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Developing and Analysing Pest-natural Enemy Systems with IPM Strategies

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Editorial

Integrated Pest Management (IPM) is an effective, long term, environmentally sensitive approach to pest management. IPM relies on a combination of biological, cultural, and chemical tactics that reduce pests to tolerable levels by augmenting natural enemies, spraying pesticides, trapping or harvesting the pests when they reach an Economic Threshold (ET, Figure 1). ET is an important concept in IPM which is usually defined as the critical density of pests in the field when control actions must be taken to prevent the economic injury level (EIL, Figure 1) from being reached and exceeded. The EIL is defined as the lowest pest population density that will cause economic damage.

Successful IPM control programmes depend on many factors. For example: factors affecting the population dynamics of the wasp *Encarsia formosa and the whitefly Trialeuroides vaporariorum* in greenhouse vegetable systems include host parasitoid ratios, the starting density and age structure of whitefly populations at the time of the first parasitoid releases, levels of host-feeding and parasitism, temperature, and the host plant. Mathematical models can help us to clarify and predict the effects of such factors on the stability of pest–natural enemy systems within an IPM control programme, to evaluate the effectivity of IPM and may tell us when the density of the pest population reaches the ET and control should be applied.

The discrete nature of human actions and possible exogenous effects leading to pest and natural enemy population densities changing very rapidly can be taken into account by impulsive (hybrid) differential equations and non-smooth dynamic systems. For instance, impulsive reduction of the pest population density of a given species is possible after its partial destruction by trapping or by poisoning with chemicals. An impulsive increase of a controlling predator or parasitoid population density is possible by artificial breeding and releases. In order to develop novel and more realistic models, the following topics should be taken into account.

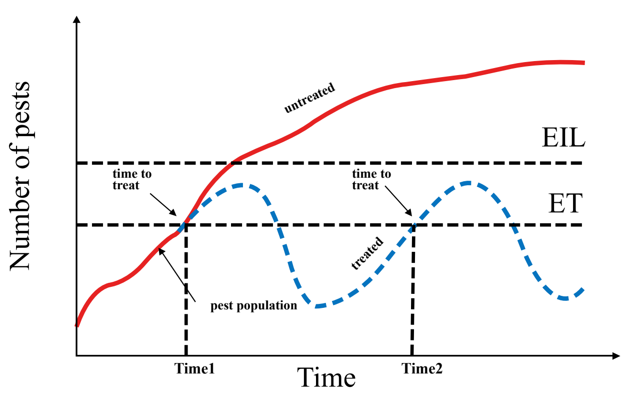

Figure 1: The IPM programme should be initiated at the level of ET in order to prevent the density of the pest population from reaching EIL due to a delayed response and uncertain factors.

Residual Effects of Pesticides

If chemical pesticides have a short residual effect on their target, repeated application is often required to suppress a pest, which can cause undesirable changes such as pesticide resistance. Meanwhile, biological pesticides are generally more environmentally friendly, but often lack residual effects and can be strongly influenced by environmental factors. For example, some insecticides used against the bed bug *Cimex lectularius* can have residual effects 1 week to 4 months after application, micro-encapsulated formulations of the pyrethroid lambda-cyhalothrin can be effective against vectors of malaria *Anopheles spp.* nine months after indoor sprays on walls and some compounds are active against termites for years.

Delayed Responses to Pesticide Applications

In practice, many pesticides not only have long-term residual effects, but also both pest and natural enemy populations may have delayed responses to pesticide applications, which suggests that pests do not succumb to pesticides until after a delay. In addition, biopesticides are increasingly being used which also have such delayed effects. For instance, the mycopesticide *Metarhizium acridum* is effective against grasshoppers and locusts but does not kill them until 1-4 weeks after being sprayed, the time taken depending on the prevailing environmental conditions. Similarly, formulations containing viruses used to kill moth larvae such as the pests *Helicoverpa armigera or Spodoptera exempta* take a few days to be lethal and viruses used against Brown-tail moth *Euproctis chrysorrhoea* may take weeks to kill and lead to secondary infections months later.

The Evolution of Pesticide Resistance

Pesticide resistance is increasing and farmers' and other pest managers' dependencies on chemical insecticides have led to a high frequency of insecticide resistance in some crop systems. In order to fight pesticide resistance and based on a knowledge of the genetics of the development of pesticide resistance, a number of principles have been proposed aimed at delaying the emergence of resistance or avoiding it entirely. These principles include pesticide rotation or switching, avoiding unnecessary pesticide applications, using non-chemical control techniques, and leaving untreated refuges where susceptible pests can survive. Thus, IPM is the optimal option for combating pesticide resistance.

Therefore, to address the above subjects for ongoing modeling

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research, some interesting questions have been raised: (a) How do the different releasing and spraying patterns and the short-term or long-term residual effects of pesticides on both pests and natural enemies affect the success or failure of pest control? (b) How can the time when the pest population reaches the economic injury level (EIL) be estimated? (c) How can the most efficient frequency of pesticide applications be determined? (d) When should pest managers switch one type of pesticide to another unrelated type? (e) How do the frequencies of pesticide applications affect the evolution of pesticide resistance? (f) What is the relationship between the evolution of pesticide resistance and the number of natural enemies released? (g) How does the cumulative number of dead natural enemies affect the number of natural enemies to be released at the next iteration of a biological control programme? Clarifying these questions through ongoing modeling research must continue to play a key role in the wise use of pest-natural enemy systems to evaluate IPM strategies.