The Benefits of Insecticide Use: Tomatoes

Tomato Fruitworm Damage

Tomato Pinworm Damage

Whitefly Damage (Irregular Ripening)

Dumping Insect Infested Tomatoes

March 2009

Leonard Gianessi
Key Points

- Tomato fruitworm larvae bore deeply into the fruit and will destroy about 20% of the tomatoes in a field.
- In the 1930s the tomato pinworm reduced the California tomato crop by 25%.
- Prior to the development of effective insecticides, whiteflies caused annual losses of $25 million in Florida tomatoes.
- Tomato shipments exceeding 2% insect infestation are rejected by processors.

Technical Summary

Growers in eighteen states harvest 25 billion pounds of tomatoes with a value of $2.3 billion from 429,000 acres. Insecticides are used on 95% of U.S. tomato acres. USDA estimates that without insecticides U.S. production of fresh market tomatoes would decline by 64% while processing tomato production would decline by 51% [30]. Individual state losses without the use of insecticides would range from 15% to 100%.

Nationally, 28 arthropod species cause damage to fresh market and/or processing tomatoes. The tomato fruitworm is the number one insect pest throughout the country followed by armyworms, aphids, and stink bugs. Other significant pests include whiteflies, (#1 in Texas and Florida), flea beetles, tomato pinworm, and cutworms. Russet mites are a severe pest in California. Colorado Potato Beetle is the number one pest in the mid-Atlantic states. Leafminers are the #2 pest in Texas and Florida while thrips rank as #1 in Georgia [30].

Beginning in the early 1900s lead and calcium arsenate were recommended for control of tomato fruitworms. Research showed that one spraying with arsenic killed half of the worms [35]. Calcium arsenate was long used as the primary insecticide for controlling fruitworm populations on tomatoes in the U.S. [36]. Research in the 1940s demonstrated that DDT applications provided superior efficacy for fruitworm control reducing the damage by 95% in comparison to a 59% reduction with calcium arsenate and a 57% reduction with cryolite [37]. DDT reduced the percent damaged tomatoes from 18% in the untreated plots to .9% while calcium arsenate and cryolite reduced the damage to 7%. By 1948 nearly all the acres of tomatoes in northern California were treated with DDT [38]. The DDT sprays were credited with the delivery to canners of fruit almost completely free of worm infestations [39]. Since the early 1970s carbamate insecticides have been widely-used for worm control in tomatoes (methomyl). Recently-introduced insecticides have been shown to reduce damage from caterpillars from 32% to 1% [41].

The tomato pinworm was largely responsible for making the growers pest-control conscious in southern California in the 1930s because they found that their crop could be a total loss if control measures were not applied [16]. The discovery of the tomato russet mite in 1940 and its rapid spread by 1942 made the growers over the entire state extremely pest-control conscious. Records show that 14,000 acres of tomatoes in California were dusted by airplane in 1936, 29,000 acres in 1942, 85,000 acres in 1946, 121,000 acres in 1950, and 411,000 acres in 1951 [16].
A study of tomatoes in Virginia revealed that uncontrolled thrips, stink bugs and fruitworm lowered marketable yield by 33% while in the insecticide-treated plots insect-damaged fruit was <.5% [27]. Insecticide costs ($230/A) represent about 5% of the cost of tomato production in Virginia. This expenditure prevented losses of from $3000-$6,883 per acre [27]. In North Carolina insecticide control of fruitworm and stink bug increased marketable tomato yield by 36% and increased net profit by $1,115 per acre [28]. In Alabama, a net profit of $1218 per acre was gained from controlling the fruitworm with a $74/acre insecticide spray [31].

Insecticide costs represent 1-5% of the costs of producing an acre of tomatoes: $27/$2200 (California), $80/$2400 (Michigan and $546/$11,101 (Florida) [32]-[34].

Biological controls have generally not been shown to be a commercially viable treatment option for many pest species present in fresh market tomatoes [59].

There have been few efforts to develop biological control programs for lepidopterous pests of fresh market tomato, primarily because of the crop’s low tolerance for insect damage and the availability of effective insecticides [29].

The value of fresh market tomatoes is entirely dependent upon the quality of the crop and, as a consequence, very little cosmetic damage can be tolerated.

An 18-year study of lepidopteran pests in California indicated that control was necessary in 16 out of 18 years (Figure 1).

All loads of processing tomatoes in California are evaluated by inspectors from the Processing Tomato Advisory Board, a marketing order, under the direction of supervising inspectors of the California Department of Food and Agriculture. A load of processing tomatoes is rejected if 2% or more of the tomatoes by weight have a worm or excreta in the flesh of the tomato [17][62]. A recent test estimated the number of insect fragments that would be present in processed tomato products depending on the percent of incoming tomatoes infested with insect larvae [62]. With a 2% infestation, there were 15 insect fragments per 200 ml of juice while with a 10% infestation in the incoming tomatoes there were 60 insect fragments per 200 ml of juice. It was interesting that there were detectable insect fragments in the processed juice even from the incoming tomatoes which had been considered to have a zero infestation level which indicates the difficulty of detecting all of the insects present in a sample (Figure 2).

**Flea Beetle**

Flea beetles derive their name from their well-developed hind legs; when disturbed, they jump like fleas. Tobacco flea beetle females can lay up to 200 eggs. Flea beetles are among the most injurious insect pests of young tomato plants [1]. Flea beetles are most common on early plantings; they apparently fly into tomato fields from weed hosts where they overwintered. In one study of 12 fields of tomato seedlings 50% of the plants were
fed upon by flea beetles [4]. The main damage is caused by the adults which kill or severely stunt small plants by feeding on the leaves and growing points [2]. High populations of flea beetles feeding on young plants can result in stand loss. Insecticides are widely-used against this pest on seedling tomatoes [2]. A single treatment is generally adequate for damaging populations. In one experiment insecticide application reduced the number of flea beetles from 30 per square feet to 3 [2]. Sprays of pyrethrin are organically acceptable for managing flea beetles [3]. In Michigan flea beetles can cause crop loss of 20% [42].

**Cutworm**

Cutworms are the most damaging pests of tomato seedlings in most areas [5]. They are generally night feeders and chew through stems at the soil line, reducing the stand.

**Beet Armyworm**

Beet armyworms are a widespread pest found in tomato fields every year. In some areas beet armyworm may be the most important caterpillar attacking tomato [3]. Eggs are laid on leaves in clusters of 50 to 150 covered with hairlike scales left by the female moth. Beet armyworm females normally deposit 300-600 eggs during their lifetime. There may be more than 100 eggs per cluster. The beet armyworm attacks both foliage and fruit, creating single or closely grouped circular or irregular holes. These holes are seldom contaminated with feces, because larvae usually feed with only the fore part of the body inside the fruit. In processing tomatoes, feeding is superficial and little loss would result if not for decay organisms that enter wounds and rot the fruit [3]. In fresh market tomatoes, the presence of the holes results in unmarketable fruit [3]. Beet armyworm eggs are generally protected from the parasite *Trichogramma* by their covering of scales [5]. Beet armyworms are often killed by a viral disease called nuclear polyhedrosis. The dead larvae turn black and become limp, often hanging from leaves. The body eventually disintegrates, releasing virus particles that readily spread to other larvae [5]. In the early 1980s, this microbe was manufactured under the name Elcar and marketed mainly for use in cotton. The material was never registered for tomatoes. Elcar was more expensive and slower acting than other insecticides and could not survive the competition. The manufacturer began phasing out the product in 1985.

Sprays of the Entrust formulation of spinosad and Bt are acceptable in an organic crop [3].

In tests in Florida, the percent of armyworm damaged fruit in a recent test was reduced from 40% in the check plot to 1% in the insecticide treated plots [45].

**Stink Bug**

Several kinds of stink bugs feed on tomatoes, but all are similar in life history and damage. The most common species statewide in California is the consperser stink bug. The redshouldered stink bug is considered the most prevalent species in the southern San
Joaquin Valley. The southern green stink bug occurs in parts of the Sacramento and northern San Joaquin valleys. When disturbed, they produce a strong odor that gives them their common name.

Adults overwinter in protected areas such as under leaf litter or brush. Early in the spring, they begin feeding on weeds or lush crop plants, if available. As these dry out, they migrate into tomato fields. Adults lay about 100 barrel-shaped eggs in groups of 25 to 70.

Stink bugs have become a major problem for production of tomatoes in California. Stink bugs feed by inserting stylettes and sucking up the plant juices. Stink bugs inject a toxin during feeding which results in a white corky area that is especially noticeable as the fruit ripens, rendering it unmarketable for either the fresh market or whole peel processing [7]. A white corky mass of unripened tissue is revealed when the skin is peeled back. The injury hardly extends to a depth of more than one sixteenth to one eighth of an inch. The tissue below this area appears normal in every respect. Processing companies have a low tolerance for stink bug feeding damage to tomatoes. 5% is the maximum damage acceptable to many growers and 5 stink bugs per 2 m of row would result in 5% damage [6]. The presence of stink bugs can also be detected by the brown liquid frass that they produce, which leaves dried spots on fruit and leaves.

Stink bugs also carry yeast and other pathogens that may cause decay when introduced into fruit on the bug’s mouthparts. This damage is scored as “mold” by state graders. Processing tomato growers whose crop is intended for paste can tolerate high levels of injury and may not need to treat for stink bugs except as protection from disease transmission [7].

The southern green stink bug is a new species in California and was first collected in the early 1980s [8]. Importation of natural enemies of the southern green stink bug to California began in early 1987. The egg parasitoid, *Trissolcus basalis* proved to be an excellent natural enemy and was selected for release. The parasitoid overwinters in California and keeps the southern green stink bug at relatively low levels by destroying up to 90% of their eggs [3]. *Trissolcus basalis* does not parasitize the other stink bug eggs [3].

A recommended cultural control method is to destroy weeds that are overwintering hosts for stink bugs around fields that are planted to tomatoes. A drawback to this method is that it denies habitat to a number of beneficial insects like lacewings and lady beetles.

Kaolin clay and insecticidal soap sprays are acceptable for use in organically certified tomatoes. 30-50 pounds of kaolin per acre is effective in protecting the fruit surface from stink bug feeding, Kaolin clay applications result in a thick, white deposit that coats the fruit and must be washed of, limiting its potential for use [3]. Expected field efficacy with insecticidal soap sprays is 30-50% [3].

When stink bugs were first identified as a major pest of tomatoes in California in the early 1950s, toxaphene was used for control [9]. Parathion was used for many years for
stink bug control. Insecticides are the only method of obtaining effective control of stink bugs [43].

**Tomato Russet Mite**

Mites have eight legs and therefore are not classified as insects, which have six legs. The tomato russet mite is arrhenotokous; that is, unfertilized eggs develop into males only, which usually develop fast enough to mate with the mother and produce a normal bisexual generation [10].

The tomato russet mite is the principal arthropod pest of tomato foliage in California [11]. Surveys have shown that mite damage symptoms were found in 60% of the processing tomato fields in the Sacramento Valley [11]. The tomato russet mite was first described in Australia in 1937 and was first recorded in the U.S. in California in 1940. Within two years, it spread rapidly throughout the state and spread through the southwestern states. By the early 1950s it appeared in damaging numbers in eastern and north central states [10].

Russet mites are so small that a 14X hand lens is needed to see them. Because of their size, these mites are rarely noticed until plants are damaged when there may be hundreds on each leaf. Russet mites remove cell contents from leaves and stems. Usually starting near the ground, infestations of this mite progress up the plant, and lower leaves dry out. Tomato russet mites can defoliate tomato plants, especially in hot weather when mite populations explode and when damaged foliage quickly dries out. If not controlled, the mite can kill tomato plants in a few days. [3]. The killing action is probably due to the saliva produced by the mite. Fruit damage results from sunburn which occurs following leaf drop. Resultant crop losses in individual fields can reach 50% [11].

There is evidence that tomato is not the original evolutionary host of the russet mite since its feeding on tomato quickly kills the plant, a disadvantage for a plant parasite [12]. Damage from the mite to other hosts (such as petunia and bindweed) is less extensive than to tomato and they have been identified as overwintering sites. The mites are blown or carried into tomato fields from these winter hosts.

Natural enemies of the tomato russet mite appear to be few. A predacious mite feeds on all its life stages. However, in commercial fields, the predacious mite does not occur in sufficient numbers to prevent breeding of high populations [15].

Control experiments were begun in 1942 and demonstrated that sulfur sprays killed 99% of the tomato russet mites [13]. Sulfur has been widely-used ever since for control of the tomato russet mite [14].

Mined sulfur dust or sprays are acceptable on organically certified tomatoes.

**Tomato Fruitworm**
The tomato fruitworm is the most serious insect pest of tomatoes in the U.S., feeding on fruit and contaminating it with insect parts, excrement, and decay-causing organisms. Fruit injured early in the season often rot before harvest. They usually bore deeply into the fruit, feeding with the entire body inside. Destruction without some type of control measure will usually amount to 20 to 30% of the tomato crop [19]. Insecticide applications can reduce the damage to less than 2% [20].

The tomato fruitworm, also called the corn earworm or cotton bollworm, is a pest of several crops including tomatoes, cotton, beans, and sweet corn. The adults are excellent fliers capable of dispersing over wide areas. Egg-laying females are attracted to plants in flowering and fruiting stages. There are more generations of fruitworms, and more severe infestations, in southern than in northern states. Four or five generations are produced each year in southern areas. A single female may lay 500 to 3000 eggs [40]. Fruitworms are very cannibalistic and when two meet, the larger one is usually victorious. The individual fruit usually produces a single fruitworm larva.

When there is fruit present, the tomato fruitworm will complete its larval development inside fruit. Larvae enter fruit at the stem end. Caterpillars may emerge from one fruit and enter another. If a tomato becomes juicy or sour, the larvae go to another one [16]. Each worm damages an average of 4.8 tomatoes. Their feeding results in a messy, watery, internal cavity filled with cast skins and feces [3]. Late in the season, small larvae will enter ripe fruit. A tomato containing a larva or its skin or excrement, can easily be included in shipments from the field to canneries or to market [16]. When an infestation is severe, more than 50% of the fruit may be destroyed [40].

When control is needed, it is essential to treat before large numbers of larvae enter fruit, where they are protected from sprays.

During the first half of the 1900s, arsenic sprays were recommended for the control of the tomato fruitworm. They were less than 50% effective [16]. Tomato growers were inclined to grow their crops and take a chance on the pests rather than go to the expense of applying insecticides [16]. Calcium arsenate was applied at 15 to 25 lbs/acre [40].

Interest in improvement of methods for control of the tomato fruitworm on tomatoes was accelerated in 1935 by the finding of worm fragments in canned products, which were subsequently seized and destroyed as contaminated foods by the FDA [16]. Studies on control methods were begun by USDA in California, Utah and Ohio beginning in 1936. From 1937 through 1946 an average of 13% of the fruits in the untreated plots were damaged. The most heavily damaged fields averaged 50% damage.

Beginning about 1936 improved control (60-70%) was obtained by using calcium arsenate or cryolite at higher dosages and with better timing of applications. In the 1940s, with a tomato crop value of $400/A and a cost of $25/A for the cryolite sprays, the increased profit after deducting the cost of dusting was calculated at $25/A.
The demonstration of the effectiveness of DDT in 1944 marked the beginning of a new era in fruitworm control with 90-98% effective control [16]. In 1947 the infestation of fruitworm was one of the most severe ever encountered. Nearly 80% of the fruit in the untreated plots were infested while DDT applications resulted in 2% infestation levels [36]. DDT was applied at 30 lbs of a 5% dust per acre.

The microbial insecticide Bt generally kills about 40-60% of tomato fruitworm larvae [5]. Sprays of Bt and the Entrust formulation of spinosad are acceptable for organic producers [3].

There is a diversity of natural enemies that can impact tomato fruitworm populations, including egg parasites, larval parasites, and predators. However, because of the low tolerance for damage to tomato, the combined action of these natural enemies does not provide economic levels of control [43]. A tomato fruitworm egg parasite, *Trichogramma pretiosum* was observed to destroy about 50% of the fruitworm eggs. Accordingly, starting in 1966 efforts were directed toward assessing the effectiveness of weekly releases of large numbers of *Trichogramma* under field conditions [21]. Twice weekly releases increased parasitism to about 80%. Further work with *Trichogramma* releases combined with weekly Bt applications demonstrated a reduction of fruitworm damaged tomatoes to 1.6% in comparison to 7.1% in the untreated plots and .7% damage in plots treated weekly with methomyl [22]. Approximately 1.2 million parasites were released per hectare. However, released parasites are not always effective [3]. The poor quality of commercially available *Trichogramma* makes the use of this practice questionable [43]. There has been no adoption of this approach in California [65].

**Tomato Pinworm**

Where abundant, the tomato pinworm may infest nearly 100% of the fruit [3][36]. They make dry burrows in the core and do not penetrate very far into the fruit. When infested fruit is picked, caterpillars may be difficult to detect unless they have been feeding long enough to create small piles of brown, granular frass at the edge of the calyx [3].

The tomato pinworm is a key pest of tomatoes in the southern portions of California, Texas and Florida. It originated in Mexico and Guatemala. The tomato pinworm was first discovered in the U.S. in 1923 in Imperial County, California. One large tomato packer and shipper near San Diego estimated that 40% of the entire tomato crop in that county in 1930 had been destroyed because of the tomato pinworm [48]. Many of the fields were abandoned after one or two attempts to market fruit from them. In southern California the damage caused by the pinworm in 1936 reduced the potential value of the tomato crop grown for the fresh market by 25% and caused a reduction in the canning crop of approximately 20% [49].

Six primary parasites attack tomato pinworm larvae, but natural control does not prevent fruit damage [50]. In California, parasitism of the tomato pinworm on tomato plantings sprayed only with Bt reached as high as 100% [47]. Despite this high level of parasitism,
the percentage of fruit infested still reached as high as 76%; parasitized larvae may still infest fruit before being killed.

Pheromone mating disruption for the pinworm is practiced on 50% of the fresh market acres in California [30]. Pheromone mating disruption can be effective in isolated fields and where all tomato fields in an area are treated. In fields surrounded by untreated fields, females may mate in the untreated fields and migrate into treated fields to lay eggs. Also some behavioral or physiological change may occur in the pinworm population in response to an environment altered by pheromone applications. Or some males may find females visually [51]. As a result, in some experiments there has been no reduction in infested fruit between the pheromone treatments and the untreated control [52]. Pheromone-mediated mating disruption is not recommended in states such as North Carolina where pinworm is a sporadic pest [43].

In experiments in Florida, insecticide treatment for pinworms increased the pounds of marketable fruit per 14 plants from 3 to 115 [61].

Leafminers

There are three leafminer species attacking tomato plants. They are similar in life history. Eggs are inserted in leaves and larvae feed between leaf surfaces, creating a meandering track or “mine.” At high populations, entire leaves may be covered with mines. Mature larvae leave the mines, dropping to the ground to pupate. The life cycle takes only two weeks; there are seven to ten generations a year. All three species feed on a wide variety of crops and weeds; development continues all year and the population moves from one host to another as new host plants become available.

Leaves injured by leafminers drop prematurely; heavily infested plants may lose most of their leaves. Defoliation can reduce yield and expose fruit to sunburn. Research in California has demonstrated that uncontrolled leafminers can reduce tomato yields by 15-25% [23].

Leafminers have been a major pest of tomatoes in Florida since the 1940’s. Losses in 1997 amounted to about 10% of the crop.

Sprays of the Entrust formulation of Spinosad are acceptable for organic production [3].

Whiteflies

Several species of whiteflies (sweet potato and silverleaf) infest tomato. Whiteflies are found mostly on the underside of leaves. After finding a suitable feeding site, the crawlers insert their mouthparts, begin feeding and usually do not move again. Whitefly feeding causes leaves to yellow and curl. Whitefly honeydew causes leaves to appear shiny or blackened (from sooty mold growing on the honeydew). This honeydew-induced fungus often covers both foliage and fruit, retarding growth and reducing the market value of the fruit. Feeding by silverleaf whitefly is especially damaging because it also
causes fruit to ripen unevenly. The disorder is characterized externally by inhibited or incomplete ripening of longitudinal sections of fruit and internally by an increase in the amount of white tissue. Whitefly has been found to be the vector of tomato infectious chlorosis virus, a virus capable of causing heavy losses in the production of tomatoes. The host range of the sweet potato whitefly includes over 500 species of plants.

The sweet potato whitefly has been noted in Florida since the late 1800s but has only been considered a pest in the state since 1986 [24]. By the fall of that year the insect was detected in all tomato growing regions of the state but was present in relatively low numbers. The first outbreak of the sweet potato whitefly in Florida tomatoes began in the late fall of 1987 in southwest Florida and continued into the spring. In that season, losses were estimated to be at least $15 million [24]. It is believed that the sudden emergence of the severe problem on tomato is related to the introduction of a new strain of whitefly, possibly introduced on poinsettia cuttings from the Middle East.

Research in California demonstrated that uncontrolled whiteflies reduced ripe tomato yields by 25%; 48% of the tomatoes showed irregular ripening when whiteflies were uncontrolled [25].

A marked reduction in whitefly incidence in Florida coincided with the availability and widespread use of the systemic insecticide imidacloprid [26] [68]. Research shows that the insecticide reduced the number of silverleaf whitefly crawlers from 74/10 leaves to 3 [46].

Adult silverleaf whiteflies are repelled by silver-or aluminum-colored mulches. The mulches lose their effectiveness when more than 60% of the surface is covered by foliage. Therefore, they are effective only for the first few weeks after seedling emergence or transplanting [3].

Sprays of insecticidal soaps and neem oil are acceptable for use on organically certified tomatoes [3].

Potato Aphid

The potato aphid feeds by inserting a stylet into plant tissues and withdrawing plant sap. Curling and stunting of leaves and stems is the most obvious damage. This damage reduces fruit set and, if severe enough, can kill the plant. In addition as a byproduct of feeding, aphids excrete honeydew, which acts as a growth medium for sooty mold. The black-colored mold, on the foliage, reduces the light available for photosynthesis and on the fruit, causes discoloration and acts as a solar heat sink, increasing the severity of fruit sunburn [53]. High levels of aphids cause significant fruit quality and yield losses. Fruit quality loss also results from sunscald because of plant defoliation resulting from aphid feeding [54].

In California the potato aphid is attacked by a number of parasites and predators, but populations of these natural enemies usually build up after the aphids have already
reached high densities and caused significant damage to the crop [54][59]. Natural enemies of the potato aphid are subject to a high level of hyperparasitism which limits their usefulness in controlling the aphid [55].

The potato aphid is commonly found on processing tomatoes in the San Joaquin and Sacramento Valleys of California. The potato aphid became a serious pest of California tomatoes in the early 1990s. Prior to that time it had been reported that tomato varieties containing the M1 gene, which confers resistance to nematodes, also were more tolerant to aphids [3]. However, the resistance proved to be no longer as effective as it used to be [3]. Tomato yield losses of 9 tons per acre were recorded from uncontrolled aphid populations [56]. Insecticides reduce the percent of aphid infested tomato leaves from 51% to 2% [57].

In past years, the potato aphid was of little importance to producers of tomatoes in North Carolina because populations had been maintained at low levels by applications of broad-spectrum insecticides. However, the more widespread use of IPM and the resultant eliminations of many insecticide applications increased the importance of the pest [58].

Potato aphids are a key pest of tomatoes in Michigan [42]. They can cause complete crop loss, but as little as 25% field loss will cause growers anticipated returns to fall below input costs of production.

Research in Virginia demonstrated that insecticides reduced the number of potato aphids per ten leaves from 277 to 4 [60].

*Colorado Potato Beetle*

The Colorado potato beetle is one of the more serious pests of tomatoes in eastern states because it can completely defoliate tomato plants resulting in substantial yield reduction. Overwintering adult beetles begin emerging from the soil in mid May when tomatoes are transplanted or when seedlings break ground in direct-seeded fields. Eggs are deposited on tomato leaves. Upon hatching, the larvae feed on the foliage for two to three weeks. Following a 5-10 day pupation period in the soil, the adults return to feed on plants. Research has shown that untreated tomato plants incurred 85% defoliation from beetles [64]. The number of larvae on ten plants in untreated plots numbered 68-108 [63]. Tomato yield in the untreated plots averaged about two tons per hectare while the treated plots yielded 20 tons per hectare [63].

*Thrips*

In southeastern states, thrips have been recognized as important pests of tomatoes because of their ability to transmit tomato spotted wilt virus and to cause cosmetic damage by egglaying in small fruit. Western flower thrips first appeared in Georgia in 1981 and Florida in 1986.
Tomato spotted wilt virus (TSWV) is transmitted exclusively by thrips and especially by western flower thrips and tobacco thrips. The fruit from an infected plant is usually unmarketable and can display irregular ripening symptoms. This ripening problem can show up after tomatoes have been treated with ethylene for the ripening process. For this reason, TSWV infected plants are typically not harvested at all [67].

Thrips overwinter in the soil but can emerge anytime it is significantly warm in the winter. Thrips are present and generally active throughout the year in the coastal plain in Georgia/South Carolina. There are 3 to 5 generations a year.

In Georgia, tomato spotted wilt virus reduced tomato yields by an estimated $8.8 million in 2000 [66]. Foliar insecticide sprays for thrips cost approximately $120/A which resulted in a doubling of tomato yield and an increase of $3239/A in the value of harvested tomatoes [66].

Reflective metallic mulch for thrips control is estimated to cost $202/A and can produce tomato yields equivalent to insecticide sprays [66]. However, reflective mulches can reduce soil heat accumulation which in some years can reduce tomato yield by 50% even though thrips are controlled and virus is absent [66]. Although there are tomato varieties with some resistance to tomato spotted wilt virus, their commercial acceptability is not as high as the susceptible varieties and growers would risk tomato marketability by planting them [66].

References


40. Michelbacher, A. E. and E. O. Essig, *Caterpillars Attacking Tomatoes*, University of California, College of Agriculture, Agricultural Experiment Station, Bulletin 625, July 1938.


42. “Crop Profile for Tomatoes in Michigan,” Available at: http://pestdata.ncsu.edu/cropprofiles/Detail.CFM?FactSheets_RecordID=162.


49. Hyslop, J. A., Losses Occasioned by Insects, Mites, and Ticks in the United States, USDA, Bureau of Entomology and Plant Quarantine, Division of Insect Pest Survey and Information, July 1938.


Figure 1. % Tomato Fruit Damaged by Fruitworms and Armyworms in Untreated California Fields.

![Graph showing % Damaged Fruit and Year](image)

EIL (Economic Injury Level) = 2%.

Source: [44].

Figure 2. Percentage of Worm Damaged Tomatoes Versus the Larval Fragments in Juice

![Graph showing % Worm Damage vs. Number of Larval Fragments](image)

Source: [62].