Trees Pull Water Up Rather Than Push It, and the Limit Is Set by Its Weight Plus the Resistance to Flow

— Atmospheric pressure can push a water column up only **10.350906** m, and capillary rise in a **40** μm conduit only **0.371846** m — the separator is whether water is pushed or pulled, and whether flow resistance is included — [Paper 794]

Yuuki YAMAGISHI (山岸 勇輝)
Yamagishi Complexity Torus Lab, Japan
September 2026

— From thinking to syncing. —

Abstract

That water reaches the tops of tall trees seems puzzling. A suction pump lifts water only about 10 m, and the capillary force of fine tubes falls short as well.Heights reached by pushing water and by pulling unbroken water under tension are derived, and the limit for pulling is counted from the sum of water weight and flow resistance.No new theorem or law is claimed. First, pushing does not reach——10.350906 m by atmospheric pressure, 0.371846 m by capillary rise in a 40 μm conduit (Section 2). **Second, pulling reaches as far as the tension allows ——for water unbroken up to 2 MPa, the limit without flow is 194.095452 m** (Section 3). **Third, and this is the core. The limit is set not by water weight alone but by its sum with flow resistance——at 40 μm and 1 mm/s, flow resistance is 0.511799 times the weight and the limit is 128.387070 m** (Section 4). **Fourth, in narrow conduits flow resistance exceeds weight——at 20 μm it is 2.047196 times the weight and the limit is 63.696407 m** (Section 4). **Fifth, the limit shifts greatly with how conduit width is arranged——a conduit narrowing to half its radius at the top with the same flow gives 57.282411 m** (Section 4). **Sixth, the separator is whether water is pushed or pulled, and whether flow resistance is included——"tree height is limited by the weight of water" has no truth value until one says which is meant** (Section 5). **Keywords**: tree height, cohesion-tension theory, negative pressure, cavitation, conduit flow resistance, capillary rise.

Scope of this paper (scope note): **No new theorem or law is claimed——the cohesion-tension theory that water in trees is pulled up unbroken under tension, the capillary rise formula, the flow resistance of narrow tubes (Hagen--Poiseuille), and water breaking into bubbles when it can no longer bear tension (cavitation) are all known (Tyree and Zimmermann 2002, Nobel 2009).Values are representative——breaking tensions of 1, 2 and 4 MPa, soil water at -0.1 MPa, conduit radii of 20, 40 and 80 μm and flow speeds of 0.5 and 1 mm/s are for comparison; applicability to any particular tree is not claimed.Only flow inside conduits——resistance of pits and conduit junctions, osmotic forces and repair after bubbles form are left out.The narrowing conduit is an extreme arrangement——it passes the same flow through one conduit ever narrower upward; how conduit numbers and widths are actually distributed is not treated.No real tree heights are claimed——which trees are how tall and why is not stated.Relation to earlier papers**: **Paper 309 showed that the length dividing gravity from surface tension is nobody's size, and counted that capillarity reaches only 0.74 m of a tree's height——its scope note stated that no plant physiology was built, the cohesion theory was not judged, and only the number showing capillarity to be insufficient was given. Here the next step, the limit when water is pulled, is counted from the sum of water weight and flow resistance.Paper 620 showed that a siphon's flow is set by the drop to the outlet and that its crest limit is 10.350906 m at 20 °C without vapour pressure——its scope note stated that whether water is "pulled" or "pushed" was not discussed. Here, inside a tree, the limit when water is pulled by tension is counted as many times that value.**What is added is **setting the two pushing limits (atmospheric and capillary) beside the pulling limit**, **deriving for six combinations of conduit radius and flow speed how many times the weight the flow resistance becomes and how far the limit falls**, **matching the limit by closed form and bisection**, and **placing the separator on push versus pull and on flow resistance**.

1. Notation and the Question

Setting: **let ρ be water density, μ viscosity, γ surface tension, r conduit radius, v flow speed, $|\psi_c|$ the tension at which water breaks, and $|\psi_{\text{soil}}|$ the tension of soil water. The two pushing limits and the pulling limit are as follows.**

$$h_{\text{atm}} = \frac{p_{\text{atm}}}{\rho g}, \qquad h_{\text{cap}} = \frac{2\gamma}{\rho g r}, \qquad h_{\max} = \frac{|\psi_c| - |\psi_{\text{soil}}|}{\rho g + 8\mu v / r^2}$$

The first term of the denominator is water weight, the second the flow resistance of the conduit. Take $\rho = 998.2$ kg/m^3, $\mu = 1.002 \times 10^{-3}$ Pa s, $\gamma = 0.0728$ N/m and $|\psi_{\text{soil}}| = 0.1$ MPa.

Question: **what sets the upper limit of tree height?**

2. Pushing

Computation 2.1: **the height reached by atmospheric pressure and the capillary rise in conduits of three radii (full wetting) were derived.**

means of pushing	height reached
atmospheric pressure (suction pump)	**10.350906** m
capillarity, radius **20** µm	**0.743692** m
capillarity, radius **40** µm	**0.371846** m
capillarity, radius **80** µm	**0.185923** m

> **Observation 2.2**
>
> **pushing does not reach the top of a tall tree.Atmospheric pressure gives 10.350906 m (the same value as the siphon crest limit in Paper 620), and capillarity even at 20 µm gives 0.743692 m (the same as Paper 309's 0.74 m)——a push from below has no room to carry water higher than that.**

3. Pulling

Computation 3.1: **the breaking tension was set three ways and the limit without flow derived.**

breaking tension	limit without flow
1 MPa	**91.939951** m
2 MPa	**194.095452** m
4 MPa	**398.406455** m

> **Observation 3.2**
>
> **pulling reaches as far as the tension allows.If unbroken water can be pulled to 2 MPa, it is lifted 194.095452 m even without flow——the limit is set not by a push but by how far water withstands being pulled.**

4. Flow Resistance

Computation 4.1: **at a breaking tension of 2 MPa, for six combinations of conduit radius and flow speed, the flow pressure gradient, its ratio to water weight, and the limit were derived. The limit by closed form and by bisection**

differed by 2.842×10^{-14} m.

radius	flow speed	flow pressure gradient	ratio to weight	limit
20 µm	0.5 mm/s	10020.000000 Pa/m	1.023598	95.916007 m
20 µm	1.0 mm/s	20040.000000 Pa/m	2.047196	63.696407 m
40 µm	0.5 mm/s	2505.000000 Pa/m	0.255900	154.546958 m
40 µm	1.0 mm/s	5010.000000 Pa/m	0.511799	128.387070 m
80 µm	0.5 mm/s	626.250000 Pa/m	0.063975	182.424844 m
80 µm	1.0 mm/s	1252.500000 Pa/m	0.127950	172.078100 m

Observation 4.2

this is the core: the limit is set not by water weight alone but by its sum with flow resistance.At 40 µm and 1 mm/s, flow resistance adds 0.511799 times the weight, lowering the limit from 194.095452 m without flow to 128.387070 m——tension is spent not only on lifting water but on keeping it flowing.

Observation 4.3

in narrow conduits flow resistance exceeds weight.At 20 µm and 1 mm/s it is 2.047196 times the weight, and the limit is 63.696407 m; at 80 µm the limit recovers to 172.078100 m——flow resistance is inversely proportional to the square of the radius, so conduit width moves the limit greatly.

Observation 4.4

the limit also shifts greatly with how conduit width is arranged.If a conduit of 40 µm at the base with 1 mm/s narrows to half its radius at the top while carrying the same flow, the limit becomes 57.282411 m——this is an extreme arrangement and the real distribution of conduits is not treated, but it shows how sensitive the limit is to conduit shape.

5. The Separator

> **Observation 5.1**
>
> **the separator is whether water is pushed or pulled, and whether flow resistance is included.Pushing gives 10.350906 m and 0.371846 m; pulling without flow gives 194.095452 m; including flow resistance gives 128.387070 m down to 63.696407 m——"tree height is limited by the weight of water" has no truth value until one says which is meant.**

> **Observation 5.2**
>
> **beside Paper 309.Paper 309 counted that capillarity reaches only 0.74 m of a tree's height, without judging the cohesion theory——here the limit when water is pulled is counted as the sum of water weight and flow resistance.**

> **Observation 5.3**
>
> **what is not said.Pit resistance, osmosis, bubble repair, the actual distribution of conduits and real tree heights are not treated——what is shown is that the limit is set by tension, which weight and flow resistance share.**

6. Roll Call and Closing

1. **10.350906 m by atmospheric pressure** (Computation 2.1): **the pushing limit.**
2. **capillarity 0.371846 m** (Computation 2.1): **radius 40 µm.**
3. **194.095452 m at 2 MPa** (Observation 3.2): **the pulling limit.**
4. **flow resistance 0.511799 times** (Computation 4.1): **added to the weight.**
5. **limit 128.387070 m** (Observation 4.2): **the core.**
6. **2.047196 times at 20 µm** (Observation 4.3): **resistance exceeds weight.**
7. **limit 63.696407 m** (Observation 4.3): **narrow conduits.**
8. **172.078100 m at 80 µm** (Observation 4.3): **wide conduits.**
9. **57.282411 m in a narrowing conduit** (Observation 4.4): **sensitive to shape.**

10. **push or pull; flow resistance** (Observation 5.1): **the separator; Paper 309.**

Closing: **Trees pull water up rather than push it, and the limit is set by its weight plus the resistance to flow.Atmospheric pressure pushes a water column only 10.350906 m and capillary rise in a 40 µm conduit only 0.371846 m, while unbroken water pulled to 2 MPa reaches 194.095452 m without flow——the limit is set not by a push but by how far water withstands being pulled.Flowing at 1 mm/s through 40 µm conduits adds flow resistance 0.511799 times the weight and lowers the limit to 128.387070 m; in 20 µm conduits the resistance is 2.047196 times the weight and the limit falls to 63.696407 m——lifting water and keeping it flowing share the same tension.The separator is whether water is pushed or pulled, and whether flow resistance is included.Placed among the earlier papers——Paper 309 counted capillarity as insufficient; this counts the limit when water is pulled.To be honest——values are representative, and neither pit resistance, nor conduit distribution, nor real tree heights are treated.**

References

1. Nobel, P. S. (2009). *Physicochemical and Environmental Plant Physiology* (4th ed.). Academic Press.
2. Tyree, M. T., & Zimmermann, M. H. (2002). *Xylem Structure and the Ascent of Sap* (2nd ed.). Springer.
3. Yamagishi, Y. (2026). *The Length That Divides Gravity from Surface Tension Is Nobody's Size* [Paper 309]. Zenodo. 10.5281/zenodo.22172337
4. Yamagishi, Y. (2026). *A Siphon's Flow Is Set by the Drop to the Outlet, and Its Limit by the Height of the Crest Above the Outlet* [Paper 620]. Zenodo. 10.5281/zenodo.23014514

— *From thinking to syncing.* —

Yuuki YAMAGISHI (山岸 勇輝)

© 2026 Yamagishi Complexity Torus Lab, Japan · Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0)