Ecological Restoration Institute

***Fact Sheet**: Genetic Considerations for Restoring Forests of the Southwest After Severe Disturbance*

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NORTHERN ARIZONA UNIVERSITY
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Genetic Considerations for Restoring Forests of the Southwest After Severe Disturbance

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INTRODUCTION

Climate change models predict increases in temperature and more frequent severe droughts and forest fires in the Southwest United States (Garfin et al. 2013). Aridity stress to forests caused by climate change will be especially severe in forests and woodlands of the Southwest because productivity is already strongly limited by low precipitation and humidity (Williams et al. 2013). Intense drought predisposes trees to disease and insect attack, such as bark beetles that have killed many trees in the Southwest in the last two decades (Raffa et al. 2008, Gaylord et al. 2013). Climate warming and fuel buildups in the Southwest are increasing wildfire -caused deforestation (Williams et al. 2010, Williams et al. 2013). There is a high risk of conversion of ponderosa pine forests to grassland or shrubs when intense burning, drought, or bark beetles cause high tree mortality, create large openings, and kill local tree seed sources (Roccaforte et al., 2012). Future increase in drought intensity caused by climate warming will reduce opportunities for ponderosa pine regeneration after deforestation (Savage et al. 2013). Moreover, climate-envelope models predict substantial shrinking of the range of ponderosa pine in the Southwest over the next century, especially at low-elevations (Rehfeldt et al. 2014).

Figure 1. Ponderosa pine seedlings planted in a high-severity burn patch in northern Arizona. *Photo courtesy of Elwood Rokala, Kaibab NF*

Active reforestation by tree planting is being considered to promote recovery of southwestern forests following deforestation. Planting can help perpetuate forest cover that is required on National Forest lands, as mandated by the National Forest Management Act of 1976. It can also promote carbon sequestration, clean water, and other forest benefits. Tree planting provides an opportunity to actively mitigate the negative impacts of climate warming on forests by establishing tree genotypes that are better adapted to warming and aridity than current populations (Marris 2009, Williams and Dumroese 2013). There is increasing evidence that tree populations located at low elevations or southern, dry edges of species ranges will become maladapted to local climate during the next century (Rehfeldt et al. 2014). Recent reports of range contraction at southern and low-elevation edges of tree species distributions strongly suggest that this maladaptation is already occurring in some regions (Allen and Breshears 1998, Lavergne et al. 2010, Fellows and Goulden 2012).

The purpose of this fact sheet is to explain the need for using emerging knowledge about climate change and tree genetics to guide post-disturbance restoration of ponderosa pine in the Southwest.

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State of Knowledge

- *Current tree planting on southwestern federal lands after intense burning (195–1,560 acres year^{-1}) is small compared with estimated needs of 140,000 acres as of 2014*:
    - ◊ Most plantings are conducted by hand at densities from 100–560 trees acre^{-1} on a relatively even-spacing.
    - ◊ Seed is gathered from local seed zones established by Schubert and Pitcher (1973).
    - ◊ Planting of non-local species and populations is currently discouraged.
    - ◊ Planting sites are selected according to need (typically areas with less seed source), accessibility (often closer to roads), and funding.
- *Genetic selection for planting*:
    - ◊ Natural selection has produced populations that are pre-adapted for future arid sites in other conifers, such as Aleppo pine (Taibi et al. 2014), Douglas-fir (Bingham and Simard 2013), and lodgepole pine (Marris 2009).
    - ◊ Past recommendations to use local seed sources of ponderosa pine for planting in the Southwest (DeWald and Mahalovich 2008) were based on tests of widely separated geographic sources planted almost a century ago during cooler, wetter periods.
        - ♦ New recommendations for southwestern ponderosa pine call for the use of non-local arid-adapted genotypes in reforestation projects. For example, planting of populations from elevations 1,500 feet lower in elevation than the planting site is recommended to provide the stand with genotypes better adapted to climate in 2060 (Rehfeldt et al. 2014).
        - ♦ New recommendations are consistent with well-documented evidence for genetic differences among pine populations located at different elevations and soil types within a region (Cobb et al. 1994, Rehfeldt 1993, Rehfeldt et al. 2014). These genetic differences within a region, also termed fine-grained genetic adaptation, suggest the current existence of populations that are pre-adapted for the more arid environments that will occur in the future.
        - ♦ Fine-grained genetic variation in aridity adaptation is likely in southwestern ponderosa pine because of the wide range of elevations, mean annual temperatures, and soil types where the species currently grows (Figure 1).

Low-elevation cinder

Low-elevation basalt

Low-elevation sedimentary

Mid-elevation basalt

High-elevation basalt

Figure 1: Ponderosa pine forests in northern Arizona occur at elevations ranging from 5,500 to 9,500 feet, mean annual temperatures between 42 and 55 degrees Fahrenheit, and soil types derived from several parent materials that differ in water availability.

- *Research needs*:
    - ◊ More investigation of genetic variation in aridity adaptation in southwestern ponderosa pine is needed to advance the use of genetic approaches as a strategy for mitigating climate change impacts.
        - Older field common-garden comparisons of broadly distributed seed sources need to be supplemented by short-term common-garden experiments in environments designed to evaluate impacts of climate change.
        - New experiments should specifically test for fine-grained genetic variation in aridity adaptation.
        - Mechanisms that promote aridity adaptation, such as specific leaf and wood structures, should be investigated to refine identification of arid-adapted populations.
        - New genomic tools offer the opportunity to link tree genes with aridity adaptation in order to better understand mechanisms of adaptation (Sork et al. 2013).
        - Flexible seed sourcing guidelines need to be investigated for forest plantings in the Southwest (e.g., related local, composites, admixtures; Williams et al. 2014).

CONCLUSIONS

Planting may become more important in coming years to reforest an increasing area disturbed by severe wildfire and drought. As climate change models show increasing aridity for the Southwest, current locally adapted populations of ponderosa pine may become maladapted to current sites. Seedlings from more arid-adapted populations may promote forest recovery from disturbance during future warming and drying. More research about genetic variation in aridity adaptation of ponderosa pine is needed in order to develop genetic-based strategies to mitigate climate change impacts on southwestern forests.

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