Strategies for managing lepidopterous pests on lettuce

Marshall W. Johnson □ Ken Kido □ Nick C. Toscano
Robert A. Van Steenwyk □ Steve C. Welter □ Norman F. McCalley

It isn't necessary to keep the crop insect-free during the entire growing season

California lettuce, valued at $438.6 million in 1981, is grown mainly in the Imperial, Palo Verde, and Salinas valleys, with smaller acreages in the San Joaquin and Santa Maria valleys. To be marketable, lettuce heads must be protected against insect contamination.

Iceberg head lettuce is susceptible to damage by several lepidopterous pests, of which the cabbage looper, *Trichoplusia ni* (Hübner), beet armyworm, *Spodoptera exigua* (Hübner), tobacco budworm, *Heliothis virescens* (F.), and corn earworm, *Heliothus zea* (Boddie), are predominant in California. Less common lepidopterous species, such as the alfalfa looper, *Autographa californica* (Speyer), may also infest lettuce. Before thinning, seedlings may be injured by flea beetles, *Epitrix* sp., and crickets, *Gryllus* spp.

Previous studies on lettuce insect pests have largely been confined to field evaluations of insecticides. No quantitative relationships have been established between insect densities during the growing season and subsequent yield reductions. The lack of such information providing reliable density treatment levels has impaired insect pest management programs for this crop. To prevent damage, growers have generally applied insecticides to maintain lepidopterous larval densities at no more than 0.05 larva per plant (5 infested plants per 100 plants examined) throughout the lettuce growing season, regardless of the pest's or insecticide's effect on preheading plants.

Our studies have shown that densities of the major lepidopterous pests infesting lettuce may fluctuate within a growing season and from one year to the next in the same area. Scheduled pesticide applications made without regard to the insect densities in the field may be unnecessary and may ultimately reduce lettuce yields. Previous studies revealed that the insecticides methyl parathion, methomyl, and permethrin can reduce leaf photosynthetic rates after a single application at recommended rates (*California Agriculture*, November-December 1981) and that yield losses are possible following multiple applications. A "pesticide threshold" is needed indicating the maximum number of applications permissible for any one insecticide at recommended rates to avoid economically significant yield reductions caused by subtle phytotoxic properties of the compound.

Lettuce growth may be divided into three stages with regard to lepidopterous pest control. The first occurs from germination to thinning, when the plant stand is established and made uniform by thinning. Lettuce may be planted by either the standard or precision method. Standard planting allocates a large number of seeds to a unit area, and the resulting high-density stands are thinned. Precision planting allocates fewer seeds per unit area, resulting in lower seed costs and reduced labor requirements for thinning.

The second (intermediate) stage begins immediately after thinning and continues until rosette formation, which marks the initial leaf formation of the lettuce head. During this period, the plant grows and establishes a leaf canopy that later aids in production of the head.

The last stage, during which the head forms, enlarges, and matures, starts at rosette formation.

We performed studies to determine the effect of lepidopterous larval infestations on lettuce plants during the two growth stages before rosette formation and to establish density treatment levels for commercial use. We also investigated the effects of methyl parathion and methomyl applications on photosynthesis and crop yield when pest densities were not economically significant during the intermediate growth stage.

The studies were conducted at UC field stations: those on density treatment levels in Imperial, Orange, and Fresno counties, and those on pesticide thresholds primarily in Orange County. In all studies, iceberg head lettuce was direct-seeded in double-row beds with 40-inch centers; plants were sprinkler-irrigated to germination and then furrow-irrigated until harvest. Carbaryl-treated bait (1 pound active ingredient per acre) was applied to all plots during plant establishment for control of crickets and flea beetles. Plants were thinned to 10,890 seedlings per acre at the three-leaf stage. Experimental replicates consisted of four beds, 50 feet long, and all treatments were replicated four times.

In the density treatment studies, 25 plants from the center two beds of each plot were inspected twice weekly for all lepidopterous larvae present between germination and thinning, and once weekly thereafter.

Seedling stage

In 1978, half of the plots were planted by the standard and half by the precision method (seeds in pairs at 2-inch and at 10-inch intervals, respectively). Insecticides were applied before thinning to maintain larval densities below preestablished levels of 0, 0.05, 0.1 and

0.2 larva per plant. After thinning, insecticides were applied when larval density was 0.05. In an untreated control, pest populations were permitted to develop naturally until thinning, after which the control was treated the same as the other treatments. The insecticides methomyl or acephate (0.9 or 1 pound active ingredient, respectively, in 60 gallons of water per acre) were used interchangeably.

Yields of lettuce heads (harvested on December 27, trimmed to commercial standards, sized, and graded) showed no significant differences between the two planting methods. An equal number of insecticidal applications was required to protect standard- and precision-planted seedlings from larval feeding damage. Keeping larval infestation at 0 as compared with 0.2 larva per plant gave no yield advantage. However, significant yield increases were associated with treatments made to maintain a level of 0.1 larva per plant as compared with the untreated check in precision-planted plots (yields of 647 as opposed to 185 cartons per acre, respectively).

Intermediate stage

During the intermediate growth period, in studies from 1977 through 1979, insecticides were applied to maintain total larval densities below preestablished levels of 0, 0.5, 1, 2, or 5 larvae per plant. After rosette formation was 70 percent complete, all plots were treated when 0.05 larva per plant was found. The same insecticides and rates as in the seedling study were compared with an untreated control.

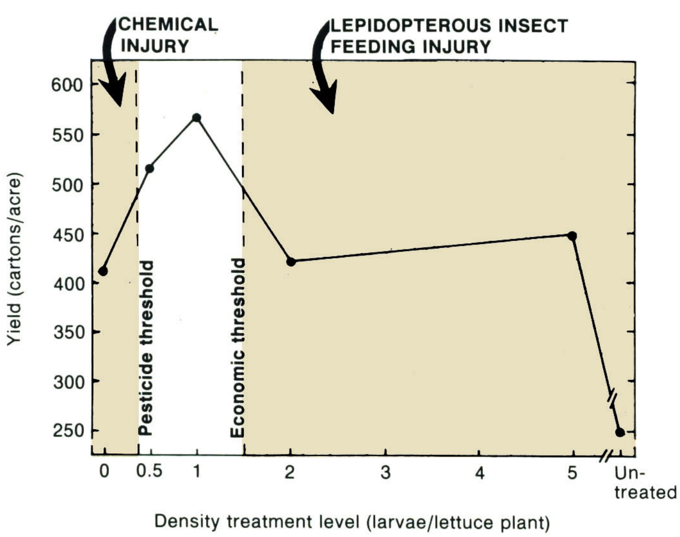
Two or more larvae per plant between thinning and rosette formation caused feeding damage and subsequent reduction in yield when compared with levels of 0.5 and 1 larva per plant (see table). Yields also were smaller when larval densities were maintained at or near 0 per plant during this growth period. Significantly lower yields from heavily treated plots may have resulted from insecticide-induced suppression of physiological processes that contribute to the vegetative growth of the lettuce plant and, subsequently, lettuce head weight.

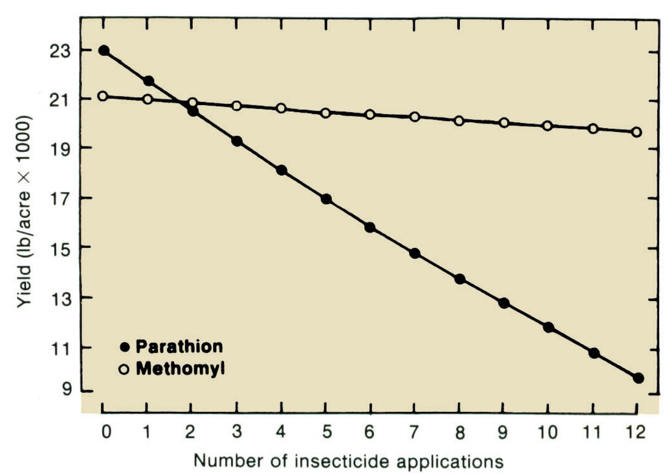
We devised a hypothetical yield response curve (fig. 1), indicating potential "economic" and "pesticide" thresholds based on mean lettuce yields from the Orange and Imperial County studies. Yield was significantly lowest where lepidopterous larvae were unchecked. Yield increased about 30 percent at levels of 2 and 5 larvae per plant. Optimum yields occurred under treatments to maintain levels of 0.5 to 1 larva per plant. Maintaining the lowest level (0), which decreased yield, required an average of three more insecticide applications than maintaining the levels of 0.5 and 1 larva per plant. Optimum

Insecticide applications required to maintain common lepidopterous larval populations below various density treatment levels on lettuce and corresponding yields

Location and date	Density treatment level (larvae/plant)	Number of insecticide applications at stage*: One	Two	Three	Yield† (cartons/acre‡)
Orange County 1977	0.0	1§	4	3	336.5 ab
	0.5	1	1	4	380.7 ab
	1.0	1	1	4	421.1 ab
	2.0	1	1	4	444.8 a
	5.0	1	0	3	439.8 ab
	Check	1	0	0	237.7 b
Imperial County 1977	0.0	2§	6	5	425.2 b
	0.5	2	2	5	518.1 ab
	1.0	2	2	6	559.4 a
	2.0	2	1	6	429.6 b
	5.0	2	1	5	425.7 b
	Check	2	0	0	20.9 c
1978	0.0	1**	5	4	616.6 b
	0.5	1	1	3	634.2 ab
	1.0	1	1	4	715.6 a
	2.0	1	0	3	470.3 b
	5.0	1	0	3	542.4 ab
	Check	1	0	0	461.0 b
Fresno County 1979	0.0	0	7	2	1167.5 ab
	0.5	0	2	3	1384.1 a
	1.0	0	2	2	1265.9 ab
	2.0	0	1	3	1195.0 ab
	5.0	0	0	2	1267.5 ab
	Check	0	0	0	1041.7 b

* Stage One: germination to thinning. Stage Two: thinning to rosette formation. Stage Three: after rosette formation; density treament level changed to 0.05 larva per plant at this stage.
† Numbers followed by same letter are not significantly different by Duncan's multiple range test (P>0.05).
‡ Carton of lettuce weighs 63.8 pounds.
§ Insecticide applied to all treatments to protect seedlings against crickets and flea beetles.
** Insecticides applied to all treaments to protect seedlings against cutworms.





yields may not always occur at these latter two levels, however, because of variations in pest population pressures and damage to the crop by the various species.

Pesticide threshold

Field studies on the influence of the number of insecticide applications on lettuce yields were conducted during the intermediate growth stage, when growers have some flexibility in their control programs. Methyl parathion and methomyl (1 and 0.9 pound active ingredient per acre, respectively) were applied two, four, six, and eight times each during the intermediate growth period. In all treatments, both insecticides were applied twice before thinning and twice following rosette formation. An untreated check was included.

Lepidopterous larval pests remained below one larva per plant during the intermediate growth period in all treatments. Plants treated with methyl parathion produced lettuce heads that weighed less than those in the untreated check. Reductions in head weight and density were correlated with the number of applications of methyl parathion that plants received during the growing season. Plants that received over three methyl parathion applications produced poorly formed (spongy) heads unsuitable for marketing as compared with the tightly wrapped heads produced in the check and methomyl plots. The percentage of lettuce plants that bolted before a marketable head formed increased with the number of methyl parathion applications (from 5 to 57 percent at 0 to a total of 12 applications during the entire growing season).

In contrast, methomyl applications were correlated with increased lettuce head weight without influencing head density. However, a positive correlation was found between the percentage of plants that bolted before formation of a marketable head and the number of methomyl applications per season, although the correlation was not as strong as under methyl parathion applications.

In additional studies at the UC Citrus Research Center, Riverside, on effects of various methyl parathion and methomyl application rates, both materials decreased lettuce leaf photosynthetic rates 24 hours after application. Reductions were of short duration, and photosynthetic rates were not significantly different from those of untreated plants four and eight days after application. However, the temporary reductions were correlated with increases in insecticide application rates. Currently, possible relationships between the suppression of photosynthetic rates by applications of methyl parathion and subsequent decreases in lettuce yield are unknown.

Pesticide-induced yield reductions are not limited to lettuce and have been reported in apples, Bartlett pears, strawberries, and cotton. Our results indicate that lettuce yield reductions caused by the application of methyl parathion resulted from reduced head weight and increased plant bolting. We calculated the total effect of methyl parathion and methomyl applications on these two factors, expressed as yield per acre, based on an initial stand density of 25,490 plants per acre (fig. 2). A maximum yield reduction of less than 7 percent was estimated for plants that received a total of 12 applications of methomyl as compared with the untreated check. Reductions of about 57 percent were estimated for replicates that received methyl parathion applications. A yield reduction of 16 percent was estimated for three applications of methyl parathion.

Summary

Provided that lettuce plants are protected during the heading stage, it is not necessary to maintain the crop insect-free during the entire growing season to achieve high yields and quality produce. Our results indicate that the season-long, low-pest-density approach may cause yield losses resulting from subtle phytotoxic properties of the insecticide applied. Density treatment levels of 0.1 and 1 larva per plant during the seedling and intermediate growth stages, respectively, should permit production of marketable lettuce while reducing the number of insecticide applications made normally.

With regard to methyl parathion applications, a pesticide threshold of no more than three applications is suggested for use on lettuce grown in southern California to avoid insecticide-caused yield reductions greater than 20 percent. This threshold may vary, depending on plant vigor and maturity, chemical adjuvants used with the methyl parathion, and environmental conditions.

Marshall W. Johnson, former Post-graduate Research Assistant, University of California, Riverside, is Assistant Professor of Entomology, University of Hawaii at Manoa; Ken Kido is Staff Research Associate, Cooperative Extension, University of California, Riverside; Nick C. Toscano is Program Director of Pest Management and Entomologist, Cooperative Extension, UC, Riverside; Robert A. Van Steenwyk is Entomologist, Cooperative Extension, UC, Berkeley; Steve C. Welter is Assistant Professor of Entomology, San Diego State University, San Diego; and Norman F. McCalley is Farm Advisor, UC Cooperative Extension, Monterey County. *The authors acknowledge the assistance of William W. Barnett, Area IPM Specialist, Cooperative Extension, Fresno County.*

Harvest and

Jujube, or Chinese date, is a deciduous fruit tree of tropical and subtropical origin, now grown primarily in home gardens in California and Florida. Among problems that have limited development of jujube as a commercial crop in California are several factors related to harvesting and postharvest handling. These include variation in ripening time among fruits, failure of green fruits to ripen after harvest, and poor storageability of ripe fruits on the tree. To help overcome these limitations, we conducted studies on compositional changes associated with maturation and ripening and on optimum postharvest handling temperatures for transport and storage of these fruits.

Fruit characteristics

The fruit of the jujube, *Zizyphus jujuba*, is a drupe that is round to oblong in shape and varies from cherry-size to plum-size, depending on the cultivar. Its skin color changes from green to whitish green to brown during ripening. The thin edible skin surrounds a whitish flesh and a two-seeded stone. Fruits ripen in September. Later, as they dry, the fruits wrinkle and change in color from reddish brown to dark brown. They can be eaten fresh, dried, or candied.

When ripe, jujube fruits contain more sugars and less acidity than most other fruits, which give them a sweet and subacid taste. They have a somewhat pithy and relatively dry flesh, since they contain less water than other fresh fruits.

Composition of ripe jujube fruits (on fresh weight basis)

Component	Range
Water (%)	71.7-74.0
Soluble solids (%)	21.9-23.0
Total sugars (%)	20.2-21.5
Reducing sugars (%)	16.9-18.0
pH	4.68-4.71
Titratable acidity (%)	0.20-0.23
Total phenolics (mg/100 g)	270-305
Total ascorbic acid (mg/100 g)	500-560