Grasshopper injury to potato:

Consumption, effect on photosynthesis, and economic injury level

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The impact of leaf mass consumers (or defoliators) such as grasshoppers on yield losses are correlated most often with the amount of leaf tissue removed. A second method to quantify plant injury is through physiological measures such as gas exchange. Despite the large number of studies, however, contradictory findings remain. For example, one study showed that the removal of either partial or entire leaves by insect herbivores increased photosynthetic rates of the remaining leaf tissue, while many other early studies found reductions in photosynthetic rates. More recent studies in a number of crops have found no effects of insect feeding on the photosynthetic rates of the remaining leaf tissue.

One explanation for the variable outcomes of these studies has been the variation in the manner in which the studies have been conducted. While some of these studies assessed the question through evaluation of the whole canopy, others evaluated only the local response or measured photosynthesis of the injured leaf, making generalizations difficult. The most extensive work to address plant response to insect injury has been conducted on soybean. Other crops including alfalfa, apple, cotton, bean, and wheat have also been studied.

A key question is whether different plant species respond similarly to the same type of insect injury. For

Abbreviations: EIL, economic injury level; ET, economic threshold; LAI, leaf area index.

Red-legged grasshopper. Photo by Gilles Gonthier/Wikipedia.

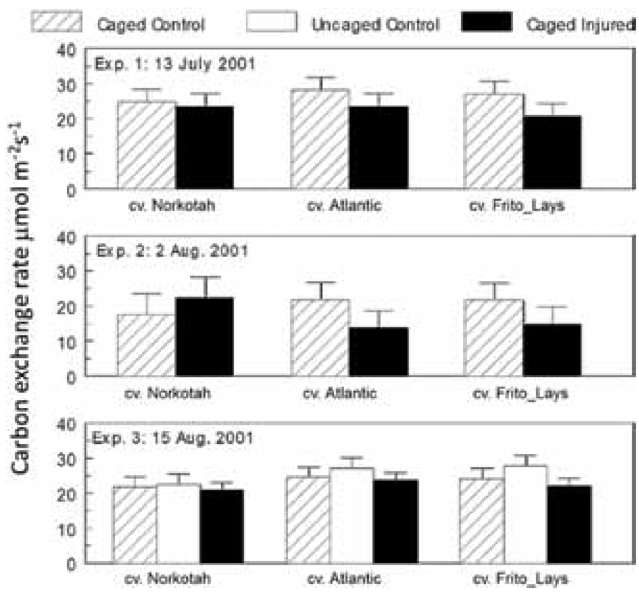

Fig. 1. Mean C exchange rates (± standard errors) of potato leaves injured by the red-legged grasshopper and controls. Rates determined immediately (<one hour) post injury after grasshoppers were caged on leaves for 24 hours. Measurements reported for three cultivars (Norkotah, Atlantic, and Frito-Lay proprietary 1845) in three experiments (July 20, Aug. 2, and Aug. 15, 2001).

example, alfalfa plants subjected to actual and simulated weevil injury failed to show any significant differences in photosynthetic rates. The same was true concerning the effects of actual and simulated injury of the cecropia moth on apple (3 and 24 hours after the cessation of injury) and crab apple and simulated injury on soybean photosynthesis. Grasshoppers are occasional pests on potato and frequently occur in conjunction with other defoliators. Establishing the photosynthetic responses of potato to grasshopper injury is an important first step in developing multiple-species economic thresholds (ETs) and economic injury levels (EILs).

Determining ETs is an important part of enhancing integrated pest management programs. Many combinations of crop species and potential pests have not been tested, and subjective thresholds are often relied on to determine when to control potential pests. One such example is potato grown in Nebraska. The majority of cultivars grown in Nebraska are used for potato chips. In Nebraska, insecticide is commonly applied when there is approximately 10% leaf loss due to pest defoliation. Using this threshold, however, does not take into account any differences that might exist in the canopies, and many studies have shown that it is the leaf area and resulting light interception rather than the defoliation percentage that determines yield.

In a recent study published in *Agronomy Journal* (103:1655–1660), the rate of injury caused by a common defoliating pest, the red-legged grasshopper, and its influence on the gas exchange parameters of the remaining tissue was evaluated. The results indicated that injury does not affect photosynthesis of the remaining tissue unless the LAI is approximately 4.5 or less, which is consistent with the pattern that researchers have observed with gross tissue removal (rapid loss of leaf tissue) by various insects on other plant species. Additionally, an ET was developed using leaf area rather than defoliation percentage for the red-legged grasshopper, which is a potential pest on potato.

Materials and methods

The study was performed at a commercial potato field in Kearney County in south-central Nebraska. Potato was at the post-flowering stage, and experiments were conducted during July and August 2001. One table cultivar (Russet Norkotah) and two chipping cultivars (Atlantic and a Frito-Lay proprietary cultivar) of potato were used. The plant spacing was 1.2 plants/ft, and the row spacing was 3 ft. The soil type was silt loam. The treatment design was a factorial of 3 cultivars × 2 treatments (caged leaf control and infested leaves) in Experiments 1 and 2. Experiment 3 was a factorial of 3 cultivars × 3 treatments (caged leaf control, uncaged check, and infested leaves). All were arranged in a randomized complete block, with eight replications. The soils were classified as Valentine–Els complex loamy fine sand (mixed, mesic Typic–Aquic Ustipsamments), 0 to 9% slope. The fields were irrigated by center pivot, and average rainfall occurred in 2001.

Two adult red-legged grasshoppers were confined in small mesh cages for 24 hours on the top five leaflets in the upper portion of the plant canopy at three different times. Grasshopper feeding produced mean injuries of 5 to 10% and 20 to 30% in three experiments. Figure 1 presents the gas exchange results by cultivar and experiment. Photosynthetic rates did not differ between injured and uninjured leaves for any cultivar in any experiment. Similarly, no significant effect for cultivar or the cultivar × injury interaction was observed.

Using the variables of LAI and the amount of leaf area consumed by the grasshoppers allowed the mathematical calculation of an ET using a 10% defoliation threshold, which is common practice in Nebraska when determining the use of insecticides.

Field trial results

The photosynthetic rate means of uninjured leaflets generally tended to be higher than the comparative ones on injured leaflets, except for Norkotah. Consistent numerical differences across multiple experiments might be taken to suggest that a biological difference exists below the level of statistical significance. Transient differences in leaf water potential and stomatal conductance might also cause minor differences in gas exchange. Clearly, some types of leaf injury (such as sucking injury, leaf mining, and some skeletonizing) cause photosynthetic rate reductions in the remaining tissue, but the situation with insects causing gross tissue removal is not as clear. In this study, however, no significant effect on gas exchange was observed, and the level of replication and absence of excess variability in measurements both indicate that sufficient power was provided to resolve underlying differences if they existed.

Increases in photosynthesis after defoliation are possible, even expected, with increased light penetration through the plant canopy. Increases in photosynthesis because of increased light, water, or nutrient availability after injury are called *extrinsic responses*. Distinguishing between intrinsic vs. extrinsic responses to injury is crucial, in part because intrinsic responses are genetic and, therefore, heritable. Intrinsic responses to injury (like tolerance and compensation) are both an evolutionary expression of plants to herbivory and a basis for genetic manipulations of plants to improve tolerance to insect damage.

The question of intrinsic vs. extrinsic factors is important in placing the findings here in the context of other research. The absence of effects in response to grasshopper injury agrees with a lot of previous work on gross tissue removal by various insects on various plant species. One study on the effect of simulated grasshopper damage on the net photosynthetic rate of wheatgrass showed a 31% reduction in net photosynthesis of injured leaves (with 25% tissue removal). This difference may represent a species difference between potato and wheat, or perhaps it represents differences in the extrinsic conditions under which the two experiments were conducted. In potato, researchers found whole-plant reductions in photosynthesis rates in response to infestation of the plant stems by the European corn borer, presumably as a result of changes to the plant water status.

Assuming no systemic effects of defoliation (which can occur with injury from some sucking insects), the two potential physiological impacts of defoliation are reductions in leaf photosynthetic rates or reductions in leaf area. In soybean, it is increasingly clear that the main effect of defoliation is to reduce the photosynthetic leaf area rather than reducing or enhancing the photosynthetic capacity of the remain-

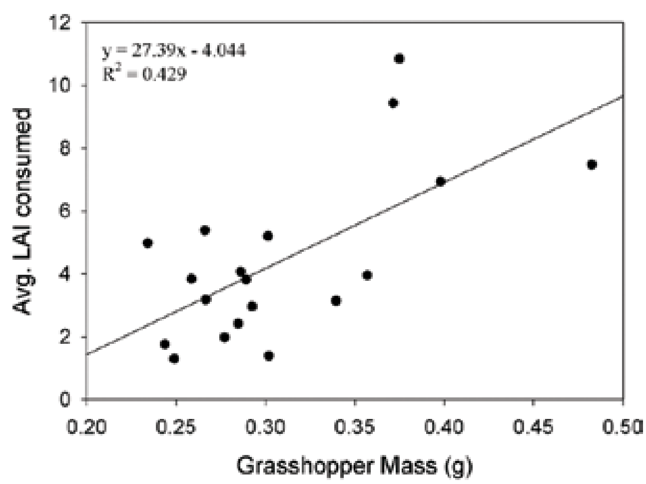

Fig. 2. Average leaf area index (LAI) consumed vs. grasshopper mass. The results from the laboratory experiments show a strong correlation between leaf area consumed and grasshopper size. From the data, it was determined that a grasshopper removes an average of 0.7 in^2/day of leaf area.

ing tissue of the injured leaves. Recognizing this mechanism underlying yield loss from defoliation leads to both improved models for yield loss and an explanation for the inherent (genetically determined) ability of plants to buffer some losses without yield loss. For example, in soybean, an LAI of 3.5, which corresponds to about 90% of canopy light interception, at the reproductive stage is considered critical for maximum yield. Under optimal growing conditions, however, soybean can achieve an LAI as high as 7.0 and could tolerate removal of half of this area without lowering yield significantly.

It is not yet clear if the light interception hypothesis for understanding yield loss from defoliation applies in species other than soybean. One expectation for it to be valid, however, is that most defoliators would not intrinsically affect the photosynthetic rates of the remaining tissue. The data from this study show that grasshopper injury to potato fits these criteria. This represents an important step in current research to explore the applicability of the light interception hypothesis for defoliation and yield loss in potato and other species.

Because the data in the current study agree with previous responses to defoliators detected in other plant species, the results suggest that a general model of response to injury guilds can be developed. Beyond the theoretical importance of establishing common injury responses, characterizing photosynthetic responses to injury provides a basis for establishing multiple-species EILs. This is especially valuable if other potato defoliators do not tend to affect photosynthetic rates.

Laboratory feeding trials and calculation of economic injury level

The laboratory grasshopper feeding trial showed that there was a correlation between leaf area consumed and grasshopper size. Figure 2 shows the average LAI consumed vs. grasshopper mass, and reductions in LAI have a linear relationship with grasshopper mass. The grasshoppers were allowed to feed on the leaflet for 24 hours, after which the leaflet was removed and the remaining leaf area measured using the LI-3000 leaf area meter (LI-Cor, Lincoln, NE). New leaflets were then supplied to the grasshoppers, and the experiment was repeated for six consecutive days. An adult grasshopper removes an average of 0.7 in^2 of leaf area per day. Given an estimated feeding longevity of 20 days, the total defoliation by an adult grasshopper would be approximately 13.5 in^2.

Key relationships were calculated (or recalculated) from data reported previously. The yield vs. proportion of light interception was linear, and the proportion of light interception vs. leaf area relationship was curvilinear. (The best fit was a one-phase association model, a form of exponential relationship.) Ironically, though, where the buffering capacity of the potato canopy is missing (LAIs of 4.0 or less), potato yields strikingly decrease in proportion to defoliation, with only 0.4 grasshoppers/yd^2 necessary for economic loss.

Each year, Nebraska potato farmers spend an average of \$165/ac to manage perceived insect pests, with a total of \$4 million spent annually on insect control.

Conclusions

With injury rates of about 10 to 25%, no significant change in photosynthetic rates on the remaining leaf tissue in any cultivar or in any of the three experiments was observed. Potato canopy areas were measured, and in the laboratory, individual insects were placed on premeasured potato leaflets. Individual adult grasshoppers consumed a total of 14.5 in^2 of leaf area. Early in the season when potato plant LAIs are less than about 4.5, grasshoppers have some potential to significantly reduce yield. In Nebraska, potential crop-feeding adult grasshoppers such as the red-legged grasshopper typically occur starting in early July when potato canopies usually have LAIs >5.0. Consequently, grasshopper densities in Nebraska are rarely, if ever, great enough in the field or field edges to warrant treatment. Only when canopy sizes are small, such as with delayed canopy development from drought or when large numbers of grasshoppers occur before July, should grasshopper management be instituted.

Adapted from the Agronomy Journal *article, "Grasshopper Injury to Potato: Consumption, Effect on Photosynthesis, and Economic Injury Level," by Cristina Bastos, Sean D. Whipple, W. Wyatt Hoback, and Leon G. Higley. Agron. J. 103:1655–1660.*