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Plant/Animal Physiology

Comparative Study of Temperature on Gas Exchange in *Blaberus gigantea* and *Vicia faba*

Background/Questions/Hypothesis:

Photosynthesis is one of the most important sources of energy for terrestrial ecosystems. CO_2 and O_2 are essential for photosynthesis and, in turn, vital to all living organisms. In photosynthesis, plants consume CO_2 and release O_2. The process of reducing CO_2 and converting it to sugar phosphates, which the plant can use to make more complex metabolites, gives off O_2 (Campbell, 1999). In the evolution of the earth, plants helped develop the atmosphere to one that would sustain these other organisms. Together with animals, plants make up a constant cycling of CO_2 and O_2: The O_2 given off by plants is then used by animals that will expire CO_2 that is used by the plants.

For this gas exchange to occur in plants, guard cells regulate the opening and closing of their stomata depending on the concentration of light available, humidity, temperature, and other environmental cues. Light intensity affects respiratory gas exchange because it is necessary for photosynthesis, but how does temperature affect this process? In the winter months, plants tend to grow relatively slowly. In summer months temperatures increase and more light is available with a corresponding increase in growth. If the plants were given the same light intensity, but at different temperatures, would the CO_2 cycle change or remain the same?

This same question can be posed for animals. Respiration is directly influenced by the metabolism of the insect (Guthrie & Tindall 1968). To maintain the metabolic process, a certain body temperature is necessary to get maximum efficiency of metabolic enzymes.

Insect respiration is a three-phase process and is discontinuous. The first phase is the consumption of O_2 from the endotracheal stores and the spiracles are closed. Next is the fluttering-spiracle phase where O_2 is inspired. In the last phase, the spiracles open and CO_2 is released (Lighton 1996). The total efflux of CO_2 and influx of O_2 dependent on body mass (Lighton 1996). Overall, metabolism is affected by temperature. What effects does temperature have on the respiration of the insect?

The overall question is: How does temperature affect the respiration rates of a plants and insects and how do they compare each other? We hypothesize that as the temperature increases in the environment, the respiration will increase in both the insect and the plant to a maximum level (threshold) of gas exchange is reached.

Methods/Design/Control:

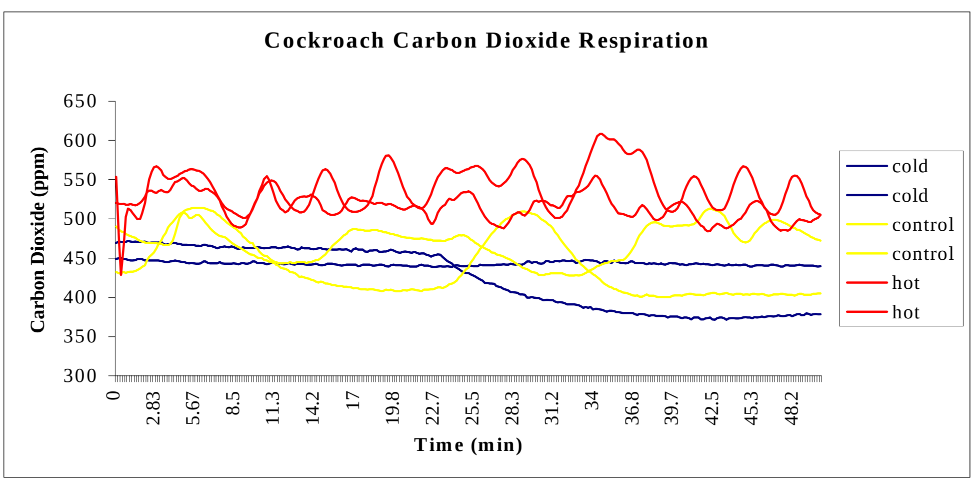
This research was done at Willamette University in November 2000. We tested the effects of both high and low temperatures on *Blaberus gigantea* and *Vicia faba*. Using the IRGA, we measured the CO_2 exchange rate of both species with fixed temperatures. All tests were done in the dark so that the varied amounts of light would not affect the respiration rates or our results. The chambers were covered with aluminum foil or paper towel.

The first of the three tests done was a control test on the plants and roaches at room temperature (23-24°C). The second test was done at higher temperatures (34-36°C). Heat lamps helped to maintain a constant increased temperature. In the final test, the temperatures were lowered (13-15°C). For the roach, we partially submerged the chamber in a container of ice. For the plant, we surrounded the plant chamber with a plastic bag filled of ice. Before the tests were conducted, the temperatures were allowed to stabilize for about 50 minutes prior to data collection. We used a total of four specimens in the experiments: two cockroaches and a leaf from two plants. Since there was an excess of cockroaches, we were able to continue our experiments even though we killed Charlie the cockroach with extremely cold temperatures. The surface area of the *Vicia faba* leaves was calculated and then coated with fusicoccin a day before the tests were done. We also calculated the surface area of the cockroaches and massed them.

Results

The respiration cycles of *Blaberus gigantea* shortened and their frequency increased as the temperatures in our experiments increased (Figure 1). In the cold tests, where the temperatures were about 15°C, the respiration cycles of the cockroaches seem to disappear. The amount of CO_2 that they excreted decreased. The control experiments show respiration cycles that repeated about every 20 minutes. The concentration of CO_2 increased to 50ppm during the open spiracle stages of the roaches. The roaches released the most CO_2 at the warmer temperature (≈35°C). At this temperature, the respiration

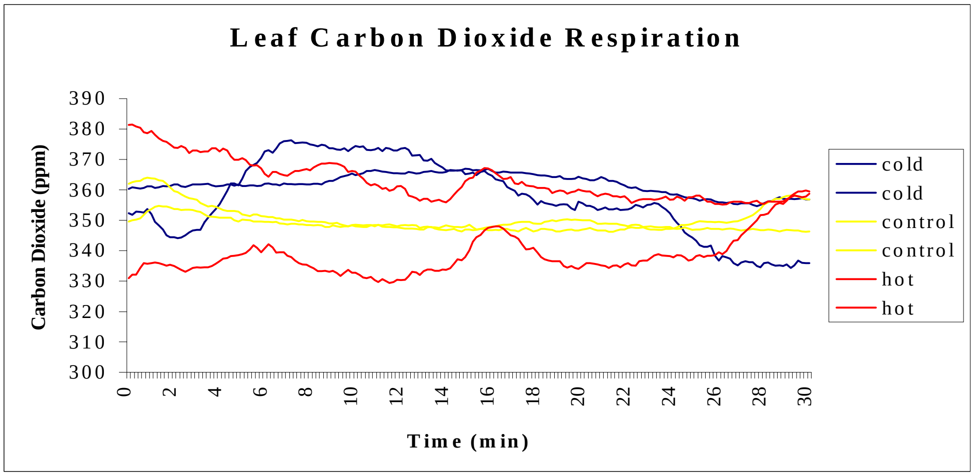
Figure 1: *Blaberus gigantea* respiration



cycles occurred more frequently, (~5-10minutes).

The CO_2 levels were relatively constant in all the experiments done on *Vicia faba* (Figure 2). The CO_2 levels did show a small net change in the control experiments. The leaf took in the same amount as it expired. The cold temperatures increased CO_2 levels by 10-20ppm more than the control. The heat experiments also varied the CO_2 levels. One of the tests showed a decrease in CO_2 levels. This shows that at high temperatures, plant inspiration of CO_2 may be greater than expiration.

Figure 2: *Vicia faba* respiration



Discussion

Figure 1 indicates that as temperature increases, expiration of CO_2 in *Blaberus gigantea* increases. The increased levels of CO_2 are most likely related to the increase in frequency of their respiration cycle. The open spiracle stage is shown in the figure by the peaks in CO_2 concentration. At higher temperatures these peaks occur more frequently, which seems to overcompensate for the smaller rises in CO_2 per cycle. This seems to support our original hypothesis.

The experiments done on *Vicia faba* do not support our original hypothesis (Figure 2). As the temperatures increased, CO_2 levels decreased, which suggests the leaf is taking in more CO_2 than it is expelling. This may be because of some photosynthetic activity in the plant. Even though efforts were made to keep the plant in the dark, the heat lamps may have penetrated the barrier. The leaf may have responded by taking in more CO_2 to facilitate photosynthesis. In figure 2, the heat test data lines show varying CO_2 levels, which makes analysis of the CO_2-temperature relationship unclear.

Equipment/Supplies/Limitations:

- Heat Lamp
- Ice and plastic bags
- IRGA
- fussicoccin
- *Blaberus gigantea* ($28.95 for 12) & *Vicia faba* ($0.00)
- Thermometer for plant chamber
- Hot water bath/ Ice bucket for chamber intake valve

Ideally, we could fully enclose the plant and cockroach to minimize fluctuations in CO_2, O_2, humidity, and to better stabilize the temperature. Also, efforts needed to be made to insure that all the plants and cockroaches are receiving the same diets, which would validate that our results are not due to a nutrient deficiency. Another factor that needed to be monitored more closely was that we needed to check to see that the stomata fully opened on all the leaves.

Literature Cited:

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