

the early destruction of virus sources such as infected volunteer potato plants and weeds known to harbor virus, and control of the green peach aphid. If fields are virus-free to begin with, other sources of virus are eliminated, and the

vectors are controlled, there should be little or no spread of PLRV from one field to another.

These cultural practices have been combined with improved field inspection techniques that result in insecticide treat-

ments being applied only when 5 percent of the leaves are infested.

Oscar G. Bacon is Professor of Entomology, and Vernon E. Burton is Extension Entomologist, University of California, Davis. Jeffrey A. Wyman is Assistant Professor of Entomology, University of California, Riverside.

Integrated pest management on vegetable crops in Southern California

Jeffrey A. Wyman ■ Earl R. Oatman ■ Robert A. Van Steenwyk

Many new approaches are being studied by scientists seeking improved insect control in the vegetable industry of southern California. Among these are insect monitoring systems using sex attractants in potatoes and tomatoes; new ways of using economic thresholds (critical pest numbers) in cole crops and lettuce; cultural methods of controlling insect pests on potatoes and squash; biological controls for tomato insects; and safer, more effective pesticides—with improved delivery systems—on all vegetable crops.

California farmers produce almost 50 percent of the nation's fresh produce. The industry is extremely intensive, providing 15 to 20 percent of the state's total agricultural return from less than 3 percent of the available farm land. Crop losses caused by insects are high (10 to 15 percent) and marketing standards are so strict that insecticides have been used heavily to achieve acceptable productivity. Because quality standards are unlikely to be relaxed in the future, pesticides will continue to be major tools for controlling the numerous insect pests on vegetables.

However, the supply of effective pesticides which the grower has relied on in the past cannot be expected to continue indefinitely. The industry has reached a stage where alternative control strategies and reduction of pesticide dependence are vital.

Insecticidal control practices often are directed against insects regardless of the extent of the populations, how they might fluctuate, or the impact they might have on crops. Nowhere is this practice more prevalent than in the vegetable industry, where high crop values and cosmetic standards, and low tolerance levels for damage and contamination, encourage rigid adherence to pesticide application schedules to produce a marketable product.

Monitoring systems can enable growers to break away from scheduled spraying by assessing insect populations and the need for pesticide applications. Two such systems have been developed. Potent sex attractants have been isolated for the potato tuberworm and the tomato pinworm. Adult populations can be accurately measured in individual fields, and the crop damage caused by the immature stages of the next generation can be accurately predicted. Necessary control measures can then be timed and unnecessary applications eliminated.

Even in cases where populations can be measured, however, levels of insect populations that inflict economic damage have not been determined. A knowledge of economic thresholds is thus extremely important in determining

appropriate control measures.

Economic thresholds can be developed on many vegetable crops. Even those crops with zero tolerance levels can benefit from higher thresholds when these are applied to growth stages that are not marketed. Broccoli exhibits a high tolerance to lepidopterous feeding injury in the growth period between thinning and heading. If seedling and heading stages are protected from insect damage, high yields of marketable produce can be produced with only limited protection during the long pre-heading stage.

Insecticides will continue to play an important role in integrated programs, and research is continually directed toward identifying more effective and safer materials. Pest-specific materials are desirable in integrated control programs, but their development by the chemical industry cannot be expected to increase because of the limited demand for such compounds. Safe, broad-spectrum materials such as the synthetic pyrethroids are being developed and have great potential in the vegetable industry when used correctly. Improved pesticide delivery systems often can overcome the adverse side effects caused by existing broad-spectrum pesticides. For example, the application of insecticide/nematicide materials to tomatoes through drip irrigation systems is being investigated.

Biological control of insect pests generally does not achieve the required levels of control for vegetable crops when used alone, but it forms an important part of integrated programs. When repeated pesticide applications eliminate natural controlling factors, secondary pests often reach economically damaging proportions. This situation is seen on tomatoes when pesticide applications to control the primary lepidopterous pests often result in serious outbreaks of dipterous leaf-miner by eliminating its natural controls.



Aluminum foil on zucchini squash provides protection from aphid-transmitted mosaic viruses. Aphids see blue light of reflected sky, fail to land on the squash.

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 re-

sulting 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 alter-

nate 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 bi-weekly 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.