Correlation Between Freezing Sites and Xylem Vessel Diameter for Three Chaparral Species of the Santa Monica Mountains

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Coastal exposures of the Santa Monica Mountains rarely experience freezing temperatures (0°C) because of the ameliorating effects of the Pacific Ocean and seashore’s specific heat capacity. In contrast, inland sites of the Santa Monica Mountains frequently experience winter temperatures below -10°C. This temperature gradient, from coast to inland, may be a major determinant of species distribution patterns. To investigate possible mechanisms by which freezing impacts chaparral distribution patterns, we examined xylem vessel diameter and vessel length of three chaparral species growing at inland freezing sites versus coastal nonfreezing sites (Malosma laurina, Umbellularia californica, and Ceanothus megalocarpus). It has been established that xylem size influences freezing-induced embolism and the blockage of xylem water transport from soil to leaves. However, it is not known if this “size effect” is primarily due to vessel diameter, vessel length, or both. We initially hypothesized that matched species-pairs at non-freezing sites would have both longer and wider vessels than at freezing sites. We determined maximum vessel length by injecting air into stems at decreasing segment lengths and measured vessel diameters by using an ocular micrometer in conjunction with a light microscope. Sample sizes were six for each species pair. For all three species, mean vessel diameters were narrower at freezing than non-freezing sites (P < 0.05) ranging between 13 μm and 0.05 μm mean differences for C. megalocarpus to 20.4 μm mean differences for U. californica. In contrast, we found no significant difference in vessel lengths for any of the species-pairs (P > 0.05). We conclude that reduction in vessel diameter is more significant than reduction in vessel length for protection from freezing-induced embolism of stem xylem. Furthermore, limits in the genetic plasticity of some species to reduce xylem diameter may preclude their survival at freezing sites.

Introduction

Observations in the Santa Monica Mountains located in Malibu, California have shown that there are physical and physiological variations in the plants based on environment’s varying temperatures. Lower temperatures have been recorded at the bases of the hills due to heat being less dense than cold air. Significant differences in outside temperatures may be affecting plants. Plants on the lower ends of the hills are shown to have more red leaves because the increased quantity of red pigment, anthocyanin, became more apparent when the temperature decreased. Significant differences in outside temperatures may also be affecting the quantity of proteins and lipids in the leaves. Plants on the lower ends of the hills are shown to have higher quantities of lipids and proteins. Significant differences in outside temperatures may also be affecting the quantity of sugars. Plants on the lower ends of the hills are shown to have higher quantities of sugars. Hence, there are physical and physiological variations in the plants based on environment’s varying temperatures. Observations in the Santa Monica Mountains located in Malibu, California have shown that there are physical and physiological variations in the plants based on environment’s varying temperatures. Lower temperatures have been recorded at the bases of the hills due to heat being less dense than cold air. Significant differences in outside temperatures may be affecting plants. Plants on the lower ends of the hills are shown to have more red leaves because the increased quantity of red pigment, anthocyanin, became more apparent when the temperature decreased. Significant differences in outside temperatures may also be affecting the quantity of proteins and lipids in the leaves. Plants on the lower ends of the hills are shown to have higher quantities of lipids and proteins. Significant differences in outside temperatures may also be affecting the quantity of sugars. Plants on the lower ends of the hills are shown to have higher quantities of sugars. Hence, there are physical and physiological variations in the plants based on environment’s varying temperatures.

Methods

Using a random number generator, we selected six plants from each species in both non-freezing and freezing areas to collect samples from. We measured the diameter of branches using calipers and cut off three branch sections from each plant measuring between 7 and 9 millimeters. We stored the branch sections in water for protection from freezing-induced embolism of stem xylem. Furthermore, limits in the genetic plasticity of some species to reduce xylem diameter may preclude their survival at freezing sites.

Results

In the Santa Monica Mountains, locations in Malibu, the USFS determined that freezing will increase vulnerability to cavitation with increasing diameter. Species with smaller diameters have higher mortality rates due to the coagulation of gas bubbles that form, ultimately resulting in embolism, the blockage of water flow. We investigated possible mechanisms by which freezing conditions cause the water in the xylem of the plants to freeze causing gas bubbles to form, which ultimately results in embolism. Our results showed that non-freezing M. laurina will experience a 65% loss, and C. megalocarpus will experience a 48% loss. Their results also showed that non-freezing M. laurina will experience 95% productivity, and non-freezing U. californica will not experience any changes at all in non-freezing areas (Davis et al.). This publication reaffirms our results because non-freezing stems would have a higher chance of embolism due to their larger xylem diameters, whereas freezing stems would have a lower chance of embolism due to smaller diameters. Freezing stems have a lower percent cavitation because they have smaller diameters that are not as likely to have embolism than stems with larger xylem diameters. Therefore, from these results we can conclude that freezing conditions affect the chaparral plants’ abilities to transport the maximum amount of water throughout their vascular systems.

Conclusions

Coastal exposures of the Santa Monica Mountains rarely experience freezing temperatures (0°C) because of the ameliorating effects of the Pacific Ocean and seashore’s specific heat capacity. In contrast, inland sites of the Santa Monica Mountains frequently experience winter temperatures below -10°C. This temperature gradient, from coast to inland, may be a major determinant of species distribution patterns. To investigate possible mechanisms by which freezing impacts chaparral distribution patterns, we examined xylem vessel diameter and vessel length of three chaparral species growing at inland freezing sites versus coastal nonfreezing sites (Malosma laurina, Umbellularia californica, and Ceanothus megalocarpus). It has been established that xylem size influences freezing-induced embolism and the blockage of xylem water transport from soil to leaves. However, it is not known if this “size effect” is primarily due to vessel diameter, vessel length, or both. We initially hypothesized that matched species-pairs at non-freezing sites would have both longer and wider vessels than at freezing sites. We determined maximum vessel length by injecting air into stems at decreasing segment lengths and measured vessel diameters by using an ocular micrometer in conjunction with a light microscope. Sample sizes were six for each species pair. For all three species, mean vessel diameters were narrower at freezing than non-freezing sites (P < 0.05) ranging between 13 μm and 0.05 μm mean differences for C. megalocarpus to 20.4 μm mean differences for U. californica. In contrast, we found no significant difference in vessel lengths for any of the species-pairs (P > 0.05). We conclude that reduction in vessel diameter is more significant than reduction in vessel length for protection from freezing-induced embolism of stem xylem. Furthermore, limits in the genetic plasticity of some species to reduce xylem diameter may preclude their survival at freezing sites.

Discussion

Our original hypothesis stated that Malosma laurina, Umbellularia californica, and Ceanothus megalocarpus in freezing zones will have smaller xylem diameters compared to those in non-freezing zones. Our results supported our hypothesis, and showed that when freezing conditions do negatively affect these plants’ xylem diameters. Therefore, further research in this field has also shown similar results. Estimates show that the relationship between mean conduit diameters (nanometers) plotted against cavitation of frozen and non-frozen plant stems creates a curve that relates mean conduit diameter to cavitation (Davis et al.). When comparing our mean values for freezing and non-freezing M. laurina, U. californica, and C. megalocarpus to the published curve, we notice that the non-freezing plants have a higher mean value than the freezing subjects, and higher percent cavitation. Non-freezing M. laurina has approximately 98% cavitation, whereas U. californica has 100% cavitation and C. megalocarpus has 50% cavitation. Freezing M. laurina has 35% cavitation, whereas U. californica has about 35% cavitation and C. megalocarpus has 2% cavitation. Freezing M. laurina will see around a 64% loss in conductivity by freezing. U. californica will experience a 65% loss, and C. megalocarpus will experience a 48% loss. Their results also showed that non-freezing M. laurina will experience 95% productivity, and non-freezing U. californica will not experience any changes at all in non-freezing areas (Davis et al.). This publication reaffirms our results because non-freezing stems would have a higher chance of embolism due to their larger xylem diameters, whereas freezing stems would have a lower chance of embolism due to smaller diameters. Freezing stems have a lower percent cavitation because they have smaller diameters that are not as likely to have embolism than stems with larger xylem diameters. Therefore, from these results we can conclude that freezing conditions affect the chaparral plants’ abilities to transport the maximum amount of water throughout their vascular systems.

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