IS AN ECOLOGICAL UNDERSTANDING A PREREQUISITE FOR PEST MANAGEMENT?

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SYNOPSIS

Comparison between the principles and the real world practices of integrated pest management (IPM) reveals severe discrepancies. The cotton agricultural system is a problem with a long and sad history, and illustrates what not to do. But, examination of IPM relative to the mobile pests of polycultures in the southeastern USA would suggest that “here we go again!”

Integrated pest management (IPM) is the current paradigm for dealing with pests; thus, it is prudent to inquire whether IPM will have a higher probability of long term success than other approaches which have failed. This paper is an attempt to compare the principles of IPM to the current control practices and to examine management approaches in two cropping systems. Primary objectives are to show that agriculturists are far from implementing programs that will solve pest problems and that such solutions will arise only from an ecologically sound foundation.

PRINCIPLES OF IPM

The concept of integrated pest management (IPM) is well documented (e.g., Rabb and Gutherie 1970, Metcalf and Luckmann 1975, Apple and Smith 1976, Smith et al. 1976, Smith and Pimentel 1978, Bottrell 1979, Barfield and Stimac 1980); however, Bottrell (1979) appears to be the first to state explicitly the principles underlying IPM.

1. POTENTIALLY HARMFUL SPECIES WILL CONTINUE TO EXIST AT TOLERABLE LEVELS OF ABUNDANCE. The objective of IPM is to lower pest populations below economically important levels; eradication is not the objective.

2. THE ECOSYSTEM IS THE MANAGEMENT UNIT. The boundaries of and the couplings among components of the system must be identified before design and implementation of an IPM program.

3. THE USE OF NATURAL ENEMIES IS MAXIMIZED. An understanding of how natural enemies work in the system must be acquired so that optimal use can be made of their impact on target pest populations.

4. ANY CONTROL PROCEDURE MAY PRODUCE UNEXPECTED AND UNDESIRABLE CONSEQUENCES. An ecologically based management strategy is less likely to result in “negative effects” within the system being managed.

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5. AN INTERDISCIPLINARY SYSTEMS APPROACH IS ESSENTIAL. The assumption is that information collected by various scientists can and will be integrated.

Implicit in Bottrell's principles is the concept of monitoring. Design or evaluation of an IPM program demands monitoring of relevant aspects of the system. Thus, any IPM program must have well defined and utilized monitoring schemes.

An examination of currently used IPM programs for a variety of crops and pests (see Bottrell 1979, Barfield and Stimac 1980, Huffaker 1980, Flint and van den Bosch 1981 for general reviews) reveals that instead of IPM programs having the above six characteristics, most existing programs have the following:

1. There is virtually no appreciation for the boundaries and characteristics of the system being managed. Target pests are dealt with as if sessile, and individual fields as though they are independent of the agroecosystem.
2. Mortality from natural enemies is poorly understood, even totally ignored.
3. Most "IPM programs" are not integrated, but are actually four unilateral efforts—one each for weeds, insects, pathogens, and nematodes. Farmors must do the integrating, if any is to occur. Potentially useful integrative tools (e.g., systems models) have not been incorporated into the mainstream of agricultural thinking.
4. The level at which a pest population is considered to be economically important is usually considered static, not a function of changes in the system being managed.
5. Monitoring is not often a part of field activities. Sampling plans are often inadequate and do not allow estimation of pest population levels with precision or accuracy.

While some programs have been deemed successful, others have not (see Barfield and Stimac 1980). Assessing why a program fails is often difficult. To evaluate the applicability of IPM as an approach, we must first delineate "true" IPM programs from the plethora of programs that are called IPM. Determining whether IPM will lead to more solutions to pest problems than other approaches requires a historical perspective. For illustration, two approaches to boll weevil (Anthonomus grandis) management are compared, with respect to their spatial and temporal utility. The amount of ecological information incorporated into particular programs is the primary focus. The thesis is that ecologically based programs will be effective, but programs that ignore significant components of pest ecology will not. Following the boll weevil example, a description of the complex of noctuids typical of polycultural systems in the southeastern USA is given. This second system forces the question "are the same mistakes still occurring?"

THE COTTON WEEVIL: A MODEL FOR IPM

After entering the United States (ca. 1892) and spreading throughout most of the range of its cotton host plant, the boll weevil caused radical changes in the way cotton was cultivated (Adkisson and Bottrell 1977, Bottrell 1983). The numerous approaches that were attempted to manage the weevil mirrored developments in Economic Entomology in the 20th
century (see Perkins 1982). To a varying degree, weevil management relied on a knowledge of pest biology and ecology. Two management approaches can be contrasted for their long term utility in space and time (robustness). PRE-INSECTICIDE ERA. Since little was known about the boll weevil prior to its introduction, early workers had to investigate weevil ecology before they could develop even a preliminary management program. Significant constituents of early management programs were strategies that maximized within- and between-season mortality (Adkisson and Bottrell 1977, Bottrell 1983). Within seasons mortality was identified primarily to be a function of two components: (1) natural enemies and (2) host plant responses to weevil infestation (Hunter and Hinds 1904; 1905, Pierce et al. 1912, Fenton and Dunnam 1929). Natural enemies were studied extensively (see Pierce 1908, Pierce et al. 1912). Of particular interest was the interaction between host plant and insect parasitoids. Since weevil immatures (eggs to pupae) developed inside the cotton floral buds (weevils also attack fruits, but prefer buds—called "squares"), parasitoids had to search buds for suitable hosts. In response to weevil attack, the plant abscised infested buds. Most buds fell to the soil surface, but some remained on the plant. These were referred to as "hanging squares". It had long been noted that parasitism rates in hanging squares consistently were higher than in fallen squares (Hunter and Hinds 1904; 1905, Pierce et al. 1912, Fenton and Dunnam 1929). To maximize parasite efficacy, Pierce et al. (1912) suggested that farmers refrain from destroying hanging squares and that a "hanging square" variety of cotton should be developed and used in production.

Abscission of infested squares also played an important role in weevil mortality. Squares that fell between rows were sunlit and dried more rapidly than those that fell in plant shade. Immature weevil mortality was found to be affected significantly by the location and subsequent drying time of fallen squares (Hunter and Hinds 1904; 1905, Fenton and Dunnam 1929, Folsom 1932). To take advantage of this source of weevil mortality, some authors suggested varying cotton row spacing (Mally 1901, Cook 1902).

Perhaps the most significant component of weevil ecology was identified to be the survivorship of overwintering weevils (Hunter and Hinds 1904; 1905, Pierce et al. 1912). Weevil adults overwinter in and around cotton fields under leaf litter and crop residue. To maximize adult mortality, two suggestions were made: (1) shorten the growing season to increase the time in overwintering sites and decrease the time suitable host material was available, and (2) destroy crop residue and other overwintering habitats (see Cook 1932).

Growers following these ecologically-based recommendations were able to produce an economically viable cotton crop for over 40 years (Adkisson and Bottrell 1977, Bottrell 1983). Although insecticides were available (e.g., calcium arsenate), they were used sparingly (Isley 1926, Folsom 1932). The advent of inexpensive, effective synthetic insecticides (e.g., DDT) led to major changes in boll weevil management—changes that ultimately led to disaster.

INSECTICIDE ERA. Following World War II, the incorporation of synthetic insecticides into cotton crop protection schemes led to a dramatic change in boll weevil management. The decimation of weevil populations following insecticide application allowed growers to maximize yields while minimizing damage (Newsom 1970, Reynolds et al. 1975). Preventative ap-
applications and "calendar sprays" (i.e., "ever so often, need it or not") were used widely, eliminating the "need" to determine whether weevil densities were above economically damaging levels (Adkisson and Bottrell 1977). With the widespread acceptance of a management plan based solely on insecticides, research on weevil ecology was de-emphasized. Eventually, this over-reliance on insecticides led to widespread ecological perturbations and near economic collapse of the cotton agricultural system (Adkisson and Bottrell 1977).

Weevil resistance to organochlorine insecticides in the 1950's was followed quickly by analogous resistance to other compounds by both the weevil and other cotton pests (Newsom 1970, Adkisson and Bottrell 1979), and growers soon found that increased application rates could not provide needed control. Organisms not formerly pests became pests, and existing pests got worse. Cotton agriculture was out of control (Newsom 1970, Adkisson and Bottrell 1977), and several major cotton growing regions faced economic ruin.

What emerged from this disaster was an approach called IPM. IPM largely adopted the recommendations made by workers in the pre-insecticide era. Focus was again on maximizing overwintering weevil mortality, shortening the cotton growing season and judicious insecticide use (Bottrell 1983). Weevil management was fortunate at least to have had an ecological template. However, examination of how much remains to be learned about boll weevil shows that agriculturists are far from implementing a complete solution to the boll weevil problem.

Although early workers identified the importance of the plant's abscission of infested squares, just how this affects weevil dynamics or whether immature parasitoids also suffer from square drying mortality remains to be learned. Given the apparent increase in parasitization in handing squares, should parasitoids that prefer to search in this region of the plant's environment be released? There are many such questions. In addition, major elements of weevil biology and ecology are still being discovered. For example, despite intensive studies on adult overwintering, it was 1959 before diapause in adult weevils was discovered (Brazzell and Newsom 1959). By 1968, only four exotic natural enemies (see Clausen 1978) had been released against the weevil, a species which itself was introduced. As late as 1975, major alternative host plants were being found (Cross et al. 1975). In 1979, a closely related weevil (Anthonomus kunteri), and a potential clue to natural enemies, was described from the boll weevil's Central American aboriginal home (Burke and Cate 1979).

What has been shown here for the boll weevil is true of many other pests. Now, examination of a second system will reveal whether today's workers have profited from yesterday's experiences.

**THE NOCTUIDAE**

The southeastern USA contains a mosa of agricultural production systems. Within these, a complex of pest organisms exists that appears to reinvade crops annually through migration and/or dispersal. Of particular concern in recent times is a complex of moths (mostly Noctuidae) that is suspected to overwinter in more southern latitudes and move northward each spring and summer. A number of recent reviews and symposia have addressed these insects and what is and is not known about them (e.g.,
Rabb and Kennedy 1979, Stinner et al. 1988). Others have reviewed and discussed the phenomenon of movement in great detail (Johnson 1969, Baker 1978, Gautheaux 1980), theoretical evolutionary problems and selection models (Walker 1980), and movement of pests relative to the structure of agricultural systems (Stinner et al. 1983, Rabb and Stinner 1978, Johnson et al. 1975, Stilmac and Barfield 1979). Inability to forecast when and where these mobile moths will occur and the reasons why also have been con- fronted (Barfield et al. 1980).

Current IPM strategies against these pests are similar to those for less mobile organisms—an individual farmer's field is scouted and the pest population treated (primarily chemically) when damaging density levels are suspected. These fields are treated as "islands," and there is virtually no consideration of the significance of the processes determining the timing and rate of influx. Though most agriculturists recognize that pest population levels are related to both the timing and magnitude of immigration, few measure influx rates and evaluate quantitatively the consequences of those influxes (see Rabb and Kennedy 1979). Research extended from the soybean plant growth model (see Wilkerson et al. 1983) is an exception to this generalization. Unless an understanding of the role movement plays in moth dynamics and "pest status" is acquired, agriculturists cannot design robust management strategies against pests such as these (e.g., Stinner et al. 1983, Rabb and Stinner 1978, Barfield 1983, Barfield et al. 1980, Rabb and Kennedy 1979).

"IPM" programs against these noctuids could, over the long term, prove to be just as unstable as boll weevil management when it abandoned an ecologically based approach. Since the general attitude of the agricultural community currently is for "judicious use of pesticides," the polycultural systems of the southeastern USA may not suffer the catastrophe seen in cotton; however, that is not the point. The thesis is that what IPM needs is robustness—it needs to be based on ecological understanding sufficient to adapt to the dynamic nature of the system being managed and to work in space and time. For a proper noctuid IPM program, the following must be known (see also Stinner et al. 1983):

1. seasonal patterns of appearance and geographical distribution of both immature and adult stages
2. overwintering (quiescence or continuous breeding) habitats and associated environments
3. methods for differentiating local from migrant populations
4. weather patterns in a fashion meaningful for interpreting moth displacement trajectories and flight behaviors
5. physiological and behavioral attributes conducive to initiating, maintaining, and terminating non-trivial flight
6. relationships between relative density estimators (e.g., light traps) and absolute densities occurring in particular crops

These six investigative areas will yield information that is crucial for understanding the role movement plays in the occurrence of moths in space and time (see Stilmac and Barfield 1979). In addition, there is need to be able to evaluate whether specific influxes cause economic damage (see Barfield et al. 1980). The agricultural community appears to be a long way from a sound ecological understanding of these mobile noctuids (see Rabb
and Kennedy 1979), hence a long way from implementing an IPM program against them.

**THE REAL MESSAGE**

Long term solutions to pest problems must have sound and broad ecological bases. Boll weevil history offers a dramatic example of what can happen with a unilateral approach that ignores the ecology of the system. Will the Noctuidae be a repeat? Not if ecological understanding of the system is a prerequisite for the design of IPM programs. This, of course, means a re-orientation of experimental emphases and academic education and training for crop protection practitioners (see Barfield and Jones 1979, Barfield and Stimac 1980, Strayer et al. 1983).

**LITERATURE CITED**


