Weed Impacts on Arthropod Pests

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An extensive review of the interactions of insect pests, their natural enemies, and weeds was published recently (Norris and Kogan, 2000). No doubt that review aroused the interest for the organization of this workshop. Full credit goes Robert Norris for having compiled one of the most comprehensive bibliographies on insect associations with weeds and having attempted to provide a system to classify those complex interactions. Table 1 gives a summary of the main kinds of interactions that were discussed in the review. The review includes also comments on research reports that illustrate the major interactions and it contains an extensive bibliography with over 550 citations, up to 1998. The field remains quite active and many relevant references have appeared in subsequent years. This paper that review as a backdrop but, as the title implies, it is limited to the one-way effect of weeds on arthropod pests, despite the fact that in nature, interactions are consistently multi-directional. Clearly, within the context of crop communities, arthropods have a marked effect on weeds, not the least of which is their role in the regulation of the seed bank in the soil. Just as important is the effect that weeds have on insects.

Table 1. Major weed/arthropod interactions discussed in the review by Norris and Kogan (2000).

1. **Direct Trophic Interactions**
   - 1.1. Insect feeds on weed as alternative host
     - 1.1.1. Weeds outside crop field
     - 1.1.2. Weeds within crop field

2. **Indirect Trophic Interactions**
   - 2.1. Insects (parasitoids or predators) find alternative hosts/prey on weeds
     - 2.1.1. Weeds outside crop field
     - 2.1.2. Weeds within crop field

3. **Other Interactions**
   - 3.1. Competition from weeds reduces nutritional value of crop plant for arthropods
   - 3.2. Arthropod feeding reduces crop growth and increases resource availability for weeds

4. **Effects on arthropods of habitat modification by weeds**
   - 4.1. Altered resource concentration
   - 4.2. Altered apparency
   - 4.3. Microenvironment alteration

Arthropod/Plant Interactions

In their trophic relationship with plants, arthropods exhibit a wide range preferences, from extreme selectivity of a food plant, or monophagy, in host specialists, to broad polyphagy, in host generalists. What once was referred as the "botanical instinct" of insects, is now defined in terms of the complement of unique secondary metabolites characteristic of the host-plant that serve as stimuli for the insect's sensorial mechanisms (Bernays and Chapman, 1994) that enable insects to orient towards the host, probe it, and finally accept it for feeding or oviposition. Thus, when assessing the effect of weeds on insects within the crop community, additional consideration must be given to the host-specialization of the insect. Many of these trophic associations are dynamic and may change in time and space. Some host-specialists have been known to shift hosts under certain circumstances. The length of time of the coexistence of herbivores and plants within a community often drive those shifts. Table 2 summarizes some of these relationships.

Table 2. Characteristics of insects and plants (weeds) that drive within-community associations.

	Space factor	Time factor	Level of specialization
Nature of Herbivore	Exotic origin	Recent invader	Oligophagous
			Polyphagous
		Long established	Oligophagous
			Polyphagous
	Native origin	Crop adapted	Oligophagous
			Polyphagous
		Evolving (host-switching)	Oligophagous
			Polyphagous
			Associated fauna
Nature of the weed	Exotic origin	Recent invader	Free of oligophages
		Long established	Associated oligophages
	Native origin	Recent association	Adapted native fauna
		Crop adapted	Adapted native fauna

Obviously, interactions of insects and weeds within crop communities are much too complex and multifaceted to be discussed within the limitations of this paper. Instead, I selected three case studies to illustrate specific ways in which weeds impact on arthropods, with short- and long-term implications to arthropod demographics, population dynamics, and consequently IPM. These will be presented in the following sections.

Weeds as native hosts of arthropods that are potential pests of long-established or recently introduced crops: Example of the Colorado potato beetle.

It does not take long for arthropods to colonize a crop that has been introduced into a new area. The following example demonstrates the transition of an oligophagous species from a native host to crop plants within the same family as the native host.

The Colorado potato beetle, *Leptinotarsa decemlineata*, is the most serious pest of potato in North America and Europe. The beetle is native to the central Mexican plateau, where about 19 other species of the same genus can be found. In its native range, *L. decemlineata* feeds on bur weed, *Solanum rostratum*. During the wet season, the female beetle lays clutches of about 20 eggs on bur weed leaves. Larvae emerge and feed on the leaves sequestering many of the leaf Solanum-alkaloids that serve in their protection against predators. The larvae are bright yellow, and blend nicely against the yellow blossoms of bur weed. When the Spanish conquistadors invaded Mexico in the 17th century, there were no potatoes in North America, so the beetle was but a curiosity for its colorful design. The Spanish had introduced cattle to Mexico and near the end of the 17th century, began driving them north to Texas markets. The cattle carried the spiny seeds of the bur weed and the weed also began a northward migration. American bison picked up the bur weed seeds and moved the plant farther northward in the early part of the 18th century. The Colorado potato beetle followed the northward migration of its host eventually reaching the Great Plains by 1819, where it was found by Thomas Say and described as a new species. Thus the common name of this insect is misleading because the beetle actually is of Mexican origin. While the Colorado potato beetle was expanding its range to the north and northeast within the North American continent, the potato was also expanding it range eastward across the Atlantic Ocean into Europe. Although the potato is native to the "altiplanos" of the Andes, it was in Europe that it developed as a cultivated tuber crop and was introduced into Ireland in the late 1500s. Around the 1720s, seed stock was sent from Ireland back to North America and the culture spread westward. *L. decemlineata* would have first encountered potatoes in the U.S. mid-West around 1820 and by 1859 it had made the transition from bur weed to potato. Populations exploded and the species, now a serious pest, spread to Europe and Asia. Recent studies show that the Mexican population still feeds only on bur weed and rejects potato. A chromosomal inversion in the potato eating race of *L. decemlineata* was identified as a dominant trait (Hsiao, 1985). This inversion seems to have enabled some beetles to switch plant hosts and accept potato as a preferred food. This potato adapted race produces larvae that are dark orange or reddish probably a warning coloration against predators to avoid eating the potato-alkaloid laden larvae (Lu and Lazell, 1996). Thus, a weed, *S. rostratum*, provided the bridge for the spread of the beetle into an area where a new plentiful food resource became established, as the potato completed its own cycle of dispersal from the South American Andes, to Europe, and then back into North America. The herbivore and the host plant met in the Midwest and from there the beetle population exploded becoming a major pest of potato. This is probably the oldest and best documented example of a host switch from a weed to a crop plant, but others less dramatic have occurred with regularity in most major and in many minor crops as well.

1. Weeds purposefully introduced into crop field to achieve control of target pest: Example of the rape blossom beetle on cauliflower in Finland.

The pest management tactic known as trap cropping has had many variants. Some trap cropping systems use a combination of susceptible varieties of the same crop plant that one is trying to protect, or strips or patches of other plants that are more attractive to the insect pest species than the crop itself. The following case-study (Hokkanen, 1991) demonstrates the selective use of a mix of weeds and non-weedy plants that provide a super stimulus for the attraction of an oligophagous pest. The rape blossom beetle, *Meligethes aeneus*, a common pest on oilseed crucifers, became a serious pest on cauliflower in Finland in the beginning of the 1980s. This host shift, to a plant in the same crucifer family, resulted in losses of up to one third of the whole cauliflower crop. Farmers had no means of controlling the beetles on harvest ripe cauliflower. The increased rape cultivation adjacent to the cauliflower fields produced swarms of *Meligethes* forcing farmers to abandon cauliflower production in some regions of the country.

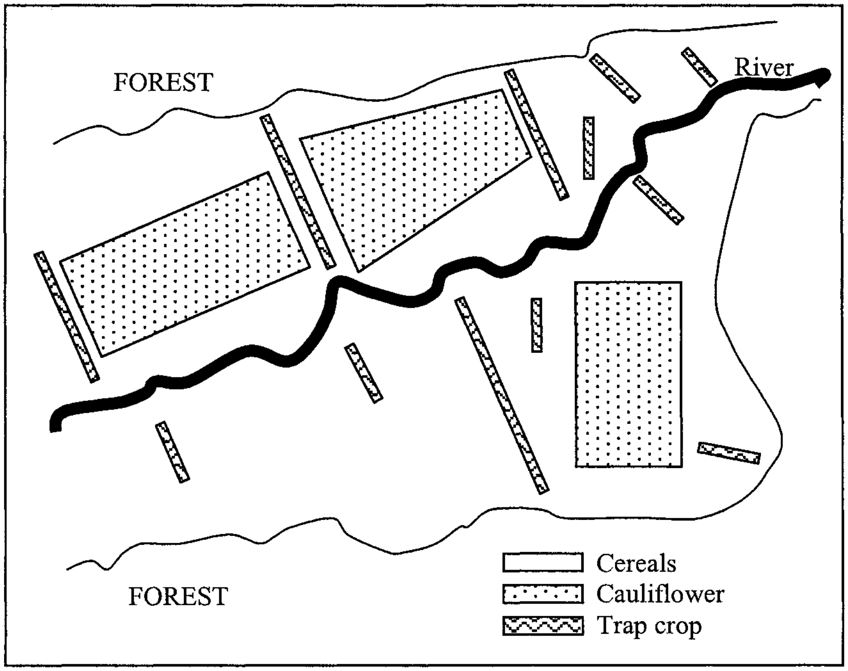

Figure1. Trap crop strips placed to intercept dispersal flights of the rape blossom beetle into cauliflower fields in Finland. (after Hokkanen, 1991).

A trap cropping system was developed using several species of trap plants that produce an intense yellow flowering, including Chinese cabbage, oilseed and turnip rape, sunflower, and marigold, often in a mixture. The trap cropping system was designed to prevent the spread of the beetles to the cauliflower plants. Because the beetles are highly mobile, the trap plants had to be grown in several strips, forming a set of barricades in the anticipated direction of infestation (Figure 1). About 15 strips, 16-65 ft wide and with a total length up to 3 mi, were used for protection of 100 a. of cauliflower. According to Hokkanen (1991) two to four insecticide sprays were needed to prevent the spread of the beetles to the crop plants, mainly because the heavy infestation quickly overloaded the trap crops unless they were periodically emptied. Despite the rather intensive management requirement of such trap cropping, the results were extremely positive, with an approximately 20% increase in marketable yield, and consequently good economic profits (Hokkanen et al.1986). This trap cropping system is practiced in Finland in areas where the blossom beetles are a problem in cauliflower. This system illustrates how weeds may interact with insects if the weed provides a super-stimulus that will divert the insect to the crop plant even if the resource is more concentrated in the crop.

2. Weeds as hosts of native pests become reservoirs for crop colonizers: Example of the areawide management of the bollworm and budworm in the southern U.S.A.

Caterpillars of the moths *Heliothis virescens*, the tobacco budworm, and *Helicoverpa zea*, the cotton bollworm, are representatives of a group of species considered the most damaging of any insect pest to major field and vegetable crops worldwide In contrast to the two species discussed in the previous sections, these are highly polyphagous; the two species have been recorded from 235 plant species in 36 families – many of those are weeds (Kogan et al., 1989). Stadelbacher (1979, 1981) reported the importance of both introduced and native early-season host plants of bollworm/budworm in the delta of Mississippi in the increase of the F1 generation. The moths of this generation subsequently invade cotton and require intensive insecticide sprays for their control. Insecticide-based control resulted in development of resistance in these species to most known insecticides. A species of wild geranium, *Geranium dissectum* (L.), an adventive , early maturing herbaceous winter annual from Europe, was the major alternate host in the area. Based on a quantitative study of larval and adult populations, as many as 180,000 bollworm/budworm larvae and 7,000 adults were estimated to be produced per acre. Stadelbacher reported that moths emerging in the spring were restricted to and concentrated in early-season alternate host plants, which occupied <5% of the total rural area. Subsequent studies on the rationale of attacking bollworm/budworm populations during this first generation and possibly the second generation suggested that a 90% reduction in areawide emergence in the first generation could be an effective management tool (Bell and Hayes, 1994a and b). An areawide IPM program was tested based on the suppression of F1 larvae with sprays of a *Heliothis/Helicoverpa* specific nuclear polyhedrosis virus over the breeding grounds where the weedy hosts were found. In this area velvetleaf was the preferred host for oviposition. The test covered an area of about

100 sq. miles. A single application of the virus reduced the size of the colonizing population on cotton by about 1/2 to 1/3 of the untreated area. The technique has been further developed for areawide application and results seem to be encouraging. Understanding the weed reservoir outside the crop area and the dispersal potential of the pest species are essential elements for the effective design of an IPM program.

Conclusions

The effect of weeds on insects is complex and manifests itself at both the physiological and ecological levels. The cases discussed here were limited to ecological effects on both oligophagous and polyphagous species. It is apparent that an intimate understanding of the responses of insects to stimuli from weeds, and the role of weeds in insect pest demographics, can offer opportunities to exploit the relationships in novel and creative ways in the context of IPM . These illustrations do not address the issue of the role of weeds in the diversification of crop communities and the effect of biodiversity on natural control. The paper by C. Picket in this workshop addresses this topic. The review by Norris and Kogan (2000) and the book by [Pickett, 1998 #284] provide insights and references on this subject.

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