HYDRAULIC REDISTRIBUTION AND WATER MOVEMENT MECHANISMS IN GRAPEVINES

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Abstract:

Context and purpose of the study - Plants have been shown to redistribute water between root sections and soil layers along a gradient of decreasing water availability. One benefit of this hydraulic redistribution is that water can be transported from roots in wet soil to others in dry soil, delaying the onset of water stress and increasing root longevity in dry environments. Grapevines are thought to redistribute water laterally across the trunk from wet to dry portions of the root system. However, it is unknown whether the phloem contributes to such water redistribution. The objectives of the present study were: (1) to determine the pathways of water transport through the vine form wet soil areas to the dry areas; (2) to determine the potential phloem contribution to this water movement.

Material and methods - This study used deuterium-labeled water (^2H_2O) as a tracer of water movement. Own-rooted *Vitis vinifera* L. cv. Merlot grapevines were grown in three-way split root pots. One of the three compartments was irrigated with ^2H_2O and the other two were left to dry. The trunk in one of the dry compartments was girdled and the other one was left intact to distinguish xylem and phloem water movement. Xylem sap and phloem sap, trunk and root tissue, and soil samples were collected. Water from each sample was extracted via a cryogenic method and analyzed for deuterium enrichment (δ^2H).

Results - Following ^2H_2O supply to the roots, strong deuterium enrichment was found in both xylem and phloem sap collected from petioles. Moreover, the δ^2H values were significantly higher in root tissues and soil collected from the dry/intact compartment than in samples from the dry/girdled compartment. These results indicate water moves from roots in wet soil to leaves via the xylem and recycles from leaves to roots in dry soil via the phloem. This xylem-to-phloem redistribution in drought-stressed grapevines keeps roots in dry soil alive, as long as a portion of the root system has access to soil water. The success of irrigation strategies such as partial rootzone drying may be linked to this physiological process.

Keywords: Grapevine, Xylem, Phloe, Drought, Water Redistribution, Hydraulic Lift, Deuterium.

1. Introduction.

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Hydraulic Redistribution and Water Movement Mechanisms in Grapevines

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Hypothesis:

- Water redistribution from wet to dry roots in grapevines occurs via recycling of water to the leaves via the xylem and from the leaves via the phloem

Objectives:

- Determine the pathway of water transport through vines from wet soil area to dry areas
- Determine the phloem contribution to water transport

Abstract

Grapevines can transport water from roots in wet soil to roots in dry soil. The objectives of this research are: to determine the pathway of water transport from wet areas to dry areas in the soil; and to determine what, if any, contribution the phloem makes in this water transport. Our hypothesis is that water redistribution from wet to dry roots in grapevines is in part due to water movement to the leaves via the xylem and recycling from the leaves to the roots via the phloem. This study is using deuterium-labeled "heavy" water (^2H_2O) to track water flow. Own-rooted Merlot grapevines were planted in pots split three-ways. One of the three compartments is irrigated and the other two are left to dry. The trunk in one of the dry compartments is girdled and the other one is left intact to distinguish xylem and phloem water movement (girdling interrupts phloem transport). The results confirm our hypothesis. They show deuterium enrichment in both xylem and phloem sap. Moreover, the deuterium enrichment is higher in root tissues collected from the intact section compared with samples from the girdled section. This indicates that the phloem moves water from leaves to dry roots.

Introduction

Plant roots are the most important water channels that circulate water via soil-plant-atmosphere chain. The phenomenon of water transport via roots from moist soil area to the dry soil areas to dry soil area due to root and soil water potential gradients is known as "hydraulic lift" or "hydraulic redistribution" (HR) (1). Since in the process of HR, plants move water from wet roots to dry roots, it is thought that grapevines may redistribute water via the root/trunk xylem. However, it is unknown whether they also use the phloem to speed up water redistribution. It is necessary to study this process in more detail with the consideration of water availability, as it increases plant longevity. It was demonstrated that water is transferred laterally from wet roots to dry roots on the same vine (2), but specific role of phloem in this transportation has not been mentioned before.

Methods and Materials:

-Heavy water (^2H_2O) was used to study water transport through drought-stressed grapevines
-Three-year-old Merlot vines (Fig.1.) were grown in three-way split root pots (Fig. 2.)
-One of the three compartments was drip irrigated (wet)
-Two other compartments were left to dry
-Wet compartment was irrigated with ^2H_2O at the onset of drydown cycle of two dry compartments
-The trunk in one of the dry compartments was girdled (Fig.3.)
-Xylem and phloem sap (root pressure chamber (Fig.4.)) trunk and root tissue samples, and soil samples from each compartment, were collected (Fig.5.)
-Water from each sample was extracted via a cryogenic method (Fig.6.) and analyzed for deuterium isotope enrichment (δ^2H)

Figure 1. Vines in three-way split root pots

Figure 2. Three-way split root pot (wet, dry girdled and dry intact compartments)

Figure 3. Girdled trunk

Figure 4. Root pressure chamber

Figure 5. Samples: soil, trunk and root tissue

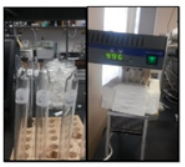

Figure 6. Water extraction from tissue and soil samples via a cryogenic method

Results:

- Deuterium was traced in both xylem and phloem sap, collected from the same petioles, which indicates water moves from the roots to leaves via xylem and recycles from the leaves to dry roots via phloem
- Soil and root tissue samples from dry intact compartment had significantly higher δ^2H values than samples from the dry girdled compartment (Fig. 7.), this indicates that water moves to dry roots through the phloem in addition to the xylem

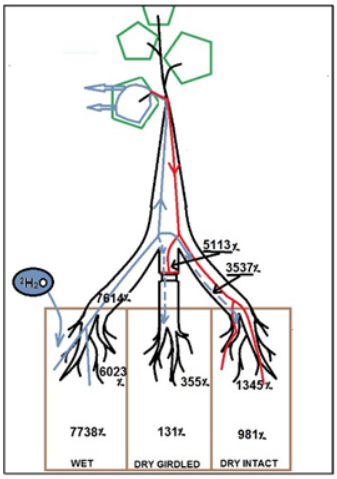

Figure 7. Difference in the δ^2H values in tissue and soil samples collected from wet, dry intact and dry girdled compartments of potted Merlot vines

Proof of Concept

To test the hypothesis that wate moves via xylem to the leaf and is recycling out of the leaf via phloem, leaf petioles were split in half. One part was fed with heavy water and the second was inserted in EDTA buffer to collect phloem sap (Fig. 8.).
The ^2H was traced in the EDTA buffer, which supports the hypothesis.

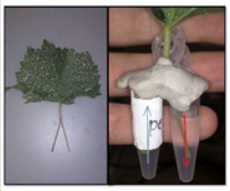

Figure 8. Split leaf petiole inserted in feeding and collection tubes, respectively

Conclusions

- Water moves from wet roots to dry roots partly due to water movement to the leaves via the xylem and recycling from the leaves to the roots via the phloem
- Xylem-to-phloem redistribution in drought-stressed grapevines keeps dry roots alive, so long as a portion of the root system has access to water somewhere in the soil
- Understanding hydraulic redistribution may allow for more insight into irrigation methods, such as partial root zone drying

References:

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