Chapter 1

Historical Perspective on Crop Protection

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Since recorded history, the impact of pests on food crops has been important. Many practices of "traditional" and "modern" agriculture have evolved because of pest problems. Without doubt, pests of food crops influenced the course of civilizations-for example, the ancient Greeks and Remans knew of and used pesticides in the Mediterranean Basin. Crop losses from pests during those times were probably even more severe in the humid tropics, just as they are today.

Over the 10,000 or more years that man has cultivated crops, he gradually evolved production systems that ensured an adequate food supply for the family or tribal unit from one harvest until the next. Seeds were selected from plants that survived the rigors of weather and pest infestations; cultivation, planting time, and other production practices were adopted that ensured consistent rather than high but variable yields. At best, however, such ancient practices were based on trial and error without the benefit of modern genetics, chemistry, and cultural capabilities; they were only moderately effective and resulted in relatively low and unstable production levels. Furthermore, effective means did not exist to deal with disasters such as locust plagues and blight.

During the last century agriculture in industrial countries has changed from relatively small, labor-intensive, diversified family units to large, highly mechanized operations. As production became concentrated in favorable areas and as monoculture, high fertility, irrigation, and other components of modern agriculture were widely adopted, pest problems frequently became more severe. Insects, disease organisms, and nematode problems were magnified, particularly on fruits and vegetables, and weed problems became more acute as those species most suited for the new cropping systems proliferated. This situation was further exacerbated by the movement of pest species from one continent to another. Many of the most serious pests in the United States were introduced from other centinents.

As a result of the increasing need for methods to prevent losses due to pests, an impressive array of crop protection technologies has evolved. Included are pest-resistant plants, cultural controls, biological controls, pesticides, behavior-modifying substances, quarantine laws, and pest eradication programs. Some cultural controls are not adaptable to high-production agriculture: some pesticides have declined in effectiveness: other controls are used successfully to manage only a limited number of pests: none are entirely satisfactory or universally applicable, Recently, the increasing dependence on chemical pesticides has raised concern regarding risks to human health and the environment.

Pest-resistant plants were recognized in the 19th century, but only in the 20th century has breeding for pest resistance become an active area of research. Numerous cultivars (varieties) resistant to one or more diseases were developed, and varieties of apples, grapes, and wheat were known to be resistant to woolly aphid, phylloxera, and Hessian fly, respectively. During the last 30 years the development of cultivars resistant to major disease organisms and nematodes has accelerated. The development of insect-resistant crops has received less emphasis partly because of the easy availability of economical and effective insecticides. Breeding for weed resistance has focused on the ability to compete but otherwise has been given little attention. Recently, allelopathy (the ability of one plant to suppress another by producing toxic substances) has received attention as a weed control tactic.

Cultural control methods are as old as agriculture and are used primarily for weed, nematode, and disease control. These methods include sanitation, destruction of alternate hosts and volunteer plants, crop rotation, tillage, trap crops, time of planting, water and fertilizer management, and use of pest-free seed and planting stock. Although cultural methods alone are not likely to ensure adequate controls, they often can reduce pest population pressures and enhance other control tactics. The availability of economical herbicides, fungicides, and insecticides has reduced emphasis on cultural controls; the integrated pest management (1PM) approach to crop protection has brought renewed attention to these old cultural methods,

Biological control is the regulation of pest organisms by their natural enemies and is important in pest management. Primarily, insects and mites are controlled by this method, but it may play an important role in the regulation of some disease organisms, weeds, and vertebrates. Natural enemies are macrobial (vertebrates, insects, and mites) or microbial (fungi, bacteria, viruses), and may be indigenous or introduced from other areas.

The earliest known use of biological control was by the Chinese who used ants to control insect pests in citrus orchards. Other better known cases were the introduction of the Vedalia beetle into California citrus groves in 1890 to control the introduced cottony cushion scale and the control of prickly pear cactus in Australia through the introduction of a lepidopterous insect in 1925.

The importance of biological control was not realized for many situations until certain insecticides that affected a broad range of organisms were used on crops such as cotton and apple. This resulted in the removal of the natural enemies for some secondary or even previously unknown pests that then became major damaging pests, The earliest planned 1PM control efforts were made in 1940 on apples in Nova Scotia in an attempt to use insecticides and fungicides that would not interfere with biological control of insects and mites.

Pesticides have been used for more than 2,000 years but, until the last century, only to a limited extent. During the late 1800's and early 1900's, the first widespread use of insecticides was initiated, Arsenical were used on potatoes, cotton, apples, and a few other crops, Bordeaux mixture and liquid lime sulfur were used on grapes, potatoes, and fruits to prevent severe losses by disease organisms. By 1903 crude but practical gasoline-powered spraying and dusting equipment was in use: by 1915 the use of chemical insecticides and fungicides on most crops had become standard practice, The inorganic predominated until the 1940's when DDT, BHC, the dithiocarbamate fungicides, and 2,4-D became the forerunners of a revolutionary new class of chemicals, the synthetic organic compounds. During the last 30 years the total use of pesticides has increased twelvefold in the United States alone; increases in the developing countries have been much more gradual, The latest figures show the rate of increase slowing for fungicides and insecticides, while herbicide use continues to expand until now its use far exceeds that of any other group of pesticides. In 1977, 7 percent of pesticide sales in the United States were for fungicides, 35 percent were for insecticides, and 58 percent were for herbicides.

Although microbial pesticides have been explored, only one bacterium, Bacillus thuringiensis, is in extensive commercial use at present for control of agricultural pests. one insect virus is registered for full use and several others have experimental-use permits for field tests as the first step toward full registration. It is noteworthy that commercially produced Microbials are considered. by law, to be pesticides. but the regulation of pests by their ‘‘natural’” enemies, which include microbial agents, is biological control.

Behavior-modifying substances such as insect pheromones are a recent development and their ultimate role in crop protection is unknown. The pheromone Gossyplure is registered for control of the pink bollworm on cot ton. They, and other attractants, are now widely used to monitor insect activity.

Quarantine regulations originated in the late 19th and early 20th centuries. Germany instituted regulatory measures in 1873 to prohibit entry of products that might spread grape phylloxera. During the next 10 years various States enacted the first quarantine laws in the United States. In 1905 the Federal Insect Pest Act was enacted, and in 1912 the Federal Plant Quarantine Act was passed by Congress. These regulations were based on the concept that the spread of pests through human activity can be prevented, especially if a geographic barrier. such as an ocean or mountain range, exists between the place of origin and the area to be protected. Today. the extent and rate of world travel and trade has led to a reexamination of these procedures in an attempt to adapt to changing conditions. In 1974 Congress passed the Noxious Weed Act which was not funded until 1978. and then only modestly.

Eradication is the complete extermination of a pest from an area and is permanent unless the pest is reintroduced. It may be the ideal method of dealing with a newly introduced species. Eradication programs are politically attractive because of their visibility and because they offer short-term relief from attacks of the pest involved, but permanent success is difficult, if not impossible, to attain for most pests with present technology. Eradication of the screw worm in the Southeast and, on several occasions, of the Mediterranean fruit fly in Florida are successful examples, but attempts to eradicate the common barberry, field bindweed. witchweed, gypsy moth. golden nematode, and fire ant have failed. Also the potential hazards to human health and the environment must be considered. Much concern exists that funds and manpower so badly needed for other crop protection efforts will be wasted on futile eradication projects.

Integrated pest management (1PM) is a concept of crop production incorporating effective, stable, long-lasting crop protection components that minimize the negative side effects of current pest control actions. As mentioned above, none of the current control tactics are entirely satisfactory or universally applicable even though U.S. farmers have achieved a high degree of dominance over many plant pests during the last century.

organic pesticides were first acclaimed as the ultimate solution to crop protection problems, but experience over time has shown that, for all their advantages with respect to human heaIth and conservation of food and fiber, they have many limitations. On cotton and a few other crops in some areas, pest resistance to insecticides and secondary induced pests have resulted in disastrous losses. Biological, cultural, host-plant resistance, and other tactics are all effective against specific pests but have Iimitations that restrict their general usefulness in crop production. These developments have led to a general recognition over the past two decades of the need for improved crop protection systems. The 1PM concept developed in response to this need.

*’Integrated pest management”’ is a term that has different meanings to different people. Definition problems have plagued the 1PM effort since its inception. It is an all-inclusive concept that should be applicable to all pests (weeds, plant pathogens, nematodes, vertebrates, insects, etc.) However, terminology, control tactics, and strategies vary among disciplinary groups so that it is difficult to arrive at a definition completely appropriate to all interests. The term “inte-

grated pest management,*' as used throughout this report, is defined as follows:

Integrated pest management (1PM) is the optimization of pest control in an economically and ecologically sound manner, accomplished by the coordinated use of multiple tactics to assure stable crop production and to maintain pest damage below the economic injury level while minimizing hazards to humans, animals, plants, and the environment.

In the above definition, 1PM is synonymous with "'integrated pest control, " a term generally used outside the United States. "Integrated pest management" and "pest management" are used interchangeably in this report.

The current definitions of some common terms used in crop protection are:

Pest—Formerly restricted in common use to insects and certain rodents, now applies to all noxious and damaging organisms including insects. mites, nematodes, plant pathogens, weeds, and vertebrates.

Pesticides—Includes insecticides, miticides, nematicides, herbicides, fungicides, etc.

Strategies— Pest control strategies are the general approaches or systems used to manage a pest or pests. 1PM is the strategy of using applicable multiple tactics to prevent pest losses.

Tactics—These are the specific methods used to achieve pest control. These include pesticides, pest-resistant varieties, cultural practices, biological control, and others.

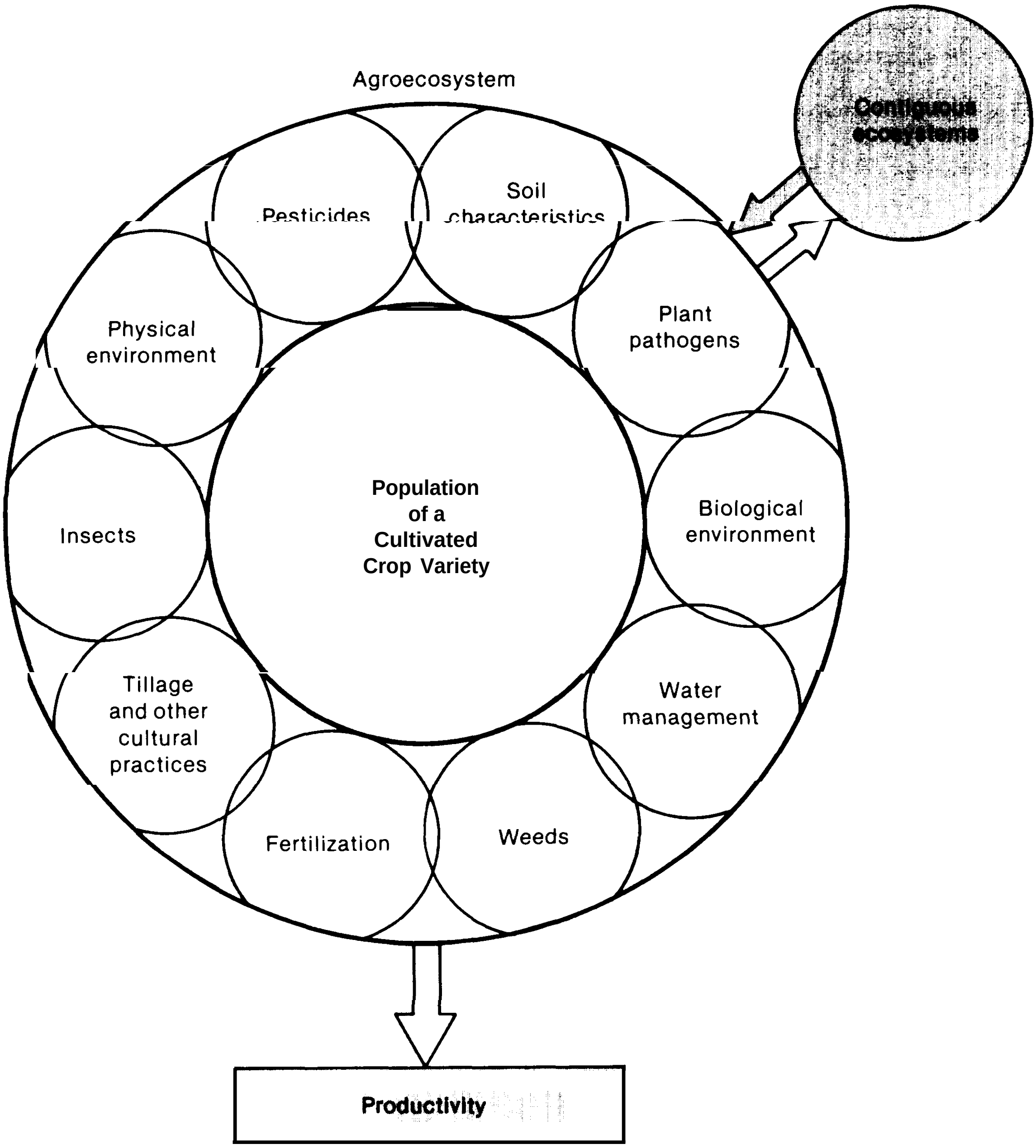
1PM in its broadest form considers all major pests in an agroecosystem and is integrated as one component of the total crop production system, However, integrated control tactics for individual or groups of similar pests can be implemented without waiting for the "perfect"' total program to be developed, These tactics can be modified, improved, and integrated with control tactics for other pests as new information becomes available,

Pest management is not a primary goal; rather, it is one component of the total crop production system which is a series of interlocking physical, biological, and management functions all interacting to determine the yield of a cultivated crop (see figure I). Crop pests are important elements of the system that interact among themselves and with other components of the system; they are managed not as a primary objective but only as they reduce productivity of the system by an amount greater than the cost of control.

As an organized, comprehensive approach to the management of crop pests, 1PM proceeds through a series of steps in planning pest management programs. These steps and their underlying principles, presented in the order of their priority in developing programs, are:

1. Identify the pests to be managed in the crop production system (agroecosystem). An organism should not be classed as a pest until it is proven to be so. A species may be a pest in some situations and not in others. Pest identification should be coupled with the establishment of economic thresholds. (See no, 4 below.)
2. Define the management unit—the agroecosystem. The limits of the agroecosystem should be determined by the characteristics of the local cropping system and the patterns of movement of the key pests involved. Multiple-species management requires a "best compromise" solution to the overall pest problems within the capabilities of the involved farmers.
3. Development of the pest management strategy. The fundamental strategy of pest management is the coordinated use of multiple control tactics in a single integrated system. The goal is to hold pest numbers and crop damage to tolerable levels. It is generally a containment strategy rather than an eradication strategy.
4 Establish economic injury thresholds. The economic injury threshold is the pest population level that causes a loss to the

Figure 1 .— Diagrammatic Concept of an Agroecosystem



SOURCE J L Apple Impact of Plant Disease on World Food Product Ion pp 39.49 In D Pimentel ed *World Food Pest Losses and the Environ ment* (Boulder Colo Westview Press 1978)

crop greater than the cost of carrying out a pest control action. Obviously, the economic threshold values (pest population levels) vary for a given crop depending on the value of the crop, the state of its development, and environmental conditions (both biological and physical).

5. Develop reliable monitoring techniques. Monitoring information on some pests provides the basis for decisions on immediate suppressive pest managment actions, whereas for other pests such information is useful only for management decisions concerning future cropping

seasons. This involves the measurement of pest populations (numbers of spores, insects, nematodes, weeds, etc.) or amount of disease.

6. Develop descriptive and predictive models. Modeling is a very useful tool in organizing research, in identifying knowledge gaps that must be filled to understand the system, and in predicting over time the behavior of the crop production system and its pest components. This is a desired goal in the development of sophisticated systems but is not an absolute requirement for all 1PM programs,