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Sustainable Commercial Vegetable Production with Minimal Use of Synthetic Fertilizers and Pesticides: Introduction to the Colloquium

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The primary objective of vegetable producers over the centuries has been to supply high-quality vegetables to consumers at affordable prices. Although consumer tolerance of blemishes and worm holes probably has decreased with time, growers have always preferred to deliver spotless produce. The only means to bring this about during the 1800s was by use of crop rotations, resistant cultivars, trap cropping, etc. (Casagrande, 1987). With the discovery of synthetic chemicals such as Paris green, Bordeaux mixture, and lead arsenate, the cultural practice techniques to minimize pest pressure were less frequently used. This trend became more marked in the 1950s, when new pesticides, such as DDT and 2,4-D, proved more effective than the chemicals used previously. A wide array of chemicals became available, and provided the grower with a number of chemical options for insect, disease, and weed control.

At the same time, warning signs started to appear that some of these compounds had detrimental side effects. DDT was found to severely reduce the populations of certain birds and fish. Dioxin impurities in 2,4-D and 2,4,5-T herbicides were implicated in increased cancer incidence in people exposed to these chemicals, and in birth defects in their offspring. To date, the registrations of ≈ 25 agricultural chemicals have been voluntarily withdrawn because of toxicological problems (EPA, 1988).

In addition, a series of widely publicized incidents, such as the

poisoning of consumers in California after eating watermelon contaminated with aldicarb insecticide and the explosion of a pesticide manufacturing plant in Bhopal, India, which killed > 2000 people, have heightened public aversion to pesticides.

At this same time, reliance on chemical control of pests, to the exclusion of other methods, has led to the development of resistance among pest populations to the chemicals employed. For instance, Colorado potato beetle populations in the Northeastern United States are currently resistant to all the major groups of insecticides (Casagrande, 1987). We may indeed be approaching the end of the "chemical era" in agriculture, as J.K. Bleasdale predicted recently.

Widespread adoption of the use of chemical fertilizers enabled farmers to grow crops without keeping livestock for manure generation. Synthetic fertilizers were more economical to apply and could supply higher levels of P than was available in manure (Thompson and Kelly, 1957). However, reduced use of manure hastened the decline in organic matter, and heavy reliance on synthetic sources of N carry the dangers of nitrate contamination of the groundwater.

But what do we have to take the place of the chemicals that we used to combat pests and efficiently fertilize our soils? Are we on the threshold of the "biological era", to quote Bleasdale again, a time when our knowledge of pest life cycles, the ecology of the

crop and its pests and their natural enemies will allow us to grow perfect crops naturally? Will the techniques of biotechnology help us to outwit the pests and develop crops that fix their own N?

For an assessment of what lies ahead, five experienced scientists discuss, in the areas of weed control, insect management, disease management, and fertilizer practices, the possible strategies that may minimize use of synthetic fertilizers and pesticides.

Literature Cited

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Vegetable Weed Control with Minimal Herbicide Inputs

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Numerous concerns among the general public and farm community have provided a renewed interest in methods for growing crops with fewer inputs of energy and chemicals and for renewed efforts to conserve soil and water resources. Pest control researchers have long realized that heavy reliance on one control strategy produces adapted pest populations that may evolve to become more troublesome than the previous generations. Therefore, there is a need to develop and implement sustainable systems that integrate biological, cultural, mechanical, and chemical strategies. To be acceptable, these systems should be economic in both the short and long term. As usual, the vegetable grower finds him or herself in a squeeze; this time, between concern for protection of the environment and the production of residue-free produce and economics, i.e., how to do this with reduced chemical input and still make a profit? The major reason for using herbicides, in the first place, was to replace expensive and often difficult-to-find labor that was required for weed control.

There are several alternative strategies available for weed control, although their effectiveness varies from region to region. The focus of this paper is on methods that growers can now employ to reduce herbicide inputs in vegetable production.

BIOLOGICAL CONTROL

The biological approach is to use another organism (a natural enemy or introduced organism) that becomes established in high enough populations to greatly reduce the weed's growth, competitive ability, or population density. In vegetable crop production, this approach is still in the research rather than the application stage. However, the approach has worked successfully in other cropping systems and in rangelands (Cullen et al., 1973; Daniel et al., 1973; Trujillo, 1985; Woodhead, 1981). In recent years, research has focused on species-specific insects, fungi, or nematodes that can control weeds without attacking crops. The best results have been obtained with plant pathogenic fungi that are sprayed on the weeds. These "mycoherbicides" have worked particularly well in the southeastern United States, where temperatures and humidity are more favorable for their development than in drier climates (Daniel et al., 1983; Woodhead, 1981). Particularly noteworthy for vegetables are the promising results obtained by Phatak et al. (1983) on nutsedges with *Puccinia* rust (Table 1). Using chemical approaches alone for control of nutsedges in vegetables generally has not been acceptable. Using the rust pathogen together with other strategies might provide better results. To perform effectively, these fungi must be protected from exposure to broad-spectrum fungicides that are sometimes used for vegetable disease control. Although biocontrol agents may be particularly useful for reducing certain noxious weed species, it must be remembered that once the former is removed, other weeds will quickly fill the vacated niche, thus presenting a new challenge to the grower. Biological weed control agents, because of their environmental safety, will undoubtedly receive more research attention. Many fungi now look promising for

controlling problem weeds that affect vegetables. However, because of the limitations imposed on their effectiveness by the environment, difficulty in integrating with other methods, and recognition that new weed pests will quickly fill the niche, biocontrol by itself will not provide a utopia.

CULTURAL CONTROL

This approach includes any manipulation of crops or their culture that can provide weed suppression. Vegetable growers in all parts of the world have used cultural approaches for centuries without an understanding of the science behind their success. "Smother crops" are an example of a cultural practice that is widely used to reduce weed populations. Cereal grains, buckwheat, and sorghum $\times$ sudangrass hybrids are examples of effective smother crops. These crops are quickly established and usurp the resources that weeds would otherwise use. Many are believed to suppress weeds through

Table 1. Effect of rust fungus on nutsedge tuber formation and survival 120 days after rust release (adapted from Phatak et al., 1983).

Nutsedge	No./m ² (120 days)	
	Rust-infected	Control ^a
Tubers		
Old	180	117
New	17	68
Plants		
Live	155	338
Dead	132	6

^aWeekly application of chlorothalonil.

Fig. 1. Relay cropping system using peas interplanted with sweet corn. Pea vines remain as mulch to suppress weeds in corn.