Corn earworm larvae can feed on foliage, as at right, but damage to the fruit is of more concern. Quality standards permit only one larva per 1,100 berries.

Corn earworm outbreaks in strawberries

William D. Wiesenborn ❑ John T. Trumble ❑ Victor Voth

Their infrequent, but damaging, occurrences may be related to environmental factors

One of the most damaging and widespread insect pests in North America is the corn earworm, whose varied diet is reflected in its other common names—tomato fruitworm and cotton bollworm. In coastal southern California, occasional outbreaks of this insect, *Heliothis zea* (Boddie), have occurred on strawberries. Severe outbreaks have been reported approximately once every ten years; infestations during other years have been moderate or absent.

Young (early-instar) larvae burrow into fruit and usually feed within the air pocket at the center. The site of penetration into the fruit is often so small that there is no obvious sign of initial infestation. After both the larva and fruit mature together, the fruit usually appears seedy and has a sunken surface with a dry, brown patch.

Burrowing by larvae into strawberries presents the grower with two problems. First, the U.S. Department of Agriculture tolerance for insects in strawberries to be processed is extremely low. Only one larva 7 mm or longer is permitted per 44 pounds of produce. Since it takes about 25 strawberries to make a pound, more than one larva in 1,100 berries can result in downgrading to juice stock. Second, accurate sampling is impractical because the fruit would have to be cut open—a problem compounded by the extremely low economic injury level.

We reviewed the Cooperative Insect Pest Report, California Bureau of Entomology, to determine when the corn earworm was recorded as a pest on strawberries during 1953-61 and 1963-69. We also included a published account of an outbreak in 1968 and our own observations during 1980-86. No information was available for the years 1970-79. Corn earworm infestations on strawberries were assigned one of three scores: 1 for no infestation, 2 for moderate, or 3 for severe.

In the 23 years examined, severe outbreaks took place three times—during June 1957 in Los Angeles County, April 1968 in Orange County, and May 1983 in San Diego County. The region most affected in 1983 was the San Luis Rey River Valley near Vista, where 0.5 to 3 percent of fruit were infested. During the 1983 outbreak, moderate infestations also occurred in Orange County and light ones in Ventura County. Moderate infestations were reported during April 1959, April and May 1960, and March 1961 in Orange County, and April 1984 in San Diego County.

Winter survival

The factors influencing this sporadic pest problem are not completely understood. Pupae of the corn earworm overwinter about 2 cm deep in soil. Adults typically emerge during April and May in coastal southern California, and it is their egg-laying that can cause larval infestation of strawberries. Adults of the next generation do not begin to emerge until around June when strawberry production is coming to an end. One factor may therefore be the proportion of pupae surviving the winter. Studies have shown that the winter survival of corn earworm pupae typically is very low, even along the southern edge of the United States where temperatures are moderate.

Winter survival of pupae probably would be affected by the intensity and duration of cold temperatures. We estimated the degree-days (double sine) below 59°F, the lower threshold of post-diapause (after-dormancy) pupal development, accumulated during December, January, and February to compare the coldness of each winter. Daily maximum and minimum air temperatures, monitored at the Irvine Ranch in Orange County, were used because reliable data on soil temperatures were not available for all the years or for the locations studied.

The total degree-days of coldness and the level of corn earworm infestation in strawberries were not related statistically (table 1). Two observations can be made from this comparison, however. First, all three years with severe infestations and two of the four years with moderate infestations had fewer total degree-days of coldness than the median. Most outbreaks were therefore preceded by mild winters that may have permitted increased survival of overwintering pupae. Second, six years had fewer total degree-days of coldness than the mildest winter in which severe infestations occurred (1957). Infestations were absent during five of these years and moderate during one (1984). Although a warm winter appears to have been required for a severe outbreak to take place the following spring, it did not by itself guarantee an outbreak.

Rainfall also has been implicated as an influence on winter survival of the corn earworm. Although flooding of the soil would be expected to decrease survival, at least one study has indicated that winter rainfall may increase survival. Total rainfall during December, January, and February at the Irvine Ranch was compared with the yearly levels of corn earworm infestation in strawberries. Total rainfall and the level of infestation were not correlated statistically (table

1). Several years (1958, 1967, 1980, 1986) had fewer total degree-days of coldness than the median and rainfall greater than the median, but they had no infestations.

Early emergence

Although corn earworm adults may lay eggs on a variety of plants, potential hosts vary in suitability for larval development and survival. Some plants, such as corn and tomatoes, are preferred. The moths may lay eggs on strawberries, a nonpreferred host, if adults emerge unusually early in the spring when preferred hosts are rare. Such early emergence would be due to unusually warm spring temperatures. To determine whether the timing of spring emergence may have influenced corn earworm infestation of strawberries, we calculated the degree-days (double sine) above 59°F accumulated during January, February, and March. Once again, we used air temperatures monitored at the Irvine Ranch.

The accumulated degree days were not statistically related to the yearly infestation levels of corn earworm in strawberries (table 1). However, four of the six years with the greatest total degree-days had either moderate (1959, 1961, 1984) or severe (1968) infestations. Outbreaks during those years occurred in March or April, earlier than in other years, when outbreaks were reported in April and May, May, or June. Although unusually high spring temperatures with early emergence of moths may have been important during some years, this factor by itself seems to have been more responsible for moderate than severe infestations.

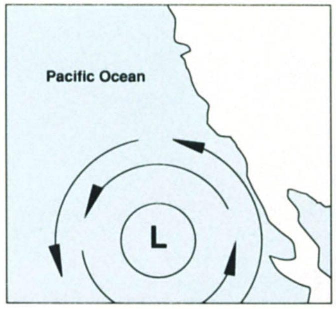

Fig. 1. Counterclockwise air circulation around a low-pressure cell caused unusual southeast winds along the southern California coast in April 1983 and may have brought corn earworm moths into the area.

TABLE 1. Yearly infestation levels of corn earworm in strawberries in relation to temperatures and rainfall*

Year	Infestation level†	Degree-days <59°F‡	Rainfall‡	Degree-days >59°F‡
		°D	*inches*	°D
1953	1	723	4.30	319
1954	1	688	6.41	**274**
1955	1	793	5.82	238
1956	1	673	8.83	207
1957	3	559	6.09	249
1958	1	477	9.85	275
1959	2	626	4.33	341
1960	2	730	7.00	201
1961	2	637	1.13	362
1963	1	541	2.48	287
1964	1	689	1.38	268
1965	1	**632**	2.29	247
1966	1	743	**5.77**	234
1967	1	564	7.97	307
1968	3	593	2.71	385
1969	1	719	17.39	168
1980	1	407	16.07	364
1981	1	507	4.90	345
1982	1	680	4.25	156
1983	3	560	7.06	212
1984	2	506	3.87	418
1985	1	640	5.26	232
1986	1	522	7.15	340

* Total degree days < 59°F and rainfall during December of previous year, January, and February; and total degree days > 59°F during January, February, and March. Median values are in boldface.
† 1 = absent, 2 = moderate, 3 = severe.
‡ Not correlated with infestation level ($P > 0.5$, Kendall's coefficient of rank correlation).

The preference of the adults for highly suitable hosts can be exploited to reduce corn earworm infestations in strawberries. Planting a trap crop of a more preferred host nearby may reduce pest density in a particular field. We have found that the distance to a trap crop influences corn earworm density more than the total area of the trap crop. It may not be economical to plant a trap crop solely for the purpose of protecting strawberries considering the infrequent occurrence of corn earworm outbreaks. But a strawberry field could be located next to a cornfield, for example, that is to be planted in any case.

Wind-borne immigration

If mild winter temperatures contributed to the severe outbreak during 1983, but was not by itself responsible, another question is what additional factors may have been involved. One answer may lie in the corn earworm's ability to migrate large distances. In the southwestern United States, wind carries this insect hundreds of miles northward during the spring. Although insect migration is not well understood, migrating moths of several species fly upward at dusk, concentrate at the top of temperature inversions, and fly downwind throughout the night. Wind patterns favoring migration have been correlated with outbreaks of several moth species related to the corn earworm.

We found that the spring flight patterns of corn earworm in Orange County may be influenced by immigration from the southeast along the coast. A sudden increase of moths during mid-April 1986 and a similar increase in egg-laying on corn about four days later followed a single period of nighttime southeast winds (110°-170° from N) at an altitude of 1,600 to 5,000 feet over San Diego. There were temperature inversions at these same altitudes.

Southeast winds along the southern California coast are infrequent during the spring. During March, April, and May of 1981-85, winds similar to those observed in 1986 occurred only three times: during two consecutive nights in April 1983, one night in May 1984, and one night in May 1985. A favorable wind direction for immigration on April 16-18, 1983, may have contributed to the outbreak of corn earworm larvae in strawberries during the next month. This unusual wind pattern was caused by a low-pressure center off the southern California coast (fig. 1). The timing of such an immigration agrees with the timing of maximum infestation during the last two weeks of May, because it would have taken about a month for third-instar larvae on strawberry plants to develop from eggs. Natural vegetation as well as crops along the Pacific coast in Baja California may have been the source of immigrant moths; the corn earworm is native to North America and is known to develop on uncultivated plants. An immigration would require that both suitable wind direction and emergence of moths in the source region take place simultaneously.

Conclusions

Outbreaks of the corn earworm in strawberries have been rare (seven in 23 years), and no trend exists to suggest that they are becoming more frequent. Although a statistical relationship was not evident (possibly due to small sample size), the occurrence and severity of outbreaks may be associated with several environmental factors.

One factor is the intensity and duration of cold temperatures during the winter that would probably influence pupal survival: severe outbreaks took place only following mild winters. A mild winter by itself, however, did not guarantee an outbreak.

The timing of spring emergence also may be important. Early emergence of adults before the availability of preferred hosts may cause them to lay eggs on less preferred hosts, such as strawberries. The moderate outbreaks during 1959, 1961, and 1984 and the severe outbreak during 1968 were all preceded by warm spring temperatures, which caused early emergence.

Finally, we suggest that wind-borne immigration contributed to the severe outbreak during 1983 by causing an unusually large population buildup.

William D. Wiesenborn is a graduate student, and John T. Trumble is Associate Professor, Department of Entomology, University of California, Riverside; Victor Voth is Pomologist, UC South Coast Field Station, Irvine. *The authors are grateful to the Irvine Ranch and Osumi Farms, Tustin, and to the Smuckers Corp., especially Rufus Lalone, Woodburn, Oregon, and Bonita Roth, Watsonville. Degree-days were calculated with the UCIPM computer system. This study was made possible by generous funding from the California Strawberry Research Advisory Board.*