The Benefits of Insecticide Use: Lettuce

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Key Points

- Worm pests can damage 60% of the lettuce heads in a field
- If left uncontrolled for thrips, lettuce yield would be reduced by 60%
- Aphids can contaminate 10% of the lettuce in a field if not controlled
- Insecticide sprays reduce losses due to insects to 2%.

Technical Summary

Lettuce grown in Arizona and California combined constitutes approximately 99% of total U.S. production. The average crop in the two states is 11.2 billion pounds worth $2.7 billion harvested from 365,000 acres.

In California lettuce fields, aphids and leafminers are the predominant insect pests in the coastal regions followed by various worms. Aphids and worms are the predominant insects in the spring-harvested lettuce in the San Joaquin valley, while aphids, leafminers, and worms are predominant in the fall-harvested crop. In the desert fields of California, worms and whiteflies are the predominant insect pests [1].

In Arizona, lettuce growers annually treat about 60% of the acreage for seedling pests, 38% for flea beetles, 5% for leafminers, 95% for beet armyworms, 95% for cabbage loopers, 50% for corn earworms, 50% for whiteflies, 10% for aphids, 35% for thrips and 33% for “trash bugs” [24].

The management of insect populations is extremely critical to lettuce producers. Not only do insects damage lettuce foliage, they also contaminate lettuce by their presence, from their feeding, or from the depositing of excrement [1]. In addition, a number of insects (e.g. aphids and whiteflies) are vectors of virus diseases. The high quality standards currently in place in the lettuce industry allow for minimal, if any, contaminated lettuce reaching the marketplace. Quality standards are even higher for those products destined for sale as packaged salad mixes and for export, where product contamination from any source is not acceptable [1]. Most lettuce fields are inspected at harvest by state inspectors to insure that product bound for market does not exceed state standards for insect injury.

Lettuce is harvested, packaged in the field, and shipped to market with no further processing. Because most lettuce undergoes so little processing, it is essential that the product be free of insect damage and contamination at harvest [8]. Because any insect, including beneficial predators and parasitoids, can act as a contaminant in lettuce, there is heavy reliance on chemical control of insect pests in lettuce [8].

High volume commercial lettuce production in California and Arizona requires repeated insecticide applications from crop establishment through harvest. This is particularly evident in the desert where insect pressures can be extreme and weekly to twice weekly application frequencies are commonplace during the fall [3]. Major pests, such as the beet
armyworm and aphids can devastate a lettuce crop in a very short period of time, if control measures are not used by the grower at early pest incidence.

Cropping systems in the desert growing areas of Arizona and California are unique in that irrigated crops exist year round in a climate ideal for optimal production. Lettuce is produced during the fall, winter, and early spring seasons. These cropping sequences provide year round habitat for a number of highly mobile insect species that feed on a large number of crops.

In the desert, fall lettuce is subjected to the most severe insect pressures. In the fall, temperatures often exceed 100 degrees and insect pests are very active. During this time cotton is being defoliated and harvested, melons are being picked, and summer annual weeds are abundant. Many of the insect pests encountered in fall lettuce originate in local fields of cotton, melons and weeds. When these sources begin to mature, their insect populations move to alternative crops including lettuce [8]. The adult moths migrate from these crops to lettuce.

The cost of insecticides for California and Arizona lettuce fields is approximately $300/A which represents about 7 % of the total cost of growing lettuce [35] [36]. Approximately 99% of the lettuce acres in the two states are treated with insecticides [37].

Without insecticide use, California lettuce production is estimated to decline by 53% [11].

Organic lettuce production in California and Arizona usually has a lower yield per acre than conventional lettuce which results from leaving pest contaminated product in the field. The yield reduction can range from 20-35%. The cost per unit for organic lettuce production with lower yields ranges from 35-45% more than conventional production [28].

Worms (Armyworm, Looper, Earworm, Budworm)

Lettuce is particularly susceptible to damage from several lepidopterous worm pests of which the beet armyworm, cabbage looper, corn earworm, and tobacco budworm occur in Arizona and California. These four species often occur simultaneously in large numbers. On fall crops, larvae may completely consume seedlings at stand establishment and high larval populations can significantly reduce plant populations and decrease plant growth [5]. Lepidopterous larvae enclosed in the growing leaves, that compose the head and wrapper leaves of lettuce, are impossible to dislodge and they render the crop unfit for sale. Control of Lepidoptera larvae on seedling lettuce is essential for stand establishment. If one larva per 100 seedling plants is present, an insecticide application is probably warranted [8].

The beet armyworm feeds on many field crops, including cotton and alfalfa, and often migrates from these crops onto lettuce in the fall. One female will lay on average 500 to 600 eggs over a 4 to 10 day period. The female moth covers the eggs with white scales.
Hatching larvae begin feeding on the leaf and may completely consume seedlings. Beet armyworms may severely stunt or kill seedling lettuce plants. Larvae may feed on the head rendering it unmarketable [8].

The cabbage looper is a very destructive pest on lettuce and feeds on many other crops. Cabbage loopers occur year round in the desert areas of California and Arizona. Loopers damage plants by eating ragged holes in leaves, and sometimes working their way into heads. They also cause damage by contaminating marketable portions with their bodies and frass. Heads contaminated with loopers, or tunneled into by loopers, are not marketable [8].

Corn earworm and tobacco budworm frequently move into lettuce from surrounding crops, particularly cotton. The larvae feed 2 to 4 weeks. When early season populations are high, these insects can decimate seedling stands of lettuce [8]. They are much more likely to bore into lettuce heads than other leptdoptera larvae, rendering the heads unmarketable [8].

The use of insecticides is the only effective way of reducing worm populations [7]. Experiments have shown that insecticide applications can reduce the number of worms from one per lettuce plant to zero [2]. The percent of lettuce heads free from worm damage was reduced to 2% with insecticide treatments from 60% in the untreated control [4]. The percent of heads containing frass was reduced from 66% to 3%; the percent of heads containing live worms was reduced from 51% to zero [5]. Because of decreased marketable yield the market price that a grower needs to breakeven financially was 2.2 times higher in the untreated versus the treated plots [5].

The use of natural pesticides (pyrethrum, sabadilla, pyrellin, Elcar) for worm control required seven applications to maintain quality standards in comparison to a single chemical insecticide application [6]. Organic lettuce growers spray Bt for worm control [34].

Non-chemical alternatives for managing worms are either not available or not cost/effective. Cultural management tactics such as crop sanitation and crop sequencing, designed to avoid these insects are inadequate because of the pests wide host range, large reproductive capacity, dispersal behavior, and high damage potential [9].

Experiments with mating disruption of beet armyworm in lettuce by synthetic pheromones demonstrated a 75% reduction in populations of the insect when populations were not severe [10]. A truer test to evaluate efficacy when populations are 5 to 10 times higher in the fall has not been undertaken [10]. Since beet armyworms are not the only worm pest targeted by insecticide sprays there would need to be separate pheromones for the other pests such as cabbage loopers in order to replace insecticides [10].

Parasites, predators and viral diseases may assist in reducing worm populations. However, their use is limited because of the short time crops are in the field (40-90 days), high crop quality standards, and a low tolerance for insect contaminated product [1].
Because lettuce is such a short-season crop, developing and maintaining beneficial insect populations is difficult. There is little time before harvest to develop sufficient food (i.e. lettuce) for insect pests to reach levels adequate for the survival of their enemies.

*Sweet Potato Whitefly*

The sweet potato whitefly was not considered an important pest until 1981 when extremely large populations became common on lettuce in the southwest. In 1981 desert lettuce plantings were virtually 100% infected with lettuce infectious yellows virus transmitted by the whitefly. Lettuce yield losses were 50-75% [15]. Prior to 1991, whiteflies remained an occasional pest. However, in 1991, sweet potato whitefly emerged as a serious annual pest causing direct damage to lettuce by removing plant sap during feeding. This shift in pest status occurred due to the development of a new strain of sweet potato whitefly (B strain). The B strain is also known as the “silverleaf whitefly”. The host range of the B strain is much greater than the old strain. Seemingly overnight, lettuce producers were faced with unprecedented infestations of a pest that previously was relatively easy to control. In 1992 the sweet potato whitefly was responsible for $56 million in crop losses in Arizona [13].

One whitefly female will lay 50 to 400 eggs. Crawlers move about until they locate a minor vein. They feed by inserting their tubular mouthparts into the vein and extracting phloem sap. Damage by large whitefly populations can result in crop injury through reduced head size, delayed harvest, and leaf yellowing associated with whitefly feeding. Whiteflies also cause economic damage through contamination associated with the insect themselves, and honeydew and sooty mold accumulation. Total destruction of early fall lettuce plantings has been observed because whiteflies have extracted such large amounts of phloem sap from seedlings [8]. Damage can be particularly severe in seedlings of fall planted lettuce because large populations can move from cotton and alfalfa with defoliation or cutting. Adults migrate in large numbers and rapidly decimate a newly-planted lettuce crop. The presence of whiteflies can indirectly result in a 75% reduction in lettuce yields in the desert due to lettuce infectious yellow virus. Protection of emerging seedlings from sweet potato whitefly is critical for producing marketable lettuce [38].

Since the mid-1990s, whiteflies have not been a significant problem for lettuce growers largely because of the application of the insecticide imidacloprid at planting [12]. The toxicant is taken up by the roots and distributed throughout the plant. Its primary activity is against adults feeding on the plants, but it also is known to repel adults and act as an anti-feedant. Consequently, colonization is significantly reduced as measured by large reductions in egg counts. Through control of whiteflies, the treatments resulted in 98% of the lettuce heads being marketable versus 20% marketability of heads in the untreated plots [14].

It is unlikely that the use of biological controls for whiteflies would have much impact in fall-planted lettuce because of the overwhelming numbers of adults that migrate when plants are small [16]. Wasp parasitoids of the genus *Eretmocerus* were studied for their
potential to control whiteflies in the desert since they had been shown to be successful in greenhouse situations. However, the parasitoid failed to contribute to control [18]. Its ineffectiveness was due to its tendency to disperse at low whitefly densities and to being completely overwhelmed by influxes of large numbers of immigrating adults. Previous reports of parasitism by *Eretmocerus* in cages likely provide an inflated view of the efficacy of the genus. The primary difficulty with these studies is that they prevent whitefly immigration and confine parasitoids to relatively small search areas of concentrated host densities [18].

Several formulated foliar sprays containing fungal pathogens have been experimentally used against whitefly. The fungus spore usually germinates on the insect. Development continues inside the whitefly and the insect dies. Finally, the fungus grows through the insect ‘skin’ and produces spores. A relative humidity of 80% or more provides favorable conditions for the growth and dispersal of the fungus. To achieve effective control of whiteflies, several applications may be necessary [17]. Effective control with the fungi was not achieved in the desert regions because of the extremely low humidity.

*Aphids*

Aphids reproduce asexually. Populations consist entirely of female aphids giving birth to female progeny who are born pregnant. This type of reproduction gives aphids a tremendous reproductive capacity. One female can easily give birth to 80 to 100 young in her lifetime of about 30 days. High aphid populations stunt plants, but contamination of the produce to be sent to market is the main problem growers face.

Aphids are a cool season pest in lettuce in the desert regions. Aphids almost achieve extinct status in the desert in the summer due to high temperatures above their physical tolerance and a lack of suitable plant hosts. Aphids start to migrate out of the coastal mountains in early fall as hosts become unsuitable, and move to the desert areas to recolonize on suitable plant hosts, like lettuce. Aphid populations build quickly since parasites were left behind [39].

An aphid complex consisting of the green peach aphid and the potato aphid has caused problems for lettuce growers since the early 1950s. A new exotic species, the lettuce aphid, was found infesting plants in the Salinas Valley of California in 1998. Several fields of lettuce were unharvestable due to aphid contamination. The aphids ruined the equivalent of 100,000 or more cartons of lettuce worth between $500,000 and $750,000 [20]. This aphid quickly spread throughout the coastal growing areas and is now considered their primary aphid pest [19]. Commonly found on lettuce in Europe and Canada, this pest had never previously been reported in the western U.S. By 2000, the lettuce aphid was found in the desert growing area of Arizona. It quickly became established in the desert growing areas and is now considered a key pest of spring lettuce in Arizona. Another new aphid species, the foxglove aphid, was found infesting commercial lettuce fields in the Yuma area for the first time in 2002. It is not uncommon to find all four aphid species simultaneously infesting lettuce fields in the desert cropping
systems, and, if not controlled, populations can quickly build up to very high densities throughout the plant [19].

Long residual control of aphids in lettuce has been achieved by a single at-planting soil application of the insecticide imidacloriprd. Through root uptake, the compound provides significant reduction of aphid colonization for up to 75 days [19]. Research has shown aphid counts of 135 per head at harvest in untreated plots versus zero in the treated plots [21]. 10% of the plants were unmarketable in the untreated plots while all of the plants in the treated plots were marketable [22].

Biopesticides have been suggested as alternatives for aphid management. However, studies have shown that materials such as azadirachtin, pyrethrum, entomophagous fungi, oils and soaps have been largely ineffective under field conditions and are not considered viable alternatives [19]. Research with lacewings as aphid predators showed 80-92% control. But the control required 25 lacewing eggs per square meter which works out to 101,000 eggs per acre. The eggs were purchased at a cost of $1.55 per thousand, which works out to nearly $157/A [23]. The cost of insecticides for aphid control is approximately $30/A [24].

Several native syrphid flies suppress populations of aphids. Many large-scale organic lettuce producers intercrop lettuce with quick-flowering annuals or “insectary crops” to provide floral resources to syrphid adults with the intention of increasing egg laying by syrphids in adjacent lettuce [25]. About 5% of the lettuce field is planted to the insectary crop [34]. Syrphid adults feed on nectar as an energy source and require pollen as a protein source. The most commonly planted insectary crop is sweet alyssum. Although conservation biocontrol is largely effective, each year experienced growers are unable to harvest about 5% of their lettuce due to aphid contamination [25]. Syrphids either do not arrive in sufficient quantities in the field or they only suppress aphid infestations after the narrow harvest window. It is possible that syrphid predation is inadequate in some fields because insectary floral resources are insufficient to support the necessary level of egglaying by females. Parasitoids may impact the effectiveness of syrphids at some sites.

An attempt to use a reflective plastic mulch to repel aphids led to the conclusion that it works in the lab, but not in the field [26]. The reflective mulch costs $150/A. The polyethylene mulch actually made the aphid problem worse. The data from the field trials showed that the plants with the reflective mulch had ten times the amount of aphids than the control plants. One explanation for the counterproductive effect of the mulch is that it prevented beneficial insects from coming to the lettuce. The count of the syrphid fly was significantly lower on the plastic mulch plots. Another explanation for the field failure is that the mulch may create a micro-climate that is conducive to aphid populations.

_Flea Beetles_

Flea beetle adults primarily move into lettuce fields from surrounding crops and weeds. They feed on the underside of leaves causing numerous small round or irregularly shaped holes or pits. Beetles on plants at harvest are considered contaminants if found in the
wrapper leaves or heads. Flea beetles found in lettuce have very few natural enemies. There are no effective biological control alternatives available in lettuce for controlling flea beetles [27].

**Thrips**

Thrips have recently become a more important pest in lettuce production in Arizona. They primarily occur in large numbers on lettuce during the fall and spring and can build up to high numbers very rapidly. Under mild winter temperatures, thrips reproduce quickly on lettuce. Thrips cause damage to outside leaves and can contaminate the inside of heads at harvest [27]. Thrips are present year round but populations increase with temperatures from January through March. They migrate into lettuce from weeds and other host plants. Thrips feed by making a hole in the epidermis, puncturing cells and sucking the sap that oozes out. As they feed, they scar edible leaves. Thrips are considered a pest because of the cosmetic damage they cause to cap leaves and the contamination in mature heads by thrips adults. Several botanical insecticides which supposedly have activity against thrips have been evaluated for lettuce. These include azadirachtin, pyrethrin, garlic and crop oil. None of the treatments provided greater than 25% reduction in thrips populations [29]. Insecticide sprays consistently provide >80% control of both thrips adults and larvae increasing lettuce yield by 60% [30].

**Leafminers**

The American serpentine leafminer was first recorded in lettuce in Arizona in 1987 and caused $75 million in losses to the crop in the 1988/89 season.

The mining of leaves by larvae is the principal cause of injury from leafminers. The mines reduce photosynthesis and render lettuce unmarketable. Leafminer populations can reach to 5 million per acre [28].

One study in Arizona estimated that 7 million leafminers per acre exited from lettuce wrapper leaves [32]. Losses occur when the outer wrapper leaves need to be trimmed. Leafminers also contaminate the heads. A population of a single leafminer larva for each two lettuce plants can cause an average of 18% in growth reduction in lettuce [31]. Yield losses to leafminers without control can reach 64%. Insecticides control 98-99% of the leafminer populations in lettuce [33].

**Trash Bugs**

“Trash bugs” is a term used to describe transitory insects (lygus, alfalfa hopper, chinch bug) that are often found in lettuce crops. Because of their transitory nature, trash bugs rarely cause direct damage to lettuce plants. However, they can be contaminants. When left untreated in lettuce, they will often move under the cap leaf [27].

**Seedling Pests**
Ground dwelling pests (field crickets, darkling beetles, ground beetles) are annual pests in early planted sprinkler irrigated lettuce fields in the desert. When they occur, they can quickly destroy most of a field by eating the newly emerged seedlings. Moving out of cotton, sudangrass, and desert flora, large numbers will migrate to seedling lettuce.

References


