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The Little Chameleon in Plant Kingdom—*Drosera spatulata*

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1. Abstract

Drosera spatulata is a species of sundews, which is an insectivorous plant that captures prey for minerals. This special feature enables sundews to survive at soil with low mineral content. Preys are trapped by the mucilage present at the tips of the tentacles on the leaves and the tentacles bend towards it to assist digestion. Enzymes are secreted by the plant to digest the insect slowly so that nutrients can be absorbed through the leaf surface.

In this project, our objectives are to study the response of sundews towards different stimuli, the significance of red pigment present in insect attraction and the effect of light intensity on the color of sundews.

From the data collected in the field studies and the results from experiments, it was believed that sundews give response to chemical stimulus. Besides, the red appearance of sundews does not help attracting prey. The abundance of red pigment present is subject to the light intensity. The higher the light intensity, the more the red pigments is present.

2. Introduction

2.1 Introduction to research topic

Sundew (*Drosera spatulata*) is an insectivorous plant which obtains minerals by catching insects. Insect is trapped by the sticky fluid on the tips of numerous tentacles present on the leaf. The leaf bends and wraps around the insect to digest and absorb the nutrients. During our field trip, it was observed that the color of the leaves in different individual plants differs greatly and it seems that there is a certain pattern for the distribution of different colors of sundews. Finding the nature of this plant interesting, our group decided to investigate the effects on its habits brought by different environmental factors.

2.2 Objectives

1. To investigate the response of *Drosera spatulata* towards different stimuli
2. To investigate the significance of red pigment present in attracting and catching insects
3. To investigate the effect of light intensity on the colors of Sundew

2.3 Research questions

1. Why do sundews have different colors of leaves?
- Does the red pigment help attracting insects?
2. Can sundews distinguish between digestible and indigestible matter?
- Referring to Q.2, if there really are differences in response, why will there be such differences?
3. How does light intensity affect the distribution of red and green sundews?
- Will the color of sundews change under sunlight with different light intensity?

2.4 Background information of *Drosera spatulata*

2.4.1 Classification [1]

Kingdom	Plantae
Subkingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Dilleniidae
Order	Nepenthales
Family	Droseraceae
Genus	Drosera L.
Species	*Drosera spatulata*

Fig.1

2.4.2 Description

Drosera spatulata(as Fig. 1)is sundew with spoon-shaped leaves. The specific epithet is Latin for "spatula shaped," which refers to the shape of leaves of the sundew [2]. They catch and digest insects using stalked mucilaginous glands covering their leaf surfaces [3]. *Drosera spatulata* is a variable perennial plant that produces small rosettes of numerous spathulate leaves. They are generally 4 cm in total length and each leaf is about 4-5 mm long. [4]The leaves are attached to the central rosette by a narrow 8 mm long petiole. Its flower can grow up to 6 mm [2]. The red leaves of *Drosera spatulata* in Hong Kong [6] are given a name called “Ruby Slippers” [5].

3. Methodology

3.1 Working Schedule

	Date	Time	Venue	Event
1st field study	12-2-2016	9:30 - 13:30	Stream in Sir Cecil’s Ride, Braemar Hill, North Point	collection of data of the distribution of sundews
2nd field study	20-2-2016	4:00 - 17:30	Stream in Sir Cecil’s Ride, Braemar Hill, North Point	- collection of data of the distribution of sundews and environmental factors - on-site experiments

				(experiment 1.1 and 3) - collection of sundews

3.2 Field Study

Two field studies were carried out on at the stream in Sir Cecil's Ride in Braemar Hill, North Point (Fig.2 refer to the map as shown below). A total of 3 zones of sundews were found at the site in the 1st field study (zones 1, 2&5, refer to Fig. 3) and two more zones of sundews were found in the 2nd field study (zones 3&4, refer to Fig.3). The data of the distribution of sundews and environmental factors are recorded.

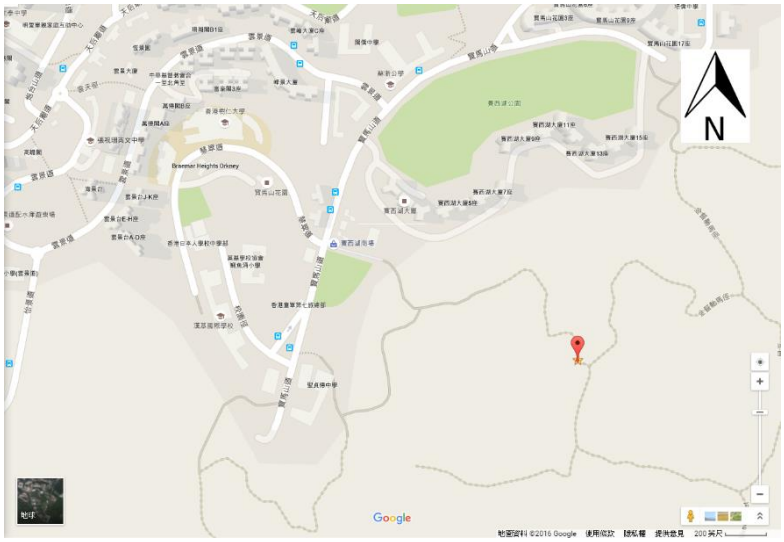


Fig.2

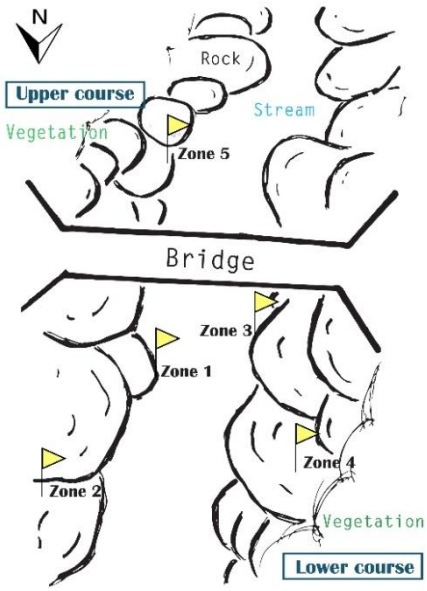


Fig.3 (Map scale: 1:100)

data collected in the field studies	
Number of sundews in each group	Light intensity
Color of the sundew	Temperature
Number of leaves per sundew	Number of leaves with insect caught per sundew

3.3 Objective 1: To investigate the response of sundew towards different stimuli

Experiment 1 was designed to investigate the response of sundews towards different stimuli, including physical stimuli and chemical stimuli. The experiment was carried out twice, once at the 2nd field study on 20-2-2016 (named as experiment 1.1) and once at the Eco pond in our school, Cheung Chuk Shan College, using samples of sundews collected from the field site on 3-3-2016 (named as experiment 1.2).

Objective of experiment 1:

To investigate the response of sundew towards different kinds of matter

Principle of experiment 1:

Numbers of matters with different natures were put on the leaf of sundew separately to see if the sundew shows response to the matter. Different matters which give different stimuli, including physical stimuli and chemical stimuli, were chosen. Living organism gives out both physical and chemical stimuli, it physically stimulates the tentacles of the leaf when struggling and it contains organic matter. Dead organism and fish food only act as chemical stimuli as they both contain organic matter. Sand is used as the only inorganic matter to see if the sundew can distinguish between digestible and indigestible matters. (Matters under test: live ants, dead ants, fish food, sand)

Procedures:

1. A living ant was put onto the leaf of sundew
2. Photo was taken immediately for record of initial condition
3. Continuous observation were made and photos were taken over different periods of time for record and comparison
4. Steps 1 - 3 were repeated as replicate
5. Steps 1 - 4 were repeated using dead ants, fish food, and sand.

(p.s. the experiment was carried out twice. One on the field study site, and the other one at the eco-pond in our school.)

3.4 Objective 2: To investigate the significance of red pigment present in attraction of preys

The discovery of the difference in colors of sundew arouses our query on the significance of the red pigment present in sundews. According to our knowledge, the presence of red pigment will reduce the amount of sunlight absorbed by the leaves and is undesirable in terms of photosynthesis. Thus, there must be a certain advantage for the production of such red pigment and we made a guess that the presence of red pigment is advantageous to the attraction of prey.

We have made two approaches to test if our guess is correct- field counting and experiment. The number of leaves with insect caught in red sundews and green sundews were counted and recorded in the field studies respectively. The average percentage of number of leaves with insect caught in both red and green sundews were calculated and compared to see if red sundews are more effective in catching preys. The predicted result is that the average percentage of leaves with insect caught of red sundews is greater than that of green sundews, supporting that the red appearance of sundew helps attracting insects.

Experiment 2 was designed to see if the red appearance of sundews helps attracting preys and was carried out right after the 2nd field study, on 2-20-2016, at one of our group mates' home.

Objective of experiment 2:

To investigate the significance of different colors of sundew on attracting insects

Hypothesis of experiment 2:
The red appearance of sundew helps attracting insects

Principle of experiment 2:
The hypothesis would be supported if the red sundews were able to capture more insects than green sundews under identical environment conditions. The color of the sundews is the only independent factor in this experiment, assuming that the effects of all other factors are not significant. Thus, if there is a significant difference in numbers of insects captured by the red and green sundews, the difference in color would be the only possible reason for the difference in abilities in attracting insects. Therefore, more insects being attracted to the red sundews than the green one supports that the red appearance do help attracting preys. Red and green sundews of similar sizes were chosen to have the fairest comparison. Assumptions were made that there is no significant difference in the sizes and conditions of the sundews used in the experiment.

Procedures:

1. Two red sundews and two green sundews were put into a plastic bowl. (refer to Fig.4 for the exact set-up)
2. 17 live ants were put into the bowl and the bowl was covered by a transparent lid with holes. (Precaution: The bowl was covered by a lid to prevent the live ants from escaping. The lid should be transparent and with holes on it to allow the sunlight and gases to pass through)
3. The number of ants caught by each sundew was counted after 1 day.

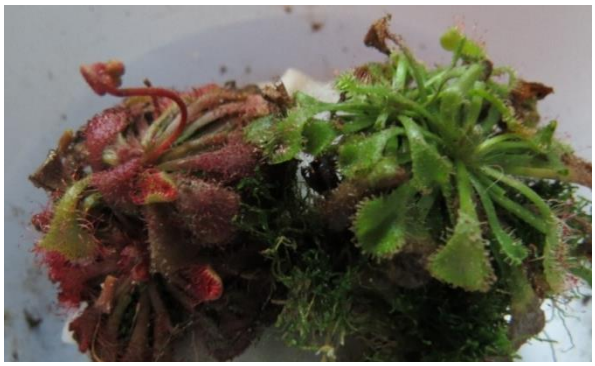


Fig.4

3.5 Objective 3: To investigate the effect of light intensity on the colors of Sundew

From our observation in the field studies, red sundews are located in areas with strong sunlight while green sundews are located in areas with weak sunlight. Therefore, we suspected that the color of sundew is subject to the amount of light received. The light intensities of the respective areas that red sundews and green sundews are located are measured by Lux Meter and compared in the 2nd field study. Experiment 3 was also designed to see if sundew will change its color under sunlight with a different light intensity. It was carried out in the 2nd field study.

Objectives of experiment 4.3
To investigate the effect of light intensity on the colors of sundew

Hypothesis on experiment 4.2.2:
Sundew changes its color under sunlight of different light intensity

Principle of experiment 4.2.2:

The hypothesis would be supported if either the green sundew turns into red under relatively intense sunlight or the red sundew turns into green under relatively weak sunlight, or both. The experiment was carried out in the field to ensure the conditions of the sundews are not subjective to the change in environmental factors other than change in light intensity. Other environmental factors (e.g. mineral and water content of soil) of the original areas that red and green sundews locate are assumed to be identical and not affecting the color of sundews.

Procedures:

1. 2 randomly picked green sundews were transplanted to red sundew zone 1.
2. Another 2 randomly picked green sundews were transplanted to red sundew zone 2.
3. One randomly picked red sundew was transplanted to green sundew zone.
   (Only one red sundew was transplanted because the number of red sundews is much less than that of the green ones. We do not want to cause too much disturbance to the environment.)
4. Continuous observation was made with photos taken for record and comparison

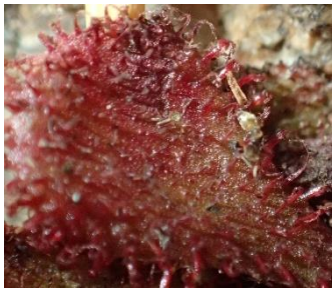
(p.s. all zones mentioned in the procedures were located in and sub-divided from Zone 2)

4. Results

4.1 Result on Objective 1: To investigate the response of sundew towards different stimuli

4.1.1 Result of Experiment 1.1:

	Live ant(1)	Live ant(2)	Dead ant(1)
20/2 14:30 (immediately)	 Fig. 5a	 Fig. 6a	 Fig. 7a
20/2 16:30	 Fig. 5b	 Fig. 6b	 Fig. 7b

21/2 16:30	 Fig. 5c	 Fig. 6c	 Fig. 7c
1/3 12:45	 Fig. 5d	 Fig. 6d	 Fig. 7d
response	no response	little response (tentacles moved towards the live ant)	little response (tentacles moved towards the ant)
	Dead ant(2)	**Sand(1)**	**Sand(2)**
20/2 14:30 (immediately)	 Fig.8a	 Fig. 9a	 Fig. 10a
20/2 16:30	 Fig. 8b	 Fig. 9b	 Fig. 10b

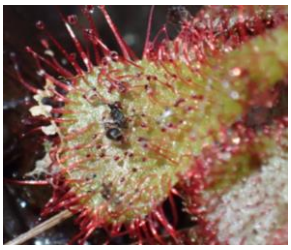
21/2 16:30	 Fig. 8c	 Fig. 9c	 Fig. 10c (disappeared)
1/3 12:45	 Fig. 8d (leaf rolled up)	 Fig. 9d	 Fig. 10d (disappeared)
response	significant response	no response	no response
	Fish Food(1)	**Fish food(2)**	-
20/2 14:30 (immediately)	 Fig. 11a	 Fig. 12a	-
20/2 16:30	 Fig. 11b	 Fig. 12b	-
21/2 16:30	 Fig. 11c	 Fig. 12c	-

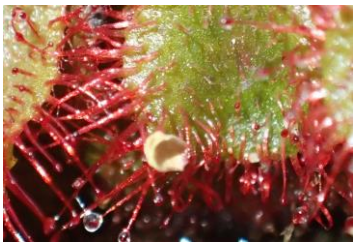
1/3 12:45	 Fig. 11d	 Fig. 12d (disappeared)	-
response	no response	-	-

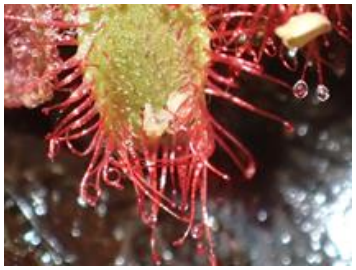
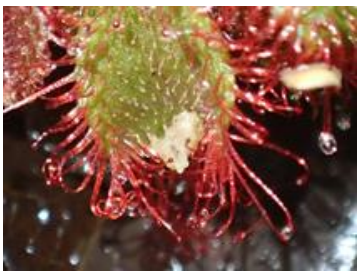
Trend of experiment 1.1:

- Little response towards live ant
- Significant response towards one dead ant
- No response towards sand and fish food

4.1.2 Result of Experiment 1.2:

	Live ant(1)	**Live ant(2)**	**Dead ant(1)**
3/3 (9:30)	 Fig. 13a	 Fig. 14a	 Fig. 15a
3/3 (13:30)	 Fig. 13b (escaped)	 Fig. 14b (died)	 Fig. 15b
4/3 (15:00)	 Fig. 13c (escaped)	 Fig. 14c (dead)	 Fig. 15c

5/3 (16:00)	(escaped)	 Fig. 14d (dead)	 Fig. 15d
response	-	no response	no response
	Dead ant(2)	**Sand(1)**	**Sand(2)**
3/3 (9:30)	 Fig. 16a	 Fig.17a	 Fig. 18a
3/3 (13:30)	 Fig. 16b	 Fig. 17b	 Fig. 18b
4/3 (15:00)	 Fig. 16c	 Fig.17c	 Fig. 18c
5/3 (16:00)	 Fig.16d	 Fig. 17d	 Fig. 18d
response	no response	no response	no response

	Fish Food(1)	**Fish food(2)**	**Fish food(3)**
3/3 (9:30)	 Fig. 19a	 Fig. 20a	 Fig.21a
3/3 (13:30)	 Fig. 19b	 Fig. 20b	 Fig. 21b
4/3 (15:00)	 Fig. 19c (leaf rolled)	 Fig. 20c	 Fig. 21c (leaf rolled)
5/3 (16:00)	 Fig. 19d (leaf unrolled, food liquefied)	 Fig. 20d (fish food became mushy)	 Fig. 21d (leaf unrolled, food liquefied)
response	significant response	little response (tentacles moved towards the food)	significant response

Trend of experiment 1.2:

- No response towards live ant, dead ant and sand
- Significant response towards fish food

4.2 Result on Objective 2: To investigate the significance of red pigment present in attraction of preys

4.2.1 Result of experiment 2:

- No ant was caught by all sundews (both red and green)
- Observation was made during the experiment that the approximate numbers of ants climbing over the red and green sundews are similar.

4.2.2 Data collected

Effect of red pigment in catching insects

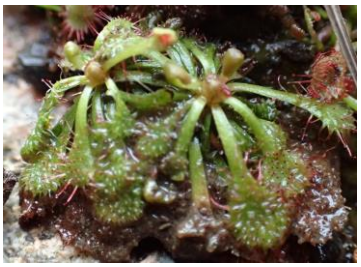
Area	Colour of Leaves (Red or Green)	no. of leaves in one *Sundew*	no. of leaves with insect in one *Sundew*	Percentage of leaves with insect caught (%)	Average percentage of leaves with insect caught(%	Range (%)	standard deviation (s.d.)
1	Red	14	2	14.3	15	0 - 30.8	7.23
		17	0	0			
		27	2	7.41			
2	Red	33	6	18.2			
		19	4	21.1			
		26	8	30.8			
		13	2	15.4			
		19	2	10.5			
		19	3	10.5			
		17	3	17.6			
		12	2	16.7			
		11	1	9.09			
		26	6	23.1			
		32	5	15.6			
	Green	14	3	21.4	23.3	8.69 - 50	11.5
		26	7	26.9			
3	Green	18	2	11.1			
		23	4	17.4			
		16	2	12.5			
		13	5	38.5			
		26	7	26.9			
		20	5	25			
4	Green	22	5	22.7			
		16	8	50			
		23	2	8.69			
		16	2	12.5			
		21	5	23.8			
		13	4	30.8			
		30	4	13.3			
5	Green	30	3	10			
		24	4	16.7			
		24	4	16.7			
		18	7	38.9			
	Green	14	6	42.9			

Table.1

Trend: Green sundews have a greater average percentage of leaves with insect caught than the red one.

4.3 Result on Objective 3: To investigate the effect of light intensity on the colors of Sundew

4.3.1 Result of experiment 3:

	Two green Sundews transferred to Red Sundew zone 1	**Two green Sundews transferred to Red Sundew zone 2**	**Red Sundew transferred to green Sundew zone**
20/2 (17:00)	 Fig. 22a	 Fig. 23a	 Fig. 24a
1/3 (13:00)	 Fig. 22b	 Fig. 23b	 Fig. 24b
9/3 (13:00)	 Fig. 22c	 Fig. 23c	 Fig. 24c
brief description of result	The green sundew turned red.	The green sundew on the left hand side was poorly grown and the one on the right hand side changed to red significantly.	The red sundew turned green.

4.3.2 Data collected (on 20/2 at about 16:00)

The effect of light intensity on the colors of sundews (Table. 2)

Area	1	2					3	4
Colour of Leaves	Red	Red			Green	Green	Green	Green
Light intensity (lux)	4700	4800	3730	2320	1090	1580	1760	330

Area	4			5				
Colour of Leaves	Green			Green				
Light intensity (lux)	280	530	730	1370	1170	1630	1800	1230

	Location where a particular color of Sundews were found	
	Green	Red
light intensity range (lux)	280-1800	2320-4800
Mean light intensity (lux)	1125	3888
Standard Deviation	520	997

Trend: Green Sundews are located in areas with relatively lower light intensity than the red.

5. Discussion

5.1 Discussion on Objective 1: investigation on response of sundew towards different stimuli

In both experiments 1.1 and 1.2, it was observed that sundews have little reaction towards live ants. Hardly did their leaves roll up to wrap the live ant to digest it. However, comparing the photo taken right at the beginning of the experiment and the photos taken afterwards (i.e. figures 6a-6d), more tentacles of the sundews bend towards the live ant. Therefore, it can be shown that sundews' reaction towards live ant is of smaller extent. This is an abnormal observation because according to our own knowledge, sundews are able to digest the insects which are stuck on their leaves by the digestive juice secreted. They will then roll up their leaves and wrap the insects inside and will slowly digest them. Therefore, the observation that sundews have little reaction is abnormal, and we think thatthey are a few reasons to it. Firstly, the chosen sundews may not be in a good health condition as not much digestive juice was seen on their tentacles. Also, the chosen ants may be too large that the juice secreted by the sundews was not enough to stick and trap the ants. As a result, the live ant escaped (as in experiment 1.2, shown in figures 13a-13c) .These are the limitations of this experiment.

Secondly, it was observed that sundews in different set ups had different reactions towards dead ant. Using the photos taken on 3/3(i.e. figures 15a-15d, 16a-16d) as references, sundews hardly react to dead ants and their tentacles only bent towards the dead ants very slightly. The dead ants were not digested by the sundews. However, a different behavior was observed according to photos taken one week after our second field trip which was on 20/2 (i.e. figures 8a-8d). The leaf rolled up, wrapping the dead ant. This difference in behavior

towards dead ant may be due to the different health conditions of the sundews, which is a factor we cannot control.

For sand, which is an inorganic and indigestible matter, sundews have completely no reaction and hardly did the tentacles bend towards the sand as shown in both experiments 1.1 and 1.2. This is the expected result as sand is non-living, suggesting it does not act as a physical stimuli and it does not contain any organic matter so it does not act as a chemical stimuli either.

Thirdly, behavioral differences were also observed from sundews with fish food placed on one of their leaves. Referring to the photos taken on 20/2 and days after (i.e. figures 11a-11d, 12a-12d), the sundews did not show much reaction towards the fish food, with their tentacles not bending towards the samples. On the other hand, it can be shown by the photos taken from 3/3 onwards (i.e. figures 19a-19d, 20a-20d, 21a-21d) that sundews do react to fish food, with two out of three tested leaves rolled up to wrap the fish food after one day. The leaves unrolled and the fish food placed on all the three leaves was liquefied two days later. Again, the different reactions observed may be due to the different conditions of the leaves of sundews.

Analyzing all the results, it seems that sundews detect chemical stimuli rather than physical stimuli and react to them by bending their tentacles towards the matter and secreting digestive juice to slowly digest the matter. However, no definite conclusion can be made because some set ups show contradictory results with this statement.

5.2 Discussion on Objective 2: investigation on the significance of red pigment present in attracting and catching insects

According to the results from experiment 2 which was carried out at one of our group mates' home, both the green and red sundews failed to catch any insects. This result was believed to be due to the different conditions of the sundews, which is an uncontrollable factor. It was observed that there were not many sticky digestive juices secreted by the tentacles on the leaves of sundews, suggesting that the plants might not be in the best health condition. In addition, the size of ants caught might be too big that the sundews could not hold the ants in place until they digest them, and so the ants could easily escape from the sundews. These are the limitations of this experiment.

However, through the observation of our group mate during the experiment, the approximate numbers of ants climbing over the red and green sundews are similar.
Thus, it can be deduced that the red appearance probably doesn't play a significant role in attracting insects.

Also, referring to the data collected, the average number of insects caught by green sundews is higher than that by red sundews, with an average of 15% of leaves with insects caught in red sundews, and an average of 23.3% of leaves with insects caught in green sundews. This difference of 8.3% in average percentage of leaves with insects caught shows

that green sundews are more effective in catching insects than red sundews. This can be explained by the locations where green sundews are found. There may be more insects in those locations. Besides, the green sundews may actually be more attractive than the red sundews.Furthermore, comparing the ranges of the percentage of leaves with insects caught of red sundews (0.00%-30.8%) and green sundews (8.69%-50.0%) respectively, it can be shown that having a red pigment does not equal to having an advantage in attracting insects. However, it should also be noted that the range is wide, which may make the results unreliable.

Our deduction is also supported by the experimental approach from G.Foot, S.P.Rice&J.Mellett (2014), suggesting that the red appearance of another species of sundew, *Drosera rotundifolia*, does not serve a prey attraction. The reason suggested is that the red color is hardly detected by insects without red receptor and the red appearance may even deter potential prey [8] . On top of that, it was suggested by another research [9] that having camouflage colour may be more advantageous for capturing prey, instead of having an outstanding color. This is also supported by our results, with a higher average percentage (23.3%)of leaves with insect caught in green sundews than that in red sundews(15%). Having an outstanding color may draw insects' attention and deter the insects, causing evasion. Unlike other carnivorous plants, sundew uses its sticky juices to capture insects which are attracted to the sundew because of the sweet mucilage secreted by the stalked glands of the sundew [3]. Having the sweet mucilage as attraction, it is not necessary for sundews to have an attractive color to play the same function performed by the sweet mucilage. Hence, with the result we have got, it can be deduced that the color of sundews is not the major reason for insects to decide which sundew to go to.

Nevertheless, it should be noted that the results are not really conclusive because of certain limitations of the experiment, such as the different health conditions of sundews and the failure of sundews to catch the ants because they are too big to capture and there are not many digestive juices secreted on the tentacles of the sundews.

5.3 Discussion on objective 3: the effect of light intensity on the colors of Sundew

According to the data collected on the light intensity, an obvious difference in light intensities of the locations of red and green sundews is shown. The higher the light intensity in the area, the more red sundews can be found. Comparatively, the lower the light intensity in the area, the more green sundews can be found.

A high light intensity which is above 4000 lux was measured in the areas where red sundews are located. Sundews have a specific type of red pigment called anthocyanin. This pigment protects the young leaves from strong UV, so direct and strong sunlight can be blocked [10].The significance of this red pigment is to prevent the breakdown of chlorophyll in sundews so that photosynthesis can be carried out normally. So, we have discovered more red sundews in the areas directly illuminated by sunlight.

On the other hand, the green sundews are located at the areas of low light intensity. As most of these areas are covered by the bridge or vegetation, the light intensities in those areas are relatively lower, which are around 500 to 1500 lux. The sundews in these areas cannot capture much sunlight and the number of red pigments of sundews will decrease in order to let the sundews absorb more sunlight to produce sufficient food by carrying out photosynthesis for maintaining daily activities. As a result, these sundews are green in color because of the less abundance of red pigments in their leaves.

To further investigate the effect of light intensity on the colors of sundews, experiment 4.2.2 was carried out. According to the results shown in this experiment, sundews will change their colors under different light intensities. Under intense sunlight, green sundews will turn red while under weak sunlight, red sundews will turn green.

Red pigments were developed on the leaves of green sundew after being put under stronger sunlight for more than 2 weeks, especially on young leaves. The amount of red pigments present in red sundews decreased after being put under weaker sunlight for more than 2 weeks, which is more obviously observed in young leaves. These can be shown by figures 22a-22c, 23a-23c and 24a-24c.

This discovery points out that the color of the sundew is due to the different expressions of their inborn genes, which are determined by the light intensity received by the sundew. There are more obvious and rapid changes in amount of red pigment present on young leaves. However, the color changes were not only observed in young leaves but also in bigger and well-grown leaves, where the changes are less obvious. This shows that the red pigment of sundews can be adjusted according to the amount of light received throughout their lifetime and the significance of having red pigment is for a better adaptation to the change in light intensity.

To conclude, red sundews can be discovered in the areas having a much higher light intensity while green sundews are found in the areas with a much lower light intensity. Also, the change in light intensity will affect the color of sundews in order to adjust and control the amount of light absorbed by the sundews.

5.4 Further investigation

1. How do sundews detect the chemical stimulus and what is the transport mechanism of signals for response?
- From our findings, sundews do give response to chemical stimulus (organic substance). However, the exact detecting mechanism and transportation of signals for response are still unknown.
2. What factors can affect the production of dew and how?
- From our experiment, we found out that the effectiveness of capturing and holding the insects is significantly subject to the amount of dew present. Thus, investigation of the production of dew is important for the full understanding on its mechanism of prey capturing.

3. Why is there a great difference in reaction time despite the difference in health condition?

- From our experimental results, the reaction time of sundew differs a lot. Despite the effect of health condition, the reason for the great difference in reaction time is uncertain.

4. Why is the feature of having a red color on the trap so common in insectivorous plants?

- From our findings. The red pigment present in sundews does not help attracting prey. On the contrary, the red color may even be undetectable by insects without red receptor, or may deter potential prey. However, having a red color on the trap is common for many other insectivorous plants like pitcher plants and Venus-fly-trap. The exact reason for the presence of the red color on the trap is still unknown.

6. Conclusion

1. Sundews show response to chemical stimulus (organic substances).
2. The red pigment present in sundew does not serve as a function of prey attraction and is believed to block strong sunlight for protection.
3. The red pigment develops when a sundew is exposed to sunlight with high intensity; and the concentration of the red pigment decreases when the sundew is receiving low light intensity for a better adaptation to the change in environmental factors

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