CONSERVATION AND ENHANCEMENT OF ENTOMOPHAGOUS INSECTS — A PERSPECTIVE

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ABSTRACT

Efforts to consistently and predictably integrate augmented and/or naturally occurring entomophagous insects into conventional management systems for insect pests of row crops continues to be a high priority yet elusive goal of biocontrol specialists. Enduring management systems will depend heavily on the conservation and enhancement of entomophagous insects. Conservation and enhancement strategies are reviewed, with comments on their attributes, limitations, practicality, and probability of successful implementation.

Key Words: Entomophagous, insect, biological control, ecosystem, management.

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INTRODUCTION

The merits of classical biological control are well documented, but as with all forms of insect pest management thus far evaluated, it is not nor will it be the panacea for all situations. In particular, classical approaches to biological control have been particularly weak against the more opportunistic insect species that attack hosts temporarily occupying disturbed environments, such as annual row crops. Within these inherently unstable environments, the host or prey, food and refuge of natural enemies are conditionally reduced or eliminated while food of pest species is generally readily available. It is within this framework that alternative forms of biological control such as conservation and enhancement of natural enemies seemingly fit more appropriately and from which success appears more attainable. For this discussion, conservation is defined as the avoidance of measures that impact negatively on natural enemies, such as the use of insecticides or other adverse agricultural practices. Enhancement is the use of measures that increase the survival, longevity, fecundity, and efficiency of natural enemies as well as enhance the attractiveness of target areas to them.

The impact of naturally occurring entomophagous insects within temporary, predominately monocultural agroecosystems of the southeastern United States remained unrealized until these insects were inadvertently removed by insecticides directed against economic pests, resulting in the now commonly recognized resurgence response of the target species. Despite this knowledge, emphasis on natural enemies remained weak for several decades because of the high level of efficiency with which conventional insecticides controlled economic insect pests. However, because of the many problems and innumerable concerns associated with the use of conventional pesticides, the lack of permanence in their effect, primary interest, if not yet emphasis, is now being directed toward alternative strategies with conservation and enhancement of natural enemies playing a significant role.

BACK TO BASICS

Too often, shortcuts have been taken in the development of biological control strategies, only to conclude eventually that the goals were unattainable. More realistically, however, a basic understanding of the predator's/parasite's biology, ecology, and/or behavior was generally not available to permit an adequate testing of the hypothesis. These situations can and must be avoided through adequate preparation so that promising biological control strategies are not abandoned prematurely.

Basically lacking in most agroecosystems is a rudimentary knowledge of the full complement of natural enemies impacting pest species. Whitcomb and Bell (1964), for instance, reported over 600 predators in Arkansas cotton fields. Since then, Whitcomb (1974) reported finding well over 1000 species of predators in Florida soybean fields. While host specific parasitoids have been most successful in natural enemy introduction programs in perennial crops, generalist parasites and predators appear to have the edge in unstable environments. Also lacking for many if not most natural enemies is information on how they interact with the developmental stages of the host, their seasonal distribution and associated population densities, their primary and secondary food sources, their sites of refuge and overwintering, and their individual and collective impact on the target species across their geographic distribution. Additionally complicating, as pointed out by Price and Waldbauer (1975) — in order to understand insect populations, studies must be done at the ecosystem level, involving several crop fields, plus the neighboring uncultivated areas.

Most of what is known of predatory-prey, host-parasitoid relationships is derived from diurnal observations. There remains a critical void in information on nocturnally foraging entomophages. Efforts like those of McDaniel and Sterling (1982) and Gardner et al. (1981) using radioactive phosphorous and preciptin test techniques, respectively, to identify insect predators provided much needed insight.

ENVIRONMENTAL MODIFICATION

Ecosystem Diversity

A quest to control the environment to his benefit in man's inherent nature. North American agriculture stands as a milestone to his success wherein vast, essentially weed-free crop monocultures are methodically produced and mechanically harvested. Unfortunately, the rising production costs, compounded with increased costs of borrowing money, have dramatically reduced the profitability of this high energy-dependent industry, leaving farmers to desire and agricultural scientists to search for more enduring and efficient alternative management systems dependent less on fossil fuels.

Much emphasis is being placed on holistic approaches to the management of agricultural communities (Southwood and Way 1970; Price and Walbauer 1975; Price 1981; Altieri et al. 1983) wherein selective diversity of crop systems is used to enhance the stability of natural community inhabitants, by creating environments that increase the survival and efficiency of natural enemies while concommitantly increasing the vulnerability of pest species. The assertion that diversity is essential to stability in ecosystems and that crops grown in monocultures have more pest problems than do crops grown in diverse plant communities, is well supported (Soloman 1949; Elton 1947; Altieri 1982; Beirne 1967; Pimentel 1961, 1970; Deloach 1970). Van Emden and Williams (1974), however, do not believe these concepts apply within agroecosystems, because they are not mature communities.

The successful employment of landscape management appears more appropriately suited to the irrigated desert agroecosystems of the western United States wherein total plant communities can be structured to optimize arthropod/plant associations. The untility of ecosystem management concepts would appear to have questionable potential in the southeastern United States because of the long growing season, the multiple generations of most primary insect pests, the influx of migratory populations, and the expansive acreages of naturally occurring diverse plant communities, many of which favor population expansion and overwintering of the pest species. The complexity of even controlled ecosystems can be awesome, and as emphasized by Knipling (1979), community diversity can be a two-edged sword wherein phytophages instead of entomophages are favored.

Besides remaining to be proven that controlled agricultural diversity can be accomplished economically over large acreages is the more imposing probability of government intervention in such planned ecosystems (Beirne 1971) wherein landowners would eventually be mandated to make specific ecological changes at designated times on their property.

Crop Diversity

Although ecosystem management offers perhaps the ideal solution to promoting community stability, polyculture (otherwise known as strip cropping, intercropping, or mixed cropping) provides a more realistic alternative of on-farm management for increasing the aggregation, survival, and efficiency of natural enemies. The practicality of this concept has been demonstrated (Laster 1974; Stern 1969; Pair et al. 1982; Fye 1971; Robinson 1972). The identification of complementary polycultural systems, their refinement and incorporation into IPM systems will require basic knowledge of both the natural enemies and their host species as well as their interaction with one another and the environment.

A more controversial yet seemingly viable approach to selectively adding diversity to crop systems was offered by Altieri and Whitcomb (1978/79, 1979, 1980), who intercropped cultivated crops with indigenous weeds that favored beneficial insect species.

Almost totally unexplored and potentially one of the most rewarding and cost-effective alternatives to polyculture is the selective breeding of plant types that possess attributes favorable to natural enemies in addition to the sought-after factors influencing host plant resistance. As suggested by Rabb (1976), many of the same benefits provided by polycultural systems such as food and refuge could surely be incorporated into primary crops on which natural enemy management of primary pests appears feasible.

ENTOMOPHAGE MANIPULATION

Provision of Supplemental Resources

Supplemental requisites for natural enemies such as hosts, artificial food, water, sites for oviposition and development, and protective refuge can greatly enhance the aggregation, retention, survival, and efficiency of natural enemies. Artificial food sprays have been shown to increase retention of a wide array of generalist predators on alfalfa and cotton (Hagan et al. 1970), corn (Schiefelbein and Chiang 1973; Carlson and Chiang 1973; Nichols and Neal 1977), potatoes (Saad and Bishop 1976), and apples (Hagley and Simpson 1981). Such approaches to pest management are highly desirable because of their safety, their compatatibility with the environment, effectiveness, relative specificity for natural enemies, and their compatability with conventional application technology. The current primary limitation to their immediate implementation is cost (Denver 1973).

The sustained provisioning of natural or factitious hosts to the environment provides opportunities for continuous propagation of dependent natural enemies (Knipling and McGuire 1968). In the southeastern United States, the need for providing supplemental food and hosts is particularly critical during early season when natural resources are minimal. The availability of supplemental nonviable hosts has been shown to increase the retention of augmented *Trichogramma pretiosum* Riley by increasing the frequency of host finding prior to attempted dispersal (Gross et al. 1984). Parker et al. (1971) and Parker and Pinnell (1972) in an extreme demonstration of the utility of these concepts controlled field populations of imported cabbage worm *Pieris rapae* (L.) with *T. evanescens* Westwood by concommitantly releasing fertile adults of the target species. Permitting prerelease parasitization of hosts by *T. pretiosum* has also been shown to decrease their dispersal, thus increasing rates of field parasitization of *Heliothis zea* (Boddie) eggs (Gross et al. 1981). Further advances are dependent on the design and production of an acceptable, cost effective factitious host, capable of being delivered with conventional application systems.

Artificially provided shelter can, in selected situations, be a key requisite for the survival and enhanced performance of natural enemies. Ballow (1915), Lawson et al. (1961), and Gould and Jeanne (1984), for instance, reported on the successful provisioning of protected nesting sites for *Polistes* spp. wasps, with notes on their respective predation on hornworms, *Protoparse* spp., cotton leafworm, *Alabama argillacea* (Hbn.), and imported cabbageworm, *Pieris rapae* (L.). Gosswald (1951) protected nesting sites of the predaceous ants, *Formica rufa,* from predaceous vertebrates. The investigation of protective artificial structures to encourage the establishment of natural enemies, and particularly predatory wasps, is deserving of much greater effort.

Provisioning of Allelochemics

Accumulating evidence has taken us from an immediate past in which natural enemies were viewed as depending entirely on random encounter for locating their host or prey to the current understanding that their behavior is regulated by numerous predominately chemical stimuli which enhances their frequency of host-finding. Interspecific chemical cues (allelochemics) emanating from the host insects, their byproducts, nonhost organisms associated with the host habitat, food sources, etc., are apparently the predominant mediators used in the host selection sequence of parasitoids (Lewis et al. 1976; Vinson 1981; Weseloh 1981; Arthur 1981), and some predators (Greany and Hagan 1981). Kairomones are allelochemics which in interspecific interactions benefit only the receiver, such as in the case of natural enemies locating their host. This group of chemical mediators is currently receiving primary attention. A review of terminology and chemistry, respectively, of parasitoid-host, predator-prey relationships is offered by Nordlund (1981) and Jones (1981).

Opportunities now appear promising for the employment of kairomones to improve the retention and efficiency of augmented and naturally occurring natural enemies. Strides have been made in enhancing the efficiency of the generalist parasitoids, *Trichogramma* spp., via the use of kairomones (Lewis et al. 1975, 1979, 1982; Gross et al. 1975; Gross 1981). Efforts to favorably direct the behavior of host specific parasitoids will be more difficult because of multiple dependent kairomones functioning at discrete steps in the host selection process (Gross 1981).

The use of allelochemicals from plants to favorably manipulate the behavior of natural enemies is another newly emerging area of promise. Altieri et al. (1981) used extracts of *Amaranthus* spp. and corn (*Zea mays* L.) to simulate plant diversity within a range of monocultural crop systems and thereby enhance the parasitization of *H. zea* eggs by *Trichogramma* spp. Evidence of plant influence on the favorable responses of female parasitoids to their insect hosts has also been reported by Monteith (1958, 1967), Nettles (1979), and Roth (1978) for tachinid parasitoids; Nordlund and Sauls (1981) for the braconid wasp, *Microplitis croceipes* (Cresson); and Elzen et al. (1983) for the ichneumonid wasp, *Campoletis sonorensis* (Cameron).

As strategies for the use of behavioral chemicals advance, there will be increasing need to fully understand the complex web of interactions that occur within and between the trophic levels in plant communities (Price 1981). In addition to the inherent biological problems associated with the development of allelochemicals, Lewis (1981) has expressed concerns regarding patentability, and particularly marketability, because of specificity of use and because allelochemicals do not lend themselves as readily to adoption and implementation by agribusiness systems as do conventional pesticides.

CONCLUSIONS

Increasing emphasis on the judicious use of pesticides and the refinement of economic thresholds of insect pest species have been proportionally effective in conserving natural enemies. Refinement of economic thresholds to include quantitative measures of natural enemies is just beginning. Although natural enemies have often been considered in making treatment recommendations, crop production consultants still rely heavily on "gut feelings," because data on quantitative relationships are generally not yet available.

As impact relationships between natural enemies and target pest species are quantified, primary emphasis will be diverted toward problem prevention rather than cure. Efforts to determine and manage environmental conditions that increase the probability of natural enemy attraction, aggregation, retention in target areas, and efficiency will be highlighted. Only through a multidiscipline commitment to basic biological and ecological research by entomologists, agronomists, an array of plant scientists, chemists, agricultural engineers, meterologists, etc., can we develop the ability to effectively employ natural enemies with predictable results.

The attainment of these ambitious goals will be paralleled with the increasing need for specialty crop production consultants. The degree of difficulty and level of expertise currently required of field crop consultants to manage the production of multi-crop systems was addressed by Jensen (1982). Compared to what will be expected of multidiscipline management teams of the future, current crop production consultation is in its infancy.

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