Potential Drinking Usage of Plant Transpiration

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Abstract

Concerns over decreased access to freshwater and ways to desalinate the ocean have increased over recent years. This experiment was done to determine a possible aid to the problem. Water was collected from a Turk's Cap, Gulf Coast penstemon, and crepe myrtle by a plastic bag. The bag was kept on there from 8:00 AM to 4:00 PM, then the water collected was measured in grams. Then the bags were kept on there for a week to obtain more water for drinking water analysis. However, no water was collected from the bags. This may be due to the small surface area used and the fall-winter season. The surface area of the leaves were still calculated. The Turk's Cap, penstemon, and crepe myrtle had a surface area of 151 cm^2, 129 cm^2, and 90 cm^2, respectively. Although the kitchen scale did not register the water collected, it was seen that the crepe myrtle had more moisture in the bag than the other two plants. This is most likely because crepe myrtle is a deciduous plant and the other two are perennials. This experiment should be repeated with a larger surface area to study in order to determine the different water outputs of deciduous and perennial plants.

Potential Freshwater Usage of Plant Transpiration

With an increasing population, freshwater availability has become a crucial topic. According to the World Health Organization (2019), "at least 2 billion people use a drinking water source contaminated with faeces." This issue is pressed further with climate change, where some places are experiencing vast amounts of flooding while others are experiencing harsh droughts (World Health Organization, 2019). This puts more stress on water distribution and cleaning systems. One solution to this problem is turning the vast amounts of seawater into drinking water; however desalination is very expensive and energy-intensive (Smith, 2019). Another alternative that has not been discussed much is extracting water from plants.

Plants evaporate water just like mammals when they are hot. This is called transpiration. The water transpired from plants can be collected by putting an airtight bag over it to allow the water to condense (United States Geological Survey, n.d.). This method has been used by humans for thousands of years during times when water was not readily available (Musa et al., 2017). According to Musa et al. (2017), the water provided from plants meets regular drinking standards of Malaysia, therefore this method can be used to produce drinking water for humans.

However, this method has not been given much thought when it comes to large-scale drinking water usage, as plants do not transpire enough water (Musa et al., 2017; Practical Survivor, n.d.). Nevertheless, this could provide more drinking water with little to no energy consumption. Even with a small amount of water produced, it could significantly reduce the amount of water needed to treat each year.

Water distribution is very expensive and energy consuming. This is mainly due to the startup processes and the vast amounts of pumping that must be done to transfer water across the city (Vieira et al., 2014). Since adding water to the pumping system increases the energy consumption, it is best to bottle the collected water, similar to drinking water companies.

In this experiment, a Turk's Cap, a Gulf Coast penstemon, and a crepe myrtle’s transpiration rate and water quality was examined. These trees were picked because of their abundance in the Texas area. The surface area of a single leaf was calculated using graphical methods, where the edges of the leaf were plotted and the area of the graph found through integration. This was calculated to determine the amount of water that can be produced from the specific surface area. A plastic bag was tied over the plant for water collection. The water collected was recorded from 8:00 AM to 4:00 PM on the first day to determine the transpiration rate of the plants during the time they receive the most direct sunlight. Then, the bags were left on the plants for a week to collect enough water to analyze.

Musa et al. (2017) discovered that water quality varies from plant to plant. Due to this, the drinking water quality of the plants in this experiment was planned to be tested using a Well Water Test Kit; this specific test kit was planned to be used because transpired water is similar to groundwater (Health Metric n.d.). However, no water was collected; therefore no analysis was conducted. It was hypothesized that these three water samples from the plants could provide ten percent of drinking water for one human for a year.

Methods

Due to no water being collected, the chemicals from the Well Water Test Kit were not used or touched. There were no safety issues.

Materials

- Three gallon-sized twist-tie bag from Walmart
- Black marker

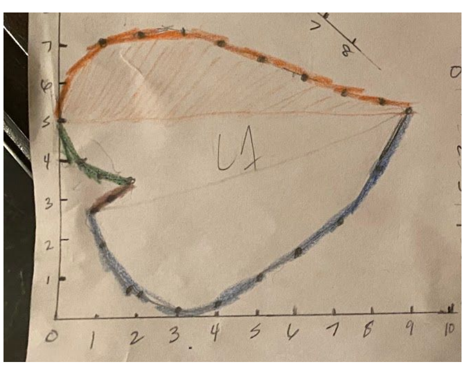
- Kitchen timer
- A kitchen scale that measures to the nearest 0.1 gram
- Three sheets of copy paper

Procedures

On the Turk's Cap tree, a piece of paper and a pencil were used to trace all of the leaves on the tree branch that water was collected from. This process was repeated with the branch section to be tested on the penstemon and crepe myrtle. For each trace made, the sketch was put on a graph with dimensions that correspond to centimeters, as shown in Figure 1. Specific data points on the graph were determined in order to find the line or curve of best fit. The surface area of the leaf was calculated by subtracting the integral of the line of best fit for the bottom of the leaf from the integral of the line of best fit for the top of the leaf. The surface area found for all of the leaves on the Turk's Cap was combined to get the total surface area studied. This was done for the penstemon and crepe myrtle.

Figure 1

Graph of Turk's Cap Leaf 1



Note: The orange outline corresponds to the top section, the green outline corresponds to the left section, the purple outline corresponds to the mid section, and the blue outline corresponds to the bottom section.

Each of the three plastic bags was labeled with one of the plant names so that one bag was labeled Turk's Cap, another penstemon, and the other crepe myrtle. They were then weighed on a kitchen scale.

At 7:50 AM, each bag was tied around the plant that corresponded to its label. After one bag was tied, the exact time was recorded, and a timer was set for eight hours. A few minutes passed by before tying the next bag in order to give some time to untie the bag before the next timer ends.

When the timer ended, the respective bag was removed from the plant. The bag remained closed until it was weighed in order to keep the water inside the bag. The measurement taken was the mass of the water collected and the plastic bag. The measurement taken earlier of the mass of the plastic bag was subtracted from this measurement to give the mass of the water collected.

The next day, the bags were weighed again once they had dried. These bags were then put on their respective plants. The next week at the same time, the bags were taken off the plants and weighed. The water collected was calculated using the method mentioned before.

No further analysis was done due to the lack of water collected and the loss of the crepe myrtle branch.

Results

Plant transpired water from a Turk's Cap, a Gulf Coast penstemon, and a crepe myrtle was collected using plastic bags for a week. The water collected was measured, but the scale found no significant difference in the mass of the bag before and after the water collection. Due to this, only the surface area of the leaves were calculated, and no further analysis of the water or transpiration rate was performed.

The surface area of each leaf was calculated using a graphical method involving integrals, as stated beforehand. Table 1 through Table 4 show the data points collected from Turk's Cap Leaf 1. The leaf was separated into 4 different sections - top, left, mid, bottom - as shown earlier in Figure 1 since there was more overlapping of the y-values. The regression equation was found for each section. Then the integral of each section was calculated using the regression equations and the endpoints of each section. The surface area of the leaf was found by subtracting the bottom and left sections' integrals from the top and mid sections' integrals, which was determined to be 41 cm^2. The regression equations, integrals, and setup can be found in Appendix B.

Table 1

Data points of the top section of Turk's Cap Leaf 1

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	8.9
y (cm)	5.0	7.1	7.3	7.4	7.0	6.7	6.2	5.8	5.5	5.3

Table 2

Data points of the left section of Turk's Cap Leaf 1

x (cm)	0.0	0.5	1.0	1.8
y (cm)	5.0	4.0	3.6	3.5

Table 3

Data points of the mid section of Turk's Cap Leaf 1

x (cm)	0.8	1.2	1.8
y (cm)	2.7	3.0	3.5

Table 4

Data points of the bottom section of Turk's Cap Leaf 1

x	0.8	1.0	1.8	2.0	3.0	4.0	5.0	6.0	7.0	8.0	8.9
y	2.7	1.8	0.6	0.5	0.1	0.3	1.0	1.6	2.4	3.7	5.3

This same method was used to calculate the other Turk's Cap leaves. The surface area of leaf 2, leaf 3, and leaf four, are 44 cm^2, 31 cm^2, and 35 cm^2, respectively. Combining the surface areas, the total surface area studied for Turk's Cap was 151 cm^2. The raw data of the leaves can be found in Appendix A. The regression equations and calculations can be found in Appendix B.

The leaves of the Gulf Coast penstemon and the crepe myrtle were calculated in a similar way to the Turk's Cap. However, there was only a top and a bottom section since there were no other areas where the graph overlapped as seen in Figure 2 and Figure 3. The bottom section's integral was subtracted from the top section's integral. The data points of the penstemon and the crepe myrtle leaves can be found in Appendix A. The regression equations and calculations can be found in Appendix B. The total surface area of penstemon studied was 129 cm^2, and the total surface area of crepe myrtle studied was 90 cm^2.

Figure 2

Graph of Gulf Coast Penstemon Leaves

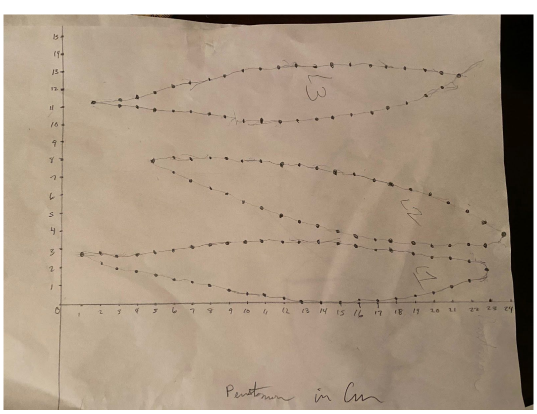
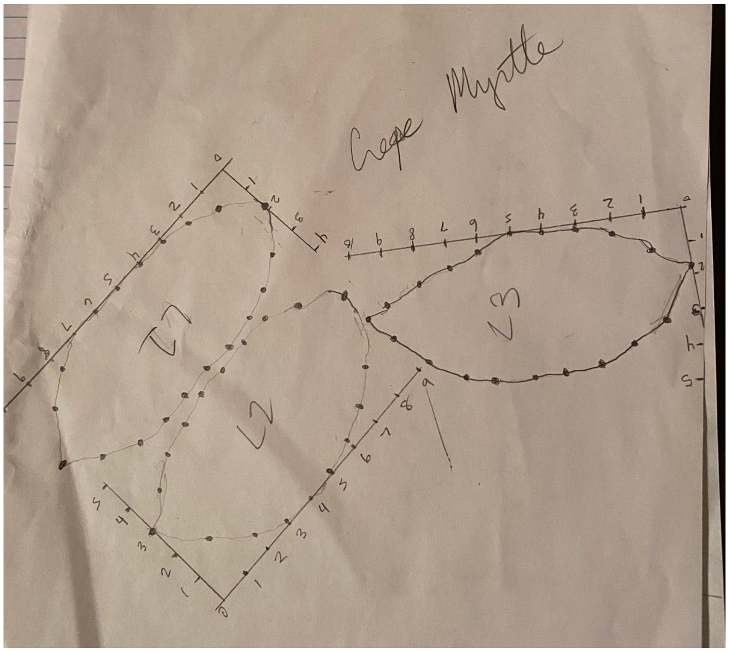


Figure 3

Graph of Crepe Myrtle Leaves



Discussion

In this experiment, plastic bags were tied over a Turk's Cap, a penstemon, and a crepe myrtle's branch. Water was collected from the bags, but not enough to analyze or determine the transpiration rate of the plants. Due to this, the hypothesis that these plants could provide ten percent of the drinking water for a single human for a year was rejected.

Throughout the experiment, it was hard to make sure the plastic bags were completely tied to where there was barely an opening for water to get out. This problem might have affected the amount of water I could collect. Some of the water could have escaped through the opening, leaving little water to condensate in the bag. Another factor that may have affected the amount of water collected could be the small surface area that was used for water collection. As seen in PracticalSurvivor's (n.d.) experiment, a half of a cup of water was collected from an entire long branch of a tree. This means that much more surface area than what was studied needs to be used in order to get an adequate supply of water. Furthermore, the fall-winter season could also have something to do with the low numbers, since it is the time that many plants lose their leaves.

PracticalSurvivor’s (n.d.) experimental numbers show that a single tree branch from the plant studied can provide about 182 cups of water in a year. Considering that the average person needs to intake about eight cups of water a day, meaning a person would need 2, 920 cups of water for a year, the plant from this study could provide six percent of the water needed for the year. This number is much lower than the hypothesized value without including the differences in the seasons and weather. However, this is a different plant, and a different amount of surface area was studied. There are also variations on how much water one should drink.

In order to determine the right numbers for this experiment, a much larger surface area should be used. The same plants should be used to determine if there is a big difference in the amount of water collected between the different plants. Although there was no water collected from the plants, it was seen that the crepe myrtle had a lot more collected water than the other two. This is because crepe myrtle is a deciduous plant, while the Gulf Coast penstemon and Turk’s Cap are perennial plants (AgriLife, 2011; Lady Bird, 2014; Southern Living, 2010).

Further experiments could be doing a long study on the effect of collecting water from plants for many years on the weather. This will help determine whether collecting water from plants on a larger scale significantly affects the water cycle and the weather patterns on earth. Data collected from this study will show the likelihood of using plant-collected water for future human drinking water.

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Appendix A

Table 1

Data points of the top section of Turk's Cap Leaf 1

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	8.9
y (cm)	5.0	7.1	7.3	7.4	7.0	6.7	6.2	5.8	5.5	5.3

Table 2

Data points of the left section of Turk's Cap Leaf 1

x (cm)	0.0	0.5	1.0	1.8
y (cm)	5.0	4.0	3.6	3.5

Table 3

Data points of the mid section of Turk's Cap Leaf 1

x (cm)	0.8	1.2	1.8
y (cm)	2.7	3.0	3.5

Table 4

Data points of the bottom section of Turk's Cap Leaf 1

x (cm)	0.8	1.0	1.8	2.0	3.0	4.0	5.0	6.0	7.0	8.0	8.9
y (cm)	2.7	1.8	0.6	0.5	0.1	0.3	1.0	1.6	2.4	3.7	5.3

Table 5

Data points of the top section of Turk's Cap Leaf 2

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	9.3
y (cm)	3.8	4.6	5.2	6.3	6.6	6.8	7.0	7.1	7.0	6.6	5.3

Table 6

Data points of the right section of Turk's Cap Leaf 2

x (cm)	8.2	9.0	9.3
y (cm)	3.7	4.1	5.3

Table 7

Data points of the mid section of Turk's Cap Leaf 2

x (cm)	8.2	9.0	9.3
y (cm)	3.7	3.1	2.3

Table 8

Data points of the bottom section of Turk's Cap Leaf 2

x (cm)	0.0	1.0	2.3	3.0	4.0	5.0	6.0	7.0	8.0	9.0	9.3
y (cm)	3.8	3.0	2.2	1.7	0.5	0.3	0.0	0.2	0.7	1.5	2.3

Table 9

Data points of the top section of Turk's Cap Leaf 3

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.5
y (cm)	3.5	5.2	5.8	5.7	5.3	5.2	4.4	3.5	2.8

Table 10

Data points of the left section of Turk's Cap Leaf 3

x (cm)	0.0	0.5	1.1
y (cm)	3.5	2.9	2.6

Table 11

Data points of the mid section of Turk's Cap Leaf 3

x (cm)	0.0	0.6	1.1
y (cm)	1.1	2.3	2.6

Table 12

Data points of the bottom section of Turk's Cap Leaf 3

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.5
y (cm)	1.1	0.1	0.0	0.0	0.2	0.7	1.4	2.3	2.8

Table 13

Data points of the top section of Turk's Cap Leaf 4

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.8
y (cm)	4.6	6.2	6.4	6.5	6.4	5.9	5.4	4.7	4.1

Table 14

Data points of the left section of Turk's Cap Leaf 4

x (cm)	0.0	0.5	0.9
y (cm)	4.6	3.6	3.2

Table 15

Data points of the mid section of Turk's Cap Leaf 4

x (cm)	0.0	0.5	0.9
y (cm)	2.0	2.9	3.2

Table 16

Data points of the bottom section of Turk's Cap Leaf 4

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.8
y (cm)	2.0	0.4	0.0	0.0	0.3	1.1	2.2	3.3	4.1

Table 17

Data points of the Gulf Coast Penstemon Leaf 1

x (cm)	Top y-coordinates (cm)	Bottom y-coordinates (cm)
1.1	2.7	2.7
2.0	2.8	2.2
3.0	2.6	1.9
4.0	2.7	1.8
5.0	2.8	1.6
6.0	2.9	1.3
7.0	3.1	1.2
8.0	3.2	1.0
9.0	3.3	0.7
10.0	3.3	0.5
11.0	3.4	0.4

12.0	3.3	0.2
13.0	3.2	0.1
14.0	3.3	0.0
15.0	3.2	0.0
16.0	3.0	0.2
17.0	2.8	0.1
18.0	2.8	0.2
19.0	2.6	0.4
20.0	2.4	0.5
21.0	2.4	0.8
22.0	2.2	1.1
23.0	1.7	1.7

Table 18

Data points of the Gulf Coast Penstemon Leaf 2

x (cm)	Top y-coordinates (cm)	Bottom y-coordinates (cm)
5.0	7.9	7.9
6.0	8.2	7.3
7.0	8.0	6.7
8.0	8.1	6.3
9.0	8.0	6.0
10.0	7.9	5.6
11.0	7.9	5.2
12.0	7.7	4.7
13.0	7.6	4.4

14.0	7.4	4.1
15.0	7.1	3.8
16.0	7.0	3.6
17.0	6.6	3.4
18.0	6.4	3.2
19.0	6.1	3.2
20.0	5.7	3.1
21.0	5.3	3.0
22.0	4.8	3.1
23.0	4.2	3.0
24.0	3.6	3.6

Table 19

Data points of the Gulf Coast Penstemon Leaf 3

x (cm)	Top y-coordinates (cm)	Bottom y-coordinates (cm)
1.7	11.3	11.3
3.0	11.4	11.1
4.0	1.6	11.0
5.0	11.9	10.9
6.0	12.2	10.8
7.0	12.4	10.8
8.0	12.6	10.6
9.0	12.8	10.5
10.0	13.1	10.1
11.0	13.2	10.2

12.0	13.2	10.1
13.0	13.3	10.1
14.0	13.2	10.2
15.0	13.3	10.3
16.0	13.2	10.4
17.0	13.2	10.5
18.0	13.1	10.8
19.0	13.0	11.0
20.0	12.8	11.5
21.0	12.7	11.9
22.1	12.4	12.4

Table 20

Data points of the Crepe Myrtle Leaf 1

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.1
Top y (cm)	1.8	3.1	3.6	3.9	4.0	3.9	3.9	4.0	3.9	3.3	2.5
Bottom y (cm)	1.8	0.8	0.3	0.1	0.1	0.1	0.1	0.0	0.5	1.2	2.5

Table 21

Data points of the Crepe Myrtle Leaf 2

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.2
Top y (cm)	3.0	3.6	4.2	4.4	4.6	4.6	4.7	4.7	4.1	3.2
Bottom y (cm)	3.0	1.5	0.6	0.1	0.0	0.1	0.3	0.7	1.3	3.2

Table 22

Data points of the Crepe Myrtle Leaf 1

x (cm)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	9.7
Top y (cm)	1.7	3.3	3.8	4.2	4.3	4.4	4.4	4.1	3.5	2.7	2.0
Bottom y (cm)	1.7	1.1	0.5	0.2	0.1	0.0	0.4	0.8	1.2	1.7	2.0

Appendix B

Table 1

Regression Equations for Turk's Cap Leaf 1

	Regression Equation	R^2 Value	Endpoint	Area (cm^2)
Top	$y = 0.02535x^3 - 0.4236x^2 + 1.7817x + 5.2532$	0.9452	[0.0,8.9]	57.55
Bottom	$y = -0.0193x^3 + 0.4724x^2 - 2.5596x + 4.0673$	0.9769	[0.8,8.9]	13.02
Left	$y = 0.7715x^2 - 2.202x + 4.9756$	0.9941	[0.0,1.8]	6.89
Middle	$y = 0.0833x^2 + 0.5833x + 2.18$	1	[0.8,1.8]	3.09

Surface Area: 58-13+3-7 cm^2 = 41 cm^2

Table 2

Regression Equations for Turk's Cap Leaf 2

	Regression Equation	R^2 Value	Endpoint	Area (cm^2)
Top	$y = -0.0079x^3 + 0.0162x^2 + 0.7481x + 3.8255$	0.9416	[0.0,9.3]	57.45
Bottom	$y = 0.0152x^3 - 0.095x^2 - 0.6074x + 3.7862$	0.9849	[0.0,9.3]	11.94
Right	$y = 0.1515x^2 - 4.1061x + 28.7818$	1	[8.2,9.3]	4.92
Middle	$y = -1.7424x^2 + 29.2197x - 118.7409$	1	[8.2,9.3]	3.69

Surface Area: 57-12+4-5 cm^2 = 44 cm^2

Table 3

Regression Equations for Turk's Cap Leaf 3

	Regression Equation	R^2 Value	Endpoint	Area (cm^2)
Top	$y = 0.0172x^3 - 0.3651x^2 + 1.6756x + 3.6431$	0.9711	[0.0,7.5]	36.74
Bottom	$y = -0.008x^3 + 0.2178x^2 - 0.949x + 1.0232$	0.9938	[0.0,7.5]	5.27
Left	$y = 0.6364x^2 - 1.5182x + 3.5$	1	[0.0,1.1]	3.21

Middle	$y = -1.7273x^2 + 0.5364x + 2.6$	1	[0.0,1.1]	2.42

Surface Area: 37-5-3+2 cm^2 = 31 cm^2

Table 4

Regression Equations for Turk's Cap Leaf 4

	Regression Equation	R^2 Value	Endpoint	Area (cm^2)
Top	$y = 0.0174x^3 - 0.3348x^2 + 1.4772x + 4.7353$	0.9774	[0.0,7.8]	45.04
Bottom	$y = -0.0224x^3 + 0.4415x^2 - 1.9431x + 1.9431$	0.9971	[0.0,7.8]	9.4
Left	$y = 1.1111x^2 - 2.5556x + 4.6$	1	[0.0,0.9]	3.38
Middle	$y = -1.1667x^2 + 2.3833x^2 + 2$	1	[0.0,0.9]	2.48

Surface Area: 45-9-3+2 cm^2 = 35 cm^2

Table 5

Regression Equations for Penstemon Leaves

	Regression Equation	R^2 Value	Endpoint	Area (cm^2)
L1: Top	$y = -0.0091x^2 + 0.1919x + 2.2556$	0.911	[1.1,23.0]	63.31
L1: Bottom	$y = 0.0152x^2 - 0.4333x + 3.2437$	0.9568	[1.1,23.0]	18.24
L2: Top	$y = -0.0163x^2 + 0.2524x + 7.088$	0.9964	[5.0,24.0]	129.71
L2: Bottom	$y = 0.0183x^2 - 0.7768x + 11.3746$	0.994	[5.0,24.0]	85.54
L3: Top	$y = -0.0136x^2 + 0.396x + 10.3818$	0.9775	[1.7,22.1]	258.83
L3: Bottom	$y = 9.3336x^3 - 0.0171x^2 - 0.0291x + 11.3716$	0.9845	[1.7,22.1]	219.16

Surface Area 1: 63-18 cm^2 = 45 cm^2
Surface Area 2: 130-86 cm^2 = 44 cm^2
Surface Area 3: 259-219 cm^2 = 40 cm^2

Table 6

Regression Equations for Crepe Myrtle Leaves

	Regression Equation	R^2 Value	Endpoint	Area (cm^2)
L1: Top	$y = 0.0025x^3 - 0.1097x^2 + 0.9121x + 2.032$	0.9226	[0.0,10.1]	35.97
L1: Bottom	$y = 0.0027x^3 + 0.0414x^2 - 0.6237x + 1.5858$	0.9461	[0.0,10.1]	5.58
L2: Top	$y = -0.075x^2 + 0.734x + 2.9565$	0.9561	[0.0,9.2]	38.8
L2: Bottom	$y = 0.1456x^2 - 1.3149x + 2.8207$	0.9764	[0.0,9.2]	8.1
L3: Top	$y = -0.1081x^2 + 1.049x + 1.9999$	0.9691	[0.0,9.7]	35.86
L3: Bottom	$y = 0.0749x^2 - 0.6693x + 1.6289$	0.9703	[0.0,9.7]	7.1

Surface Area 1: 36-6 cm^2 = 30 cm^2
Surface Area 2: 39-8 cm^2 = 31 cm^2
Surface Area 3: 36-7 cm^2 = 29 cm^2