LINKING ECONOMIC AND ACTION THRESHOLDS IN PEST MANAGEMENT: IMPLICATIONS FOR ADVISORY SERVICES

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Introduction

In the last few years, considerable interest has evolved in the concept of Integrated Pest Management (IPM). IPM is defined as the use of multiple tactics to maintain pest populations at levels below those causing economic injury while providing protection against hazards to humans, domestic animals, plants and the environment. It is the thesis of this paper that much interaction between research and advisory (extension) services is needed before the concept can become operational.

This paper focuses on the concepts of economic and action thresholds in pest management. Concurrently, agricultural economists are working toward a more realistic definition of the economic threshold while physical scientists, especially within the advisory services, are specifying action thresholds in the field. On the one hand, current definitions of the economic thresholds are of a theoretical nature pertaining to the situation of one pest and one control measure on one crop; on the other, for economics to make a practicable input to the pest management concept, the models must become sufficiently sophisticated to include alternative control strategies, uncertainty, risk aversion and a plurality of pests on any one crop. Meanwhile, the action threshold must be improved in the field by monitoring pest populations and

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increasing our knowledge of factors affecting the growth rate of pests and diseases. Empirical results from a pilot project to advise New York apple growers on pest management are examined in light of the economic threshold concept for pest management control practices.

Discussion of the Economic Threshold

The first attempt at a mathematically rigorous definition of an optimum pest population was made by Headley (1972), who introduced the concepts of the value of production and the cost of control with pest population levels and the corresponding damage of the pest population. Headley assumes continuous functions for the value of production and the cost of control, both of which are functions of the pest population. The value of production is assumed to decrease at an increasing rate as the pest population increases while the cost of control decreases at a decreasing rate. The functions are shown in Figure 1.

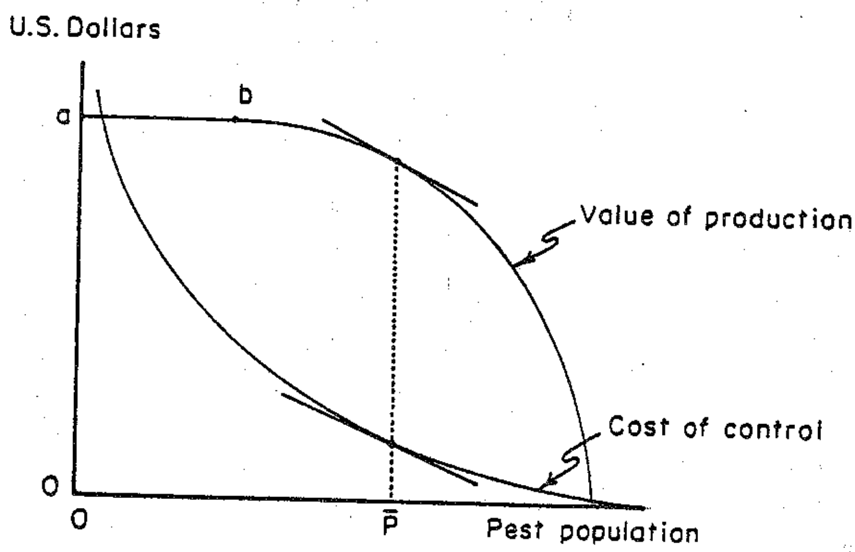

Figure 1. Relation of production, control costs, and pest population

The economic threshold is the pest population, $\bar{P}$, at which the incremental losses in value of production as pest population increases **are** equal to the incremental cost of preventing that damage. This maximizes the distance between the value of production and the cost of control, therefore, $\bar{P}$ is the "optimal" population in an economic sense. This differs from the perception of many farmers, who appear to consider the flat interval, a - b, on the value of production curve to be optimal. This flat interval indicates the wide range of possible pest population levels before there is any perceptible loss in the value of production. Thus, the emphasis should be on managing pest population levels, not attempting to eradicate them.

As with any economic theory, the solution is limited by its assumptions. For clarification of the Headley model the assumptions are enumerated as:

1. The economic threshold is concerned with one pest on one crop for one profit-maximizing producer. The producer is a price taker and all prices are known;

2. The relationship between pest population and damage, and between the pest management control practice and the pest population, are known. (Assumptions 1 and 2 together imply that decisions are made without risk and uncertainty);
3. The cost of control is continuous, though Headley points out that the model may be adapted to handle discrete control measures;
4. The model extends for one season only, inferring that the economic consequences of a decision have no or insignificant repercussions in subsequent seasons;
5. Potential yield is given, and the pest population is a "surprise" each season. The yield with no damage is established by inputs such as seed, fertilizer, land, etc. and the exogenously given weather. Therefore, the use of these inputs may not be altered in anticipation of pest damage in substituting for expected use of pesticides; (Russell, 1978)
6. Side effects are assumed at zero: a) The pesticide is target pest specific. Therefore, there will be no target pest resurgence nor secondary pest outbreak. b) The concept of resistance through selection pressure is assumed zero. c) The producer is geographically isolated, and is therefore unaffected by the pest control actions of neighboring farmers;
7. The definition gives net return maximizing levels of pest population with the exception of total eradication of the pest.

By implication, when the assumptions do not hold, the economic threshold (as defined) no longer represents the optimal pest population level. Some endeavor is made in the following paragraphs to relax some of the assumptions and to discuss the threshold in relation to the "real" world. The assumptions are relaxed by allowing for risk, uncertainty and target pest resistance.

Uncertainty and Risk Aversion

Assume that the grower knows the current insect population level by estimating an average number of eggs or larvae per plant, or knows a disease level by noting the temperature and humidity conditions. Given changing weather conditions, or predator and parasite population levels in relation to the pest population, the predicted pest population is uncertain. Thus, there is no single value of crop (revenue) loss from the specified population levels, but rather a range of possible outcomes, each with some probability of occurrence. The crop represents an investment of seed, fertilizer, labor and management inputs, and the farmer uses pest management to protect this investment by reducing expected losses. The grower who maximizes expected profits would use the economic threshold to choose the optimal pest population. However, there may be the small probability of a very large loss which the grower is unwilling to bear. Under these conditions, a grower may be willing to settle for a higher level of pest control than is economically optimal, and may adopt "insurance" spraying. Norgaard (1976) noted that there is a commonly held view that a substantial proportion of total pesticide applications occur for insurance purposes.

Given the risk aversion associated with pest control, it is possible that there are gains from substituting knowledge for uncertainty. It is known that the growth rate of the pest is not constant but depends on the pests ecosystem, (i.e., the micro and mesoclimate), populations of competing species and the abundance of food (the crop). The most exogenous of these factors affecting the agro-ecosystem is the weather; thus relevant information on the weather (specifically forecasts) and entomological and mycological knowledge of the interdependencies of pest growth with its ecosystem would alleviate some of the uncertainty and reduce the total quantity of precautionary sprays.

Information of the type required for pest management such as specialized weather forecasts and crop disease and pest predictions, may be considered as a public good. Therefore, once available, few can be precluded from benefiting from its provision. Under-provision of such goods can arise if left to the private competitive market and net benefits to society could accrue if the information were provided. Such information could be furnished by the agricultural advisory services.

Target Pest Resistance

Target pest resistance occurs through the high selection pressure as a result of repeated applications of any one treatment method and in the case of pesticide use, results in higher usage rates to achieve previously attained control levels. Further costs of pest resistance include increased research and development costs for replacement of redundant chemicals and the expected cost of being unable to cope with acute pest epidemics. The former point is aggravated by the decrease in the rate at which pesticides become available following policy actions such as the banning of chemicals and the imposition of highly restrictive tests for new chemicals. These policy actions are taken because high environmental costs and hazards to human health are associated with many organic pesticides.

Carlson (1977) took an interesting perspective of pest resistance by pointing to the common property nature of a genetic pool of nonresistant pests. This suggests that private producers underinvest in preserving the resource and that collective efforts for regions through cooperative pest management programs or through the national (or regional) agricultural advisory services may increase total net benefits or aggregate profits. Gains would accrue as a) an informed advisor substitutes knowledge for prophylactic pesticide applications, b) target pest resistance to controls decreases as a wider variety of measures are employed to manage pest populations, and c) regional collective control becomes possible and indivisible control measures are employed as in the cases of sterile male release, some other biological control techniques, and quarantine control.

The preceding sections of this paper have been concerned with the definition of the economic threshold and complexities of the real world which have limited its usefulness. In the following section, the action threshold is examined.

Discussion of the Action Threshold

An action threshold is defined here as the state at which some control measure is employed. This state may occur when a) a specific number of pests such as larvae, mites, aphids or mature insects are found on the plant, in the vicinity of the fields or in set traps, b) when a combination of temperature and humidity provides ideal conditions for the growth of a disease or c) when there is specific plant damage attributable to a pest. The obvious key difference between (a) and (b) is that the former alludes to something which can readily be observed, whereas the latter assumes spores of diseases to be present and merely requires the correct conditions for growth. The complex part of the action threshold is that it is not a consistent measure. For one pest on one crop, the action threshold will vary from one area to another, from one variety to another, possibly from one field to another depending on agronomic factors, and from one period to another as the crop grows. Further complications ensue once the concepts of pest mixtures and broad spectrum pesticides are incorporated into action thresholds.

Problems also arise when certain farm management decisions are taken into account. If labor and fuel costs and the possibility of spraying pesticide mixtures are taken into account, additional precautionary applications may be made with justification. The marginal cost of including an extra chemical is extremely small if the spray rig is already in operation; thus, treatment costs are not completely independent of each other.

Furthermore, the opportunity cost of labor is not constant throughout the year, thus providing economic rationale for precautionary sprays. These sprays could be made at a time of low opportunity cost of labor on the intention that pesticide residues would prevent pest attack during periods of high opportunity cost of labor. An example may be on a fruit farm where both apples and cherries are grown. Throughout the period of cherry harvesting the grower may wish to have all available labor on that task. Consequently pest management activities would be coordinated on the apple crop so that minimum effort would be required on pest control while cherries are picked.

An Empirical Study

That IPM projects have not successfully linked action thresholds with economic thresholds can be illustrated by the results of research to evaluate the New York State Tree Fruit Pest Management Program (NYSTFPMP). The NYSTFPMP began in 1973 with the objective to reduce the quantity of pesticide use without affecting fruit quality or the quantity produced. Farm advisors trained in pest management monitor selected orchards in Wayne County, New York and use their expertise to advise growers. These growers pay 12 U.S. dollars per acre for the service.

Data collected since the inception of the program generally showed that pesticide costs were reduced for participants in the program by about 25 U.S. dollars per acre. In 1978, a more complete study of the differences between the program's participating and nonparticipating growers was conducted. Records of amounts of pesticides, along with timing and method of application were collected from the two groups. From 23 nonparticipating growers, 33 blocks of apples were matched with an equal number of blocks from 19 participating growers. Criteria for matching the blocks included a) the proportion of fruit intended for the fresh or processing market, b) the height of the trees (which acted as a proxy for age and spacing) and c) the varietal mix of the blocks. Standard prices of pesticides were used based on 1978 prices.

The results are shown in Table 1. Participants had spray material costs averaging 68 U.S. dollars per acre, while nonparticipants had costs of 93 U.S. dollars. Thus participants had more than a $25 per acre advantage in lower costs. When the 12 U.S. dollar participation fee is accounted for, participants still had a 14 U.S. dollar advantage which is significant at the 5% level for a one-tailed separate variance estimate test of difference between means. The use of materials is further broken down into costs for insecticides, miticides, and fungicides. Participants had a clear cost advantage over the nonparticipants for each of these pesticide groups. Furthermore, no difference in yield or quality of apples was observed between participant and nonparticipant blocks. (Thompson, 1979).

Table 1 - New York State Tree Fruit Pest Management Program results for 1978. Tests of differences between means of spray material costs per acre for 33 blocks.

	Costs Per Acre		Separate Variance Estimate	
	Mean	Range	T Value	1-tail Probability
	U.S. dollars			
Total Spray Materials				
Participants	67.67	29-96	-3.60	0.000
Nonparticipants	93.39	46-248		
Total Spray Materials and Participation fee*				
Participants	79.67	42-108	-1.92	0.031
Nonparticipants	93.39	46-248		
Insecticides				
Participants	20.45	9-45	-4.15	0.000
Nonparticipants	32.84	12-75		
Miticides				
Participants	9.87	0-23	-1.88	0.033
Nonparticipants	13.74	0-54		
Fungicides				
Participants	37.36	18-60	-2.58	0.006
Nonparticipants	46.18	17-119		

*Participation fee is 12 U.S. dollars per acre

Thus it is apparent that the NYSTFPMP was successful in its objective to reduce pesticide costs while not affecting quality or quantity of apples. However, it is also apparent that the action thresholds utilized by the farm advisors do not permit the attainment of the economic threshold as defined by Headley. In terms of Figure 1, the value of damage attained is on the interval a - b, indicating the possibility of sustaining higher pest population levels without incurring additional crop loss. To reach the economic threshold it is likely that some damage will be incurred. This points out a gap between the economic and action thresholds utilized by farm advisors in the field.

<u>The Relevance of the Economic Threshold</u>

Theorists such as Headley have pointed the way to the economically optimal use of pest control resources but many pest management programs, such as the NYSTFPMP have not included the definition in their day-to-day operations. Is the concept workable in apple production? Several obstacles to its potential adoption could be hypothesized.

One objection by growers may be that there is a danger of infestation that, if allowed to perpetuate, may gain momentum and cause a large crop loss. This is the case particularly for a high valued crop such as apples. Furthermore, farm advisors may have insufficient information to make exact estimates of control needed to attain the economic threshold. They may want to apply some criterion to their recommendations to preclude liability for the small chance of a large crop loss. As experience is gained, growers and farm advisors should have more confidence in the ability to predict the rapidity and severity of pest population buildups.

A second objection (especially fresh fruit growers) has been the desire to maintain the reputation for quality for a particular region. However, this should not be a concern in this instance since the value of damage prevented should allow, as damaged fruit increases, for a larger proportion of fruit going into lower-value grades. The apples reaching market after selective grading are not affected by blemishes associated with insect or disease damage, so consumer acceptability is not affected. It should be noted, however, that a) an increased percentage of apples with blemishes may result in higher grading costs, and b) costs that a grower may incur entering a new market must be considered in the value of production function.

Still another obstacle to adoption may be a built-in bias for attaining maximum yields or quality. This bias is present for many growers as well as those farm advisors without economic training. Maximum yield or quality is often erroneously thought to be equivalent to economic optimal production, although economic theory shows clearly this to be false. The remedy would appear to be a more thorough economic training for both growers and farm advisors.

No doubt the most important obstacle to link the action threshold with the economic threshold is the lack of knowledge of the relationship between the pest population and the value of production, along with the impact of other variables such as other pests, predators, parasites and the weather.

The role of advisory services in pest management should increase as some of these obstacles are overcome. Advisory personnel, working closely with researchers, could facilitate the linkage of action thresholds with economic thresholds so that economic considerations can be given their proper emphasis in pest management decisions. The development of crop simulation models could serve to unite the thresholds and are important in delineating the relationships between yield or quality losses, and pest population density. These models should enable the more efficient use of existing data on economic thresholds. To enhance the practicability and facilitate installation of the models data must be standardized so that the models may be tested against situations close to reality, and solutions or recommendations must be presented in a form which is of use to the grower or the farm advisor. Such models may allow, for example, for projection of variability in net income per acre over many years of weather data and the identification of the most important parameters involved in the pest control decisions. An emphasis on computerized pest management decisions may enable economic considerations to be incorporated, and provide a better link between the action and economic thresholds. This would ameliorate understanding between the economic researcher and agricultural advisor.

Summary and Implications

Empirical findings from the NYSTFPMP were presented which showed a 25.72 U.S. dollar per acre cost advantage in spray materials for pest management participants over nonparticipants, with no reduction in fruit quality or quantity. This is evidence that the action thresholds employed by the advisory service may increase net income of growers but do not permit the attainment of the economic threshold.

In the conceptual framework, the complicating factors of risk-averse growers (and farm advisors) and target pest resistance are noted. Given a) the nature of these and other assumptions which are not met in the real world, b) the nature of some pest management information (a public good), and c) the possibility of economies of scale of pest management delivery systems (through training advisors, incorporating the latest research into recommendations, and computer hardware and software development), an effective vehicle for delivering integrated pest management programs is the national agricultural advisory service.

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