**Transpiration**

**Introduction**

Most of the water a plant absorbs is not used for a plant’s daily functioning. It is instead lost through transpiration, the evaporation of water through the leaf surface and stomata, and through guttation, which is the loss of water from the vascular tissues in the margins of leaves.

There are three levels of transport in plants: uptake and release of water and solutes by individual cells, short distance cell to cell transport at tissue and organ levels, and long distance transport of sap by xylem and phloem at the whole plant level. The transport of water is controlled by water potential. Water will always move from an area of high water potential to an area with low water potential. This water potential is affected by pressure, gravity, and solute concentration.

Water moves into the plant through osmosis and creates a hydrostatic root pressure that forces the water upward for a short distance, however, the main force in moving water is the upward pull due to transpiration. This pull is increased by water’s natural properties such as adhesion and cohesion. Transpiration decreases the water potential in the stele causing water to move in and pull upward into the leaves and other areas of low water potential. Pressure begins to build in the leaves, so to prevent downward movement, guttation occurs. Guttation occurs through leaf openings on the leaf margins called hydrathodes. Loss of water through transpiration can be facilitated by the opening and closing of the stomata depending on environmental conditions.

There are three types of cells in plants: parenchyma, sclerenchyma, and collenchyma. **Parenchyma** cells are the most abundant and are not specialized. They are found in the mesophyll of leaves, the flesh of fruits, the pith of stems, and the root and stem cortex. **Sclerenchyma** are elongated cells that make up fibers. Sclerenchyma cells are lignified and dead at maturity. They have thick secondary walls and the protoplasts often die as they grow older. They are used for support and are found in vascular tissue. **Collenchyma** cells are living at maturity and have a thickened secondary wall. There are also three types of tissues found in plants --- **xylem, phloem, and epidermal**. The epidermal cells make up the outermost layer of cells on a plant and function in protecting the plant. Xylem is the water conducting tissue of the plant, while phloem is the food conducting plant tissue.

**Hypothesis**

In Lab 9A, all of the plants in this experiment will lose water through transpiration, but those affected by the heat sink and the fan will lose a larger amount of water due to the environmental conditions. This transpiration will pull water from the potometer into the plant. The structure and cell types of a stem cross-section can be observed under a microscope.

**MATERIALS**

***Exercise 9A: Transpiration***

* a pan of water,
* timer,
* a beaker containing water (heat sink),
* scissors,
* 1-mL pipette,
* a plant cutting,
* ring stand,
* clamps,
* clear plastic tubing,
* petroleum jelly,
* a fan,
* lamp,
* spray bottle,
* a scale,
* calculator,
* a plastic bag.

***Exercise 9B: Structure of the Stem***

* single-edge razor blade,
* plant stems,
* distilled water,
* a microscope slide and
* cover slip,
* pencil,
* paper,
* a light microscope.

**METHODS**

***Exercise 9A: Transpiration***

The tip of the pipette was placed in the plastic tubing and they were submerged in a tray of water. Water was drawn into the pipette and tubing until no bubbles were left. The plant stem was cut underwater and inserted into the plastic tubing. Petroleum jelly was immediately placed around the tube edging to form an airtight seal around the stem. The tubing was bent into a "U" shape and two clamps were used on the ring stand to hold the potometer in place. The potometer was allowed to equilibrate for ten minutes.

The plant was exposed to a fan, which was placed one meter away and set on low speed. The time zero reading was recorded and then it was continually recorded every three minutes for 30 minutes. After the experiment, all the leaves were cut off the plant and massed by cutting a one cm2 box and massing it.

***Exercise 9B: Structure of the Stem***

A nut-and-bolt microtome was obtained and a small cup was formed by unscrewing the bolt. The stem was placed in the microtome and melted paraffin was poured around the stem. The paraffin was allowed to dry and the excess stem was cut off. The bolt was twisted just a little and then cut with the blade. The slice was placed in the 50% ethanol. The slices were left in the ethanol for five minutes. Using the forceps, the slices were moved to a dish of the toluidine blue O stain and left for one minute. The sections were rinsed in distilled water. The section was mounted on the slide with a drop of 50% glycerin. A cover slip was placed over the slide. The cross section was observed under a light microscope and drawn.

**RESULTS**

**Table 9.1: Individual Potometer Readings**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Time (min)** | **Beginning (0)** | **3** | **6** | **9** | **12** | **15** | **18** | **21** | **24** | **27** | **30** |
| **Reading (mL)** | .02 | .03 | .04 | .05 | .06 | .07 | .09 | .10 | .11 | .13 | .13 |

**Class Potometer Readings**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Time (min)** | **Beginning (0)** | **3** | **6** | **9** | **12** | **15** | **18** | **21** | **24** | **27** | **30** |
| **Room** | .53 | .54 | .55 | .56 | .57 | .58 | .59 | .60 | .61 | .62 | .63 |
| **Mist** | .34 | .36 | .38 | .40 | .42 | .43 | .43 | .44 | .45 | .45 | .46 |
| **Light** | .67 | .68 | .69 | .70 | .71 | .72 | .73 | .74 | .75 | .77 | .79 |
| **Fan** | .02 | .03 | .04 | .05 | .06 | .07 | .09 | .10 | .11 | .13 | .13 |

**Mass of leaves = 1.1 g
Leaf Surface Area = 0.0044 m2**

**Table 9.2: Individual Water Loss in mL/m2**

|  |
| --- |
| **Time Interval (minutes)** |
|  | ***0-3*** | ***3-6*** | ***6-9*** | ***9-12*** | ***12-15*** | ***15-18*** | ***18-21*** | ***21-24*** | ***24-27*** | ***27-30*** |
| **Water Loss (mL)** | .01 | .01 | .01 | .01 | .01 | .02 | .01 | .01 | .01 | 0 |
| **Water Loss per m2** | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 4.55 | 2.27 | 2.27 | 2.27 | 0 |

**Table 9.3: Class Average Cumulative Water Loss in mL/m2**

|  |  |
| --- | --- |
|  | **Time (minutes)** |
| **Treatment** | **0** | **3** | **6** | **9** | **12** | **15** | **18** | **21** | **24** | **27** | **30** |
| *Room* | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| *Light* | 0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 4 | 4 |
| *Fan* | 0 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 4.55 | 2.27 | 2.27 | 2.27 | 0 |
| *Mist* | 0 | 4.17 | 4.17 | 4.17 | 4.17 | 2.08 | 0 | 2.08 | 2.08 | 0 | 2.08 |

**Analysis of Results**

**Calculate the average rate of water loss per minute for each of the treatments:
Room: 1.67 mL/m2Fan: 0.76 mL/m2Light: 0.93 mL/m2Mist: 0.83 mL/m2**

**Explain why each of the conditions cause an increase or decrease in transpiration compared with the control.**

|  |  |  |
| --- | --- | --- |
| **Condition** | **Effect** | **Reasons** |
| ***Room*** | No effect | The room temperature plant is the control in the experiment. |
| ***Fan*** | Increased transpiration rate | The wind blowing on the plant should have caused evaporation to increase in the plant causing more transpiration. |
| ***Light*** | Increased transpiration rate | The heat hitting the plant increased the amount of water pulled in by the plant because it increased the rate of evaporation on the leaves. |
| ***Mist*** | Decreased transpiration rate | The moist environment and shielding decreased the transpiration rate because less evaporation was occurring. |

**How did each condition affect the gradient of the water potential from stem to leaf in the experimental plant?**

The light and the fan decreased the water potential in the leaves and water moved up the stem by transpiration pull. The room temperature had little or no effect on the water potential. The mist increased the water potential of the air causing less transpiration to occur from the leaves.

**What is the advantage to a plant of closed stomata where water is in short supply? What are the disadvantages?**

The closing of the stomata would prevent transpiration of water and minimize this loss if water was in short supply. It is a conservational adaptation. However, closing stomata prevents the exchange of gases in plants and limits their carbon supplies.

**Describe several adaptations that enable plants to reduce water loss from their leaves. Include both structural and psychological adaptations.**

Plants that are adapted to drier climates are called xerophytes. Some of these plants have adapted small, thick leaves with a reduced surface area. They may also have a thickened cuticle to protect themselves from the environment. The stomata may be sunken into pits. Some xerophytes shed their leaves during the driest seasons and others can store water such as cacti. CAM plants uptake CO2 at night and change it into crassulacean acid that can be broken down during the day for sugars. These plants can close their stomata during the day.

**Why did you need to calculate leaf surface area in tabulating your results?**

The surface area has to be calculated because this greatly affects the amount of water lost through transpiration. Smaller leaves may lose less water than the larger ones, but by calculated water loss by surface area creates comparable data that is constant and consistent.

**Error Analysis**

This lab had many opportunities for error. The potometer set up was a complicated procedure. If any air bubbles were present in the plastic tubing, it could cause drastic error to occur. Any miscalculations or inaccurate weighing could also account for error.

**Discussion and Conclusion**

Transpiration in plants is controlled by water potential. This change in water potential in leaves causes a gradient by which water can be moved upward. When the water potential of the air was increased by the mist and plastic bag, less water evaporated from the leaves, decreasing the water potential gradient between the root and stem. This decreased the transpiration pull. The fan and floodlight simulated environmental conditions such as wind, heat, and intense light. These conditions increase the amount of water transpired by plants. This in turn increased the water potential gradient causing more water to be pulled through the stem. The control plant should have had normal rates of transpiration.

The stem must have specialized cells for support and transport. The epidermis is the outermost layer of the stem. The xylem is a transport tube for water, and the phloem transports food and minerals through the plant. Parenchyma are non-specialized cells and are located in the interior. The tougher sclerenchyma and collenchyma make up the structural outer support of the epidermis and the transport tubes of phloem and xylem.