systems evaluated were not operating in the optimal range. The empirical results suggest that the emission uniformities of many, but not all, of these systems can be improved through careful attention to pressure regulation, emitter plugging, and the performance of filtration systems.

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Measuring irrigation flow.

Clogged screen.

Lepidopterous pests of tomatoes in southern desert valleys

Robert A. Van Steenwyk

California produces approximately 30 percent of the total U.S. production of fresh market tomatoes and approximately 85 percent of the processing tomatoes. Of the California total, the southern desert valleys produce about 10 percent of the fresh market and 5 percent of the processing tomatoes. The tomato fruitworm, tobacco budworm, and beet armyworm are major pests of both fresh market and processing tomatoes in the southern desert valleys, attacking the fruit and sometimes causing serious economic loss. The tomato fruitworm and beet armyworm also are major pests of tomatoes in other areas of California.

The tobacco budworm was found feeding on cotton in the Imperial Valley, California, in 1972. Before then it had been primarily a pest of ornamental plants. Possibly a new strain of tobacco budworm changed host preference or immigrated into southern California. In 1978, the tobacco budworm was found feeding on tomatoes.

Imperial Valley studies

Studies on seasonal fruitworm/budworm and beet armyworm development and the damage caused were conducted in the Imperial Valley, California, during the 1979 and 1980 growing seasons. In 1979, four fields of commercially grown fresh market bush tomatoes, three fields of commercially grown processing tomatoes, and two untreated, fresh market, bush tomato fields were used. In 1980 four commercial and one untreated field of fresh market, bush tomatoes were used. The commercial fields ranged from 35 to 100 acres, and the untreated fields were 1 acre each.

The fields were planted from mid-January to mid-February. Insecticides were applied to the commercial fields at the grower's discretion. In 1979, 6 to 7 (mean = 6.3) insecticide applications were made in the commercial processing fields and 3 to 15 (mean = 7.25) in the commercial fresh market tomatoes. In 1980, 2 to 5 (mean = 3.25) applications were made to the commercial fresh market tomato fields. The insecticides used were azinphosmethyl, methomyl, methamidophos, endosulfan, dimethoate, and mevinphos.

Each field was divided into four equal sections, and samples were taken from each section in both study years. The fields were sampled weekly for fruitworm/budworm eggs, beet armyworm larvae, and fruit damage.

Fruitworm/budworm egg populations were monitored weekly from March 14, 1979, and from March 20, 1980, until harvest: 12 meters of foliage per field (3 meters per section of the field) were inspected early in the growing season, decreasing to 4 meters per field (1 meter per section) as the season progressed. All eggs were reared to the adult stage in the laboratory for species identification.

Beet armyworm larval populations were monitored weekly from March 14, 1979, to harvest in the commercial fresh market fields, April 4, 1979, to harvest in both the commercial processing and untreated fields, and from March 27, 1980, to harvest in both the commercial and untreated fresh market tomato fields. Monitoring was done by shaking 12 meters of foliage per field (3 meters per section).

Fruit damage was evaluated weekly until commercial harvest by inspections of a minimum of 200 fruit early in the season and a maximum of 400 fruit per field late in the season (50 to 100 fruit per section). In the 1979 study, fruit sampling began on April 3 in the commercial fresh market tomato fields, May 3 in the commercial processing fields, and May 29 in the untreated fresh market fields. In 1980, sampling began on April 23 in the commercial fresh market fields and May 13 in the untreated fresh market field.

All fruit were classified as to the presence of fruitworm/budworm or beet armyworm larvae within the fruit, or internal and external damage without larvae present. Internal damage was that caused by a lepidopterous larva (primarily fruitworm/budworm) feeding within the fruit; external damage, by a lepidopterous larva (primarily beet armyworm) feeding on the outside. All fruitworm/budworm larvae found feeding within the fruit were reared to adults for species identification.

Results and discussion

During the spring of 1979, in all commercial and untreated fields, fruitworm/budworm females had two peak egg-laying periods. One peak occurred on the April 18-25 sampling dates and the other at the end of the growing season. The first egg-laying period was soon after moth emergence from overwintering diapause and averaged from 0.2 egg per meter of foliage in the untreated fresh market fields to 0.8 in the commercial processing fields. In Arizona, fruitworm/budworm moths have been observed emerging from diapause from March through May with a peak in late April.

The second egg-laying period, approximately six weeks after the first

peak (May 30 to June 6), may have resulted from a second generation of moths produced in these fields. The number of eggs per meter of foliage during this egg-laying peak averaged 0.6 in the commercial fresh market fields and 2 in the untreated fresh market fields. When adult moths were reared from these eggs, the tomato fruitworm comprised 71.2 percent of the population and tobacco budworm, 28.8 percent.

In 1980, only one peak egg-laying period of the fruitworm/budworm complex occurred, between May 1 and May 22. The eggs per meter of foliage at the peak averaged 0.6 in the commercial fresh market fields and 2 in the untreated field. The delayed egg-laying in 1980 as compared with 1979 may have resulted from cooler temperatures during the spring of 1980. The species composition was similar to that in the previous year's study: 75 percent were the tomato fruitworm, and 25 percent tobacco budworm.

The mean number of beet armyworm larvae per meter of foliage in the untreated fields increased gradually during the spring of 1979 (less than 0.5 larva per meter until May 16), reaching a peak of 8.6 larvae per meter on June 6. This late-season increase may have resulted from the dispersal of moths from nearby mature alfalfa and sugarbeet fields, where beet armyworm populations normally reach a peak in late May and early June in the Imperial Valley. In the commercial fresh market tomato fields, larval activity reached a peak on April 14 (1 larva per meter) and again on May 2 (2 larvae per meter). In the commercial processing tomato fields, only one peak occurred (1 larva per meter on May 2). In commercial fresh market and processing tomato fields during 1979, the late-season population buildup was suppressed by repeated application of insecticides.

In 1980, beet armyworm population trends were similar to those in 1979. In the untreated fresh market tomato field, the population was less than 0.5 larva per meter through the early spring, reaching a peak of 4 per meter on May 29. In the commercial fresh market fields, populations were similar to those in the untreated field until late in the growing season, at which time beet armyworms were suppressed by repeated insecticide applications.

The percentage of fruit damaged by all lepidopterous larvae in 1979 was 5.3, 6.1, and 21.7 percent in the commercial fresh market, commercial processing, and untreated fresh market tomato fields, respectively (see table). In 1980, damaged fruit decreased to 2.7 and 8.5 percent in the commercial and untreated fresh market tomato fields, respectively. Most lepidopterous larvae found in the fruit were fruitworm/budworm, and there was little difference in infestation between commercial and untreated fields. Means of 0.5, 0.9 and 0.8 percent of the fruit in commercial fresh market, commercial processing, and untreated fresh market tomato fields, respectively, were infested with fruitworm/budworm in 1979. In 1980, a mean of 0.6 percent fruit was infested by fruitworm/budworm in both commercial and untreated fresh market tomato fields.

The lack of difference between the treated and untreated fields in the number of larvae found in the fruit may have resulted from the egg-laying behavior of fruitworm/budworm. These insects generally lay eggs on the periphery of the plant near the flowers. This behavior may allow the larvae to enter the fruit with little exposure to insecticide residues. Thus, spring tomatoes provide a suitable host crop for larvae that arise from the overwintering generation of both the tomato fruitworm and the tobacco budworm. Subsequent generations of these pests may also cause considerable damage to cotton in the southern desert valleys during the summer.

When fruitworm/budworm larvae present in the fruit were reared to adults, the population was 70 percent tomato fruitworm and 30 percent tobacco budworm in 1979, and 77 percent and 23 percent, respectively, in 1980. These percentages are similar to those obtained from the foliar egg samples, indicating that there was no apparent change in species composition and no apparent species-specific mortality.

The mean percentage of fruit infested by beet armyworm in 1979 was 0.2 and 0.1 in commercial fresh market and processing fields, respectively. In untreated fields, the percentage increased to 1.2, apparently as a result of a large late-season population increase. Until recently, the beet armyworm was not known to feed internally in tomatoes. It apparently has changed its feeding habits and now feeds externally and internally in much the same manner as the fruitworm/budworm. In 1980, the mean percentage of fruit infested by the beet armyworm was 0.1 and 0.2 in commercial and untreated fields, respectively. The late-season population increase in the foliage in the untreated control was not reflected in the number of beet armyworm larvae infesting the fruit.

The mean percentage of fruit internally or externally damaged without larvae present accounted for most of the damaged fruit. Internal damage, caused primarily by fruitworm/budworm, was generally less severe than external damage, caused primarily by beet armyworm. From these studies, the beet armyworm appears to be an important pest of both fresh market and processing tomatoes and may cause as much damage as, or more than, the fruitworm/budworm complex does, despite repeated insecticide applications.

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Beet armyworm larva feeding on green tomato.

Tomato fruit injured by the fruitworm/budworm complex and beet armyworm in Imperial Valley, California, 1979 and 1980

Field type	Mean % fruit infested		Mean % fruit damaged		Total
	Fruitworm/ budworm	Beet armyworm	Inter- nally	Exter- nally	% damage
		1979			
Commercial fresh market	0.5	0.2	1.7	2.9	5.3
Commercial processing	0.9	0.1	2.4	2.7	6.1
Untreated	0.8	1.2	6.3	13.4	21.7
		1980			
Commercial fresh market	0.6	0.1	0.5	1.5	2.7
Untreated fresh market	0.6	0.2	1.1	6.6	8.5