Coast redwoods with signs of past drought stress make new needles that have modified hydraulic structure by reducing surface waxiness

FOTAKIS, E.[1] (presenting author), DIAZ, G.[2], GANESH, A.[1], GRABBE, B.[3], LEMAS, M.[1], McCARTHY, T.[1], WALTERS, L.[4], ZARZA, M.[1] and GEARY, M.*[1]
* michelle.geary@westvalley.edu (to whom correspondence should be addressed)

Coast redwoods recovering from drought stress are constructing needles that optimize water uptake over CO2 uptake

Less wax correlates with greater fog uptake

Sprout needles from stressed trees have less wax than their own canopy needles or than any needles from unstressed trees

Introduction

Coast redwoods are resilient after fire and flood, yet they are predicted to see significant range shifts with climate change[1]. Monitoring of responses among planted, urban and semi-urban redwoods may give us insights into the future. Our previous study showed drought-stressed redwoods at West Valley College began recovery when the atmospheric rivers of winter 2022-2023 ended the prevailing drought[2]. We hypothesized that recovery might show plant responses including changes in needle structure related to improving water uptake, since coast redwoods can absorb fog water through their needles[3].

Study Background

Coast redwood needles have high phenotypic plasticity, and needle traits depend in part on relative position on the tree. Increased height correlates with hydraulic constraints that affect needle development, and overall water status is critical for needle development[4].
Stomatal density and needle wax fraction are two of the traits most correlated with coast redwood water uptake[5].
As part of our drought recovery study on our campus[2], we wanted to assess new needles on trees that had been visibly affected by drought conditions in 2019-2022. Changes in needle characteristics might change rates of water uptake or CO2 uptake.

Methods

Needles were collected in summer 2024 from an avenue of planted, non-irrigated redwoods on West Valley College campus in Santa Clara County. We collected from both lower canopy branches and stump sprouts, and designated exposure as sun/exposed or shade. Each tree was assessed as healthy or stressed; many stressed trees showed signs of recovery, such as new needles on trunks and branches.
We evaluated stomatal density and wax fraction in the needles. The needles we collected were post-drought, forming and fully expanding during spring 2024.
We used the wax fraction analysis technique outlined in Chin et al. 2023[5] and a modification of their stomatal density protocol. For wax fraction analysis we took digital microscope photos of needle undersides. For stomatal density we took photos of nail polish peels of those abaxial (lower) needle surfaces. Both the wax fraction and the stomatal density photos were analyzed using ImageJ.
(Use the QR code to read more about our methods.)

Results

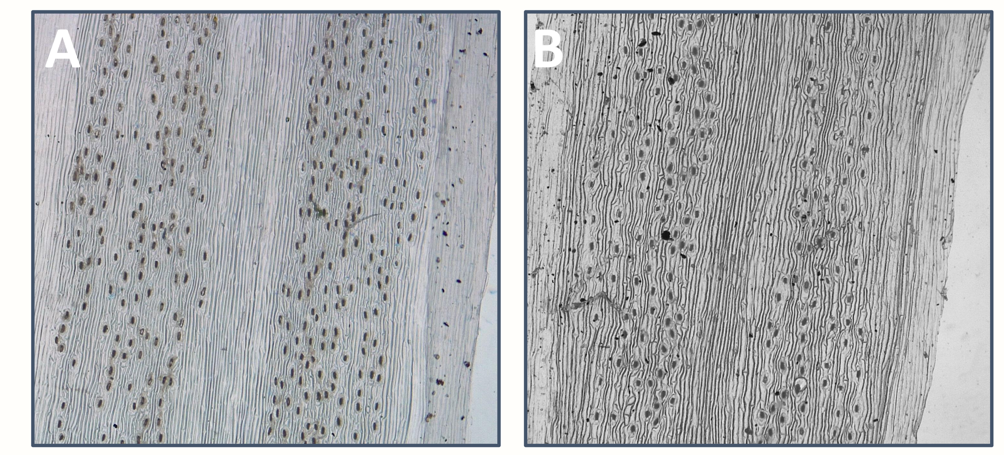

Fig.1 A & B: *Examples of the variation in stomatal density between different needles, with high (A) & low (B) density.*

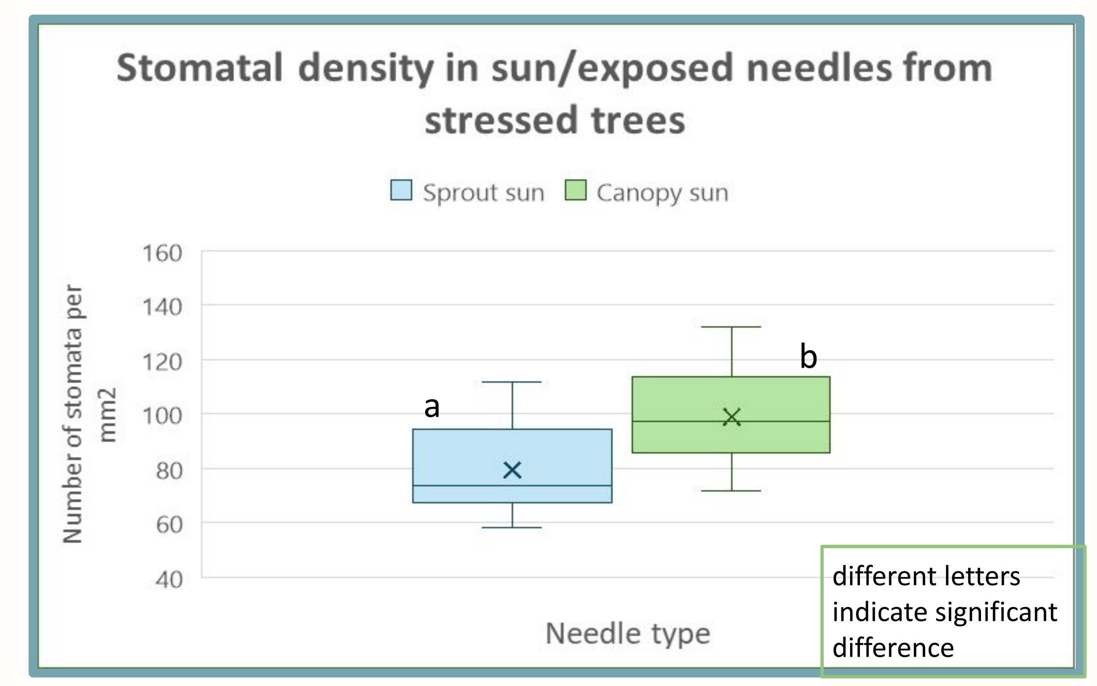

Fig.2: *Box-and-whiskers plot: sprout needles in stressed trees had lower stomatal densities than canopy needles.*

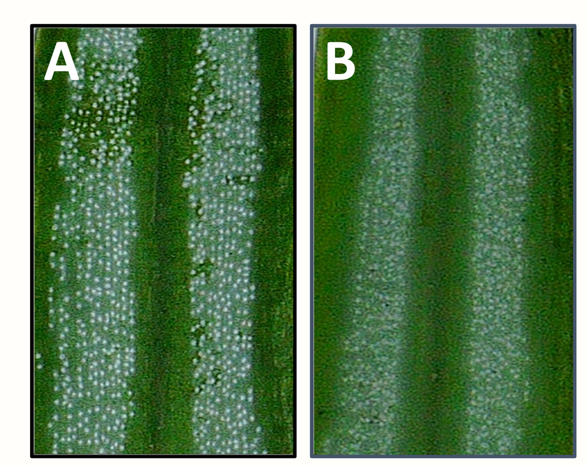

Fig.3 A & B: *Examples of abaxial wax fraction variation between different needles, with high (A) & low (B) wax levels*

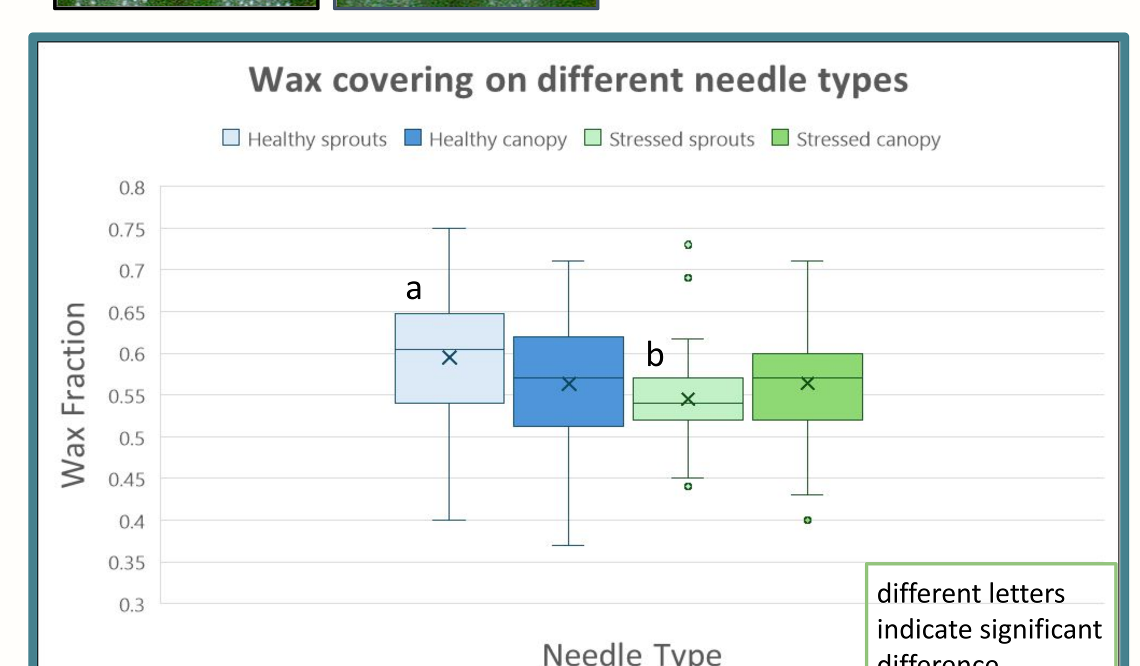

Fig.4: *In healthy trees, sprout needles were waxier than canopy needles; pattern reversed in stressed trees (Student's T, both p< 0.03). Stressed tree sprout needles had the least wax (ANOVA, F-stat = 5.19, overall p< 0.02, not all differences highlighted).*

Discussion

Stomatal density was highly variable, but patterns emerged. Lower canopy needles had more stomata per area than sprout needles in both healthy and stressed trees; this pattern was more significant when comparing needles that had developed in more exposed locations rather than in shade. The lowest stomatal densities were in sprouts from stressed trees. Abaxial wax fraction results also showed differences, but the pattern differed between healthy and stressed trees. In healthy trees, sprouts were waxier, but sprout needles were *less* waxy than canopy needles in the stressed trees.
This study has been challenging, in part because the analysis techniques may allow user variation on top of needle variation and understanding relationships between needle structures and hydraulic uptake is not straightforward. We developed SOPs to reduce user to user variation. We piloted a modification of the original stomatal peel method (see QR code) and introduced a measurement (wax half-fraction) that may be useful to differentiate stomatal from non-stomatal wax.

Fig. 5 A & B: *tree photo of lower canopy (A) versus photo of sprouts coming from the trunk (B).*

Conclusion: next steps

Our results suggest that redwood trees recovering from significant drought stress are 1) constructing new needles with differing characteristics, and 2) building sprout needles specifically with characteristics that correlate with enhanced water uptake rather than CO2 uptake.
Future directions include testing patterns of variability in stomatal density and waxiness in stressed trees, as well as determining if epicormic needles in general (needles growing from buds elsewhere along the trunk, not just at the base) have phenotypes that optimize water uptake.

West Valley College

MESA USA

See our sister team's poster (Poster 2) to learn about redwood seedling regeneration in challenging parts of the species range

For more information, including full abstract, author names and affiliations, literature cited, and supplemental data and discussion:

SCAN ME