NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

Unintended Consequences of Plant Domestication on Plant-Insect Interactions

by
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Part I – Background

Podrick went on a field trip to the Stone Lake Environmental Refuge in Sacramento, California. His middle-school teacher, Miss Ray, kept showing flower after flower to the class. When they approached some native sunflowers, Podrick raised his hand and exclaimed, "My father grows sunflowers! But, why are these wild sunflowers so small?" His teacher replied, "Podrick, you'll be interested to know that these wild sunflowers are the same exact species as the ones growing on your farm. They are both called *Helianthus annuus*. However, wild sunflowers were domesticated into the different varieties of sunflowers we have today, some of which are bigger in size."

Figure 1. Agricultural sunflower field (left). Native sunflowers in a field (right).

Podrick leaned in for a closer look and was surprised that he did not see any striped caterpillars on the wild sunflowers or damage to the plants like he was used to seeing on the flowers back home on his own farm. This puzzled him, and so he asked Miss Ray why this was so. She responded, "I have some ideas. I'll look into it tonight and let you know in class tomorrow."

Figure 2. Infested sunflower with larvae that look like striped caterpillars.

Questions

Refer to Figures 1–3 to help you answer the following questions.

1. What traits in sunflowers might people have selected for that have agricultural uses in the modern world?
2. With your group, propose at least two hypotheses for why Podrick sees more pest damage on the sunflowers on his farm than on the field trip. Explain your rationale for each hypothesis.

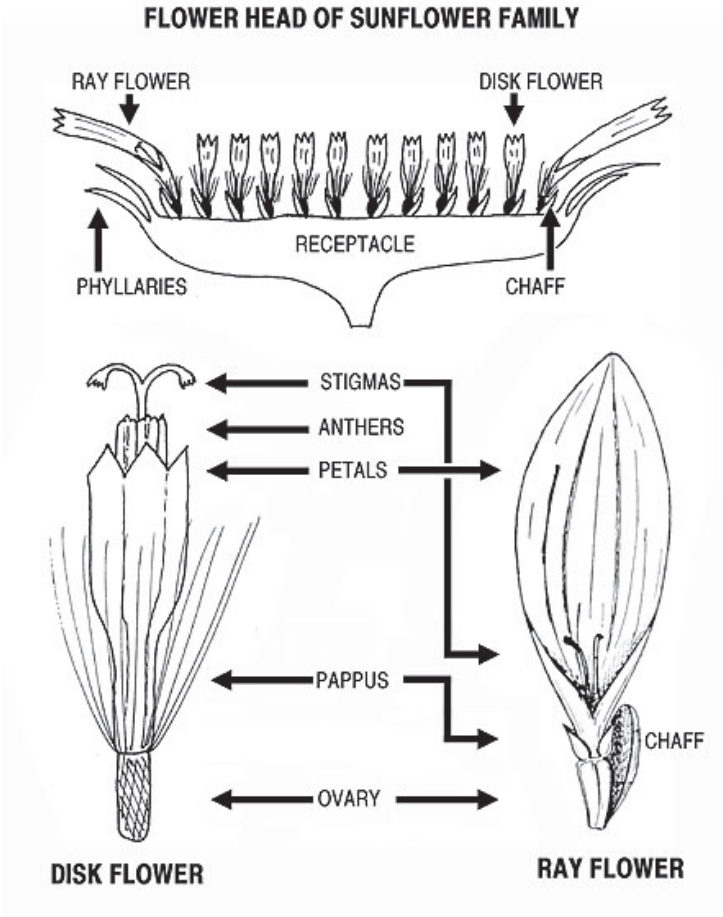

Figure 3. Floral structure of a sunflower, which is a composite of many flowers, some of which are found in the center (disk) in groups called florets and some of which frame the center (ray). Each ovary develops into a seed after fertilization. *Source:* Illinois Natural History Survey.

Part II – Answering Podrick's Quesiton

Miss Ray went online and figured out that the most common species of "caterpillar," or moth larva, found on sunflowers is the sunflower moth *Homoeosoma electellum* (Figure 4). Their eggs develop into larvae that feed on the sunflowers. Based on Podrick's description, she guessed that this was probably the same caterpillar.

Figure 4. Sunflower moth (left) and larvae on top of sunflower seeds (right), which are located at what would have been the bottom of the florets.

Miss Ray also found two research papers written by Dr. Yolanda Chen and Dr. Stephen Welter from the University of California, Berkeley. In one study, Drs. Chen and Welter set up a greenhouse choice experiment where sunflower moths were each put in cages to choose where to lay their eggs. The cages contained agricultural and wild sunflowers, grown at two different fertilizer levels, which the sunflower moths could choose to lay eggs upon. Different nitrogen fertilizer levels were of interest because agriculturally grown sunflowers receive nitrogen fertilizers while wild sunflowers only receive the nitrogen that is available in the environment.

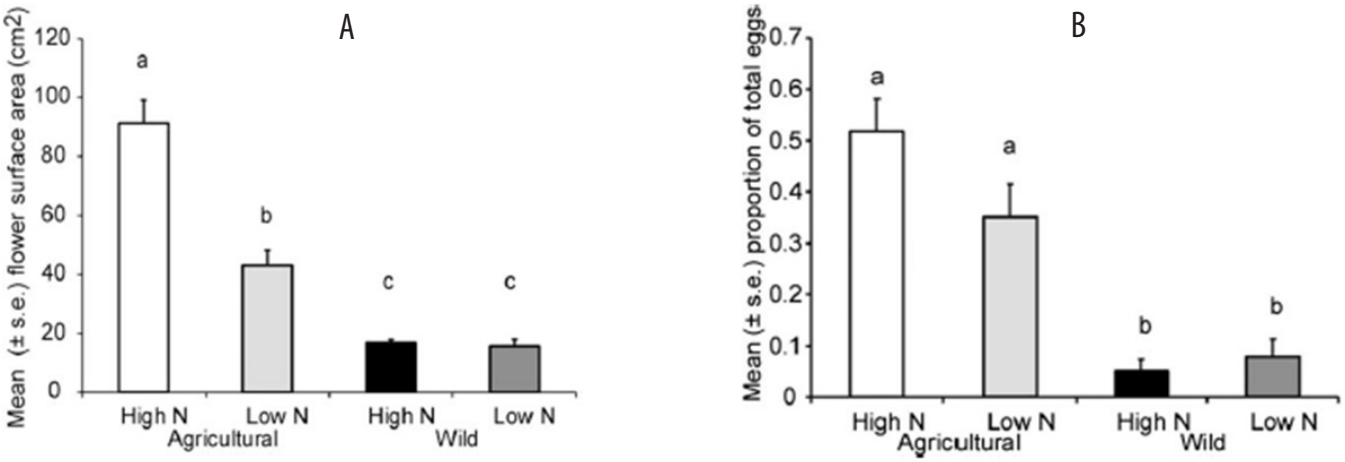

Figure 5. Flower size (A) and female moth ovipositional preference (B) of agricultural and wild plants at two different nitrogen levels: high and low. Lowercase letters represent significantly different treatment means using a Tukey test ($P < 0.05$). *Source:* Reprinted from Chen & Welter (2003) with permission from Elsevier.

Question

1. What differences did Drs. Chen and Welter find between agricultural and wild sunflowers (Figure 5A)? On which flowers did moths lay the most eggs (Figure 5B)? Did fertilizer level play a role in influencing the results (Figures 5A and 5B)?

When scientists consider three organisms in a food chain, they call it a tri-trophic interaction. Drs. Chen and Welter also wondered if the sunflower moth might be less attacked by natural predators within its food web in agricultural fields. In a second study, they decided to test if domestication affects the activity of a tiny parasitoid, called *Dolichogenidea homoeosomae* (Figure 6), which lays its eggs in the sunflower moth larvae. Parasitoids are considered natural enemies of insect pests. They lay their eggs inside the developing body of the larvae, where they grow like a parasite, depending upon the moth larvae for nutrition. When they reach the appropriate size, the parasitoids kill the host, pupate, and then emerge as adults.

Figure 6. Parasitoid of sunflower moth larvae.

In order to test their hypothesis, Drs. Chen and Walter monitored the total time spent foraging, or walking, probing, or resting, on a sunflower, by the parasitoid. The parasitoid forages in order to seek its prey, the sunflower moth larvae. The scientists also documented the percentage of time that foraging by the parasitoid resulted in successful parasitism of the sunflower moth larvae. Finally, larval density was manipulated because the larger size of the agricultural flowers could lower the frequency of contact with host larvae.

To manipulate larval density, the scientists placed ten larvae on high density treatment flowers and five larvae on low density treatment flowers. Behavioral assays were conducted in cages where a female parasitoid was exposed to a wild and an agricultural flower with the same larval density (either low or high).

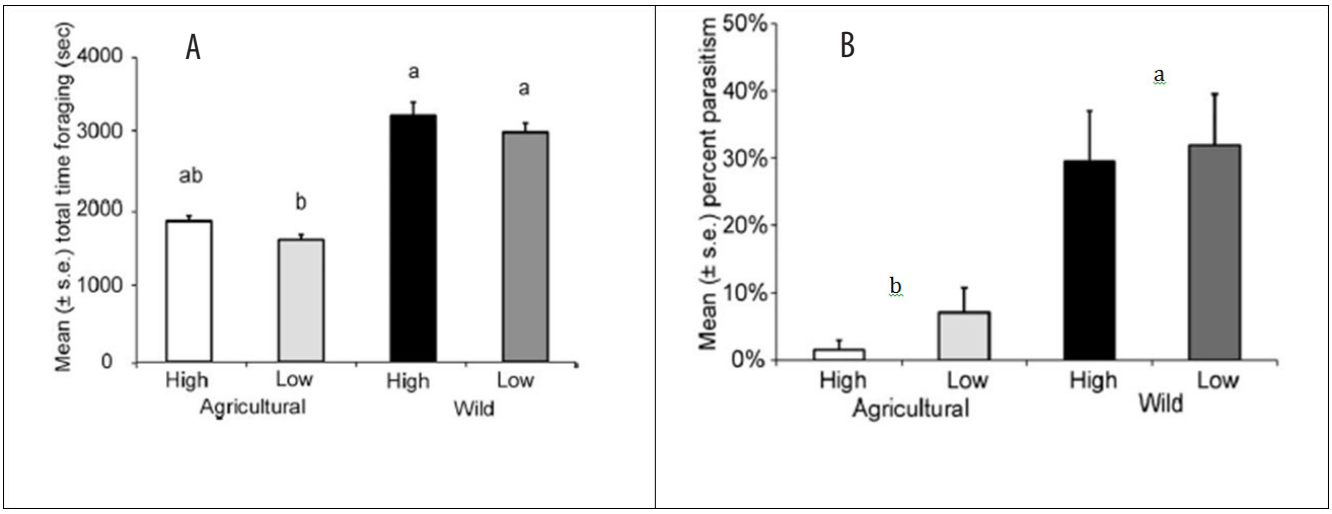

Figure 7. Total time spent foraging (A) and percent parasitism on sunflower moth larvae (B) by experienced parasitoid females on agricultural and wild plants with two different densities (high vs. low) of larvae. Lowercase letters represent significantly different treatment means using an F-test (A) and a Chi-square test (B) ($P < 0.05$). *Source:* Reprinted from Chen & Welter (2003) with permission from Elsevier.

Question

2. How did the tiny parasitoid forage differently on the wild sunflowers compared to the agricultural sunflower (Figure 7A)? Were they less successful in parasitizing sunflower moth larvae on one type of flower (Figure 7B)? How did the density of moth larvae (high or low) affect parasitoid foraging behavior and parasitism? (Figure 7A and 7B)?

Drs. Chen and Welter had read that wild sunflowers possess a phytomelanin layer, which is a hard seed coat that can prevent penetration of seed by small, young larvae and is lacking in many domesticated varieties of sunflowers. As a result, they also examined the feeding behavior of *H. electellum* larvae in more detail to compare with the patterns observed in Figures 7A and 7B. (Refer back to Figure 3 for a review of sunflower anatomy.)

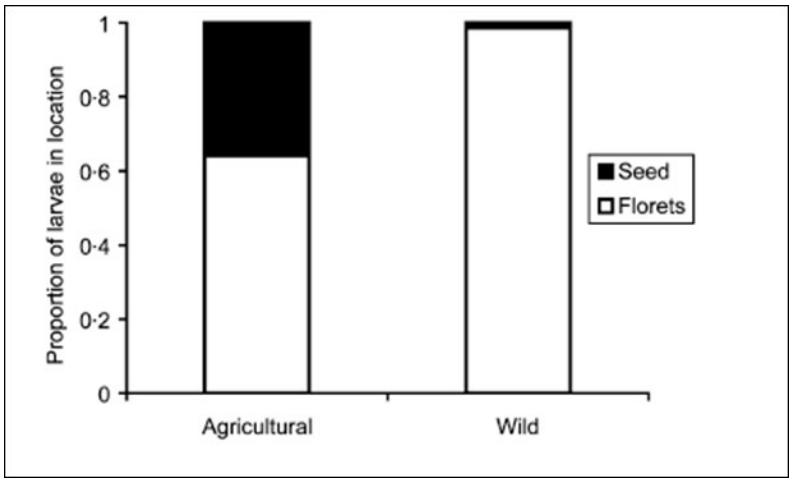

Figure 8. Proportion of *H. electellum* larvae feeding on sunflower structures in parasitoid accessibility behavioral studies. Florets are groups of disk flowers. *Source:* Reprinted from Chen & Welter (2007) with permission of John Wiley and Sons, Inc.

Questions

3. Where do the larvae of the sunflower moth feed on agricultural and wild sunflowers (see Figure 8)? Could this variation contribute to the lower parasitism by *D. homeosomae* on the domesticated sunflowers? If so, describe at least one possible explanation that might explain why.
4. You are Miss Ray. Summarize Professor Chen and Welter's experimental design and findings to Podrick, a middle school-aged boy. Try to avoid jargon (unless it is defined) and be concise. Podrick may have a short attention span after all.

Part III – Other Examples?

Drs. Chen and Welter's experiments represent one example of how domestication of plants had unintended consequences for plant-insect interactions. Conduct research to find a different example of where plant domestication had unintended consequences for interactions between (an) insect pest(s) and their plant host. Explain the mechanism for why this is. A good starting place may be to return to the hypotheses from Part I.

After you find your example, prepare a poster you can share in class. Also be ready to summarize your findings aloud using your poster to share data and pictures. You'll have five minutes to do so.

References

Chen Y.H., and S.C. Welter. 2003. Confused by domestication: incongruent behavioral responses of the sunflower moth, *Homoeosoma electellum* (Lepidoptera: Pyralidae) and its parasitoid, *Dolichogenidea homoeosomae* (Hymenoptera: Braconidae), towards wild and domesticated sunflowers. *Biological Control* 28:180–190.

Chen Y.H., and S.C. Welter. 2007. Crop domestication creates a refuge from parasitism for a native moth. *Journal of Applied Ecology* 44:238–245.