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Stern V M, Smith R F, van den Bosch R & Hagen K S. The integration of chemical and biological control of the spotted alfalfa aphid: the integrated control concept. *Hilgardia* 29:81-101, 1959.

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Integrated control combines biological and chemical control. A pesticide is used only when natural mortality agents are inadequate and the pest reaches a density level sufficient to cause crop loss above treatment and external costs. Selective pesticides allow natural enemies of pests to survive treatment. [The SCJ® indicates that this paper has been cited in over 130 publications since 1959.]

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When DDT and other organic insecticides became widely available after World War II, entomologists suddenly had new answers to old pest problems.¹ By the mid-1950s millions of pounds of the new pesticides were being applied on agricultural crops throughout the world. Without question, organic pesticides brought incalculable benefits to mankind. However, our research and observations in California revealed that pesticide-induced problems were increasing rapidly. These problems included resistance to pesticides, destruction of natural enemies, resurgence of treated species, appearance of new pests, misuse of the chemicals, toxic residues, and hazards to field workers.

It became apparent to us that pest control is a complex ecological problem. Eventually we formulated a philosophy including definitions and graphs to better explain and provide a more comprehensive understanding of how and why arthropods are or can become pests and how best to solve pest-control problems.

Some problems were encountered in publication. One reviewer personally regretted

that two of his faculty colleagues were "involved in writing the damn thing." The editor of *Hilgardia* was upset because the worldwide requests for free reprints required a second printing—the only time, ever, for a *Hilgardia* publication.

The reason this paper has been widely cited is that, by 1959, the world of pest control needed drastic improvement. This paper was a significant first step and laid the basis for all that followed. An author commented recently, "[E]conomic entomology has had nothing quite so fashionable as Integrated Control. It gathered momentum from its very breadth. It was all things to all entomologists. Above all, it acquired the characteristics of a religious movement, with its own priesthood, faithful following, and body of doctrine. Such, indeed, was its strength."²

A basic principle of integrated control is the economic threshold.³ This concept stresses the need to determine that level of pest density accountable for a discrete amount of crop loss in order to justify cost of treatment plus external costs. Naturally, agricultural economists had to butt in. In most cases, they were looking at economic theory rather than simple down-on-the-farm pest-control cost/benefit ratios. However, most farmers do not understand economic theory any more than entomologists do.

During the 1960s the entomological concept of integrated control⁴ was broadened considerably and soon encompassed nematology, plant pathology, and weed science. This entire field now includes not only biological and chemical control but also, importantly, cultural control, climatic factors, plant growth analysis, and modeling as well as social ramifications and political aspects. As a result the term "integrated pest management" largely replaced our term "integrated control." Today, BS, MS, and PhD degrees are offered in this subject. About 20 states now require agricultural pest-control advisers to be licensed. Each of the authors of this paper reached the highest rank of professorship in the University of California system. R.F. Smith helped carry our message throughout the world and was elected to the US National Academy of Sciences in 1980.

1. Metcalf R L. Changing role of insecticides in crop protection. *Annu. Rev. Entomol.* 25:210-56, 1980.
2. Jones D P. Agricultural entomology. (Smith R F, Mittler T E & Smith C N, eds.) *History of entomology.* Palo Alto, CA: Annual Reviews, 1973. p. 307-32.
3. Stern V M. Economic thresholds. *Annu. Rev. Entomol.* 18:259-80, 1973.
4. Kennedy J S. The motivation of integrated control. *J. Appl. Ecol.* 5:492-9, 1968.