Saving Southwestern White Pine trees from climate change and invasive pathogens

Climate change and invasive species pose a severe threat to worldwide ecosystems. The Southwestern White Pine (*Pinus strobiformis*), a species of five-needle pine, is vulnerable to both of these. **Dr Kristen Waring**, from Northern Arizona University and **Dr Richard Sniezko** (USDA Forest Service), are focused on conserving this species, mainly by developing resistant populations and silviculture (forestry) management strategies.

The importance of forest ecosystems cannot be underestimated. Not only are forests of great economic value, providing services and an income for many people, but they also provide habitats and food for wildlife, prevent soil erosion and act as a natural carbon sink – mitigating the effects of climate change.

However, forest ecosystems are becoming increasingly fragile and less stress-resilient as climate change and invasive species disrupt the ecological balance. One tree species that is particularly vulnerable is *Pinus strobiformis*, or the Southwestern White Pine (SWWP) as it is otherwise known. To help protect this species, Dr Waring and Dr Sniezko are working with a team to improve our understanding of the natural genetic resistance and environmental tolerance found in SWWP and how management strategies can be beneficially utilised.

THE EFFECT OF INVASIVE PATHOGENS AND CLIMATE CHANGE

SWWP is a five-needle white pine species, native to North America, with distinct populations found in western Texas, Arizona, New Mexico, southwestern Colorado, and Mexico. However, this species is susceptible to the lethal invasive fungal pathogen *Cronartium ribicola*, which causes white pine blister rust disease (WPBR).

Originally from Eurasia, this pathogen appeared in North America during the early 1900s. Being a wind-borne pathogen, *C. ribicola* spreads rapidly and today affects the majority of five-needle pines in North America. *C. ribicola* symptoms include yellow or red spots on the pine needles, dead branches and perennial cankers (lesions in the bark). Once infected, mortality from WPBR can exceed 95%.

Climate change further endangers SWWPs. It has been predicted that a hotter, drier climate, particularly in the south west of the USA will increase wildfire intensity and frequency. Wildfires can cause widespread damage – for example in 2011, over 8 million acres of forest were destroyed in the USA alone.

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Preventing climate change and the spread of WPBR is an almost impossible task. Therefore, Dr Waring and her research team are focusing on designing and developing risk mitigation strategies.

CURRENT MANAGEMENT STRATEGIES

A wide range of silviculture management strategies can be used to conserve SWWPs. For example, SWWPs are relatively fire resistant and 'prescribed fires' can reduce competing vegetation, thus encouraging SWWP regeneration.

Establishing risk management zones can also prove beneficial. *C. ribicola* only thrives when moisture levels and temperature are optimal.

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Left: Ethan Bucholz measuring tree physiology at White Pockets garden Right: Kristen Waring and Jessica DaBell look at likely triplets (three seedlings from one seed - close-up below)

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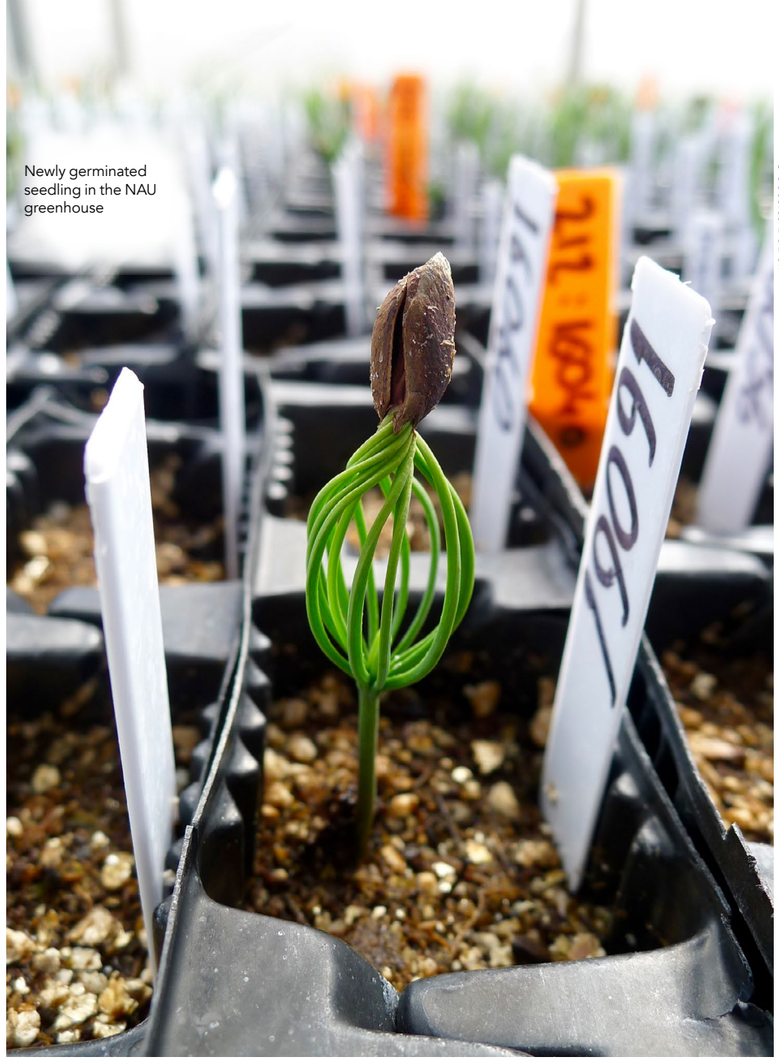
Risk zones can be developed by identifying locations that are conducive to these environmental requirements. The pathogen cannot be eradicated, but by identifying sites of low versus high risk management actions may vary accordingly, including identifying sites where planting seedlings with genetic resistance to white pine blister rust would be essential to any restoration efforts.

Additionally, the lower branches of SWWP provide an ideal microclimate for *C. ribicola* to prosper – therefore, pruning (cutting) lower branches can significantly reduce its spread. Not only that, but pruning rust-infected areas can also prolong the life of the pine.

However, these methods are only partially effective. Because of this, Dr Waring and Dr Sniezko are looking into alternative strategies, including an investigation into the natural genetic resistance of SWWP to WPBR.

Genetic diversity within any population is the foundation of natural selection, and resistance to invasive pathogens, wild fires and drought is variable within a population. Some SWWP individuals are more genetically resistant to disease and will survive, despite environmental stress. In fact, only a small percentage of SWWP have resistance and the frequency across the populations is currently being investigated. Only resistant individuals survive, and therefore genes corresponding to those beneficial adaptive traits will be inherited by future generations. As such, resistance will then spread throughout the population.



Newly germinated seedling in the NAU greenhouse

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TESTING FOR DISEASE RESISTANCE

Early work, starting in 2002 with relatively few seedling families of SWWP at Dorena Genetic Resource Center, had demonstrated that there was genetic resistance to WPBR. To further characterise the level of resistance to WPBR, its frequency and its geographic distribution, several inoculation trials involving seedlings from hundreds of parent trees from throughout the range of the species are being undertaken. Seedlings started in 2014, 2016 and 2017 are being grown for two years and then inoculated with WPBR spores. The trials will each be assessed for up to five years to document the level and types of resistance present in different populations.

ENVIRONMENTAL TOLERANCE

To determine how different SWWP populations respond to increased temperature, Dr Waring and her colleagues used an experiment that naturally simulates global warming.

SWWPs naturally inhabit a range of elevations. The higher the elevation, the cooler the temperature. The research team showed that seedlings growing in lower elevation gardens have a higher mortality rate than those grown in high elevation gardens. These first-year results suggest that the survival of southwestern white pine may be threatened by increased temperatures associated with climate change.

However, despite these higher mortality rates, seedlings grown at low elevations actually showed an increased tolerance of higher temperatures. The results of this study demonstrate that SWWP has the ability to adjust leaf architecture in ways that increase water use efficiency, enabling them to tolerate higher temperatures.

Dr Waring and Dr Sniezko have greatly improved our understanding of the natural resistance of Southwestern White Pine populations to both increased temperature and white pine blister rust

Q&A

Why is it important to conserve the Southwestern White Pine (SWWP)?
Conserving SWWP will help maintain the biodiversity of mixed conifer forests, ensure ecological function is also conserved, and provides important wildlife habitat (birds and small mammals feed on the large seeds).

Why can invasive pathogens be more harmful than native pathogens?
Since they did not co-evolve together, there is often little or no natural resistance to non-native pathogens (whether in plants, animals, or people) and forest pathogens such as white pine blister rust, chestnut blight and Dutch elm disease have had tremendous negative impacts on some of our native tree species.

How can current silviculture management strategies be improved to protect SWWP?
There are two management strategies that are likely to help. First, ensuring large SWWP have enough resources to reproduce and are at lower risk of dying from wildfire or insect attacks. Generally, this means reducing the number of trees in the stand. Second, we can manage for more regeneration (young trees) to increase the speed at which natural selection against susceptible trees occurs and allow resistant trees to grow into older trees that reproduce.

How might genetic resistance be transferred to all vulnerable SWWP?
The key will be to document the level and frequency of genetic resistance that exists in the different parts of the geographic range of SWWP. At that point, decisions can be made to either collect seed from the rare resistant trees in the field, or to develop seed orchards by grafting these parent trees (or some of their resistant progeny) into seed orchards. In both cases, the idea will be to greatly raise the natural frequency of resistance while maintaining the genetic variability of the species and its adaptability to the different environments in which it will be planted.

We envision ... a model system for other species facing similar threats

Where will your research focus be over the next five years?
Over the next five years, we will continue to address similar questions related to different aspects of the genetic variation that exists within the species, its resistance to WPBR, and its potential future under a changing climate and the presence of a non-native pathogen, while adding to our understanding of how the genetics of southwestern white pine vary across the landscape and how the distribution of the species may change under different climate change scenarios. As we collect additional data, our predictions will be better. We also envision Southwestern White Pine and our research programme serving as a model system for other species facing similar threats.

FUTURE CONTROL STRATEGIES

Overall, the research of Dr Waring and Dr Sniezko has greatly improved our understanding of the natural resistance of SWWP populations to both increased temperature and WPBR. Further research is needed to identify the specific genetic and molecular mechanisms that enable resistance and tolerance. Within the group, other PIs are focused on epigenetics, remote sensing, SWWP genomics, and landscape genetics. Once determined, selective breeding of SWWP could potentially be used to increase resistance throughout SWWP populations, providing pines with the defences to protect themselves against the destructive powers of invasive pathogens and climate change.

Detail

RESEARCH OBJECTIVES

Dr Kristen Waring's research focuses on silviculture and applied forest health. Her latest project involves a collaborative effort, alongside Dr Richard Sniezko and other collaborators, to develop tools capable of conserving a tree called the Southwestern White Pine, a species native to both the SW US and Mexico.

FUNDING

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COLLABORATORS

For full list visit: http://bit.ly/2sgVF2g
Co-PIs on the NSF-funded project: Dr Richard Sniezko, USDA Forest Service Dorena Genetic Resource Center; Dr Amy Whipple, Northern Arizona University; Drs Chris Still and Michael Wing, Oregon State University; Dr Andrew Eckert, Virginia Commonwealth University; Dr Sam Cushman, USDA Forest Service Rocky Mountain Research Station; Dr Lluvia Flores-Renteria, San Diego State University; Dr Christian Wehenkel, Universidad Juarez del Estado de Durango, Durango, Mexico

BIO

Kristen Waring is a forest scientist who studies applied forest health issues. She is passionate about finding management solutions for forest health problems, including invasive species and climate change. She loves the outdoors and spends her free time exploring the world around her.

CONTACT

Kristen M Waring, PhD
Associate Professor of Silviculture
School of Forestry
Northern Arizona University
Flagstaff, AZ 86011, USA
E: Kristen.Waring@nau.edu
T: +1 928 523 4920
W: nau.edu/cefns/forestry/faculty-and-staff/directory/waring/