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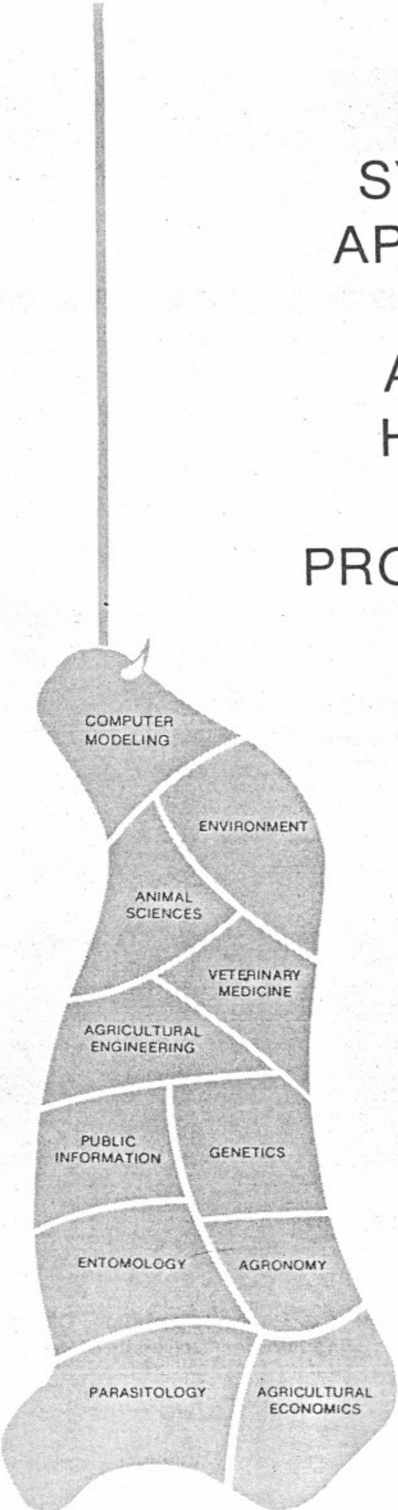
SYSTEMS APPROACH to ANIMAL HEALTH and PRODUCTION



LIVESTOCK INTEGRATED PEST MANAGEMENT (IPM): PRINCIPLES AND PROSPECTS

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Abstract.--The principles and definitions of terms used in Integrated Pest Management (IPM) are discussed and related specifically to the management of pests associated with livestock (including poultry) production. A conceptual framework for livestock IPM as a subsystem of livestock production systems is presented. A confined-livestock IPM pilot program for poultry and swine production systems in North Carolina is described.

Additional keywords: economic threshold, poultry, swine, flies, mites, mosquitoes, rodents, diseases, waste management.

INTRODUCTION

All agricultural systems, including livestock production systems, are biological systems organized and structured by humans for the goals set by humans (Spedding 1975). The basic biological systems are greatly modified with considerable impact from economic, sociological and political constraints. Consequently, we must take an all-encompassing view of agricultural production systems in our society and in our fragile environment. As we focus closer on specific components (subsystems) of livestock production systems, we should keep in prospective the interrelationships of those components with the overall long-term welfare of humans and the environment. One important subsystem of livestock production is Integrated Pest Management (Apple and Smith 1976, Allen and Bath 1980, Bottrell 1979).

Livestock (including poultry) production by necessity includes measures to manage insects, ticks and mites attacking the animals. Direct losses due to these arthropod pests have been estimated at nearly four billion dollars a year in the United States (Anon. 1979). Further significant losses occur from vertebrate pests such as rodents which consume feed and damage farm building foundations. Wild birds consume feed and may harbor disease-causing pathogens which may be vectored to the livestock. Many animal pathogens are vectored by insects, ticks and mites or at least those arthropods facilitate the maintenance of the pathogens in the environment.

Management of the arthropod pests, vertebrate pests, and disease pathogens (including internal parasites) of livestock is not a simple process. Many different species of pests and disease pathogens are involved and several different livestock hosts along with different production systems. Regional and climatic

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differences further complicate the picture. More and more it has become apparent that simplistic control measures are not the answer to these complex problems. This realization has been fostered by many factors important among which are: (1) Lack of effective insecticides or drugs for some pests and pathogens, (2) Rapid development of resistance to insecticides and drugs by some pests and pathogens, (3) Problems of insecticide and drug residues in animal tissues and products, (4) Changing animal production systems (especially the trend to higher density confined systems) which encourage pest and disease outbreaks, and (5) A greater awareness of ecology and the environment in agricultural production and society in general. Also important has been the realization that the economics of livestock production requires that pest and disease management be cost effective. Too often expensive insecticide or drug applications have been made in the absence of critical rationale for doing so or for when to do so. As a result of these and other considerations, it has become apparent that an integrated multi-method, multi-pest, ecological approach to managing livestock pests is required. Such a realization is already gaining practical implementation in several crop production systems and is practiced in some areas with organized mosquito abatement programs (Axtell 1979). This approach is referred to as INTEGRATED PEST MANAGEMENT (IPM). The term "pest" may include one or more of the following groups: insects and other invertebrates, pathogens (of plants or animals), weeds, parasites (internal or external) and vertebrates.

PRINCIPLES OF IPM

The IPM concept has evolved rapidly in the past few years. Although various definitions differ slightly in emphasis, they all convey essentially the same meaning. As examples: IPM means a systems approach that encompasses not only the immediate objective of preventing pest losses, but also consideration of long-term objectives with regard to economics, society, and the environment (Glass 1976). It is the selection, integration and implementation of pest control action on the basis of predicted economic, ecological and sociological consequences (Rabb 1972).

Definitions and Explanations of Terms

Although Integrated Pest Management is more than the sum of the constituent terms it is useful to examine those terms. Pest is an anthropocentric concept meaning simply an organism which is detrimental to humans. Man selects the criteria for designating a pest and man also may create and intensify pest problems. Arthropods attacking livestock, rodents in livestock quarters, and pathogens and parasites infecting or infesting livestock are all pests in the eyes of man because they reduce the efficiency of livestock production and hence increase the costs. Ironically, man often accentuates the populations of these pests by changing the livestock production system. Foremost is the rapid trend to higher and higher animal densities in order to satisfy the desire for increased production with less labor and land. Cattle feedlots, swine finishing houses and caged-poultry houses, as examples, all have similar accentuated problems of high filth fly and rodent populations and severe risks for rapid parasite and disease spread. All have problems of manure disposal and when the "solution" of using anaerobic lagoons is incorporated into the high density production system the lagoons often become severe *Culex* mosquito breeding sites (Axtell et al. 1976, Rutz and Axtell 1978). Man's choices of land use may further accentuate the status of a pest. Examples are: the encroachment of human dwellings into agricultural lands resulting in people living close to animal production systems and complaining about the flies, odors and dust; the raising of livestock on land requiring irrigation for pasture growth and consequently, creating new mosquito breeding sites; the clearing and raising of livestock on coastal lands near marshes breeding mosquitoes and biting flies which aggressively attack livestock; the use of irrigated crop culture (e.g. rice) which produces hordes of mosquitoes to attack nearby livestock. Thus it is important to recognize that the status of pests is dynamic due to man's changing livestock production systems and land-use patterns.

Management is the act, art or manner of handling, controlling, administrating or directing affairs; the judicious use of means to accomplish an end. Thus in IPM the term conveys the concept of a continuous on-going process and the meshing of several methods. In contrast, the term control conveys more the notion of finality within a limited time scale and implies a simple (often one method) solution to a problem. In dealing with pests of livestock the term "management" is more realistic and appropriate than "control".

Inherent in the concept of management is the setting of some level of achievement. In Integrated Pest Management it is the setting of some level of loss or harm that is acceptable and realistic, i.e. an economic injury level. As illustrated in fig. 1, the pest populations naturally undergo fluctuations above and below some mean level. The economic injury level is the pest population density that produces incremental losses equal to costs of preventing the losses. The costs are usually the direct monetary ones, but costs should include also the indirect ones such as the environmental impacts of control methods which are used in a management program. Losses are difficult to measure, but they can often be estimated. Data on economic losses due to livestock pests are very limited (Anon. 1979, Steelman 1976). It is expensive to gather the data under varying conditions, but it is obviously important to do so. An excellent example is the superb analysis of the effects of mosquitoes on livestock production in Louisiana (Steelman 1979). The gathering of data on economic injury levels for livestock production is complicated by the complexities of pest species and their interactions, the multiple host species and breeds, and the effects of feed rations and regimes. It is important also to recognize that economic injury levels are not static, but rather they will change with time and circumstances. A good example is the problem of filth flies; if human dwellings are close by the animal production system then the acceptable density of flies will be much lower than in a case where no one lives nearby. One should not be discouraged by the difficulty in obtaining data on economic injury levels. Temporary "best estimates" can be used until such times as more data are obtained. Management is an on-going process and setting of economic injury levels will be an ongoing process.

In IPM we rely heavily on the economic threshold which is a little lower than the economic injury level. The economic threshold is the pest density at which specific control measures in a management program should be applied to prevent an increasing pest population from reaching the economic injury level. This recognizes that we cannot wait until the losses are equal to the cost of control measures because there is a time delay in the measures having an impact on the pest population density. The objective of IPM is to reduce the mean population density level so that it is below the economic threshold most of the time (from A to B in fig. 1). It should be obvious that, as a consequence, the IPM approach requires practical methods for monitoring the pest population and for predicting whether or not the population is likely to increase in the absence of control actions being taken. Such predictions require knowledge of the pest population dynamics and the ability to measure and predict environmental and host conditions.

Integrated means to form into a whole, to unite, to incorporate into a larger unit. It conveys the idea of a judicious meshing of parts into a whole. In IPM, integrated refers to the judicious meshing of control methods and skills (or disciplines) into a management system. All possible pest control methods should be evaluated including those in the broad categories of natural, biological, physical and cultural, chemical and legal. Usually a combination of two or more methods will be the most effective and efficient. With multiple pests, hosts and production systems, the possibilities of incompatible control methods are great and must be considered. Actions taken against one pest may be counter-productive by causing increases in another pest.

The integration of skills is logical in light of the fact that livestock IPM is dealing with a production system. Effective livestock IPM requires the integrated skills of not only entomologists, but also animal scientists (production, nutrition, breeding), agronomists (pasture production), parasitologists, veterinarians, engineers (irrigation, waste disposal) and economists (costs anlaysis).

Conceptualization and Prospects for Livestock IPM

As iterated earlier, Integrated Pest Management is more than the constituent terms, however. It is not a method of control *per se*, but rather a holistic approach providing for decision-making based on both scientific and value judgements. Whether or not to take action to suppress a pest population and what kind of action to take is decided after consideration of what is in the best long term interest of the public as well as the short and long term interests of the livestock producer. The prime objective of IPM is to lower the mean level of abundance of the pest so that the frequency of fluctuations, spatially and temporally, above the economic threshold is reduced or eliminated. Choices are made in light of the ecology of the pests and of the livestock production system. This is quite logical and compatible since livestock production, as emphasized by Spedding (1975), is a biological system. The pests are one key element in that biological system. An IPM program requires a conceptualization of all recognizable components affecting the pest population level and the effects of candidate suppression tactics. This is inherently complex with many factors and interactions involved. Thus a systems approach is required, i.e. an orderly approach to the complex events by means of breaking the system down into manageable parts and subsystems. This may be initially descriptive through the use of flow charts and diagrams. Where needed and feasible, more and more use of mathematical models will evolve. For effective IPM programs to evolve in livestock production, we need much more research on the population dynamics of the pests and the concurrent economic impacts in relation to livestock dynamics (breeds, nutrition, behavior, etc.) and the various types of livestock production systems. Due to lack of data and research funds, there has been little use of the systems analysis approach to livestock IPM, but that is the orientation needed in the future.

A conceptualization of the interrelationships among the major components in the development and operation of a livestock IPM system as part of a livestock production system is shown in Fig. 2. On-going research is required on pest population dynamics, livestock dynamics, management methods (including pesticides and drugs) and environmental impacts, along with measurements of livestock performance or efficiency in order to arrive at estimates of costs versus benefits as the basis for selecting the components of an IPM program based on economic thresholds (pest densities). However, IPM programs can be implemented based on the available technology at any given point in time and be improved from experience and the results of the on-going research. A practical operational IPM program requires pest monitoring and means to predict (to whatever level of accuracy is realistic) future trends (increases or decreases) in the pest populations as well as means to predict the probable results of taking various management actions. Feedback from experience allows improvement in such an operational IPM program. It should be made clear that research, development and implementation of a livestock IPM system is not a static goal to be reached and "finished". As livestock production management systems change the livestock production ecosystem changes which results in changes in pest densities. Changing pest densities along with changes in production and market economics, costs of management options, values of environmental factors, and human goals will change the economic thresholds. What is required is a means for rapid analysis and adjustment to those changes. Presently, livestock IPM is in its infancy, but there is great need and potential as was concluded by the 1979 national workshop on livestock pest management (Anon. 1979). Livestock IPM is a major subsystem in an animal health and production system.

CONFINED-LIVESTOCK IPM

The prospects for developing IPM programs are particularly attractive in the confined-animal high-density production systems. There we have the advantages of a discrete area analogous to an "ecological island". The number of different pests is usually few, but their numbers can become tremendous. The environmental conditions are reasonably predictable being, to varying degrees, under man's control; the system is man-made and hence subject to considerable manipulation.

An example is caged-layer poultry operations. The first step historically to developing an IPM program for that system was to analyze the pest and disease problems and priortize these. In the North Carolina Agricultural Research Service (NCARS) we concentrated on developing an integration of methods for the management of flies (Axtell 1970a,b; 1981). This in essence involved the following components: (1) Cultural & Physical.--Maintaining the manure as dry as possible by eliminating water leaks and excess watering of the hens, using structural design to promote air flow (curtain sides or fans for cross ventilation), site selection and grading for maximum drainage; (2) Biological.--Maximizing the natural population of predators and parasites of flies by promoting manure drying, by removing only part of the manure once a year during the cool non-fly season, limiting the use of insecticides on the manure to only the few spots producing large numbers of fly larvae, introducing additional parasites and/or predators; (3) Chemical.--Using only chemical control tactics against the adult stage of the flies by means of toxicant-bait stations and selective residual sprays on the upper portions of the structure where the flies rest at night. Standardized sampling methods (sticky ribbons, spot cards, bait traps) to measure the fly population have been developed and somewhat subjective economic thresholds set. The poultry housing systems which do not rely on manure accumulation, but rather use a flush or scraper system with a lagoon, present a different problem in that we cannot enhance the action of predators in the absence of manure. In that system, however, some scattered manure does occur, which is sufficient for fly breeding and hence the parasites are important. The chemical tactic directed against the adult fly still is appropriate.

With a system for dealing with flies, it became apparent that the producers were interested in the entire spectrum of pest management not just one pest category. Also it became apparent that the principles of IPM in confined poultry operations could be readily applied to confined swine operations which were common in the same areas. Obviously, research information was not adequate, but even what was known was not being effectively used in a management approach to the severe pest problems in these production systems. Further, attempts to put into practice what we know was conceived as an excellent way to reveal the questions that should be addressed in future research.

Consequently, the North Carolina Agricultural Extension Service (NCAES) initiated in 1979 a Pilot Livestock and Poultry Integrated Pest Management Program in two areas of the state under the direction of Dr. Donald A. Rutz (Rutz 1981). The pilot project has a Steering Committee composed of a poultry scientist, animal scientist, economist, agricultural engineer, avian veterinarian, livestock veterinarian, and extension administrators (district and program leaders). The Steering Committee advises on overall policy and priorities as well as provides specific expertise when needed. Each of the two principal counties involved have a Pest Management Agent who works with the existing Livestock Extension Agent. The PM agent uses standardized sampling methods to monitor the pest populations (weekly or biweekly) and makes written pest management recommendations to the producer with copies to the Livestock Agent and to the relevent contractor or "integrator". The pilot program includes poultry and swine operations. For poultry the pests included are: flies, ectoparasites (northern fowl mite, lice, bedbugs), darkling beetles, mosquitoes (in waste lagoons), rodents, and wild birds. For swine the pests included are: flies, ectoparasites (mange mites, hog lice), mosquitoes (in waste lagoons) and rodents. Procedures are being developed at the request of the producers and contractors to include monitoring for internal parasites of both poultry and swine in the program. Thus the North Carolina program has developed into the IPM systems level II as conceived by the USDA/SEA (Allen and Bath 1980).

The pilot program is presently funded jointly by the NCAES (about two-thirds) and payments by the producer and/or contractor (about one-third). Charges per visit are $4.00 base plus various amounts according to the numbers and types of animals (e.g. 10¢ per 1,000 caged layers, 12¢ per 1,000 breeder chickens, 3-8¢ per sow, 25¢ per 100 feeder pigs).

The Pilot Livestock and Poultry IPM program has been well received in North Carolina and the demand from producers and contractors to join have exceeded the capacity of the program. Participants have reduced their costs by more judicious use of insecticide sprays and much more effective rodent control as a result of following the recommendations based on the PM agents systematic monitoring of the pest populations. An economic analysis of the program is in progress.

The North Carolina pilot program has demonstrated that Livestock and Poultry IPM is practical, needed, readily accepted, improves pest management, and reduces costs of production. At the same time, the implementation of presently known technology reveals great short-comings and the need for more research on many facets including: pest population dynamics, economic thresholds, pest monitoring methods, control methodologies, systems modelling and delivery systems.

The Livestock IPM programs in California (poultry), Louisiana (pasture beef) and Nebraska (feedlots), along with the North Carolina program, point the way for greater development of IPM systems as part of livestock production systems. This will require much greater indepth research on the major subsystems and their interrelationships in the development and operation of livestock IPM in different types of livestock production systems. A continuing interdisciplinary research and extension effort is required for the effective evolution of livestock IPM.

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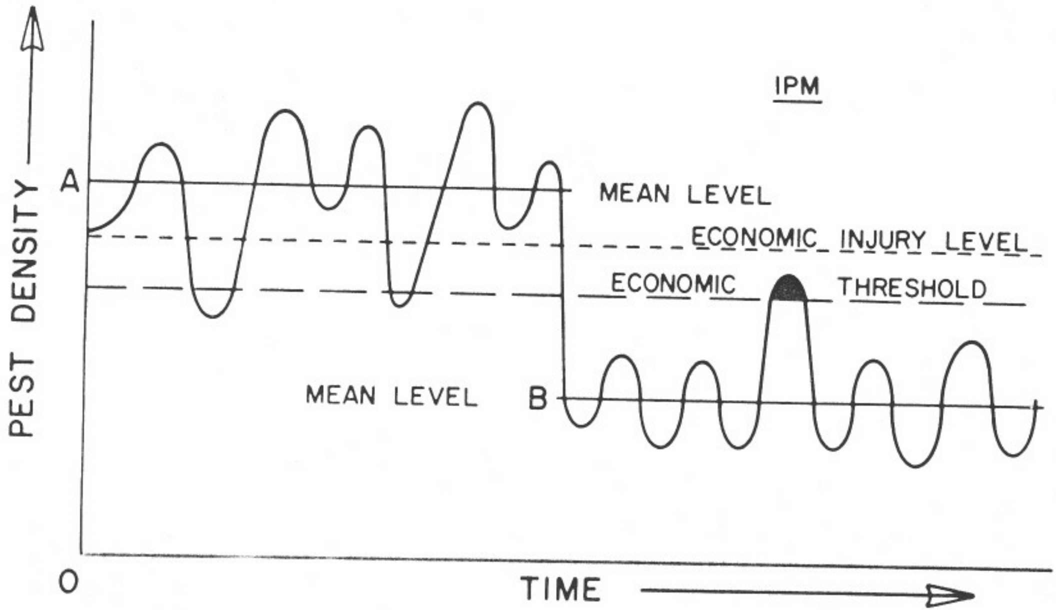

Fig. 1.--Diagram of natural fluctuations of the density of a pest population, over a period of time, above and below a mean population level A. The objective of IPM is to lower the mean population level to B. The relationship of economic injury level and economic threshold are shown. (from Axtell 1979)

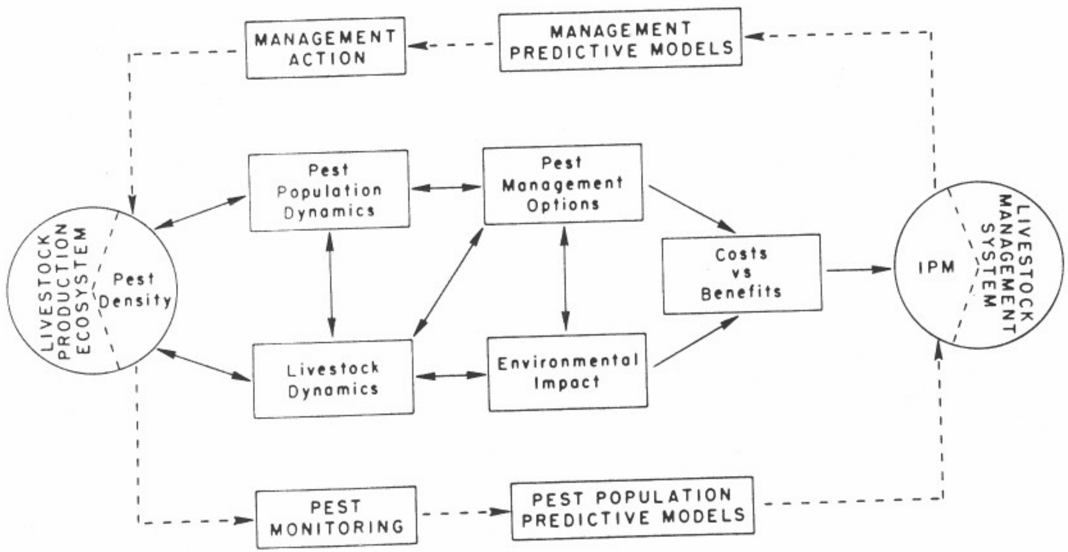

Fig. 2.--Diagram of the interrelationships among the major components in the development of an appropriate IPM program for a livestock production system. The inner boxes represent research inputs required for the design of an IPM program. The outer boxes connected by a broken line represent the operational inputs of an IPM program based on pest monitoring and predictive modelling.