Augmentation of naturally occurring beneficial insect populations by releases of laboratory-reared parasites or predators also can be utilized in integrated programs.

Tomato fruitworm can be controlled to economically acceptable levels by releases of a naturally occurring egg parasite in combination with a biotic larvicide without disrupting natural controlling factors for other tomato pests.

Cultural controls offer still another approach, which has been successfully utilized to reduce insecticide applications on potatoes. Cultural procedures and irrigation practices that prevent potato tuberworm access to tubers, in combination with sex attractant monitoring, can almost eliminate the need for chemical control of this pest. Reflective mulching in high-value vegetables offers a means of controlling aphid-transmitted mosaic viruses that cannot be achieved with pesticides. For example, squash plantings mulched with aluminum foil yielded 86 percent more than unmulched plantings. Aphids entering the mulched plants were reduced by 96 percent with a resulting 85 percent reduction in mosaic virus infection.

Effective alternative control strategies are being developed and will be available. Vegetable growers using such controls in integrated pest management programs will reduce their dependence on pesticides and yet retain high quality standards for the products they market.

Jeffrey A. Wyman is Assistant Professor, Division of Economic Entomology, Earl R. Oatman is Professor, Division of Biological Control, and Robert A. Van Steenwyk is Assistant Professor, Division of Economic Entomology, Department of Entomology, University of California, Riverside.

Integrated pest management on artichoke and tomato in Northern California

W. Harry Lange James S. Kishiyama

The artificial nature of the ecosystems in vegetable fields often results in a scarcity of natural enemies of crop pests. In many cases only a few days lost in making a control decision can necessitate the application of chemical or biological insecticides for immediate reduction in pest populations. Often numerous applications are necessary.

The globe artichoke and the tomato are examples of two extremes in pest management in northern California vegetable crops: one is a long-term crop (artichoke) and the other is a relatively short-term crop (tomato), and the problems involved are somewhat different.

Artichokes

There is one key pest of artichoke, the artichoke plume moth *(Platyptilia carduidactyla)*. In 1975-76 it caused about $13,000,000 damage in the Castroville area. The reasons for the loss included: (1) higher than normal temperatures and drought conditions resulting in high egg deposition and a delay in bud formation; (2) almost complete resistance to ethyl parathion and some resistance to methyl parathion; and (3) cultural methods conducive to the movement of moths from one field to another.

Integrated pest management (IPM) procedures put into operation in one of the larger farms in the Castroville area in 1976 included the following: (1) fewer applications of methyl parathion and no ethyl parathion applications; (2) the use of other insecticides and their application by ground whenever possible; (3) better cultural methods (control of alternate thistle hosts, replanting old fields, complete cutting of plants at least once a year and placing the cut tops in a ditch between the rows and covering with soil to a depth of at least 6 inches, removal of all wormy buds, cutting off of new growth if heavily infested with eggs and larvae); and (4) the use of virgin female pheromone traps to monitor moth flight and time insecticide applications. The results of the sanitation methods look very promising to date.

Also being investigated are the effects of biological control in fields where no insecticides are applied compared with the results of constant biweekly insecticide usage; resistant varieties; the relation of plant growth type (for example numbers of shoots and spacing) to infestation levels; the cutting-off of new growth—once or several times—to destroy eggs and larvae; trapping techniques; chemicals to control adults; and the use of insecticides, such as pyrethroids, which may not cause secondary pest outbreaks.

Tomatoes

The key pests of tomato in the Sacramento Valley include the tomato fruitworm *(Heliothis zea)* and the beet armyworm *(Spodoptera exigua)*. In recent years the latter species has become more of a problem. The tomato pinworm *(Keiferia lycopersicella)*, a key pest in southern California (Fresno area south), does not ordinarily occur in the Sacramento Valley.

Control of the lepidopterous pest complex on tomatoes has ordinarily involved the application of insecticides based primarily on fruit development.

Our research, beginning in 1962 and continuing to the present time, has shown a relationship between planting dates and pest populations. An integrated program for pest control on processed tomatoes in the Sacramento Valley was developed. Insecticides for worm control are usually not necessary for an April 1 planting date. One or two applications may be necessary for a May 1 planting, and for plantings June 1 or later a careful watch of the worm population is necessary and two to three applications may be required. An economic threshold was established: 0.25 percent wormy, green fruit (based on an examination of 200 to 400 fruit), or when five moths or more come to a black light trap in two to three consecutive days.

Our research is concentrating on investigations of sources of resistance for the fruitworm, pinworm, leaf-mining Diptera *(Liriomyza spp.)*, fleabeetles, thrips, loopers, and pink biotype of the potato aphid. In cooperation with the Vegetable Crops Department at Davis we have located sources of resistance to aphids, leaf-miners, thrips, flea beetles, and fruitworm. There are real possibilities for breeding tomatoes resistant to some of these pests. The use of entomophagous viruses, *Bacillus thuringiensis*, and the fungus, *Beauveria bassiana*, have been investigated with little or inconclusive results.

W. Harry Lange is Professor of Entomology, and James S. Kishiyama is Staff Research Associate, University of California, Davis.