

Relationship Between Simulated Chinese Rose Beetle (Coleoptera: Scarabaeidae) Feeding and Photosynthetic Rate Reduction

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ABSTRACT

Photosynthetic rate measurements of the remaining leaf lamina tissue were taken from snap bean and corn plants after simulated Chinese rose beetle, *Adoretus sinicus* Burmeister, feeding. There was a linear decline in photosynthetic rate for snap bean leaves and a curvilinear decline for corn with increased amount of simulated feeding. Percent photosynthetic rate reduction for corn increased at a greater rate than for snap bean with increased defoliation. The differential feeding pattern on monocotyledonous (interveinal and veinal feeding) and dicotyledonous (interveinal feeding) plants by the Chinese rose beetle is suggested as evidence for the photosynthetic rate differences of snap bean and corn.

The Chinese rose beetle, *Adoretus sinicus* Burmeister, is one of the most destructive nocturnal defoliators of a wide range of plant species in Hawaii (Habeck 1964). Previous authors have indicated that damage by this beetle can be easily recognized by the characteristic interveinal feeding pattern (Arita et al. 1988). While the interveinal feeding pattern is consistent among dicotyledonous plant leaves, our preliminary observations indicate that feeding may not necessarily be confined to interveinal areas in monocotyledonous plants.

Simulated defoliation studies on dicotyledonous leaves have shown that the amount of cut surface exposed by injury is more important than the actual leaf area removed (Hall & Ferree 1976). In addition, retaining the integrity of the leaf veins was important when simulating injury by insects that feed discriminately on interveinal areas (Hall & Ferree 1976, Poston et al. 1976).

Monocotyledonous and dicotyledonous plants have distinct anatomical and physiological differences. For example, monocotyledonous plants typically utilize the C₄ photosynthetic CO₂ fixation pathway and have Krantz anatomy (bundle sheath) whereas dicotyledonous plants typically utilize the C₃ photosynthetic CO₂ fixation pathway and do not possess bundle sheaths (Hatch & Slack 1970). Caswell et al. (1973) proposed that these anatomical differences result in differential feeding patterns by insects in monocotyledonous and dicotyledonous plants. This study was therefore designed to 1) compare the feeding pattern of the Chinese rose beetle on monocotyledonous and dicotyledonous plants and 2) determine the effect of simulated feeding on the photosynthetic rate of remaining leaf lamina in monocotyledonous and dicotyledonous plants.

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MATERIALS AND METHODS

Studies were conducted from July to October 1988 at the University of Hawaii at Hilo, College of Agriculture greenhouse facility.

Plant Material. Snap bean, *Phaseolus vulgaris* L. cv. Poamoho, and sweet corn, *Zea mays* L. var. *saccarata* cv. Super Sweet no. 9, plants were started from seeds sown 1.0 cm deep in 9.6 cm diameter standard plastic pots filled with a commercially prepared potting mixture (Pro-Mix BX, Pro-Mix Co., Quebec, Canada). The pots were placed on benches in a fiberglass covered greenhouse and fertilized 1 week after sowing, with a slow release fertilizer (17-6-12, N-P₂O₅-K₂O, plus minor element formulation, Sierra Chemical Co., Milpitas, Calif.) at a rate of 2.0 g per pot. The plants were grown for 17 to 20 days before experimental use.

Chinese Rose Beetle Feeding Protocol. Four snap bean plants and 15 beetles were placed in a wooden framed cage, 40 × 40 × 65 cm, screened with organdy. The beetles were confined to the cage for 48 h during which time they were allowed to feed on the leaves. After 48 h, the leaves were visually inspected for the location where lamina tissue was removed. The experiment was replicated five times. Identical methods were used for corn plants.

Simulated Injury on Snap Bean and Corn Leaves. Preliminary observations indicated that beetles feed on the interveinal portions of snap bean leaves while feeding both on the interveinal and veinal portions of corn leaves. To simulate the interveinal feeding pattern in snap bean leaves, a cork borer (4.0 mm dia) was used to remove leaf lamina tissue between the major veins. Indiscriminate feeding of corn was simulated by removing both veinal and interveinal leaf lamina tissue. Snap bean and corn plants were grown as described in the Chinese rose beetle feeding protocol to the 3 true leaf stage and only the most recently matured leaf was used for experimentation. Snap bean leaves were punched 0, 5, 20, or 30 times and corn leaves were punched 0, 1, 3, 4 and 8 times to simulate feeding. Simulated feeding was utilized in order to obtain a range of feeding damage on specific leaves that were to be measured. Each treatment consisted of 10 replicate plants. Percent defoliation was obtained for each leaf by measuring the leaf prior to and after punching with a portable leaf area meter (LI-COR INC., Lincoln, Nebraska). In addition, photosynthetic rates for each leaf were measured (see Photosynthetic and stomatal conductance measurements section) 24 hrs after the leaves were punched. The relationship between the percent defoliation and the photosynthetic rate was determined by regression analysis (Steel & Torrie 1960).

To simulate the damage to the vascular elements following indiscriminate feeding in corn leaves, a razor cut was made perpendicular to both leaf margins, leaving only the mid-rib uncut. The cut was made one-third the distance from the leaf base. Photosynthetic rate and stomatal conductance measurements (see Photosynthetic and stomatal conductance measurements section) were taken at 0, 3, 10, 15 and 20 minutes after the leaves were cut. The experiment was replicated 3 times.

Comparison of Photosynthetic Rates of Veinal and Interveinal Leaf Lamina Explants of Snap Beans. Five leaf lamina punches (lamina explants) 7.0 mm in diameter were sampled with a cork borer from both veinal or interveinal areas of a single recently matured snap bean leaf. The explants were placed in a 15 × 150 mm test tube containing 10 mls of sodium phosphate - citric acid buffer solution (pH 6.8) and a drop of Tween 20 which enhanced the wetting of the lamina explants. The tube was then evacuated to 150 mm Hg (150 Torr) until all of the lamina explants sank to the bottom of the test tube (approx. 3 to 4 min). The buffer was decanted and the test tube refilled with 10 mls pH 6.8 sodium phosphate - citric acid buffer containing 0.02% NaHCO₃, sodium bicarbonate. The tubes containing the lamina explants were immediately placed under light at 1,200 u

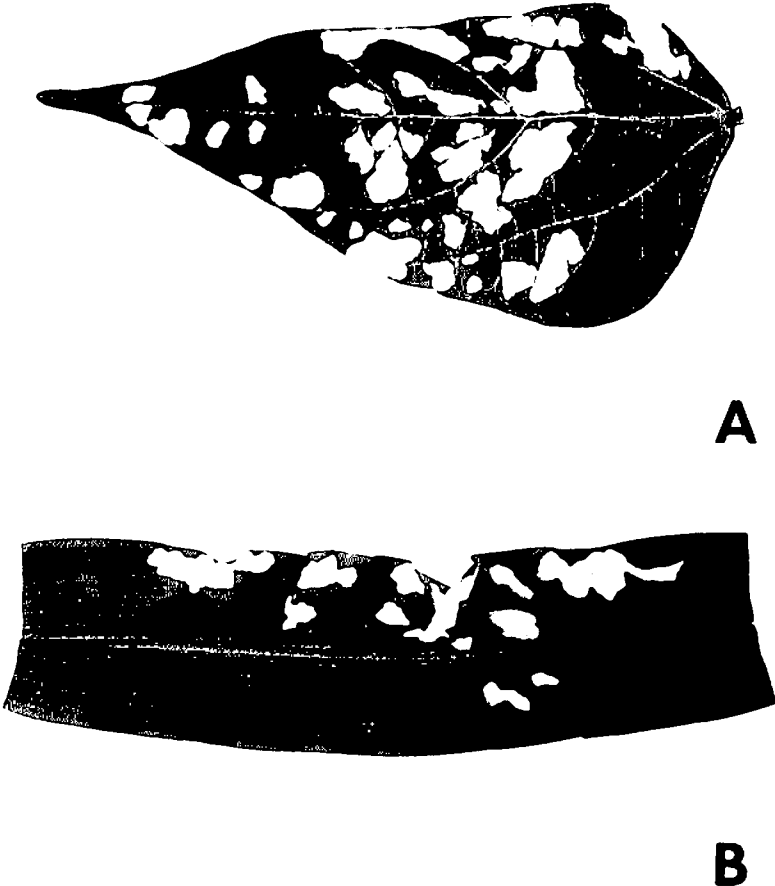


FIGURE 1. Chinese rose beetle feeding pattern on snap bean (A) and corn (B) leaves.

Einsteins/m²/sec of photosynthetically active irradiation, supplied by a 400 watt high pressure sodium lamp. A water bath was positioned between the lamp and the tube to act as a heat sink to prevent heating of the test tube. The time required for each lamina explant to rise to the surface of the sodium bicarbonate - buffer solution was recorded. The experiment was repeated 30 times.

Photosynthetic and Stomatal Conductance Measurements. A portable photosynthesis system, (LI-COR INC., Lincoln, Nebraska) equipped with a 4 liter chamber was used to measure photosynthesis (umol CO₂/m²/sec). The average photosynthetically active irradiation used for corn was 1,200 and 700 u Einsteins/m²/sec for snap beans. Light was supplied by a 400 w high pressure sodium lamp. A 3 cm deep water lens was placed between the lamp and the leaf to capture excess heat emitted by the lamp. Stomatal conductance readings, mol/m²/sec, were also measured on corn leaves, by the same methods for photosynthesis measurements.

RESULTS AND DISCUSSION

Chinese Rose Beetle Feeding Pattern. There was a distinct difference in the areas consumed by the beetles in snap bean as compared with corn leaves (Fig. 1). Regardless of the amount of leaf lamina removed in snap bean leaves, the major veins were left intact. This resulted in the distinct "skeletonized" appearance that has been used to characterize Chinese rose beetle feeding damage. In corn leaves, however, the major veins as well as the interveinal leaf tissue were removed. Caswell et al. (1973) proposed that there are distinct anatomical and physiological differences between monocotyledonous and dicotyledonous plants which could account for the differential feeding pattern, such as the location of active photosynthesis and starch accumulation areas within the leaves. Dicotyledonous leaves such as snap beans have active photosynthetic sites in the interveinal areas where most of the mesophyll cells are located. Hence, most of the photosynthates are accumulated in these areas as starch. The results from our veinal and interveinal leaf lamina snap bean explants provided evidence of the photosynthetic rate differences. Leaf disc punches (lamina explants) taken from interveinal areas of snap bean leaves rose to the surface 39% faster compared to lamina explant punches from veinal areas. The mean rising time for veinal and interveinal lamina explants were 5.07 ± 0.58 and 3.07 ± 0.04 minutes, respectively. The earlier rising times for the interveinal explants indicated that there was greater production of oxygen within the tissue (increasing buoyancy) as a product of photosynthesis. The greater rate of oxygen production, as measured by the earlier rising time, indicated a higher rate of photosynthesis. Since interveinal tissues include little to no veinal tissue, a larger portion of mesophyll tissue is present. Mesophyll tissues are the primary tissues which house chloroplasts, thus making these tissues more "photosynthetically active". The feeding of beetles on the "more photosynthetically active" areas may be the major factor influencing the linear relationship seen in Fig. 2 between percent defoliation and per-

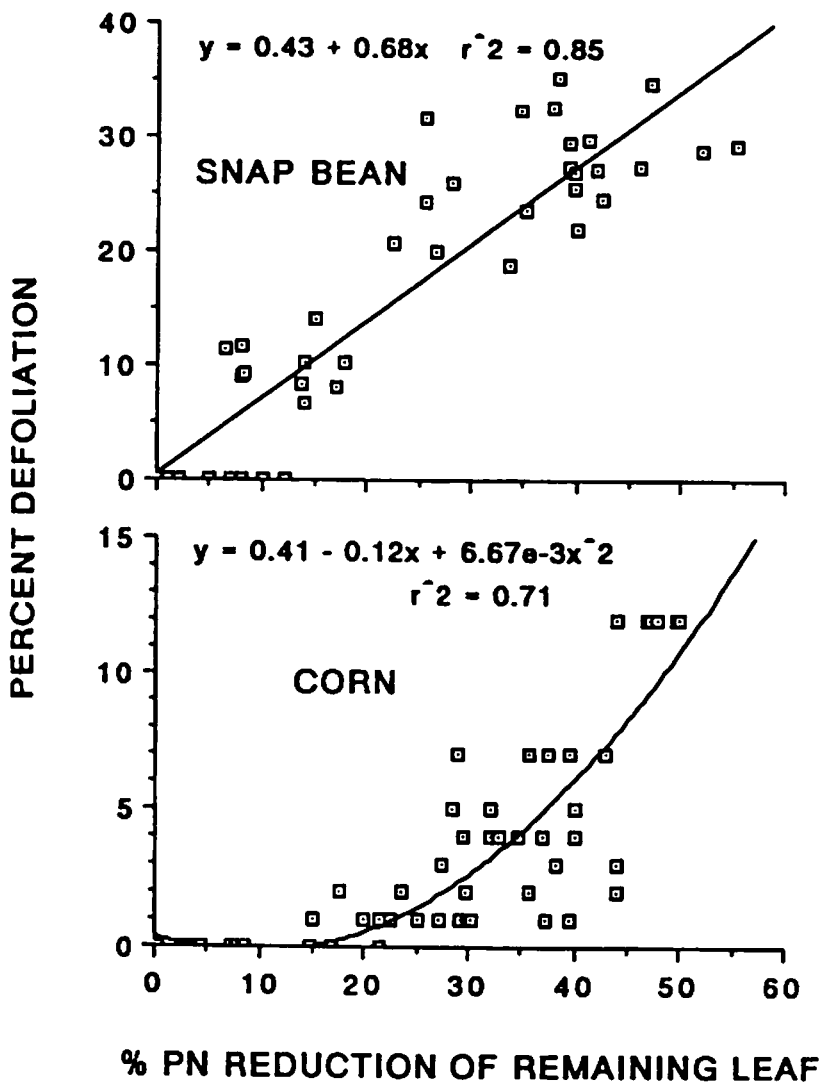


FIGURE 2. Influence of simulated Chinese rose beetle defoliation on photosynthetic rate, $\mu\text{mol CO}_2/\text{m}^2/\text{sec}$, reduction on the remaining (uneaten) leaf lamina for corn and snap bean.

cent photosynthetic reduction for snap beans. Discriminate interveinal feeding on the dicotyledonous snap bean leaves would selectively remove those areas with higher chlorophyll content, thus increasing the ratio of veinal to interveinal tissue and lowering the photosynthetic rate of the remaining leaf lamina.

In contrast, active photosynthesis occurs in the bundle sheath cells which surround the vascular tissue in monocotyledonous leaves such as corn (Mauseth 1986). Unlike snap bean leaves, starch is concentrated around the veinal tissue in corn and, thus, may induce beetle feeding in this area.

Simulated Injury on Snap Bean and Corn Leaves. Both snap bean and corn plant leaves exhibited a reduction in photosynthetic rate after simulated beetle feeding. The reduction rate in comparison to percent defoliation, however, was much greater for corn than for snap beans (Fig. 2). Snap bean leaves showed a linear relationship between the remaining leaf lamina and photosynthetic rate reduction while corn leaves displayed an increasing curvilinear decline. Fifty percent reduction in photosynthetic rate was obtained after 35% defoliation in snap bean and after only 12% defoliation in corn. The greater reduction rate for corn appears to be related to stomatal conductivity (Fig. 3). In corn, the photosynthetic rate was reduced to less than half that of the controls 20 minutes after the veinal tissue was severed. Stomatal conductance concomitantly decreased with photosynthetic rate. The decrease in stomatal conductance is due to the nonconductance of xylem fluid distal to the severed vascular tissue. Thus, the Chinese rose beetle simulated feeding injury on corn leaves demonstrated that damage to the vascular tissues induces water stress on the leaf area distal to the injured area, thereby lowering the stomatal conductance and photosynthetic rate of the leaf. Smith & Poos (1931) observed similar symptoms when the potato leafhopper, *Empoasca fabae* (Harris), was allowed to feed on veinal tissues of alfalfa. They attributed the wilting of leaves to direct injury of water conducting cells which secondarily induced the wilting in distal leaf tissues. Therefore, in corn, a monocotyledonous plant, water transport to tissues distal to the injured area becomes limited, resulting in decreased stomatal conductance and photosynthetic rate of the remaining leaf lamina.

Clearly, the photosynthetic rates of snap bean and corn leaves are reduced after simulated defoliation by the Chinese rose beetle. In snap beans, the beetles feed on interveinal lamina tissue which contains high quantities of chlorophyll. This results in a reduction of interveinal tissue which is the major site for active photosynthesis in snap bean leaves. This seems to be the major factor in lowering photosynthetic rate on defoliated snap bean leaves. Unlike feeding on snap beans, the Chinese rose beetle feeds on both veinal and interveinal tissue in corn leaves. Since major vascular tissue is fed upon in corn, water stress is induced to the leaf area distal to the injury, resulting in lowered stomatal conductance and photosynthetic rate. Further research is currently being conducted to investigate the relationship between starch content of leaves and feeding by the Chinese rose beetle.

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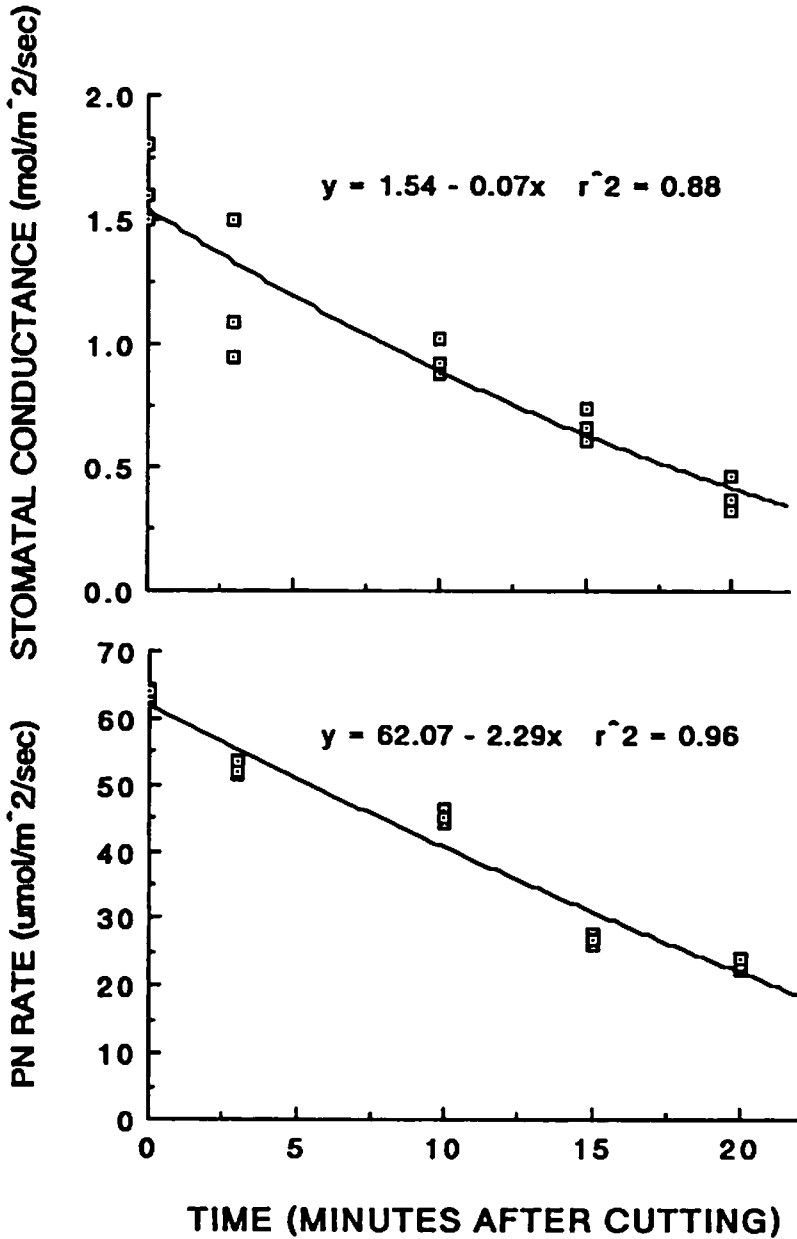


FIGURE 3. Effect of simulated Chinese rose beetle injury on corn leaf photosynthetic rate, $\mu\text{mol CO}_2/\text{m}^2/\text{sec}$ and stomatal conductance $\text{mol}/\text{m}^2/\text{sec}$.

REFERENCES CITED

- Arita, L.H., S.C. Furutani and J.J. Moniz. 1988. Preferential feeding by the Chinese rose beetle Burmeister (Coleoptera: Scarabaeidae) on ethephon treated plants. J. Econ. Entomol. 81:1373-1376.
- Caswell, H., F.R. Reed, S.N. Stephenson, and P.A. Werner. 1973. Photosynthetic pathways and selective herbivory: a hypothesis. Am. Nat. 107:465-480.
- Habeck, D.H. 1964. Notes on the biology of the Chinese rose beetle, *Adoretus sinicus* Burmeister (Coleoptera: Scarabaeidae). Proc. Hawaii. Entomol. Soc. 18:399-403.
- Hall, F.R. and D.C. Ferree. 1976. Effects of insect injury simulation on photosynthesis of apple leaves. J. Econ. Entomol. 68:245-248.
- Hatch, M.D. and C.R. Slack. 1970. Photosynthetic CO₂-fixation pathways. Ann. Rev. Plant Physiol. 21:141-162.
- Mauseth, J.D. 1986. *Plant Anatomy*. Benjamin/Cummings Publishing Company, Inc., Calif. 533 pp.
- Poston, F.L., L.P. Pedigo, R.B. Pearce and R.B. Hammond. 1976. Effects of artificial defoliation on soybean net photosynthesis. J. Econ. Entomol. 69:109-112.
- Smith, F.F. and F.W. Poos. 1931. The feeding habits of some leafhoppers of the genus *Empoasca*. Agri. Res. 43:267-285.
- Steel, R.G.D. and J.H. Torrie. 1960. Principles of statistics with special reference to the biological sciences. McGraw-Hill, New York.