres Nature Reviews in Immunology, 2008, 8(11):889-895)

Tolerance: the ability of an individual host to survive an infection (infestation) at a given pathogen (insect) load relative to a fully susceptible plant

- When tolerance increases, the impact on plant health decreases.
- Is a measure of the impact of the pathogen/insect on the host

(Schneider & Ayres Nature Reviews in Immunology, 2008, 8(11):889-895)

Susceptibility

Plant can be infected by a pathogen, fed on by an insect, or is negatively affected by an abiotic stressor

Vulnerability

Opportunities- partners/PR tool and/or- Feasibility- are there opportunities for this to work?

Economic/costs

Level/degree of resistance

Seed Transfer guidelines/seed zones

Seed zone is a geographic or ecological area/unit from which seed is collected, represents the origin of the seed

Eastern Seed Zone Forum http://eszf.sref.info/definitions and Forest Genetics book (White et. al. 2007)

Seed transfer guideline is instruction on how to match seed source to site, and how far the seed can be moved (distance wise) from its original zone/point of collection

Eastern Seed Zone Forum http://eszf.sref.info/definitions and Forest Genetics book (White et. al. 2007)

CAPTURE – (Conservation Assessment and Prioritization of Forest Trees Under Risk of Extirpation)

A modelling approach that groups similar tree species into vulnerability classes that may require different management and conservation strategies for maintaining the adaptive genetic variation (Potter, et. al. New Forests, 2017, 48(2):275-300).