Effects Total Solar Eclipse to Nasty Behaviour of the Several Legume Plants as a Result Student Research

S Anggraeni*, S Diana and B Supriatno
Departemen Pendidikan Biologi, Universitas Pendidikan Indonesia, Bandung, Indonesia
*anggraeni_said@upi.edu

Abstract. Some group students of plant Physiology course have given task to do free inquiry. They investigated of the nasty behaviour of several legume plants in response to changes in light during the partial solar eclipse that occurred at March 9, 2016. The investigation carried out in UPI Bandung, West Java, Indonesia, which is in the penumbra region of a total solar eclipse with the location coordinates of latitude: -6.86105, longitude: 07.59071, S 6057' 37.53553 "and E 107035' 24.29141". They were measuring the movement of opening leaves every ten minutes at the beginning of the start until the end of the eclipse compared with the behaviour without eclipsing. Influence is expressed by comparing the leaf opening movement (measured in the form of leaf angular) at the time of the eclipse with a normal day. Each group was observed for one plant of the legume, there are: Mimosa pudica, Bauhinia purpurea, Caesalpinia pulcherrima, and Arachis pintoi. The results showed that the changes in leaf angular in plants Mimosa pudica, Caesalpinia pulcherrima, and Arachis pintoi differently significant, except for Bauhinia purpurea. In conclusion, the total solar eclipse in the penumbra area affects the movement of some nasty legume plants. It is recommended to conduct a study of the nasty behaviour of legume plants in the area umbra in the path of a total solar eclipse.

1. Introduction
The total solar eclipse that crosses Indonesia at March 9, 2016 is a very rare phenomenon. The eclipse not only crosses Indonesia but also Asia, Australia and the Pacific. Especially in Indonesia, the eclipse across Sumatra, Borneo, Sulawesi and Maluku islands [1] tracking the umbra's shadow from the moon on the earth is called the Totality path. It is usually 10,000 miles long but only about 100 miles wide. It covers less than 1% of the entire earth's surface area. To see the Sun being completely obstructed by the moon, the observer must be somewhere in the narrow path of totality. The shadow of the solar eclipse also swept the island of Java [2].

There was an atmospheric anomaly in the British Isles caused by a partial solar eclipse on March 20, 2015. Decreased temperatures indicate consistent cooling and increased humidity associated with eclipse events [3].

Solar eclipses affect animals too; birds will stop singing when the moon passes in front of the sun. The darkness of clogged sunlight triggers the behavior of nocturnal birds. Nocturnal animals become alert and livestock, pets looking for a place to sleep. Insects, moths and butterflies are affected by the change of light. A total solar eclipse will affect the way moths and butterflies, because they fly use light for navigation [4]. While [5] studied at a farm in Ternate, apparently during a total eclipse on
March 9, 2016 several species of birds (Columbiformes, Galliformes, Anseriformes) were silent and immobile. While some fish species (Clariidae, Cypridae) take shelter in shallow waters. This is due to the influence of environmental factors such as light, temperature, and humidity. Behavior of animals is observed by the method of continuous recording during the eclipse.

How about plants? [6] An observation to circadian rhythm of Mimosa pudica plants have been conducted. Observations were made since the total solar eclipse on March 9, 2016. The results showed that the period of total solar eclipse was very short, but it has influence on showing by behavioral change of Circadian rhythm of this plant.

Students that participate in the Plant Physiology course at Universitas Pendidikan Indonesia, each approaching the end of the lecture is always given the task to conduct free inquiry. This task is intended to explore physiological phenomena around the campus or the daily life. Along with that total solar eclipse event, this triggered the spirit of students to search the topic of research on the physiology of plants associated with solar eclipse.

There are many tropical plants that showed phenomena influences by sunlight. Thus, it is very interesting to examine these behavioral changes during a total solar eclipse. The motion of chloroplast a photo nastic phenomena or even at the rate of photosynthesis and respiration are examples. In tropical plants, many physiological phenomena are affected by light, temperature or humidity. For example, red beans (Phaseolus vulgaris) have circadian rhythmic behavior or biological clocks that are influenced by infrared and far red rays. Bending up and down of the leaves in red beans are influenced by phytochrome that is sensitive to changes in sunlight [7, 8].

Students make some research topics about plant physiology relating to solar eclipse. Almost groups of students proposed about nastic behavior of plant and others about plant metabolism. How they do and what their results, will share in this paper, especially about what effects of total solar eclipse to nastic behavior of the several legume plants. So, the aims of this study to describe some of the physiological behavior of tropical plants primarily nastic movement the legume plants during a total solar eclipse in the penumbra area that occurred on March 9, 2016 in Bandung city.

2. Method

Four group students proposed research as a free inquiry for nastic movement of the leaf from the legume plants. Each group worked with one of these plants, that is Mimosa pudica, or Bauhinia purpurea, or Arachis pintoi, or Caesalpinia pulcherima. Their planning was evaluated by lecturer before they did the work.

They conducted the research at the place of the occurrence of partial solar eclipse on campus Universitas Pendidikan Indonesia in Bandung, West Java with coordinates: latitude: -6.86105, longitude: 07.59071, S 6°05'37.53553 "and E 107°35'24.29141". On Wednesday (March 9, 2016) morning in Bandung starts at 06.19 and ending at 08.32 when a partial solar eclipse occurs and at the same time on Thursday morning (March 10, 2016). They were using tools like hygrometer, light meter, thermometer, hand phone camera, Canon camera, standing camera and computer.

The effect of partial solar eclipse on the legume plant as a nastic movement is expressed by measuring the change in the magnitude of the movement of the opening and closing of the legume leaves during the solar eclipse. The size of the leaf angle is measured using Corel Draw based on the leaf motion picture. The magnitude of the angular is expressed in degrees.

The behaviour of opening the closing of the leaves is followed by photo recorder every ten minutes from the beginning of the solar eclipse to completion. Measurements were also performed on other days of normal circumstances beyond the day of a solar eclipse. Their observations were recorded using observation sheets by several observers and recorded using a camera. Meanwhile, the changes in light radiation will be measured using flux meters, air temperature and humidity using a Hygrometer per ten minutes.

First, normal distribution of the data calculated to determine using of parametric or nonparametric tests. The data of leaf angular between the partial solar eclipse and the normal angular calculated using t tests.
3. Result and Discussion
They have worked hard and enthusiastic. Their lecturer was give guiding and controlling for ensure the investigated enough valid. They have hypothesis that there was no significant difference in opening movements of the plant leaf legume between partial solar eclipse and normal day. They results have been resume and report here.

Table 1. Normal distribution and independent sample t test of angular leaf from legume plants

| Legume plants          | Sig. Normal distribution test of the Kolmogorov Smirnov | independent sample t - test |
|------------------------|--------------------------------------------------------|----------------------------|
|                        | Non solar eclipse | Solar eclipse |                                |
| Mimosa pudica          | .003            | .129*        | .011*                         |
| Bauhinia purpurea      | .678*           | .678*        | .403                          |
| Caesalpinia pulcherrima| .445*           | .973*        | .000*                         |
| Arachis pintoi         | .174*           | .982*        | .000*                         |

Because data on the four plants have normally distributed so we continued with independent sample t-test to examine the difference. It turns out that from the four legume plants has significant difference except Bauhinia purpurea. The results showed that there was a significant difference of the leaf angular between the partial solar eclipse and the normal condition (without solar eclipse). The difference was seen in three legume plants tested, that is Mimosa pudica, Caesalpinia pulcherrima and Arachis pintoi. The leaves opening at a partial solar eclipse slightly smaller than at normal day, but for Bauhinia purpurea shown the angle of the leaf look coincident at the both conditions.

Figure 2. Leaf angular difference of Mimosa pudica (A) and Caesalpinia pulcherrima (B) between Partial Solar Eclipse (PSE) and normal day
Figure 3. Leaf angular difference of Bauhinia purpurea (A) dan Arachis pintoi (B) between Partial Solar Eclipse (PSE) and normal day.

*Mimosa pudica, Caesalpinia pulcherrima* and *Arachis pintoi* opening of the leaf at a partial solar eclipse is smaller angular than during normal day (non PSE). This phenomenon was corresponded to environmental factors as light intensity, temperature and humidity. Partial solar eclipse influenced environmental factors, both on the intensity of light reaching to the earth and the temperature of the environment. This can be seen from the following graph, the intensity of light at the time of the eclipse decreased compared to normal times. Reduced light intensity will lower the environmental temperature, but it will not automatically affect the humidity. This is evident from the following graph:

Figure 4. Light intensity and environment temperature between Partial Solar Eclipse (PSE) and normal day

The phytochrome system provides information for plants about the quality of light. The sensing mechanism allows plants to adapt to changes in lighting conditions [7].

Light affects the blue pigment (Phytochrome) present in plants. In the morning the phytochrome should absorb the red light wave as much as possible to transform itself into the phytochrome far Red (Pfr). Sunlight in the morning contains a lot of red light, so converting to Pfr is faster than converting to Pr, therefore the ratio of Pfr to Pr increases in sunlight. If the sunlight is weak, so the formation of Pfr will decrease this will affect the metabolism of plants, so the energy to implement the K + pump was reduced. This will affect the movement of nasty because the plants in the morning will open the leaves with perfect energy. According to [7] most plant processes, such as the transpiration and synthesis of certain enzymes, rise and fall throughout the day. Some of these cyclical variations are responses to changes in the intensity of light, temperature, and humidity that accompany the 24-hour day-to-night cycle. If there were more energy will more actively the K + pump works and the more leaf will open perfectly. Conversely, if the light intensity is less, the temperature decreases it will decrease the activity of metabolism so the energy decreases. That is, which causes the difference of leaf angle when legume plants *Mimosa pudica, Caesalpinia pulcherrima* and *Arachis pintoi* starting opening in the morning when a solar eclipse comparing with normal day.

The changes leaf angular of *Bauhinia purpurea* not significant because the plant not more sensitive than to the other plants in light changes, although *B. purpurea* is often seen to have closed and leaf-opening movements, especially if the temperature decreases or the humidity rises high enough. The fact in heavy rain or late afternoon this plant will close its leaves. So the changes in temperature and light intensity at the time of the eclipse cannot be responded well or less affect the daily activity of this
B. purpurea. Other possibilities B. purpurea is not sensitive to light and temperature drop, but more sensitive to moisture enhancement. While based on data, the humidity in both conditions is not too different.

![Figure 5. The Humidity between Partial Solar Eclipse (PSE) and normal day](image)

The cycle of opening and closing leaves or flowers in frequency of 24 hours and not directly controlled by environmental variables is called circadian rhythms. Circadian rhythms are common present in all eukaryotic organisms. In the legume plant, this rhythm is shown with nastic movement that is the closing and opening the leaves are driven by motor cells in the pulvinus region [8]. The wide of leaf angle when it opening, it can be influenced by the amount of Pythochrome which absorbed more red rays of light. If more the red light can be absorbed in the morning so the leaves will ability to open perfectly.

The factor that sets the biological clock up to 24 hours a day is light. Phytochrome and blue light receptors can adjust the circadian rhythms in the growing nature; the interaction between phytocrom and biological clocks causes plants to measure the passage of night and day [7].

Some legume plants are able to show the mechanism of this circadian movement clearly as in Phaseolus vulgaris plants. Starting from 12 pm, this plant and upright (bending up) leaves slowly until at 12 am really open perfectly. After that, the petiole of leaves began to bending down slowly and completely down (hyponastic) at 12 pm and this happens rhythmically [7, 8].

4. Conclusion
Based on student data of the difference in the opening and closing the leaves of the legume, it can be stated that their research hypothesis “There is no significant difference in the movement of legume leaves between a partial solar eclipse and normal day” is rejected, especially for Mimosa pudica, Caesalpinia pulcherrima and Arachis pintoi. So, partial solar eclipse gives influence to nastic movement on some legumes plants. While the influence of the total solar eclipse (penumbra) on nastic movement in Bauhinia purpurea is not proven.

It is interesting to examine the nastic movement on the Bauhinia purpurea. This plant does not provide a positive response to the solar eclipse phenomenon so it should be further investigated whether including nyctinastic or photonastic, thermonastic, or hygronastic movement.

Another suggestion is to examine the nastic behaviour of legume plant actually in the umbra line that is in the path of total solar eclipse. It is also interesting to examine other physiological behaviour of plants during solar eclipses, such as photosynthesis, respiration and transpiration.

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