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Compatibility of Host-Plant Resistance and Biological Control of *Heliothis* spp. (Lep.: Noctuidae)*

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ABSTRACT

The available literature concerning the compatibility of host-plant resistance and biological control, with particular reference to *Heliothis* spp., is reviewed. There has been a large amount of successful research on host-plant resistance and biological control as individual components for the management of *Heliothis* spp., and it has often been postulated that these components are compatible, or even synergistic. However, there are few reports of experimentation to test their compatibility. Research done at ICRISAT on the effects of host-plant resistance on parasitism in *Heliothis armigera* Hübner larvae on pigeonpea and chickpea is reviewed. It is suggested that the effect of host-plant resistance on the biocontrol elements must be tested in large plot field trials before these components are used in integrated pest management projects.

The widely publicized disasters in which *Heliothis* spp. developed resistance to insecticides in the Americas (Adkisson 1971) and in Australia (Wilson 1974) stimulated research on the alternatives to insecticides for the management of these and other pests. Biological control (biocontrol) and host-plant resistance (HPR) are both very attractive components of integrated pest management (IPM) which have received substantially increased research attention in recent years. This paper reviews the research into the effect of HPR on biocontrol and their compatibility or otherwise in the control of *Heliothis* spp. Throughout this paper, biocontrol is used in its wider sense, to include the endemic control elements as well as actively introduced parasites, predators, and insect pathogens.

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THEORETICAL CONSIDERATIONS

Many entomologists have theorized on the influence of HPR on biocontrol; one of the earliest, and perhaps the most pragmatic, was Painter (1951), who wrote:

> There appear to be only a few cases on record in which a study has been made of the influence of plant host on insect parasites or predators by way of the insect host . . . The information available indicates that the relationship between resistant varieties of plants and the insect parasites of the pests affected by the plant resistance may take two or more trends. First, reduction of the population level of the insect hosts might make it difficult for the parasites to find them and thus would have an adverse effect on biological control by parasites. Second, the profound effect on the physiology of the host which may result from feeding on resistant plants, might affect the establishment of insect parasites favourably, or unfavourably. Again the effect of resistant plants on host size would influence the prolificacy, size and perhaps sex of the insect parasite. Thus any relationship between resistant plant varieties and insect parasites cannot be predicted with certainty before hand but will need to be worked out in each individual case.

Although Painter stressed that the effects of HPR on biocontrol may be adverse in some cases, subsequent reviewers have tended to be optimistic, concentrating upon theories that stress the compatibility of the components. For example, Adkisson and Dyck (1980), when reviewing the role of resistant cultivars in pest management systems, considered that "resistant varieties are highly compatible with biological control." They postulated that the integration of HPR and biocontrol into a pest management system may result in synergism. The reduced rate of pest increase on a resistant cultivar may greatly prolong the time required for the pest's population to reach the economic, or action, threshold for insecticide use. Such delay offers an increased opportunity for the biocontrol elements to become established and effective. In some cases such combined effects of HPR and biocontrol may obviate the need for insecticide use.

A similar synergistic effect may also occur when the antibiosis of a resistant plant prolongs the nymphal period of a pest, or weakens it, so increasing its vulnerability to biocontrol elements, including the insect pathogens (Maxwell 1972). Morphological characters associated with host resistance may also provide a favorable environment for increased predation and parasitism, as in the open-headed, partially resistant sorghum hybrids (Teetes 1976).

PUBLISHED REPORTS

There are many published reports on the occurrence, development and utility of host plant resistance against *Heliothis* spp. in a range of crops.

These reports have been reviewed and summarized by Rogers (1982) and by Lukefahr (1982), who was not optimistic about the short-term utility of HPR for *Heliothis* spp. management:

> *Heliothis* spp. have a wide host range and are multigeneration pests. Therefore a population may build up on one crop and then move to another in large numbers. Since the population increase may not occur within the crop as in monophagous pests, high levels of resistance are required if populations are to be stabilized below the economic threshold level . . . . Progress in host-plant resistance research is a long-term proposition and requires considerable resources. With the limited financial resources available today, many host-plant resistance projects have suffered. Unfortunately, funding is available only when a crisis is looming and with the availability of the synthetic pyrethroids, there is no crisis on the horizon . . . . However, there are many crops where pesticide is not part of the production system. These are usually crops that have a low cash value per unit of land or crops grown in regions where growers do not have access to chemicals or the equipment to apply them. It is in these situations that host-plant resistance will have its potential impact.

There are also many published reports concerned with the biocontrol agents that attack *Heliothis* spp. King et al. (1982), provided a comprehensive summary of the literature and the prospects for utilization of parasites and predators in the management of *Heliothis* spp. Similarly, McKinley (1982) and Bell (1982) reviewed the prospects for the use of pathogens in the management of these pests.

However, there appear to be few publications that report the results of studies on the effects of HPR on biocontrol against *Heliothis* spp. Wiseman (1982), when reviewing the use of crop cultivars that are resistant to *Heliothis* spp. in pest management systems, reported, "Interactions that involve *Heliothis* resistant plant and predators or parasites have not been published." Consequently he was forced to utilize the frequently quoted reference of Starks et al. (1972), which involved studies of an aphid and its parasite on resistant and susceptible barley!

At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), a computer search of the available literature, as abstracted in the *Review of Applied Entomology* from 1972 to July 1985 (84,976 references), revealed an abundance of references reporting work on *Heliothis* spp. (3,321), but of these only 6 referred to both HPR and biocontrol. Of these six publications, two were general reports referring to HPR and biocontrol agents separately, with no consideration of their interaction. Two more referred to work carried out at ICRISAT; this work will be reviewed in the next section. The remaining two reports follow.

Mussett et al. (1979) studied the populations of predatory arthropods on a standard commercial variety of cotton and on experimental varieties that had been bred for resistance to *Heliothis* spp. in Oklahoma fields. They found a 68% reduction of predatory arthropods on the resistant cotton when compared with the populations on the standard variety. They were not able to determine whether this predator reduction was caused by a reduction in prey availability (*Psallus seriatus* [Reut] populations, which formed part of the prey, were also reduced on the resistant cotton) or by some antibiotic factors in the resistant cottons.

The second report was by Lingren et al. (1978), who studied augmentative releases of the *Heliothis virescens* (F.) larval parasite, *Campoletis sonorensis* (Cameron), on cotton lines that were resistant and susceptible to *H. virescens* in field cages in Texas. Here HPR and biocontrol were found to be compatible, for parasitism was heavy and F_1 larval populations failed to develop on the resistant cotton.

There are also a few reports concerning investigations on the mechanisms/chemicals in host plants that influence searching behavior by the parasites of *Heliothis* spp.—for instance, those by Elzen et al. (1984a, 1984b)—which may help us to understand some plant × biocontrol interactions. Such studies also appear to be few and far between.

STUDIES AT ICRISAT

Heliothis armigera Hübner is a pest on all five of ICRISAT's mandate crops—pigeonpea, chickpea, sorghum, millet, and groundnuts, but damage is most severe on the first two of these. It has been estimated that the cost of losses of pigeonpea and chickpea to *H. armigera* in India may exceed $300 million per year (Reed and Pawar 1982). The heavy damage caused by *H. armigera* on these crops may be partially a result of the relatively low parasitoid activity. More than 26% of the eggs of *H. armigera* were found to be parasitized by *Trichogramma* spp. on sorghum but only 0.1% on pigeonpea and none on chickpea. Parasitism in *H. armigera* larvae was found to average 27% on sorghum but only 11% on pigeonpea (Bhatnagar et al. 1982). Although at least 26 parasitoids and many predators have been recorded from *H. armigera* in central India, there are massive outbreaks of this pest on pigeonpea. Such outbreaks are not the result of the disruption of natural enemies by insecticide use, for few farmers use pesticide on these crops.

Research at ICRISAT has been primarily directed towards identifying and developing pigeonpea and chickpea genotypes that have resistance or tolerance to attacks by *H. armigera* and other pests. Both of these crops are typical of Lukefahr's (1982) concept of crops on which HPR is likely to have a "potential impact." This research has been particularly successful in chickpea, for several lines with considerable resistance have been selected and developed (Lateef 1985). There is also a considerable range of susceptibility/resistance in pigeonpea, but problems of outcrossing have limited progress in breeding for resistance in this crop (Bhatnagar et al. 1982).

Preliminary field studies at ICRISAT in which *H. armigera* larvae were collected from resistant and susceptible genotypes tended to indicate lower parasitism rates from the resistant genotypes both on chickpea (Sithanantham et al. 1982) and on pigeonpea (Sithanantham et al. 1983). Data from these and subsequent studies have shown that the percentage parasitism rates in larvae collected from the resistant genotypes were lower than in those collected from the susceptible genotypes in almost all samples. These differences were significant for all larvae collected from pigeonpea, but only for older larvae collected from chickpea. However, the reductions in populations of larvae caused by plant resistance were great enough to more than offset the small reductions in mortality due to parasitism. All of these data were collected from small plot (< 20 m) trials, so interplot effects may have been important.

The mobility of *Heliothis* spp. and their natural enemies may cause substantial, and misleading, interplot effects where small plots are used. To determine the real effects of plant resistance on biocontrol, it will be necessary to record data from large (ca. 0.5 ha) plots of resistant and susceptible genotypes. The differences in parasitism/predation on such plots may simply reflect the differences in the density of the *H. armigera* populations, for the resistant genotypes will have lower populations of the pest. To determine whether the differences are other than density-dependent effects, it will be necessary to inoculate with eggs or larvae to ensure that approximately equal populations of the pest are available on both resistant and susceptible genotypes. We hope to collect such data at ICRISAT in the future.

CONCLUSIONS

In common with several other aspects of IPM, the effect of HPR on biocontrol is frequently discussed but seldom subjected to research in the fields. There is a large quantity of published data on HPR and on biocontrol of *Heliothis* spp. from several crops, but almost all report HPR and biocontrol as separate components. Specialization has ensured that HPR and biocontrol research is usually handled by workers in separate departments or institutions. If IPM is to become a reality, the various components must be evaluated in combination to determine whether they are compatible. Such testing can be initiated in cages or on small plots on research stations, but eventually we must obtain data from large fields replicated under typical farming conditions.

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