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Effect of Silicone Lubricant on Gas Exchange in the *Vicia faba* bean plant and *Blaberus gigantea* the Giant Cockroach

Introduction

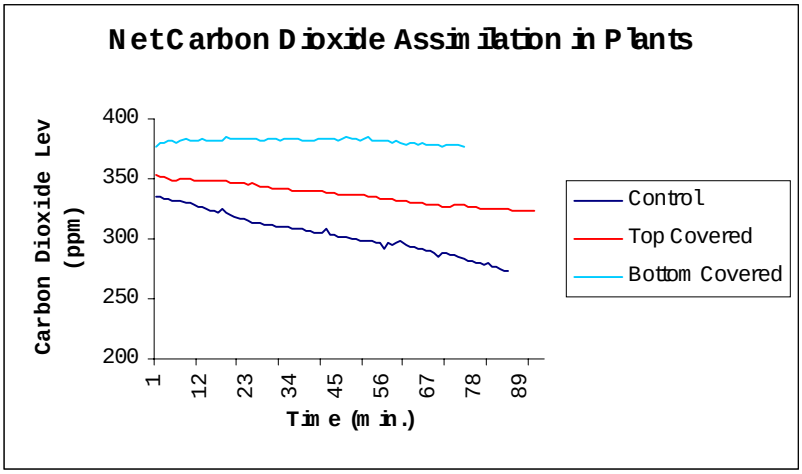
Gas exchange is essential for organism survival as it supports the metabolic process of cellular respiration. Plants exchange respiratory gases by simple continuous diffusion. A waxy cuticle prevents respiration through the entire leaf surface, therefore carbon dioxide (CO_2) uptake and oxygen (O_2) release is regulated by the opening and closing of microscopic epidermal pores called stomata (Campbell 1996). CO_2 is a vital component of photosynthesis as it is consumed in sugar production, while O_2 is produced and released as a bi-product of photosynthesis (Campbell 1996). Leaf stomata, heavily concentrated on the abaxial side of the leaf, facilitate this CO_2/O_2 gas exchange. In insects, gas exchange occurs within a tracheal system. Diffusion through the cuticle of a cockroach is negligible, therefore air must enter 10 pairs of laterally located spiracles and travel through smaller tubes, tracheoles, before gas exchange can occur at the cellular level (Lighton 1996). Cockroaches respire in a discontinuous gas exchange cycle (DGC) that consists of three specific phases. The closed spiracle phase is marked by an absence of external gas exchange as O_2 is consumed from endotracheal stores. During the fluttering stage O_2 is taken up from the atmosphere; then CO_2 is released in the open phase (Lighton 1996). At 21 C, the rhythmic respiratory cycle consists of regular CO_2 bursts approximately every 14 minutes (Guthrie and Tindall 1968). Thus, in order to sustain life each species employs a distinct mechanism for gas exchange.

Hypothesis

The addition of a viscous silicone lubricant to respiratory anatomy will inhibit overall CO_2/O_2 diffusion. Covering the majority of respiratory structures will significantly reduce gas exchange ability in *Vicia faba* and *Blaberus gigantea.* Specifically, addition to the abaxial side of a leaf will reduce gas exchange more dramatically than an addition to the adaxial side; completely covering the posterior spiracles will have a greater effect than application to the posterior spiracles of a single side.

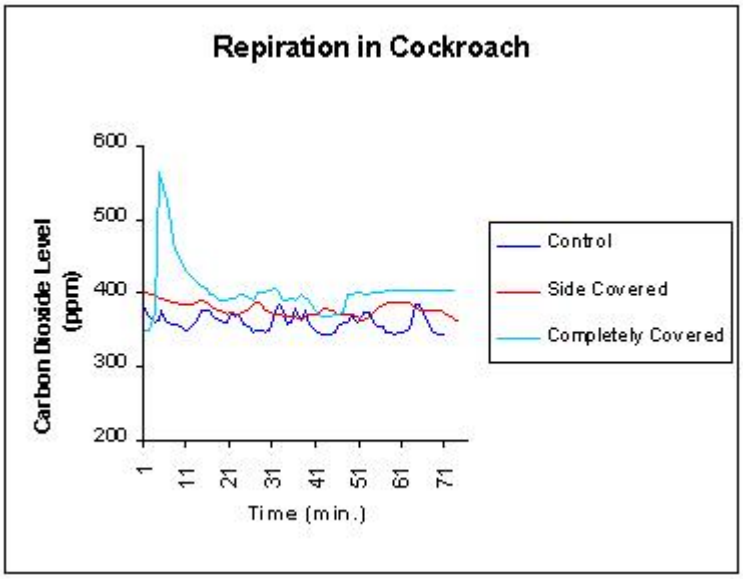
Results

**Graph 1*



The control plant demonstrated a steady decline in CO_2 concentrations ($[CO_2]$) of 61 ppm. However, $[CO_2]$ declined only 31 ppm when the adaxial leaf surface was covered. A change in $[CO_2]$ of +0.15 ppm occurred when the abaxial leaf surface was covered.

**Graph 2*



In the control cockroach, [CO_2] distinctly cycled between ~355 ppm and 380 ppm roughly every 18 minutes. [CO_2] gently oscillated between ~380 and 400 ppm when half the spiracles were covered. When all the posterior spiracles were completely covered, the [CO_2] rapidly escalated to ~575ppm, returned to 400 ppm after 15 minutes, and did not cycle.

**Scanning electron Microscopy*

Figure 1

Figure 2

SEM produced clear photographs of respiratory anatomy. The stomata are shown partially open, when gas exchange may take place (Figure 1). The spiracle is displayed in the open phase of DGC during which CO_2 is released (Figure 2).

Interpretation

Silicone lubricant effectively reduced gas exchange ability in *Vicia faba* and *Blaberus gigantea*. Plants respire by simple continuous diffusion that is regulated by opening and closing of leaf stomata. Light triggers CO_2 uptake and O_2 release by slowly opening stomata (Figure 1). [CO_2] in the experimental chamber served as a measurement of gas exchange ability, therefore a decline in [CO_2] indicated plant photosynthesis and respiration. Thus, the control plant engaged in respiration as observed by the steady decline in [CO_2] (Graph 1). Application of the greasy lubricant inhibited overall gas exchange in *Vicia faba*. The viscous topical agent obstructed stomatal openings and thus prevented gas diffusion between the interior leaf and the external environment. Although leaf stomata are heavily concentrated on the abaxial side of a leaf, application of silicone to the adaxial leaf surface noticeably inhibited gas exchange (Graph 1). The plant continued limited respiration, indicating the abaxial stomata may be able to compensate for the loss of function of the adaxial stomata. However, covering the abaxial leaf surface completely prevented respiration (Graph 1). Adaxial stomata were unable to sustain respiration when the vast majority of functioning units (i.e. all the abaxial stomata) were severely handicapped.

Cockroaches respire in discontinuous gas exchange cycles that include regular bursts of CO_2 during the open spiracle phase (Figure 2). [CO_2] rises and falls in a fairly predictable pattern; the respiratory cycle of the control cockroach was every 18 minutes (Graph 2). However, cockroaches treated with silicone did not respire in distinct DGC's. Although respirations of the cockroach with one side of posterior spiracles covered appeared to cycle

moderately, the gentle oscillations did not resemble natural respiratory cycles (Graph 2). Gas exchange was inhibited, but the remaining spiracles maintained a modified respiratory cycle despite the loss of functioning neighboring anatomy. The respirations of a completely covered cockroach, with all 6 posterior spiracles greased with silicone, did not resemble normal respiratory patterns. The experiment revealed an initial dramatic burst of [CO_2], most likely a result of massive excitation and panic due to the lubricant application process and a sudden loss of respiratory ability. The CO_2 spike is followed by steady, non-cycling and non-oscillating [CO_2]. In addition, the insect's behavior indicted obvious respiratory distress; the cockroach remained motionless and secreted a white chalky substance that may be an alarm odor from glands located in the walls of the trachea close to the spiracles (Guthrie and Tindall 1968).

In conclusion, silicone lubricant effectively obstructed respiratory pathways, handicapped crucial respiratory anatomy and consequently altered gas exchange ability of *Vicia faba* and *Blaberus gigantea*.

References

Guthrie D.M., Tindall A.R. 1968. The Biology of the Cockroach. *The Physiology of Respiration*: 354-363

Lighton John. 1996. Discontinuous Gas Exchange in Insects. *Insect Ventilation*: 309-342

Campbell Neil A. 1996. Biology. 4th ed. Menlo Park: Benjamim/cummin Publishing Company, Inc.