DETERMINATION OF THE TRANSPIRATION RATE OF DIFFERENT PLANT SPECIES WITHIN THE NAMIBRAND NATURE RESERVE AREA

By
Name: Thomas Neema
Student #: 200545388
Tutor's Name: Dr W. Jankowitz
Duty station: NaDEET

June 2006

CONTENTS

INTRODUCTION

This report is covering the research I have conducted at the Namib Desert Environmental Education Trust (NaDEET) during my six months in-service training. The main aim of this research was to compare the quantity of water transpired by various plant species into the atmosphere and to recommend the plant species that will produce the best results for the activity "Making your own water" at NaDEET Centre. NaDEET is situated in the NamibRand Nature Reserve in the Namib Desert and the surrounding area is mostly characterized by only a few number of different plant species such as the *Acacia erioloba*, *Acacia hebeclada* and *Boscia foetida*. The three main factors that make a desert a desert are: extreme temperature, low rainfall and high evaporation rate. These weather conditions influence the rate of transpiration here in the desert. In nature, different plant species have a variety of ways to prevent water loss. For example by closing their stomata, shedding off their leaves, having a small surface-area-to-volume ratio (pers.obs) and having a reflexive colour. "Unless the surface of the desert plants and animals is 100 percent waterproof which it never is - water is lost from it through evaporation. The amount of moisture that evaporates varies, depending on external factors-the temperature and water vapour pressure of the surrounding air as well as on the organism's ability to minimize water loss" (Lovegrove, 1993).

During my stay at NaDEET, I assisted in the NaDEET centre programme. There is a water activity done with all participants at NaDEET Center called "Making your own water". Learners are expected to capture/trap water from the water cycle in whatever way possible without starting with water. It was really amazing to see the amount of water that each group of people made using different methods to capture the water. The quantity of water that each group made during the same period of time given was dependent on the method and materials used, and the point where they "interrupted" the water cycle (i.e.transpiration, evaporation from soil). I also participated in this water activity using the same method implemented in my project to demonstrate another viable method.

OBJECTIVES

Project objectives

The objectives of my project are as follows:

1. To determine the species of plant that loses the most water.
2. To determine the time of the day at which plants lose the most water.
3. To determine the part of the leaf that loses the most water into the atmosphere.
4. To determine the weather condition that affects transpiration rates.

Personal objectives

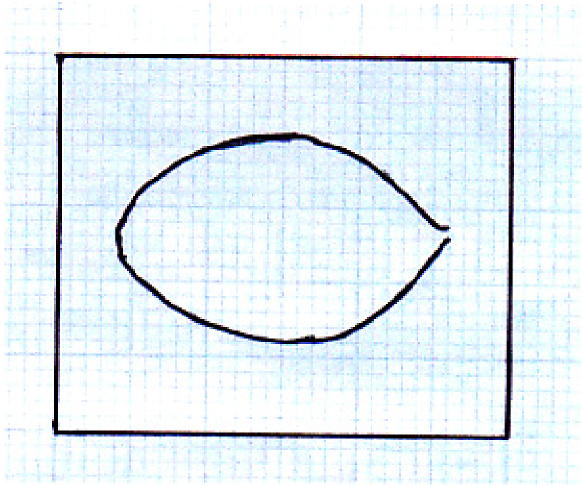
The following are my personal objectives:

1. To observe and understand the relationship between dunes and other creatures of the desert.
2. To become more knowledgeable in computer usage
3. To have a broader understanding on using solar power as a source of energy and to sustain the scarce resources.
4. To assist in the development of NaDEET

MATERIALS AND METHODS

Determination of plant species that loses the most water:

To carry out this experiment, three different tree species that grow naturally in the desert (*Acacia erioloba*, *Acacia hebeclada* and *Boscia foetida*), three different tree species that were introduced here in the desert at NaDEET office (*Ceratonia siliqua*, *Sclerocarya birrea* and Orange tree) and three common vegetables (Onion, Watermelon and Tomato) were subjectively selected to be part of the research project. The elastic bands, a syringe, wire cutting plier and clean clear plastic bags of the same size were used in the investigation. I tied the plastic bags around the selected region of the plant, the leaves, and the plastic was firmly secured with the elastic band to prevent it from being blown away by the wind. I also made sure that the leaves were exposed to the sun and no other branches of the tree made a shadow over the leaf for the whole time of the experiment. The syringe was used to draw in the water found accumulated in the plastic bag to observe the reading of the water volume. A record sheet was used to record all the data of each experiment. "Most biological specimens have an *irregular* form, and their surface area is difficult to measure exactly" (Biology, 2002). At the end of each experiment, all branches covered by the plastic bags were cut off for the calculation of the leaves' surface area. The leaf's surface area was then calculated using a graph paper method as follows: A graph paper is made up of one-millimetre squares (1mm^2) and one centimetre squares (1cm^2). Each leaf was placed on the graph paper and its outline was drawn onto the paper. The number of large (1cm^2) squares within the leaf tracing was counted, and then the smaller (1mm^2) squares on the outside of the leaf tracing that forms part of the large centimetre square was counted by the *gate method.* The leaf area was calculated as illustrated below:



Total number of large (1cm²) = 3.1 cm²
Total number of small (1mm²) outside leaf tracing on the large squares = 117mm²
Total area of one leaf surface
$= 3.1cm^2 + (117/100)$
$= 3.1+1.17$
$= 4.27cm^2$
Two leaf surfaces $=8.54cm^2$

Finally, the volume of water obtained from each group of leaves was then divided by the size of their leaves to the volume of water per centimetre square. With this data I could determine which plant species loses the most water. "Clearly one sample is too few and clearly one million samples is too many" (Joubert, 2005). As at the beginning of my project I did not know what sample size is appropriate to gather enough data, I did not have a predetermined sample size. Therefore, the number of samples for the experiments of all the project objectives I conducted was determined according to the variability of the results produced by each investigation after several samples were taken.

To determine the time of the day at which plants lose the most water

To collect data for this objective, I used the same method of plastic leaf covering, the wire cutting pliers to cut thorns to prevent holes in the plastic bags and the syringe to measure the water. I conducted this investigation three times a day: in the morning before sunrise, later in the day and the last one later in the evening. I collected the results in exactly six hour intervals. However, the results of the experiment that lasted for twelve hours (overnight) and was collected the next morning before sunrise was divided by two for the consistency of six hour intervals. At the end of every experiment I calculated the surface area of the leaves to determine the amount of water obtained from each group of leaves. I recorded the data of each experiment which I used to compare the outcomes of all the samples taken in various days.

To determine the part of the leaf that loses the most water into the atmosphere

During this investigation, I used the same materials as in the previous experiments together with petroleum jelly. To conduct this investigation, I prepared four leaves of each plant species. Each leaf of each species was given a distinctive letter for easier identification and placed into one of four groups. The condition of the leaves was always taken into consideration. I applied the petroleum jelly on the upper surface of all leaves in the first group, on the lower surface of all leaves in the next group, on both surfaces of all leaves in the third group and finally I left the last group's leaves untouched (Mackean, 1962). With the plastic bag around each leaf the accumulated water in the plastic was again collected the same way. Due to the fact that the smearing of the petroleum jelly onto the leaf's surface needed to be done very carefully not to spoil the other side of the leaf, this experiment took considerable time to set up. However, all the leaves were first completely treated with the petroleum jelly before covering them with the plastic bag to make sure that all experiments started at the same time and were well exposed to the sun. This method was applied to all trees as chosen to be part of the investigation and the time given to each group of leaves was exactly the same. Very importantly, the area of the leaf's surface was again calculated and the volume of water was divided by the size of the leaves to compare the quantity of water to the ratio of the leaf's size in each of the sample taken.

To determine the weather condition that affects transpiration rates

Due to the impossibilities of predicting what the weather condition will be like the next day here at NaDEET, I decided to do my research randomly. The time given to all the experiments was still the same. I also recorded the weather conditions of each day of the investigation. When I compared all the outcomes of this investigation after eleven randomly collected samples the difference in weather conditions was not that big. Therefore the outcomes of the experiments were nearly the same and I decided to change my sampling approach. The next samples were collected systematically without skipping a day in between using only one species of plant (*Boscia foetida*). I once again used the same method of plastic bags to cover the leaves, and the transpired water collected inside the plastic at each sample was transferred into a syringe. As usual, the leaf size was again measured and used as a divisor of the water volume that was measured in the syringe. Because the amount of water transpired by the plants does also depend on the size of the leaf (*pers.obs.*), I compared the quantity of water transpired, to the leaf size of all the experiments conducted. The comparisons were also done according to the weather report that was always recorded. Even though my experiments could have been exposed to a greater variety of weather conditions experienced in the desert, (fog, rain and strong wind) unfortunately, none of my experiments were conducted at those times. However, my research was made under the following weather conditions: sunny/clear sky, cloudy, partly cloudy and more importantly in the two different seasons of the year (summer and winter).

RESULTS

Table 1.1 Water loss of tree species

	Sclerocarya birrea			*Acacia erioloba*			*Acacia hebeclada*			*Boscia foetida*			*Ceratonia siliqua*			Orange		
	mm	cm²	mm/cm²	mm	cm²	mm/cm²	mm	cm²	mm/cm²	mm	cm²	mm/cm²	mm	cm²	mm/cm²	mm	cm²	mm/cm²
1	25	224	0.112	27.7	77.2	0.3588	31	130.08	0.2384	14.8	60.93	0.2429	16.1	624.35	0.0257	8.7	222	0.0391
2	3	63.1	0.048	4.2	38.74	0.1085	8.6	59.7	0.144	1.5	28.2	0.0531	6.2	64.55	0.096	5	57.5	0.0869
3	0.4	63	0.006	5	37.92	0.1319	5.5	50.31	0.1093	1.5	9.78	0.1533	7	45.99	0.1522	6.5	47.7	0.1362
4	0.7	18.1	0.039	3.9	48.3	0.0807	4.1	59.17	0.0692	1.7	27.53	0.0617	4.3	51.03	0.0842	3.9	37.5	0.104
5	1.9	31.5	0.059	4.8	35.53	0.135	5.3	39.56	0.1338	2.3	38.26	0.0601	5.5	38.71	0.142	6.1	33.1	0.1842
6	0.3	63.5	0.005	0.9	88.55	0.0101	0.5	77.8	0.0064	0.4	91.4	0.0043	1.3	99.4	0.013	1.3	97.8	0.0132
7	0.9	26.4	0.035	1.7	21	0.0809	1.7	22.88	0.0742	1.3	18.8	0.0691	4.2	42.84	0.098	3.3	35.7	0.0924
8	1.7	17.1	0.1	4	52.2	0.0766	1.9	15.8	0.1202	1.2	17.8	0.0674	8.1	56.28	0.1439	7.2	37	0.1945
9	2.7	28.8	0.093	8.1	59.46	0.1361	7.9	62.09	0.1272	3.7	34.71	0.1065	8.3	57.88	0.1434	8.8	61	0.1442
10	1.3	18.9	0.068	9.1	85.49	0.1064	8.7	88.23	0.0986	3.3	37.3	0.0884	5.5	49.01	0.1122	5.5	41	0.1341
11	3.1	49.8	0.062	5.7	48.15	0.1182	6.9	69.7	0.0989	2.1	33.17	0.0633	7.8	63.13	0.1235	7.1	50	0.142

Table 1.2 Water loss of vegetable species

	Tomato			Watermelon		
No.of samples	mm	cm²	mm/cm²	mm	cm²	mm/cm²
Sample 1	0.9	28.05	0.032	1	49.28	0.0202
Sample 2	0.7	40.83	0.0171	0.5	50.09	0.0099
Sample 3	0.9	31.03	0.029	1.1	59.98	0.0183
Sample 4	0.4	19.26	0.0207	0.9	58.45	0.0153
Sample 5	0.5	22.02	0.0227	1.3	68.71	0.01892
Sample 6	0.7	28.34	0.0247	0.9	47.98	0.0187
Sample 7	1.1	29.41	0.0374	1.1	31.14	0.0353
Sample 8	1.5	24.03	0.0624	1.9	39.73	0.0478

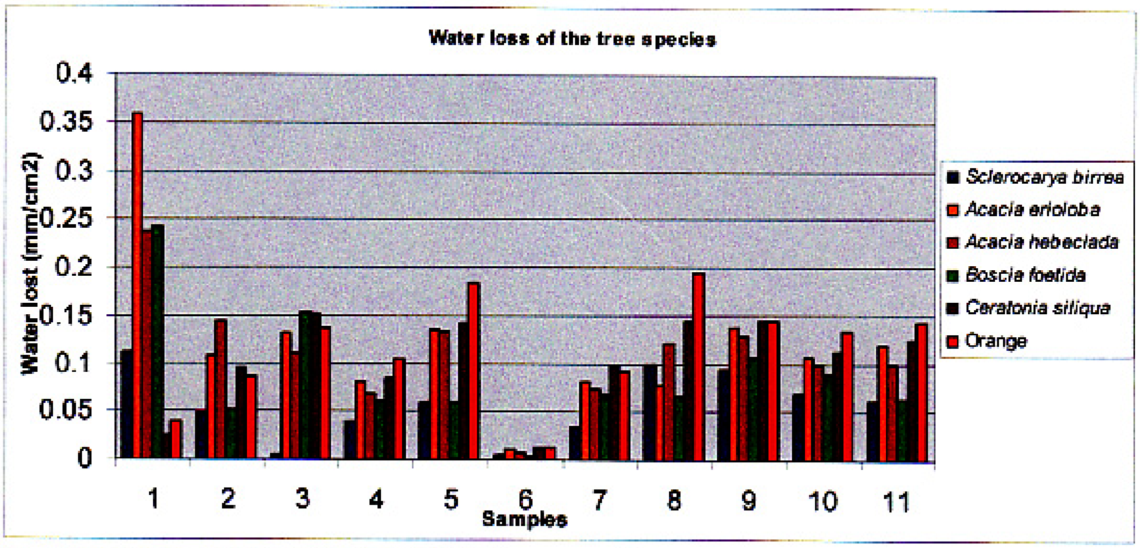


Figure1.1 Shows the water loss of each tree species

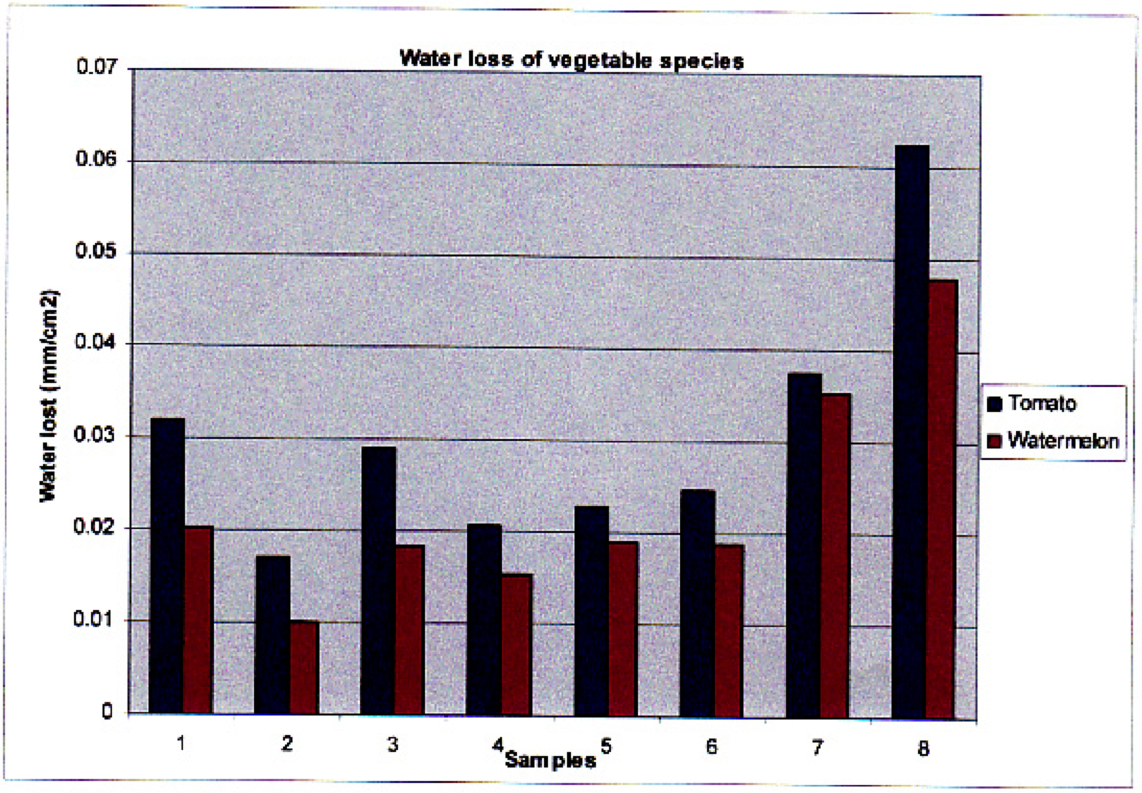


Figure 1.2 shows the species of vegetable that loses the most water.

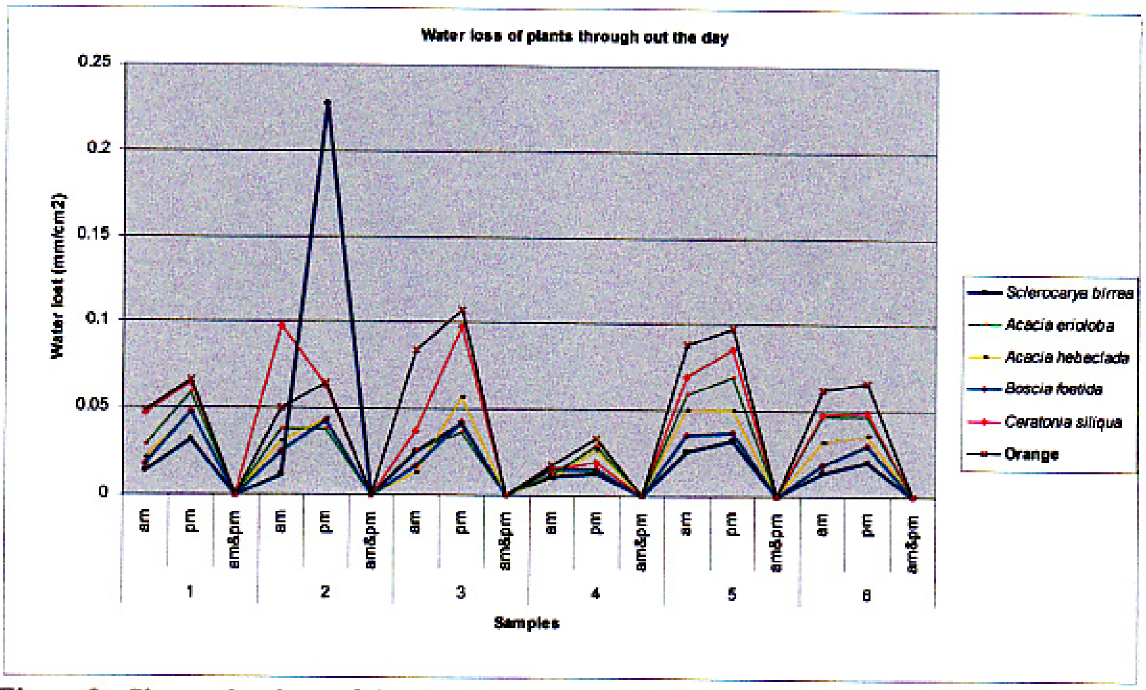
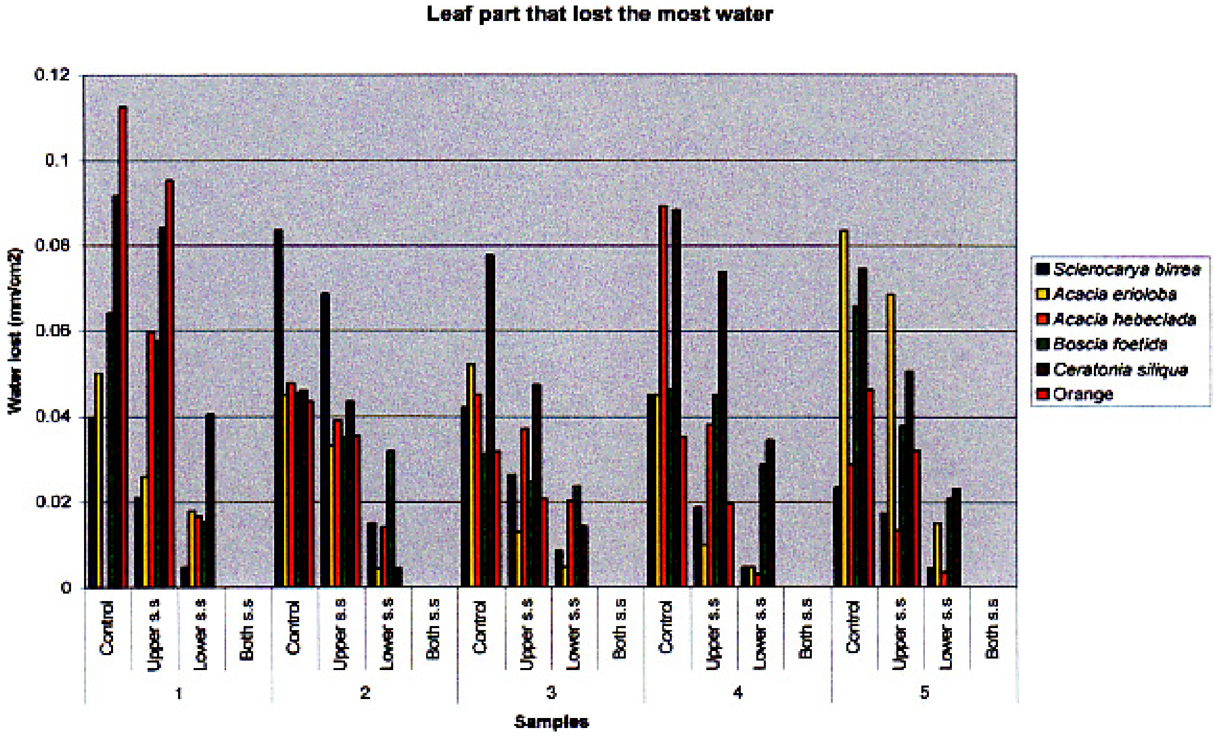


Figure2. Shows the time of the day at which plants lose the most water



Control = leaf left untouched
Lower ss=Lower surface smeared with petroleum jelly
Upper ss= upper surface smeared with petroleum jelly
Both ss= both surface smeared with petroleum jelly
Figure3. Shows the part of the leaf that lost the most water

Table 3. Shows the weather conditions that affect the rate of transpiration in *Boscia foetida*

Water Loss Compared to Weather Conditions

Samples	Max °C	Min °C	Water loss mm/ cm²	Conditions
6	31	16	0.0043	Cloudy
12	30	21	0.0241	P-cloudy
19	31	11	0.0257	P-cloudy
13	31	18	0.0284	Clearsky
14	32	12	0.0297	Clearsky
20	33	9	0.0366	P-cloudy
15	33	14	0.038	Clearsky
17	34	10	0.0473	Clearsky
18	36	12	0.0509	Clearsky
2	38	18	0.0531	P-cloudy
16	37	18	0.0539	Clearsky
5	39	15	0.0601	P-cloudy
4	39	13	0.0617	P-cloudy
11	40	21	0.0633	Clearsky
7	42	12	0.0691	Clearsky
10	41	18	0.0884	Clearsky
9	41	20	0.1065	Clearsky
8	43	26	0.1439	Clearsky
3	43	21	0.1533	Clearsky
1	46	15	0.2429	Clearsky

DISCUSSION

As this project has four very different objectives, they will each be discussed separately.

Objective 1. Tables 1.1 and 1.2 shows the actual water loss, size of the leaf and the water loss per centimetre square. The objective was to get the size of the leaves and compare it with the quantity of water obtained from each group of leaves from the various plant species. This was the only way to determine the plant species that has lost the most water. Table 1.1 and table 1.2 could not be combined together, because the vegetable samples were not taken on the same day. They first had to be planted from seed and grow. The main idea was not to compare the quantity of water transpired by vegetables and trees but to compare the transpired water between different tree species and between different vegetables separately. Therefore in this case I only compared trees to trees and vegetables to vegetables. However, I could not include the Onion in table 1.2 although it was also part of the research. This is because the shape of the Onion leaves was too complicated to calculate using the graph paper method. According to the first table, the Orange tree is the plant ranked the highest in transpiration. This could be because of the broader leaves of the tree which contain numerous stomata that aid transpiration. As this tree does not grow naturally in the desert, it is also possibly that it is not genetically structured in such a way that it can save water. From figure 1.1, one can also determine all the plants in order, from the plant that loses the most water to the plant that loses the least amount of water. When I ranked all the trees in order to find out the tree that loses the most water to the one that loses the least amount of water, it was *Sclerocarya birrea*. This was not what I expected the outcome to be because the leaves are bigger than the indigenous *Acacia* species. My three suggestions as to why *Sclerocarya birrea* transpired very little water are as follows. Compared to all other trees, I noticed that the branches and especially the rachis of this tree are much more flexible and can shake in the wind all the time. This is reducing the direct contact of the leaves with the sun rays, preventing the plant leaves from overheating and therefore resulting in low water loss. Apart from the other characteristics that many plants have on their leaves, I also noticed that the leaves of this plant have a clearly visible white coat colour which helps it to reflect much of the sun radiation and reduce transpiration. Due to the fact that *Sclerocarya birrea* is one of the deciduous trees, I also noticed that this tree was at its time of abscission. Therefore it could be that the vessels of all or most of the leaves that I sampled were already becoming blocked so that the leaves become deprived of water to die out.

Figure 1.2 shows that the Tomato plant is transpiring more water than the watermelon. When I looked very closely and felt the texture of the leaves of the tomato plant and that of the watermelon, I find out that the leaves of the watermelon feel waxier and hairier than the tomato leaves. This is probably the reason why watermelon only loses a small amount of water. In addition, when I was setting up my experiment or watering these vegetable plants, I also noticed wilting in the tomato plant almost every time which is also an indication that tomato is not that effective in minimizing the water lost.

Objective 2

Figure 2 is showing the quantity of water transpired by each species of plant at different times of the day. It is commonly believed that high transpiration and high evaporation is mostly occurring during the afternoon hours (Keding, pers.comm). This belief is supported by the data collected and presented in figure 2. Even though the results of the experiment that lasted for twelve hours (overnight) were divided by two to give the interval of six hours, there was not even a drop of water transpired during that time. Theoretically, there is no transpiration happening during the night as many plants close their stomata. In addition the weather condition at night is cool and dark so there is no need for the plant to cool itself down, which also correlates with the data shown in figure 2.

Objective 3
Figure 3 indicates the part of the leaf that loses the most water. It is believed that plants lose water on both surfaces, but to different extents. Since the layer of petroleum jelly prevents loss of water, according to the graph it is deduced that the lower surface was responsible for the greater transpiration than the upper surface. The graph is also indicating that there is no water lost from the leaves that were covered on both sides with the petroleum jelly. All trees lost water through the upper surface except for the orange tree. Judging by the size of the orange leaves, I was really expecting it to also lose water from the upper surface. Although I am not sure why there was no water loss from the upper surface, I suggest that it could be possibly because the thick layer of cuticle on the upper surface of the leaves which could act as a waxy protective layer. I also noticed that the leaves of this tree are shinier. Shiny things also reflect sun light preventing the overheating of the object and in this case it aid in preventing water loss from the leaves.

Objective 4
Table 3 is showing the outcomes of the investigation conducted about the weather conditions that affect the rate of transpiration. As I have stated earlier under the method section that one of the tree species was subjectively selected to carry on with this investigation, the graph is only indicating the selected species *Boscia foetida*. The table is indicating how the water transpired by the leaves changed in quantity as the weather changed on different days. Interestingly, the graph also shows that the first eleven samples are a little bit higher than the last nine samples. The reason being that the first eleven samples were taken in summer when it was still warm, while the last nine samples were taken in winter as the weather was becoming cold. According to the results presented in figure 2 I believe that the minimum temperature recorded has no effect in the transpiration rate because the temperature is always at night time when there is no transpiration takes place. The amount of water lost on each day is only correlating with the either the maximum temperature and the cloud cover. The table therefore shows that the high the temperature the more water was lost. When it was cloudy, less water has lost at the same temperature most of the time.

CONCLUSION

In general, all different species of plants on planet earth do not lose water at the same rate. This is because of the different categories under which plants fall, the arrangement of the external and the internal structures of the cells inside the leaves and also because of the habitat on which different plants are growing. Regarding the different times of the day, it is with no doubt that the highest transpiration is happening during the afternoon hours. As the rate of transpiration also depends on how the weather is, this does not necessarily mean that plants are permanently losing more water in the afternoon; because the weather can be sunny in the morning and suddenly cloudy and raining in the afternoon and in this case, the result of transpiration can now become the opposite. Amazingly, high transpiration is mostly happening from the lower surface of the leaves even though theoretically, the shade can also be one of the conditions that is affecting the transpiration rate and in this case, the lower surface of the leaf is mostly in the shade cast by the leaf itself. It is also clear that both surfaces of the leaves lose but at different rates. In addition to that, the weather conditions such as the cloud cover and the temperature plays a very big role in the amount of water lost by the plants.

Recommendations

During the activity "Making your own water", I noticed that many learners mostly focus their experiments on uprooting the grass to make water. I am therefore recommending to the NaDEET staff that they set up a demonstration experiment to present a method to the learners how they can obtain clean water from plants without uprooting them. I also strongly recommend to all the NaDEET staff to only water their plants later in the afternoon or early in the morning when there is less evaporation. During the "water evaluation" activity where learners discuss methods to save water, NaDEET staff can use the results of my project as evidence as why plants should not be watered during the day.

Acknowledgements

I would like to extend my vote of thanks to Mrs Viktoria Keding for her time, assistance and much other support that she gave me throughout the course of my in-service training. I particularly grateful to Mr Marc Dürr for sharing his knowledge in nature with me. I am also indebted to Dr Willem Jankowitz for his wonderful guidance throughout my in-service training.

REFERENCES

Anon. 2002. Biology. Windhoek: TUCSIN.
Joubert, D. 2005. Ecology 2, Study guide Windhoek: Polytechnic of Namibia.
Keding, V. 2006. Personal communication. Director Namib Environmental Education Trust. Namibia
Lovegrove, B.1993. The Living Deserts of Southern Africa. Cape Town: FernWood Press
Mackean, D.G.1962. Introduction to biology. London: John Murray Publishers.
Neema, T. 2006. personal observation. Windhoek: Polytechnic of Namibia.

Appendix 1

RECORD SHEET

Date	Temperature		Start time	Finishing time	Species	Type of experiments	Water volume (mm)	Leaf surface (cm^2)	Notes	Other weather condition
	Max	Min								