INSECT PEST MANAGEMENT AND INSECTICIDE RESISTANCE MANAGEMENT IN THE URBAN ENVIRONMENT

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Abstract - The premise of the discussion presented here is that some of the traditional components of agricultural integrated pest management (IPM) and insecticide resistance management (IRM) programs are either not applicable or not practical for the urban environment. The overall goal of this discussion is to review the relative key aspects of these two concepts, to provide a framework for evaluating pest control programs in the urban environment, and narrowing the gulf between theoretical expectations and practical application. The utility of urban IPM programs is based on the principles of designing a program that meets the needs of the audience, with the understanding that in the urban environment the pest species may be few, but audiences diverse; and the understanding that decision-making and sustainability of urban IPM is linked to aesthetics, but in large part to economics. The utility of insecticide resistance management in the urban ecosystem does not mean that such an endeavor is feasible. The factors that influence the success of IRM in agricultural are generally not available in the urban environment.
Key words - Urban integrated pest management, urban pest control, realistic IPM

INTRODUCTION

The application of integrated pest management (IPM) and insecticide resistance management (IRM) to pests in the urban environment has a 20-year history. These concepts were introduced here soon after they proved useful in production agriculture. In the urban environment they are usually linked to reducing the use of pesticides. For the most part, IPM and IRM programs have been applied to peridomestic and domestic habitats with templates taken from agriculture. The results of these efforts have been varied, due in part to a limited research base on sampling and action thresholds for IPM, and the lack of support of the target audience for IRM. During the last 20 years it has become apparent that the majority of the components of the agricultural model of IPM are inappropriate for the urban ecosystem, and the academic model for IRM too simplistic a structure for the real world of controlling urban pests.

These twin concepts for managing pests and the use of pesticides have undergone some changes in the urban ecosystem. Just as the realities of global politics and economics have led to replacing blackboard ideology with the more practical Realpolitik and Realeconomic, the realities of pests and pesticide use in urban ecosystem have produced ‘on-the-street’ or realistic versions of IPM and IRM. What has evolved in the case of IPM is a practical and economically feasible approach to controlling or limiting pests in the living environment. And for IRM the realization that the conditions that characterize pesticide-use in the agroecosystem are generally not available in the urban ecosystem, and there is limited prospect for managing insecticide exposure of key pests.

The objectives of this paper are to provide a perspective of the status of integrated pest management and insecticide resistance management in the urban environment; and to offer the premise that realistic versions of IPM can be implemented, and the basis will be economics and will be driven by the customer and not the implementor (Hutchins, 1995); and that IRM has limited feasibility for pests in the urban environment. Analysis of these concepts, and the ultimate consequences of various programs, will begin with a review their framework in the agricultural environment.

INTEGRATED PEST MANAGEMENT IN THE AGROECOSYSTEM

IPM evolved from the basic concept of integrating disciplines (such as plant pathology, entomology, agronomy) into a comprehensive program to control or manage pest in large scale agriculture (Stern

Proceedings of the 3rd International Conference on Urban Pests.
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et al., 1956) The early impetus was the emerging and growing threat of insecticide resistance in crop pests, but later IPM would also shoulder the objective of reducing pesticide use and environmental protection. The academic model of IPM had limited practicality and user acceptance, but gradually was improved with the addition of the economic injury level and improved methods of sampling (Pedigo *et al.*, 1986). It has now had enough time and background to find a level of utility and feasibility, and has moved from a blackboard concept to an international precept for production agriculture on any scale.

The concept of managing agricultural pests below an economic threshold with the use and timing of various control methods continues to evolve, along with changes in the methods and the expectations of the user. However, the adoption and success of agricultural IPM programs will likely always be driven by expected economic benefits, and the value these programs add to the product (Hutchins, 1995). Successful programs in the urban ecosystem may be little different in their need for an economic foundation and financial benefit to the user. The implementation principles Hutchins (1995) applied to agriculture IPM programs may also be applicable to urban programs: the customer determines the value; if value is present it will exploited as a business enterprise; the control tactics integrated are not limited; if value is present the enterprise will be sustained.

INTEGRATED PEST MANAGEMENT IN THE URBAN ECOSYSTEM

Peridomestic

The peridomestic environment, which includes ornamental plants and turgrasss, provided an early opportunity to introduce IPM programs to the urban ecosystem. The first of these retained the major framework and components and philosophy of agricultural programs (Hellman *et al.*, 1982; Smith and Raupp, 1986). There were trained scouts and periodic sampling, action thresholds, reduced pesticide use, and financial support from the audience support. The results of these programs were consistent with the expectations that an agricultural format IPM was applicable to other ecosystems. Once in place, this conception would remain, and ten years later it would influence the U.S. Environmental Protection Agency guidelines for using IPM in public school buildings and grounds (Anonymous 1993). This was a domestic environment (buildings) in which sampling and action thresholds were proposed, but had little relevancy or practical application.

Although the academic model of IPM for the peridomestic environment was successfully implemented, there seems to have been only limited success in extending it to the market place and privatization (Raupp *et al.*, 1992). There may be several reasons for this, but the link to the principle of defining value (proposed by Hutchins, 1995) is probably the key. Unless the customer (homemakers) assigns value to the program it can not be sustained by free enterprise. Value in this case is linked to both aesthetics (features of the ornamental plants and turfgrass) and economics. The outcome of these early efforts was the development of a more realistic approach to designing and implementing urban IPM programs. Successful programs include economic incentives for the implementor and the user.

Domestic

Traditional IPM programs have been applied to pests (rodents, cockroaches, house flies) in the domestic environment, which includes the indoor living space and the structure. However, without a research base, the basic components of sampling, thresholds, and alternative control measures can not be practically applied. Unlike the peridomestic environment, there are few if any academic models that can serve as a foundation for real-world programs (Robinson and Zungoli, 1985). Without this base, IPM in the domestic environment has become primarily a shorthand term for any pest control program that attempts to reduce the use of pesticides. This includes programs based on sticky traps, baits, and treating with chemicals when needed and not simply on schedule.

There are limits to the general design of domestic IPM programs. Tolerance of insects in the living space is nearly zero (Wood *et al.*, 1981), and without some aesthetic or economic threshold there is little basis for making control decisions; and alternative methods, such as non-chemical or biological have provided varied results (Slater, 1984; Thoms and Robinson, 1987). In the domestic environment the

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traditional IPM format is inappropriate, and the idealistic (reduced pesticide use) format is impractical and usually ineffective. It is realistic IPM that has emerged as the relevant, 'on-the-street' version (Green, 1996) . This may be simply a program of prevention, limited monitoring, and treatment based on need (and not scheduled). Their success is based on value being defined by the user; and value in the market place for these programs.

Value defined by user and the market place

Individual users, such as homemakers, food service managers, and health care facilities managers will assign value to an IPM program that suits their needs in regards to pesticide use and expected control. The environment, pests, and the objectives of each user group dictate the need for flexibility in program design and delivery. The user (customer) of urban IPM programs are managing complex environments in which pests are only one consideration. Professional pest control operators (implementors) must have the ability to tailor programs to fit the aesthetic and economic parameters of these clients.

Realistic IPM will remain available in the urban environment for as long as it is economically feasible for the implementor and the user. There is no question as to the utility of a decision-based control program that includes lest toxic methods in the living environment. But unless there is a realistic need for these programs they will not be sustained. Until now emphasis has been placed on the professional pest control community to adopt the principles of IPM, when effort would be better placed on the user of these services. More than a few pest control operators have provided an integrated pest management approach based on monitoring and treatment-on-need, only to be informed by the customer that a scheduled spray to all areas–as it has always been done–is preferred (Stanbridge, 1999). In the urban environment the need and value for IPM begins with the customer and works back to the implementor. Once the user assigns value to IPM, whether aesthetic or economic, the implementor will have an economic incentive for designing and providing this level of service.

Conclusions

IPM in the urban environment seems to have gone through three stages: an initial phase of enthusiasm, a period of extrapolation, and a new tendency toward pragmatism. At first we thought we could simply fit the agricultural model to peridomestic pests and habitats, but this simplicity was not applicable to the people/pest interface. Then we thought the professional pest control could extend the concept to the domestic habitats, but without demand from key clients this was not practical. Now we realize that urban IPM needs a skilled implementor and an informed audience, that an economic incentive must exist for both, and that the urban version of IPM, realistic IPM, is a practical blend of thresholds and control methods.

INSECTICIDE RESISTANCE MANAGEMENT

The decreasing insecticide susceptibility in some arthropod pests in the urban environment is an important issue. Pests such as the German cockroach, house fly, and head louse have a worldwide distribution, and individuals from resistant populations in one region can move or be transferred to another. The result of this may be control problems developing quickly in isolated populations. As insecticide resistance becomes more apparent in populations of public health pests, there is increased interest in methods of preventing or delaying it. Taken as a group these various methods are considered part of insecticide resistance management (IRM) programs.

The phenomenon of resistance has a long history and considerable economic importance in the agroecosystem. Here pest-specific IRM programs have been designed and implemented by academia, pesticide manufacturers, and government agencies (National Research Council, 1986; Sawicki and Denholm, 1987; Cox and Forrester, 1992; Matten, 1997). Until recently there has been only limited interest in resistance management programs for household and public health pests. However, as the ability of some key pests to develop resistance gains on the availability of insecticides to control them, the importance of resistance in the urban environment increases.

The objective of IRM is to extend the effectiveness of one or more active ingredients to control a pest population(s). This is accomplished by reducing the use of certain compounds so that efficacy is maintained for an extended period. Tactics for accomplishing this include 1) sequential use of an active ingredient until control-failure develops in the target pest population, 2) applying insecticide mixtures or alternating the use of insecticides with different modes of action or different physiological mechanisms of resistance, or 3) applying no insecticide or alternating crop plants. Regardless of the tactic, the key to extending the time insecticide resistance develops in any pest population (in any ecosystem) is limiting exposure to specific insecticides (Georghiou, 1983). However, controlling insecticide use is often difficult, and it may be more achievable in some ecosystems than others.

Agroecosystem

IRM in agriculture is feasible because pest population and insecticide application are usually linked directly to the grower. Because of this link there may be control of the type, timing, rate, and frequency of insecticides applied to pest populations. And there may be strong economic incentives to extend pest susceptibility to low cost insecticides (Hutchins, 1995).

Urban ecosystem

There are obvious aesthetic, medical, and economic reasons for preserving insecticide susceptibility in pest populations of cockroaches, flies, and head and body lice. Despite improved application methods and the efficacy of modern insecticides, physiological and behavioral resistance has developed in populations of these species. IRM programs have been suggested or attempted for the German cockroach, *Blattella germanica* (L.), the house fly, *Musca domestica* (L.), and the head louse, *Pediculus capitis* De Geer (Cochran, 1990; Burgess *et al.*, 1995; Mumcuoglu, 1996). The need for IRM programs for these and other pests in the urban ecosystem is obvious, and programs proposed to achieve these goals may appear objective and scientifically sound, but that does not make them feasible. The concepts and general framework for modern pest control (e.g. integrated pest management), resistance management, or other programs that may have been successful in one ecosystem are often incorrectly assumed to be applicable to another (Robinson, 1996; Rice *et al.*, 1997). The IRM concept may be practical for some agricultural pests because conditions necessary for success are available in the agroecosystem. However, these conditions are usually not available in the urban ecosystem. The conclusion defended here is that the IRM concept is neither feasible nor practical for common household and public health pests, and efforts in this direction might be better applied in other areas.

Insecticides and applicators

Insecticides for domestic and peridomestic pests are widely available to the public and their use is often indiscriminate and excessive (Whitmore *et al.*, 1992). Because of this the insecticide exposure history of most urban pest populations is not known, and if so, is likely to be very complex. The availability of a large variety of insecticides or combinations of insecticides available to consumers may result in the exposure of more than one active ingredient to a pest population. At first, this variety of insecticides and the potential for alternating use may appear to delay the development of resistance. But inexperienced homemakers are unlikely to treat properly, and more likely to deliver (sublethal) doses that favor the development of resistance. They may not consider the active ingredient when selecting an insecticide, nor understand the potential of their selection in increasing the level of cross resistance between modern insecticides.

Exposure history

Each pest population has a different history of insecticide exposure, and usually there is no record of this. Exposure history of a pest population is important because it provides some indication of the frequency of susceptible or resistant genotypes present, which is necessary for the design of any IRM program. But this information may not be known (or accurately predicted) at the start of most urban IRM programs. Without some knowledge of the previous insecticide exposure, and control of the future exposure in a pest population, there is little chance of managing the loss of susceptibility in that population. Insec-

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ticide-resistance profiles (Robinson and Zungoli, 1985) can be prepared prior to treatment, but this may not be feasible for all situations.

Consider the long history of chemical control of the German cockroach and head louse. There is considerable actual and potential resistance and cross resistance in existing populations of these cosmopolitan pests, and also the possibility of movement of resistant individuals from one pest population to another. IRM programs to maintain susceptibility in pest populations of *B. germanica* or *P. capitis* may be jeopardized by individuals supplementing the prescribed treatment with consumer products (Wood *et al.*, 1981; Burgess *et al.*, 1995; Mumcuoglu, 1996). In addition, the introduction of resistant genotypes from areas of intense selection pressure to areas under resistance management may lead to a decrease in susceptibility and further compromise an ongoing IRM program.

Incentives

In the urban ecosystem, traditional economic or other pragmatic incentives for individuals to reduce the use and prolong the efficacy of an insecticide may be limited—at best. It is generally understood that the homemaker has an emotional or aesthetic motivation to remove an unwanted or threatening pest from the living space (Wood *et al.*, 1981; Byrne *et al.*, 1984). Cooperation in response to requests to curtail insecticide use to preserve susceptibility in pest populations for future control efforts may be limited in modern society (see Ridley and Low, 1993). Consumers are unlikely to defer treatment of an infestation of head lice or cockroaches on behalf of general society. Eliminating the target pest is the primary concern of the resident treating for cockroaches (Zungoli and Robinson, 1984; Robinson and Bao, 1988), and it is likely the same for head lice and other pests. A more pragmatic approach would be to expect that chemical controls will be used, perhaps misused, but to encourage that they be part of a program, and their use directed to the target pest.

From the standpoint of the manufacturer there may be little economic incentive to limit or manage the availability of household pest control products (= active ingredients) to consumers that want these materials. Consumer products are often mixtures of more than one active ingredient, which makes alternating chemicals difficult and may increase cross resistance. These features of limited incentive for the manufacturer and the demands of the public can undermine an urban IRM program that seeks to reduce exposure to specific chemicals.

Alternative control methods

There are few guidelines available for integrating nonchemical methods in urban pest management programs; in the past emphasis has been in the agroecosystem. The public may be aware of the underlying causes of pest infestations, but they are usually unaware of and less interested in nonchemical control methods (Wood *et al.*, 1981; Robinson and Atkins, 1983). Chemicals are often the first control option considered for pests such as German cockroaches and mosquitoes, and populations of these insects are prone to high levels of resistance. Increased emphasis on generating information and effective preventative and nonchemical methods for controlling urban pests could contribute to slowing the development of resistance in key pest species. However, there is limited scientific data on the effectiveness of alternative control methods for urban pests. Before these methods are suggested or recommended, they should be evaluated for efficacy and suitability to the habitat (Farmer and Robinson, 1984; Thoms and Robinson, 1987). Ineffective nonchemical methods can mislead and disappoint the consumer and may result in increased chemical application.

Conclusions

IRM for major pests in the urban ecosystem may have significant appeal to science and the public, but there are features that limit the potential success of such programs. Control of insecticide exposure may be the key ingredient missing in this ecosystem, but the combination of variability in the exposure history of pest populations, the availability of insecticides to multiple decision makers, and the potential of variable rates and treatment frequency, also work against the likelihood of success. Improvements in delivery systems of consumer-use products and in instructions for use, and the availability of practical guidelines for the integration of chemical and nonchemical methods may be the best areas for increased emphasis for household and public health pests.

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