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Comparative Study of Gas exchange in Terrestrial Organisms:
Effect of Obstructing Respirative Openings the Giant Cockroach from the *Blaberus* family and *Vicia faba*, the Faba Bean Plant, on Respiration Rate

Introduction

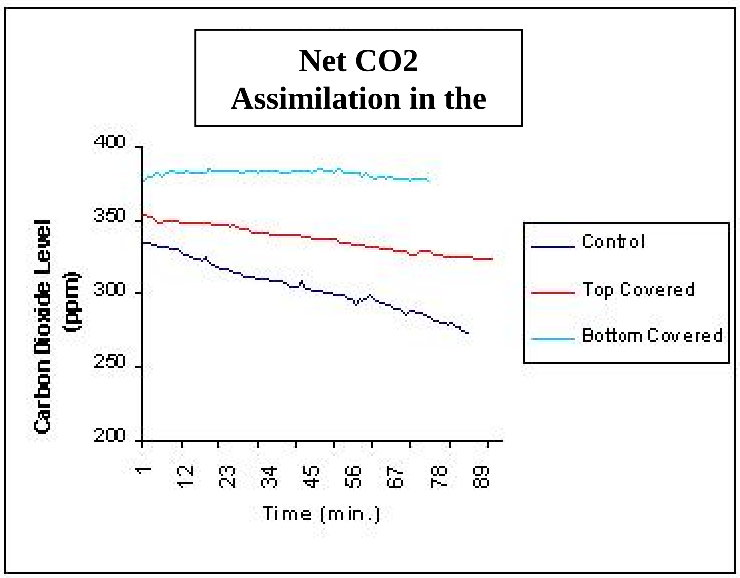
All terrestrial organisms are intrinsically connected in their need and ability to utilize gas in order to function. Plants have highly evolved openings called stomata, which are the microscopic pores in a plant leaf epidermis that allows gas exchange between the environment and the inside of the plant. It is well documented that plant stomatal openings are concentrated on the underside of the leaf; an adaptation that minimizes water loss as the underside of the leaf is often not faced with direct sunlight (Campbell 685). Alternately, air enters the insect respiratory system through spiracles generally located on the sides of the insect body (Guthrie 357), a placement, perhaps, to minimize potential obstruction from above or below.

This study attempts to confirm this phenomenon of spatially arranged respirative openings and also compare how obstructing the stomata of the bean plant, *Vicia faba*, and the spiracle openings of the giant cockroach from the *Blaberus* family, effects the respective organism. Our hypothesis is that the respiration rate of both the bean plant and the cockroach would be most compromised when regions of concentrated respirative openings are obstructed.

Results

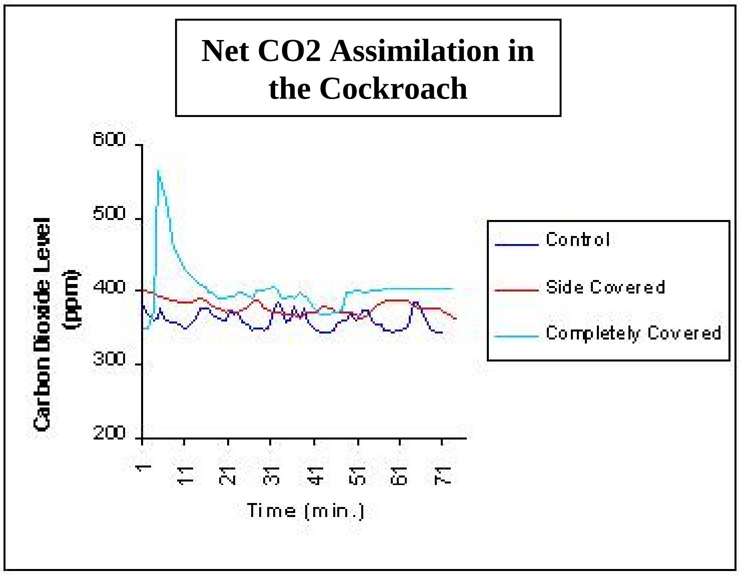
Carbon dioxide levels recorded in the control and adaxially and abaxially covered leaves are illustrated in figure one. The uncovered control plant demonstrated a steady decline in CO_2 concentrations ($[CO_2]$) of ~105 ppm. Obstructing stomatal openings on the adaxial or dorsal surface of the leaf resulted in a net reduction of only ~10ppm CO2. No net change in $[CO_2]$ occurred when the abaxial or ventral leaf surface was covered.

Figure 1



The results for the cockroach portion of the respiration experiment are detailed in figure two. The control cockroach exhibited a distinct CO2 cycle ranging between ~355 ppm and 380 ppm roughly every 18 minutes. Obstructing half of the spiracles resulted in an oscillation between ~380 and 400 ppm CO2. Covering all the posterior spiracles resulted in an initial spike in CO2 production to ~575ppm, and the levels then returned to 400 ppm after 15 minutes, and did not cycle.

Figure 2



The stomatal and spiracle openings can be viewed via the scanning electron microscopy pictures in figures three and four, respectively, which produced a clear illustration of the respiratory anatomy. Notice in figure three the stomata are pictured partially opened, when gas exchange may take place. Figure four shows a spiracle in the open phase of its discontinuous gas cycle, during which time CO_2 is released.

Figure 3

Figure 4

Interpretation

Respiration in *Vicia faba* and *Blaberus gigantea* was effectively hindered by the application of the silicone lubricant. The opening and closing of leaf stomata are crucial to the simple continuous diffusion mechanism for gas exchange employed by plants. While our methods did not directly measure the respiration of the plant, the CO2 levels in the experimental chamber serves as a measurement of gas exchange ability. A resulting decline in CO2 would suggest plant photosynthesis was taking place by implying an increase in CO2 taken up through the stomata. Thus, we can assume that the control plant is actively photosynthesizing because we observe a steady decline in CO2 levels in the experimental chamber (figure one). By applying a viscous topical agent, namely the silicone gel, we observed an overall inhibition of gas exchange in *Vicia faba*. This phenomenon occurred because the gel obstructed stomatal openings and thus prevented gas diffusion between the interior leaf and the external environment. Literature shows that leaf stomata are heavily concentrated on the abaxial surface of the leaf, however, application of silicone to the adaxial leaf surface noticeably inhibited gas exchange (figure one). The CO2 levels continued to decline at a slower rate when the adaxial surface was covered, suggesting the abaxial stomatal openings may be able to compensate for the compromised adaxial surface. We see the importance of the abaxial surface with regard to stomata when considering the observation that complete abaxial coverage completely prevented respiration (figure one). The steady CO2 levels illustrated by the light blue line in figure one suggest the plant is not absorbing any CO2 needed for photosynthesis when the abaxial surface is obstructed.

Where plants employ a simple continuous gas exchange cycle, the cockroach respires using a discontinuous cycle that includes regular bursts of CO_2 during the open spiracle phase (Figure three). During these bursts the CO2 levels rise and fall rhythmically every 18 minutes, as suggested by our data gathered from the control (figure two). This discontinuous gas exchange cycle (DGC) was disrupted by obstructing the spiracles, as shown by the observation that treated cockroaches did not respire in distinct DGC's. When one set of posterior spiracles were covered with the silicone gel the DG cycle appeared to cycle moderately, suggesting the other set of spiracles was able to continue respiration, although the oscillations did not resemble natural respiratory cycles (figure two). Completely blocking all posterior spiracles generated abnormal respiratory patterns that seems random and unpredictable (figure two). The initial spike in the CO2 level is a likely result of the trauma endured during application, and the stress of the sudden loss of full respirative ability. This is supported by the initial behavioral observation, which exhibited a struggling and excited cockroach. After the CO2 levels decline and level off, the graph in figure two shows a steady, non-cycling and non-oscillating concentration of CO2. Behavioral observations showed a non-moving and depressed cockroach. Interestingly, the cockroach secreted a white chalky substance that is thought to be a possible alarm odor from glands located in the walls of the trachea close to the spiracles (Guthrie and Tindall 1968).

In conclusion, application of a silicone lubricant is effective to obstruct respiratory pathways, thus limiting and compromising imperative anatomical respiratory functions consequently altering the respiration of *Vicia faba* and *Blaberus gigantea*.

References

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