The effect of light and temperature on petal movement of Oxalis corymbosa

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Content

Abstract

Oxalis corymbosa(紫花醋漿草)[2] is a common herb which bears lilac flowers. Its flowers open at daytime and close/sleep at night. In our investigation, we conducted a series of observations and experiments in order to find out the effect of light and temperature on petal movement of its flowers. We found that flowers opened when the temperature was relatively higher and hence this exhibited thermonasty. While flowers opened when the light intensity was higher and closed when the light intensity was lower. This exhibited photonasty. The effect of temperature was found to be much higher than that of light in causing the opening of flowers.

The possible role of leaves in the petal movement was also studied. It was found that the petal movement was not affected by leaves. Even without leaves, flowers still opened when temperature and light intensity were appropriate.

Introduction

One day, while we were walking around our garden in the school, trying to find what topic we could have for our biology project. We suddenly spotted the *Oxalis corymbosa(紫花醋漿草)* in one corner of the garden. We thought that it is a quite interesting plant. We then continuously made observations on the changes of the plant and found that its flowers open and close at different environmental conditions and time of the day.

Oxalis is the largest genus in the wood-sorrel family – *Oxalidaceae*. *Oxalis corymbosa* is a common herb easily seen everywhere. It is considered as a troublesome weed of pot plants and gardens. Its common name is lavender sorrel. Its flowers are bisexual and bear five lilac petals. *(Thrower 1974)* In preliminary observations, it was found that its flowers opened at around noon when the light intensity and temperature were higher. However these flowers would close (sleep) at around 5-6p.m. and open in the late morning of the following day. Such petal movement is documented for some other species e.g. *Gentiana* species. *(Sofia 2006)* In this investigation, we aimed at finding out the effect of light and temperature on the opening and closing of flowers of *Oxalis corymbosa*. Moreover we also studied the role of leaves in this petal movement.

(For simplicity, 'Oxalis' used in the rest of this report represents 'Oxalis corymbosa(紫花醋漿草)'.)

Method of investigation

It was observed that the petals curved out and the flower opened. When petals curved in, the flower closed (or 'slept'). Therefore we focus on the petal movement in response to changes in light intensity and temperature.

In order to achieve the objectives mentioned above, we used the following methods:

1. Observations of the *Oxalis* flowers at our school's rooftop garden:
   By using a time-lapsed camera, we recorded the changes of flower conditions from morning to evening. At the same time, a data logger connected to temperature and light intensity sensors was set up to record the changes in temperature and light intensity.
2. Experiments to find out the effect of light and temperature on the petal movement of *Oxalis* flowers:
   We moved few pots of *Oxalis* from rooftop garden to the Biology laboratory. Table lamps were used as artificial light source. Data logger connected with temperature and light intensity sensors were used to record changes in the temperature and light intensity during experiment. A time-lapse camera was set up to record changes in the flowers. At times, photographs were taken by digital cameras. We conducted a series of experiments in order to achieve our goals.

In order to find out the possible role of leaves in petal movement of Oxalis, we conducted an experiment in which all leaves were cut and condition of flowers were observed then.

Details of the methods, results and discussions of our work are listed below:

i.) Field work at our school rooftop garden

We have been observing the *Oxalis* at the rooftop garden of our school.

Date	Time	Environmental Condition	Condition of flowers	Remarks / Photograph
6/3	07:50	Cloudy	Flowers close	The opening and closing of flowers were observed.
	13:25	Cloudy	Flowers open	
7/3	08:25	Cloudy High humidity	Flowers close	 Fig.1 we set up a time-lapse camera at our school rooftop garden to record the changes of flowers
	12:50	Few rain patches high humidity	Few flowers opened slightly	
	16:00	- light intensity: 3615 lux - temperature: 19.0℃	Flowers close	 Fig.2 flowers close at 16:00 on 7/3

8/3	10:28	- light intensity: 5700 lux - Temperature: 18.6℃	Flowers close	/
	13:36	- light intensity: 11720 lux - Temperature: 18.8 - 19.1℃	Flowers slightly open	/
12/3	11:00	- cold and humid - Light intensity: 8160 lux - Temperature: 13.4℃	Flowers close	 Fig.3 flowers at 11:00 on 12/3
	13:30	- Light intensity: 12060 lux - Temperature: 14.5℃	Flowers close	 Fig.4 flowers at 12:30 on 12/8
14/3	11:12	- Light intensity: 29500 lux - Temperature: 18.1℃	Flowers open	 Fig.5a flowers at 11:12 on 14/3
	13:54	- Light intensity: 39200 lux - Temperature: 19.5℃	Flowers open	 Fig.5b flowers at 13:54 on 14/3
15/3	12:08	Sunny at times relatively warmer	Flowers open , Four kinds of insects found at/around flowers	 Fig.6 flowers open at 12:08 on 15/3

20/3	8:48	- Light intensity: 15600 lux - Temperature: 20.2℃	Flowers close	 Fig.7 data logger and time lapse camera were set at our school rooftop garden on 20/3
	13:24	- Light intensity: 40530 lux - Temperature: 23.8℃	Flowers open	 Fig.8 flowers open at 13:24 on 20/3
			other observation: leaves folded up	 Fig.9 leaves from one pot droop at 13:24 on 20/3
	16:05	- Light intensity: 14950 lux - Temperature: 22.1℃	Flowers open	 Fig.10 flowers open at16:05 on 20/3

From the above observations, we discovered that the ***Oxalis*** flowers opened generally when the temperature was above 18°C and the light intensity was above 11000 lux. However, from the observation made on 20/3, flowers did not open at the early morning even though the temperature and light intensity were 20.2°C and 15600 lux respectively. This suggested that the opening of flowers may be related to the time of the day. It was also observed that flowers started to open at around 11a.m. and fully open at noon, provided that the light intensity and temperature were above the suggested values. Moreover flowers start to close at around 5p.m.

At the rooftop garden, there are various kinds of weeds. We found that other than *Oxalis*, *Hypoehoeris radicata* (Catsear 貓耳菊) also exhibited petal movement in different conditions in the environment. The periodic petal movement was similar to that of *Oxalis*.

Besides we found snails, caterpillars, hoverflies, spider and butterfly – *Indian Cabbage White (Pieris canidia)(東方菜粉蝶)*[3] *on leaves or flowers of Oxalis*. Few snails crawling around the densely grown Oxalis. Caterpillars ate leaves. Snails appeared in the morning with dim light while caterpillars haunt in the morning but much more in the afternoon. Pieris canidia was found to feed nectar of Oxalis flowers at warmer and brighter days and of course the flowers were open.

Fig.10 Hoverfly stay on the leaves of *Oxalis*

Fig.11 *Indian Cabbage White* feeding nectar of *Oxalis* flower

Fig.12 Spider passing the leaves of *Oxalis*

ii.) Laboratory work

We moved some pots of *Oxalis* from the rooftop garden to the biology laboratory. We carried out a series of experiments to study the effect of light intensity and temperature on the petal movement of *Oxalis*. After finishing one experiment, we interpreted the results and then designed another experiment to do further investigation.

Table showing the overview of our experiments:

Date	Aim	Question raised after interpretation of results
10 / 3	Experiment A: To study effect of light on the petal movement of *Oxalis* flowers.	Which organ, leaf or flower, is responsible for the petal movement of flowers?
12 / 3	Experiment B: To study whether the leaves absorb the light to allow the petal movement of *Oxalis* flowers.	Whether the light intensity or the temperature change affects the opening of the *Oxalis*' flowers?
13 / 3	Experiment C: To study whether the temperature changes affect the petal movement of *Oxalis* flowers.	Does a higher temperature causing the opening of *Oxalis*' flower?
15 / 3	Experiment D: To study whether leaves are essential for causing petal movement of *Oxalis* flowers.	/
20 / 3	Experiment E: To study the effect of high temperature on petal movement of *Oxalis* flowers.	/

Experiment A: To study the effect of light on the petal movement of Oxalis flowers.

Identification of variables:

Independent variable: Covering and not covering the pots

Dependent variable: The petal movement of *Oxalis*

Controlled variables: Humidity, time duration of experiment

Apparatus used: 2 table lamps, 2 data loggers connected with temperature sensors, light-proof box, and time-lapse camera

Fig.13 two of our members making a light-proof box

Procedure:

1. Prepare 2 pots of *Oxalis*. Label them A and B respectively.
2. Make a light-proof box and cover pot A.
3. Put two lamps (with 100W light bulbs) next to pot B.
4. Set up 2 data loggers with connections of temperature sensors and light level sensors to measure and record the change in temperature and light intensity respectively in the surroundings of the pots.
5. Take photos of the two pots of *Oxalis* every 30 minutes to record the changes of the flowers.

Set up for pot A:

Fig.14 set up for pot A In experiment A

Set up for pot B:

Fig.15 set up for pot B in experiment A

Result:

Table showing the petal movement of the flowers in pot A and pot B after the experiment

Pot A	Covered with a light-proof box	Flowers closed and leaves faced down	 Fig.16 two team members observing pot A
Pot B	Exposed to 2 table lamps (100W light bulbs)	Flowers open and leaves faced up	 Fig.17 *Oxalis* flowers opened in experiment A

Interpretation of result:

In this experiment, we can see many of the flowers opened in pot B while none of the flowers opened in pot A. We can see that only the leaves of the pot that was shined by light faced up while the other faced down.

Sources of error:

The two pots of *Oxalis* are not identical, causing the two pots of *Oxalis* are not identical such that they may have different responses to different environment.

Follow up:

We believed the petal movements of flowers of *Oxalis* depends on either light intensity or temperature of the surroundings.

During the experiment, some of the flowers in pot B which is not shined by the lamps directly has opened as well. So, we design another experiment to test whether the leaves or flowers detect light/temperature to cause opening of flowers.

Experiment B: To study whether the leaves absorb light to allow the *Oxalis* petal movement

Identification of variables:

Independent variable: leaves exposed to light or not

Dependent variables: petal movement of *Oxalis*

Controlled variables: humidity, temperature

Apparatus used: Aluminium foils, 4 table lamps (with 100W light bulbs), time-lapse camera, light meter, 2 data loggers connected with temperature sensors

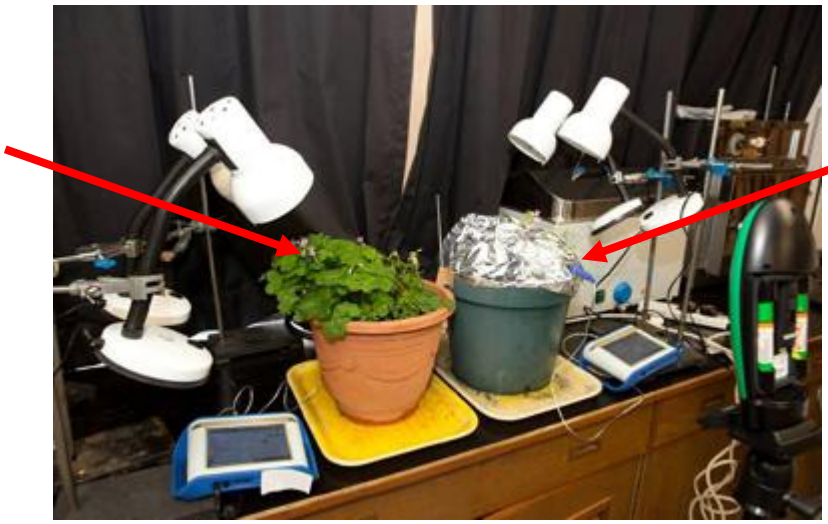
Procedure:

1. Prepare two pots of *Oxalis*. Label them A and B respectively.
2. Use aluminium foil to cover all the leaves of the pot of *Oxalis* B. (make sure the flowers expose to light)
3. Put four lamps (with 100W light bulbs) next to the pots.
4. Adjust the light source to make light intensity on both pots to similar.
5. Set up 2 data loggers with temperature sensors inside and outside the aluminium foil to measure and record the temperature changes.
6. Set up a time-lapse camera to record the movement of flowers within time intervals. (one photo per minute)
7. Switch on the lamp for 40 minutes and observe the results obtained.

Set up for pot A & pot B:

Result:

Pot A



Pot B

Fig.18 set up for experiment B

Table showing the petal movements of flowers of *Oxalis* pot A and pot B in the experiment

	Pot A	Pot B
Condition	- Leaves and flowers exposed to light	- Leaves covered by aluminium foil
Movement of flowers	Total number of flowers of pot A: 28 10 flowers opened  Fig.19 flowers open in pot A of experiment B	Total number of flowers of pot B: 27 15 flowers opened  Fig.20 flowers open in pot B in experiment B

Interpretation of result:

After doing this experiment, we have found that the petals open even when the light cannot reach the leaves. The petal movements even come faster in pot B than that of in pot A.

In pot B, leaves are covered by aluminium foil, heat is kept under the aluminium foil. So that temperature under the aluminium foil, which is in touch with the soil is higher than that in pot A. Few flowers under the aluminium foil still opened. As a result, higher temperature led to the petal movement of the *Oxalis* flowers.

Sources of error:

The two pots of *Oxalis* are not identical. The data recorded show the temperature is higher than the environment when pot B is covered by the aluminium foil.

Follow-up:

From the result of this experiment, we can conclude that the petal movement of flowers does not depend on whether leaves can absorb light or not. The table lamps lead to a higher temperature. Therefore, it is most likely that high temperature led to the petal movement. However we ruled out the effect of light on the petal movement. So, we are going to do another experiment to further test the effect of temperature on petal movement of *Oxalis*.

Experiment C: To study whether the temperature change affect the petal movements of flowers.

Identification of variables:

Independent variables: The temperature of surroundings

Dependent variables: The petal movement of *Oxalis*

Controlled variables: Time duration of applying lamps or covering with aluminium foil, humidity

Apparatus used: Aluminium foils, 4 table lamps (with 100W light bulbs), time-lapse camera, light meter, 2 data loggers connected with temperature sensors,

Procedures:

1. Prepare 2 pots of *Oxalis*. Label them A and B respectively.
2. Cover pot B with aluminium foil (to produce a relatively lower light intensity and higher temperature)
3. Put four lamps (with 100W light bulbs) next to the pots. (relatively higher light intensity and temperature)
4. Set up 2 data loggers with connections of temperature sensors and light level sensors to measure and record the temperature changes in the surroundings of the pots.
5. Take photos of the two pots of *Oxalis* every 1 minute to record the changes of the flowers within time intervals.
6. Switch off the lamps after 40 minutes to prevent the *Oxalis* from overheating.
7. Observe and record the result in certain period of time.
8. Uncovered the pot after two hours and observe and record the result.

Set up for pot A and pot B:

Fig.21 set up for pot A and pot B in experiment C

Result:

Table showing the opening of flowers of **pot A** in different condition of environment over time

Time	Light intensity(lux)	Temperature (°C)	Observation	Photos
08:30	11200	15.1	- Flowers open and facing upwards	 Fig.22 flowers in pot A at 8:30
09:10	Lamp switched off	18.3	- Flowers open and facing upwards	 Fig.23 flowers in pot A at 9:10
09:20	1830	15.5		 Fig.24 flowers in pot A between 9:50 and 10:35
09:50	2090	15.0		
10:35	1990	14.9		

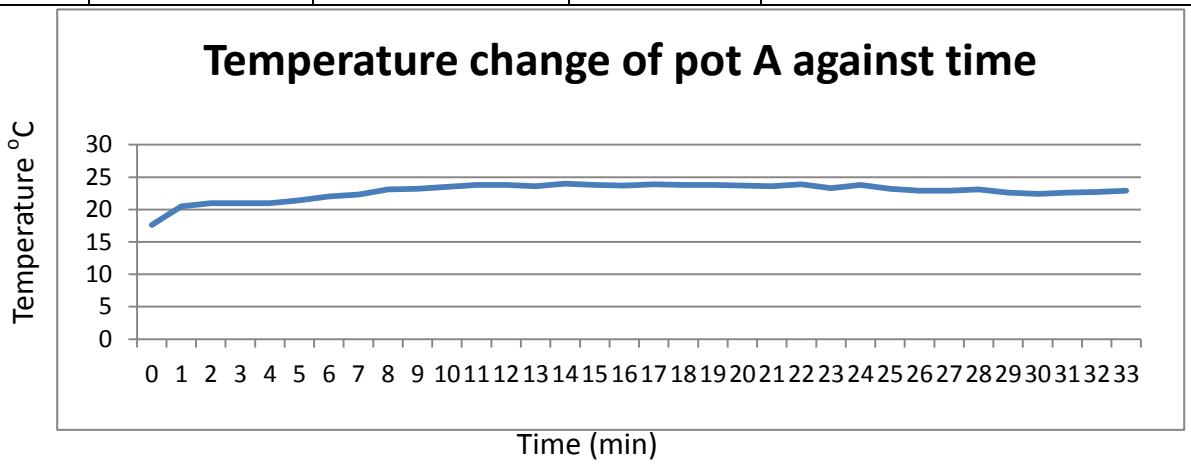
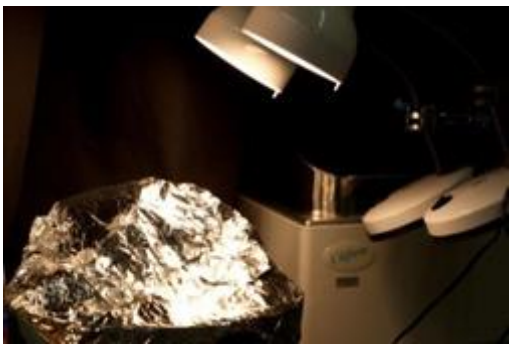


Table showing the opening of flowers of **pot B** in different condition of environment over time

Time	Light intensity(lux)	Temperature (℃)	Observation	Photos
08:30	11200	15.1	/	 Fig.25 pot B being covered by aluminium foil
09:10	Lamp switched off	20.5		
09:20	2390	15.2		 Fig.26 flowers in pot B during 9:20 and 9:50
09:50	2490	15.1		
10:35	2390	14.9	- Flowers open widely	 Fig.27 flowers in pot B at 10:35

Interpretation of result:

In this experiment, the flowers in both pots of *Oxalis* open, exposing the interior structures of the flowers. Although the whole *Oxalis* plants in pot B were covered by aluminium foil, flowers opened. As a result, the opening of flowers is independent of the presence of light. Flower opening and closure are traits of a reproductive syndrome, as it allows pollination. *Oxalis* flowers open to attract the insects to come for pollination.[4] Higher temperature increases the enzyme activity of the insects. So the insects are in a more active state, they can then feed on nectar of Oxalis flowers and hence help transferring pollens at the same time.

Sources of error: Heat was not evenly distributed.

Experiment D: To find out whether leaves are essential for causing petal movement of Oxalis flowers.

Identification of variables:

Independent variable: Presence or absence of leaves

Dependent variable: Petal movements of flowers

Controlled variables: Humidity, Light intensity, Time duration of applying lamps

Apparatus used: scissors, 4 table lamps (with 100W light bulbs), time-lapse camera, light meter, 2 data loggers connected with temperature sensors.

Procedure:

1. Prepare two similar pots of *Oxalis*. Label them A and B.

Fig.29 cutting all the leaves in pot A

Fig.28 pots A and B before treatment

2. Cut away all the leaves in pot A.

Fig.30 putting vaseline on the cut ends of plants in Pot A

3. Cover the cut ends of plants in pot A by vaseline. (To prevent water loss of plants by evaporation.)
4. Put pot A and B under 4 table lamps (with 100W light bulbs).
5. Measure and adjust the light source, until both pots of *Oxalis* receive similar amount of light.
6. Set a time-lapse camera (one photo per minute)
7. Record the changes of both plants within time intervals.

After cutting the leaves in pot A:

Fig.31 pot A after cutting the leaves

Set up for pot A and pot B:

Fig.32 set up for pot A and pot B in experiment D

Result:

Table showing the numbers of open flowers in in pot A and B at different time

Time	0830		0910		0920		0930		0940		1020		1120	
Pot	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Temperature (^{o}C)	20.5	18.1	23	18.3	23.6	18.6	23.6	18.8	23.8	19.0	23.8	19.1	22.9	18.4
	No. of flowers													
closed	8	11	6	8	5	7	4	6	4	5	2	2	1	0
slightly open	0	0	2	3	3	4	0	0	0	0	0	0	0	0
half open	0	0	0	0	0	0	3	2	2	3	1	1	2	1
fully open	0	0	0	0	0	0	1	3	2	3	5	8	5	10
Total no. of mature flowers	8							11						

	Pot A	**Pot B**
Condition	All the leaves were cut away	Normal condition
Observations	– Most of the flowers opened – Appearance of water droplets on the tips of the cut stems	– Most of the flowers opened
Photos	 Fig.33 the opening of flowers in pot A of experiment D	 Fig.34 the opening of flowers in pot B of experiment D

Interpretation of result:

In the above experiment, all the leaves of pot A were cut away while that of pot B still remained as the normal condition. Obviously flowers of both pots A and B *Oxalis* opened widely. This clearly shows that leaves are not essential for petal movement.

There is also appearance of water droplets on the tips of the stems that cut. Water was pushed out by root pressure even when vaseline is applied at cut ends. But this does not affect the opening of flowers. Therefore, water loss does not affect the accuracy of this result.

Sources of error: The two pots of *Oxalis* are not identical.

Follow up:

In this experiment, we can see the flowers open in both situations, either with or without leaves. The result shows that the leaves are not involved in the petal movement of flowers. The flowers

themselves are responsible for the detection of environment, causing the petal movement of flowers.

With respect to the analysis, we have designed another experiment to ensure that the flowers detect the temperature change of environment, and lead to the petal movement.

Experiment E: To study the effect of temperature on petal movements of *Oxalis*.

Identification of variables:

Independent variables: temperature around the pots of *Oxalis*

Dependent Variables: The petal movement of *Oxalis*

Controlled variables: light intensity, humidity

Apparatus used: plastic wrap, a tray, 10 packs of hand warmers, a light-proof box, 2 data loggers connected with temperature sensors,

Procedures:

1. Prepare one *Oxalis* pot and 10 packs of hand warmer.
2. Take the pot of *Oxalis*, cover the bottom of the pot with plastic wrap, and put it on a tray.
3. Put ten opened hand warmers on the tray besides the pot.
4. Cover the whole pot and the hand warmers along with the tray with a large light-proof box.
5. Set up two data loggers connected with temperature sensors to measure and record the temperature inside and outside the box.
6. Leave the pot for a period of time.
7. Check the pot at intervals of time and take photos of the flowers.
8. Observe the changes of the *Oxalis* flower and record the observation.

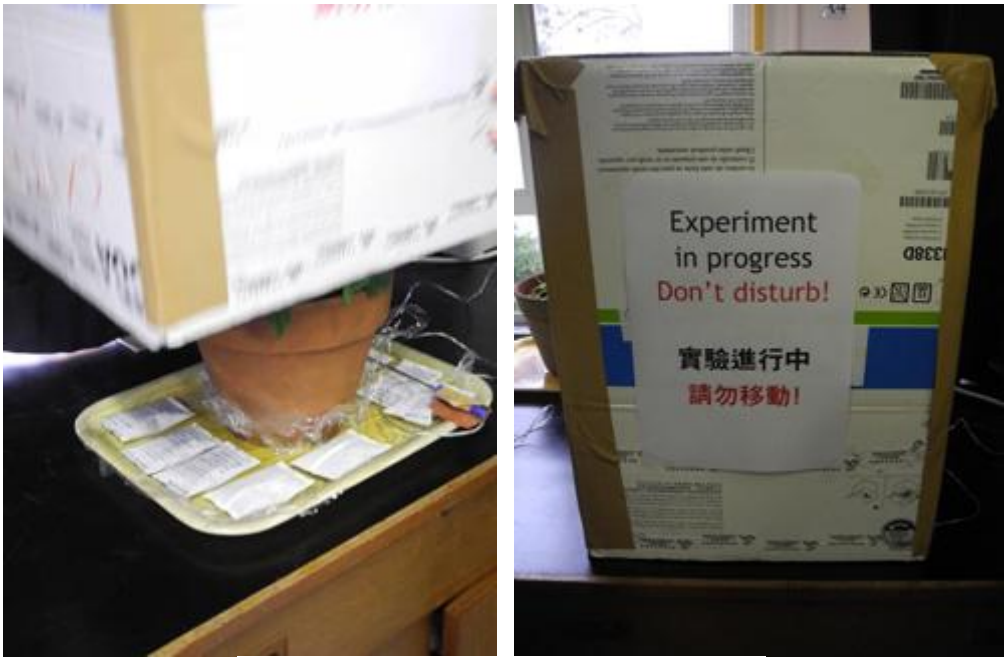


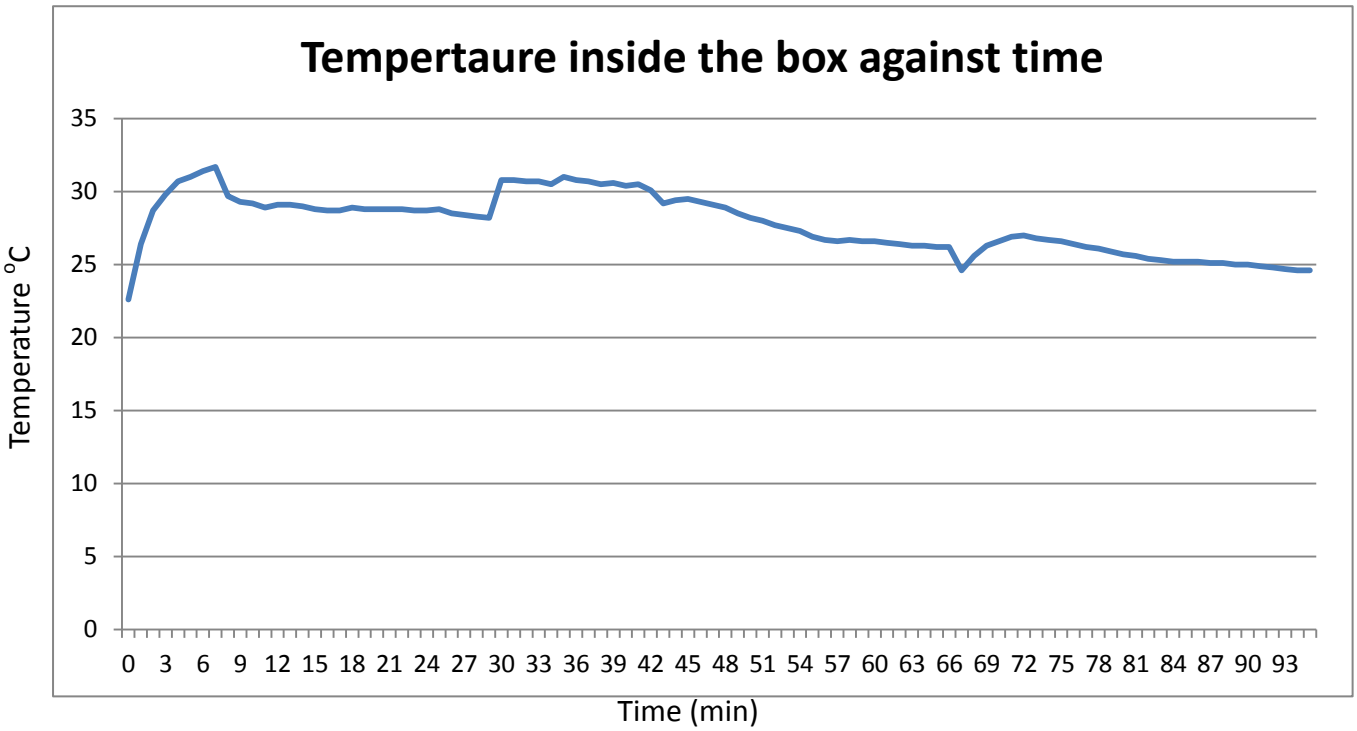
Fig.35 covering the pot in experiment E

Result:

Table showing the petal movement in the pot of *Oxalis* within time intervals and temperature

Time	Temperature(^{o}C)	Condition of flowers	Photographs
08:01	22.6	Flowers close and face down	 Fig.36 flowers in pot of experiment E at 8:01
10:35	28.4	Flowers open and face down Leaves faces down	 Fig.37 flowers in pot of experiment E at 10:35
13:37	25.9	Flowers open and face down Leaves face down	 Fig.38 flowers in pot of experiment E at 13:37
15:57	24.8	Flowers open and face down Leaves face up	 Fig.39 flowers in pot of experiment E at 15:57

Graph showing the temperature inside the box against time (min):



Interpretation of result:

In the presence of hand warmers, the temperature inside the box rose to 32°C, which was about 9.5 °C higher than the room temperature. At intervals, the box was removed to allow observations and photo-taking. The temperature inside the box was kept at around 30 °C for an hour. We can see the petals open even when light is absent. The result shows that petal movement mainly depends on temperature. When the temperature gets high, it opens. Similarly, whenever the temperature is low, it closes instead.

Overall Discussion

i) Effect of light on the petal movement of *Oxalis*

From observations at rooftop garden, light intensity affects the petal movement of *Oxalis*. Flowers open only when light intensity is relatively higher and closes when light intensity is low. If flowers open on a particular day, they would close at around 5 p.m. where light intensity drops significantly.

In contrast, the findings from laboratory work did not show the similar effect of light on petal movement. By comparing the results of experiments A and E, flowers open when the temperature is high. The petal movement was independent of the presence of light.

The differences in findings from field work and laboratory work worth further investigations in future.

ii) Effect of temperature on the petal movement of *Oxalis*

In experiment A, we concluded that the petal movement of flowers of *Oxalis* depends on either light intensity or temperature of the surroundings. Therefore, the setup of experiment C is similar to that of experiment A, but using aluminium foil instead of using a box to cover it.

Moreover, we focused on both light intensity and temperature differences between pot A and B and recorded down the details in Experiment C.

We discovered that the petal movement of *Oxalis* is mainly affected by the temperature change; we found that when the temperature is higher, the petals of *Oxalis* would open wider. In experiment C, we mainly focused on the effect on change of light intensity; temperature change was a minor consideration. However, as aluminium foil covered pot B, air was being trapped inside and the temperature started to rise slightly. We figure out the petals of pot B opened wider than that of pot A. Therefore, we further setup Experiment E to see if high temperature can cause opening of flowers. From the result, as the petals of pot B opened much wider. As a result, we concluded that temperature is a main factor leading to the petal movement of *Oxalis*.

iii) Role of leaves in petal movement of *Oxalis*

From experiment B, we can deduce that the opening of flowers is independent of absorption of light from leaves. From experiment D, we can deduce that the opening of flowers is not directly affected by leaves. Even without leaves, the flowers can still open on its own.

We then can deduce that flower can detect changes in light intensity and temperature which then lead to the opening and closing of flowers. All in all, leaves play no role on the petal movement of Oxalis flowers.

iv) Other observations

a) Relationship with pollinators

Butterflies (Indian Cabbage White) were found to feed nectar of Oxalis flowers. They actively visited the flowers when light intensity and temperature were high. Butterflies were cold-blooded animals, therefore they were active when temperature was high and vice versa. Oxalis flowers open only when temperature and light intensity were high. This ensures that flowers open to allow pollinators to get nectar and pollens. When the environmental conditions were not favourable for pollinators, flowers closed to protect the floral parts.

b) Similarities between *Oxalis* and *Catsear*

From our observations at the rooftop garden, we found that flowers of *Oxalis* and *Catsear* both response to the changes of the environmen. Their flowers open up in warm surroundings and closes in cold surroundings. They have similar petal movements under the same conditions.

C) Sleep movement of leaves of *Oxalis*

In the experiments conducted, except the petal movements of flowers, we have discovered that the leaves also have sleep movements. When the light intensity is high, the leaves face upwards. And when the light intensity is low, the leaves face downwards. However when the light intensity is very high, leaves may fold up.

Limitations of investigation

Due to the limited time, we could not study if the other factors, such as humidity and rainfall, in the environment affect the petal movement of *Oxalis*. Also, we cannot check for the change in sensitivity of *Oxalis* to the temperature during their lifespan.

We could not carry out observations and experiments at night to check if a biological clock exists in *Oxalis* which may affect its petal movement.

We could only find out the condition needed for petal movement e.g. high temperature, but we cannot determine the critical value for causing such petal movement.

Suggestions of further investigations

- To check if the other factors in the environment affect the petal movement of *Oxalis*
- To check which part of the light spectrum is responsible for the opening and closure of flowers
- To find out the critical temperature and light intensity leading to opening and closing of flowers
- To find out the mechanism of petal movements
- To see if the flowers of *Catsear* open and close in a similar way as *Oxalis*

Conclusion

We have found that the petal movement of flowers of *Oxalis corymbosa(紫花醡漿草)* depends mainly on the temperature in the surroundings. When the temperature is relatively high, flowers open. And when the temperature is low, flowers close instead. The effect of light on petal movement is not certain. In the field work, flowers open when light intensity is relatively high and close when light intensity falls significantly at around 5-6 p.m. However flowers in the laboratory can still open in the absence of light provided that temperature is relatively high. In addition, the leaves play no role on the petal movement of *Oxalis* flowers.

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