The Effects of Heat and Wind on Transpiration and Water Use in *Tagetes lucida.*

John Doe

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Dr. Mark Hart

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Abstract

The transportation of water against gravity is an important adaption of all plants. The cohesion-tenion theory has long been the accepted explanation for water transportation. The theory states that transpiration from leaves creates a negative water potential in leaves which draws water up from the roots by capillary action. This theory was tested by exposing *Tagetes lucida* samples to heat and wind treatments and measuring water use. At the end of one hour, the control plant had taken up .22 mL of water, the heat treatment had taken up .2 mL of water, and the wind treatment plant had taken up .25 mL of water. The difference between the control and the heat ($p < .005$) and the wind ($p = .05$) were both significant. The high water use in the wind treatment supports the cohesion-tension theory, while the low water use in the heat treatment suggests the heat actually resulted in closed stomata.

Introduction

Every organism requires water to survive. Water is a solvent that dissolves almost any substance, and many of the compounds necessary for life—including proteins, enzymes, and lipids—react to water in specific ways that make it possible for those molecules to fill their biological roles. One of the most important functions of water is to transport these necessary compounds and elements throughout an organism.

Due to its chemical structure, water has several unique properties that make it ideal for dissolving and transporting substances. Because of its polarity, water displays both adhesion (like molecules clinging together) and cohesion (unlike molecules clinging together), and cohesion leads to surface tension (the clinginess of molecules on the surface of a liquid). The combination of surface tension and adhesion leads to capillary action (the ability of water to travel against gravity up a narrow tube).

Plants use these properties to transport water from the soil to the leaves. In most plants, the roots of a plant absorb water from the surrounding soil, and capillary action moves water through long transport tubes called xylem. The cohesion-tension theory has long been the accepted explanation for the mechanism by which plants move water against gravity (Dixon-Joly, 1894). According to this theory, the loss of water through transpiration (the loss of water in leaves through evaporation) creates a pressure differential in leaves and causes water to effectively be pulled up from the roots.

Transpiration takes place through small openings in the leaf surface called stomata. Stomata are also the opening through which plants take in carbon dioxide, which means leaves much balance the need to open stoma and take in carbon with the need to close stoma in order to preserve water. Thus, the environment surrounding the leaves should impact a plant’s water use by changing the rates of transpiration. This experiment will measure the effects of heat and air movement on transpiration and water use. Because heat and air movement are known to increase evaporation, the authors hypothesis that both will increase transpiration and thus overall water use.

Materials and Methods

A potometer will be used to measure transpiration. A 1 mL pipette was inserted in one end of a 25 mL length of flexible plastic tubing. The tube was submerged in water until the tube and pipette were both filled, the later to the 1 mL mark. The tube was then bent into a U-shape, and clamped in place. The stem of a Mexican marigold (*Tagetes lucida*) was cut and inserted into one end of a flexible plastic tube. Petroleum jelly was used to create a water-tight seal. The leaf area of each plant was measured by tracing the leaves onto graph paper and calculating the area. This procedure was repeated to make three potometers.

The three potometers were placed on a bench in a sheltered area indoors. Plant #1 was placed under a 205 watt heat lamp. Plant #2 was placed in the path of a fan kept on a low setting. Plant #3 was the control.

The water level in the pipette was recorded for each treatment every five minutes for one hour. The final water use for each plant was found by subtracting the final pipette reading from 1 mL. The water use was normalized by dividing the total amount by the leaf area for each plant. The average rate of change of water use was found by averaging the change in water height over each five minute period.

Results

Over the course of one hour, the normalized water level dropped to .78 mL for the control, .8 mL for the heat treatment, and .75 mL for the wind treatment (see Fig. 1).

Fig. 1. Water height in mL for control, heat, and wind treatment.

At the end of the hour, the control plant had taken up .22 mL of water, the heat treatment, had taken up .2 mL of water, and the wind treatment plant had taken up .25 mL of water (see Table 1). The difference between the control and the heat ($p < .005$) and the wind ($p = .05$) were both significant.

Table 1. Water Use and Average Rate of Change.

Treatment	Water Use (mL)	Average Rate of Change (mL/min)
Control	.22	0.0037
Heat	.2	0.0033
Wind	.25	0.0042

The average rate of change for the control treatment was 0.0037 mL/min; for the heat treatment the rate of change was 0.0033 mL/min; and for the wind treatment it was .0042 mL/min. (see Table 1). The difference in the rate of change was not statistically significant ($p > .05$).

Discussion

As expected, the plants in all three treatments drew water from the pipette. Compared to the control treatment, the plant receiving the wind treatment took up more water. This can be explained by the cohesion-tension theory of water transport. Because the wind creates a constant negative water potential around the leaf, more water transpired from the stomata, which in turn created a negative water potential in the cells of the leaves. This potential drew water from the pipette and through the stem.

Unexpectedly, the heat treatment did not result in higher transportation. According to the cohesion-tension theory, the heat should have increased transpiration, resulting in more water use by the plant. In fact, the plant in the heat treatment used less water than the control. This could be because the heat lamp was not warm enough to increase transpiration, or heat might take longer than the one-hour observation time to affect transpiration rates. Another possible explanation is that the heat affected separate pathways that closed the stomata. For example, it's possible that *T. lucida* closes its stoma when exposed to high temperatures in order to conserve water (see Feller, 2006).

One possible source of error in this study is human error in observation, since the height of the water had to be visually estimated. It's also possible that different conditions throughout the room resulting from ventilation systems and windows affected transpiration.

In order to further explore the relationship between heat, wind, and water use, it will be necessary to test a range of temperatures to determine if the pattern observed in this study hold through a range of heat conditions. It would also be illuminating to repeat this study using different plant species, since plants adapted to different conditions will likely respond to the conditions differently.

Works Cited

Dixon, H, Joly. 1894. On the ascent of sap. Ann. Bot. 8: 468–470.

Feller, U. 2006. Stomata opening at elevated temperature: an underestimated regulatory mechanism? Gen. Appl. Plant Physiology. 19-31.