Crop Profile for Parsley in Arizona

Prepared: November, 2001

Family: Apiaceae (syn: Umbelliferae)

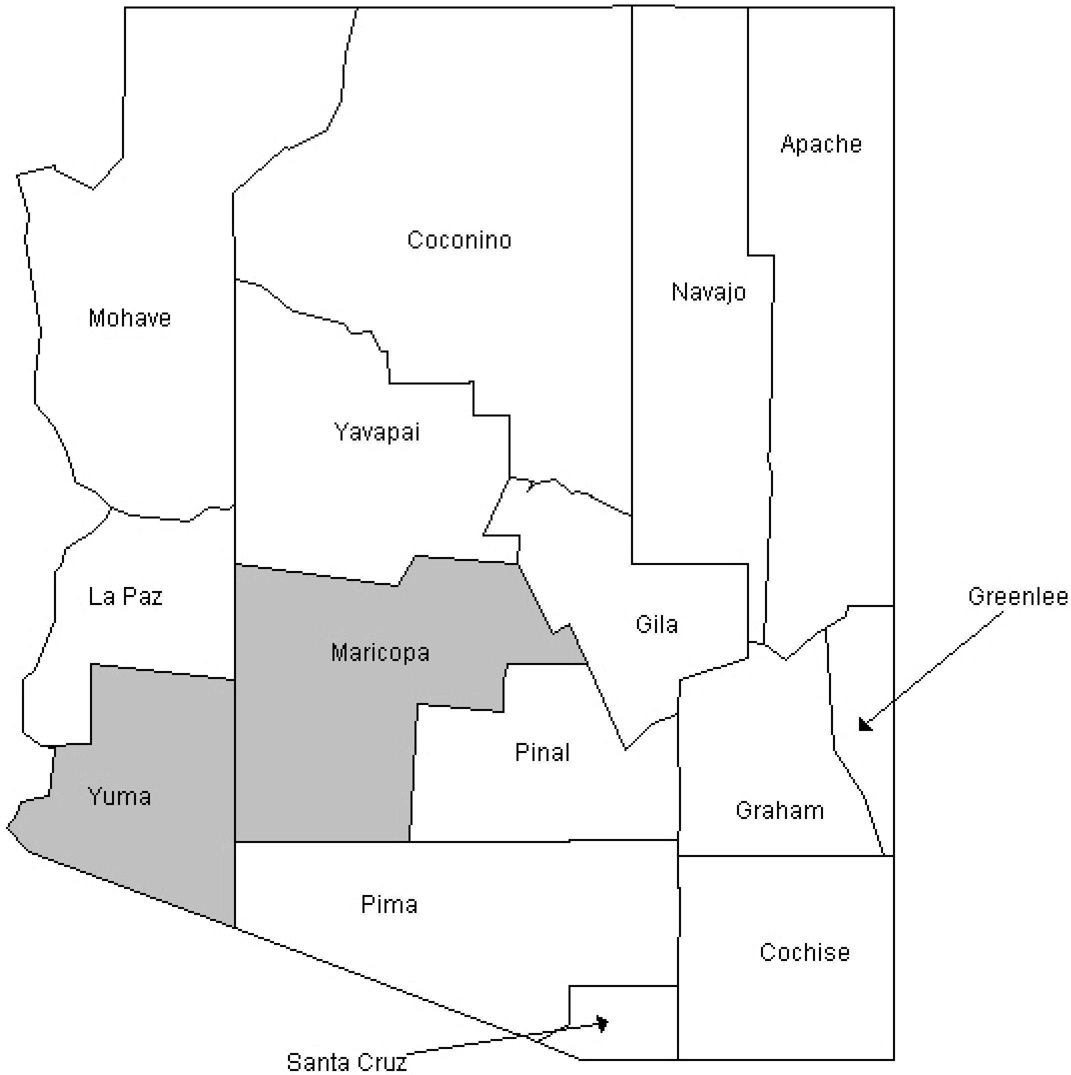
Scientific name*: Petroselinum crispum* (Mill.) Nyman ex A.W. Hill (syn: P. *hortense* Hoffm. or *P. sativum* Hoffm.)

Edible portions: leaves, stems, consumed raw, cooked, dehydrated.

Use: fresh vegetable, garnishing, seasoning

Alternative names: American Parsley, Italian Parsley, Perejil and Persil.

General Production Information



- In 1997, Arizona ranked 7th in the United States for parsley production, contributing approximately 1% of the nations parsley[3].
- Between the years of 1994 and 1998, Arizona produced approximately 98 acres of parsley[2].
- An average of 118,440 cartons/year of parsley was produced between 1994 and 1998[2].
- Celery production had an average yearly value of 369 thousand dollars between 1995 and 1999[2].
- Celery is grown in both Maricopa and Yuma County, but the majority of production occurs in Maricopa County.
- Land preparation and growing expenses for celery are approximately $1.45/carton[5].
- Harvest and post harvest expenses for celery are approximately $3.40/carton[5].

Cultural Practices

General Information[7, 8]: In Arizona, parsley is grown during the fall and winter. Parsley is planted twice, once at the beginning of August and again at the beginning of September. During the months of parsley production, temperatures may range from 30°F to 90°F. In Arizona, parsley is grown on soils that range from a sandy loam to a clay loam with a pH of 7.5-8.0.

Cultivars/Varieties[6]: In Arizona, the most commonly grown varieties of parsley are: 'Evergreen' and 'Forest Green'. These two varieties are very similar and are in fact quite difficult to differentiate. Both have an excellent dark-green color, double-curled leaves and are good for bunching. These varieties also have a fast regrowth if multiple harvests are desired.

Production Practices[7, 8]: Prior to planting, the field is deeply tilled, disced, land planed, the beds are formed and the field is pre-irrigated. A preplant herbicide may be applied prior to bed formation. If a pre-plant fungicide, such as mefenoxam, is utilized it is usually applied after bed formation but prior to planting.

Parsley is directly seeded ¼ to ½ an inch deep in beds that measure 40" across. Sprinkle irrigation is often used to promote germination and allow seedling establishment. There are 4 to 6 rows per bed and plants are spaced 2" apart within the row. The field is cultivated two to three times during production. Side dressing fertilizer is applied two to three times during production depending on necessity. Furrow irrigation provides a consistent water supply for the parsley.

Harvesting Procedures: From time of seeding, parsley requires 70 to 90 days to mature[1]. Harvesting of parsley can begin as early as October and is usually completed by the end of March[7, 8]. Parsley can be harvested multiple times; usually it is harvested two or three times. After harvesting the leaves, the plant is watered and allowed to grow back so it can be harvested again.

Parsley is hand-harvested and is trimmed, washed and tied into bunches in the field[9]. Wax cardboard boxes are packed with 2 dozen bunches of parsley. A large percentage of grown parsley is delivered directly to institutional trade (restaurants, hotels etc.) or is sent to be dehydrated[4]. Fresh parsley may be stored for up to two months if kept at 32°F and high relative humidity[4]. In the state of Arizona, a minimum of 90% of the parsley must be free of insect injury, worms, mold, decay and other serious defects that affect the appearance or shipping quality[10]. All fresh and processed parsley must meet the same standards in Arizona.

Insect Pests

(7, 8, 11, 12, 13, 14, 15, 16, 17, 18, 19)

Hymenoptera

Harvester Ant (*Pogomyrmex rugosus*)

Ants are not a frequent pest of Arizona crops; however, when they do occur in a field they can be insidious. The harvester ant is primarily a pest during stand establishment. They eat seedlings and will carry the planted seeds and seedlings back to their nest. When there are ants in a field, typically there is no vegetation surrounding the anthill. Ants generally do not cause damage to the mature parsley plant. Ants can also be a pest to people working the field, by swarming and biting workers.

Sampling and Treatment Thresholds: University of Arizona experts suggest that a field should be treated at the first signs of damage[16].

Biological Control: There are no effective methods for the biological control of ants.

Chemical Control: Hydramethylnon is often used to control harvester ant populations, by placing it around the anthill. Worker ants will carry the poisoned bait back to their nest and distribute it to the other ants and the queen. Hydramethylnon, however, can only be used on bare ground, outside borders and ditch banks. Carbaryl baits can be used within the crop field to provide control of ant populations.

Cultural Control: Surrounding the field with a water-filled ditch can help control ant migration into the field. This method, however, is of little value if the ants are already in the field.

Post-Harvest Control: There are no effective methods for the post harvest control of ants.

Alternative Control: Rotenone is an alternative method used by some growers to control ant populations. Another method is to pour boiling water that contains a citrus extract down the anthill to kill populations inside.

Coleoptera

Striped flea beetle (*Phyllotreta striolata*)

Potato flea beetle (*Epitrix cucumeris*)

Western black flea beetle (*Phyllotreta pusilla*)

Western striped flea beetle (*Phyllotreta ramosa*)

The color of flea beetles varies between species, but all species have a hard body and large hind legs. When flea beetles are disturbed, their large hind legs allow them to jump great distances.

Flea beetles can cause damage to parsley during the initial seedling stages. The female flea beetle lays her eggs in the soil, on leaves, or within holes and crevices in the parsley plant. Depending on the species, the larvae feed on the leaves or the roots of the parsley plant. The adult beetles will also feed on the parsley plant, chewing small holes and pits into the underside of leaves. These insects are the most damaging during stand establishment. Even a small population can stunt or kill a stand of seedlings. Mature plants, however, are more tolerant of feeding and rarely suffer severe damage. If the parsley leaves are damaged, however, the leaves are unmarketable.

Sampling and Treatment Thresholds: Flea beetles often migrate from surrounding production areas and Sudan grass. Fields should be monitored weekly for flea beetles and damage. Experts at the University of Arizona recommend treating prior to leaf formation when there is 1 beetle per 50 plants[15]. After leaf formation, treatment should occur when there is 1 beetle per 25 plants[15].

Biological Control: There are no natural predators or parasites that can effectively control flea beetle populations.

Chemical Control: Methomyl, diazinon and pyrethroids such as lambdacyhalothrin and permethrin are frequently used treatments for the control of flea beetles. Methomyl is foliar applied; diazinon and pyrethroids can be foliar applied or chemigated. Diazinon and pyrethroids applied by chemigation have the added benefit of targeting crickets, grasshoppers and lepidopterous larvae.

Cultural Control: It is important to control volunteer plants and weeds, in and around the field, which could act as a host for flea beetles. Crop rotation is important; however, flea beetles have a wide range of hosts so not all crops are suitable for rotation. Parsley fields should be disked under immediately following the final harvest to kill any larvae pupating in the soil. It is also important that Sudan grass is plowed under within a week of the final harvest, as this crop often harbors flea beetles.

Post-Harvest Control: There are no effective methods for the post-harvest control of flea beetles.

Alternative Control: Some growers use rotenone dust and pyrethrins to control flea beetles. Alternative control of these pests, however, is very difficult.

Darkling Beetle (*Blapstinus* sp.)

Rove Beetle (*Staphylinids* sp.)

Darkling beetles are dull black-brown in color. They are often confused with predaceous ground beetles, which are also black-brown but are shiny and lack clubbed antennae. It should be noted that the predaceous ground beetle is beneficial because it feeds on caterpillars and other insects.

Rove beetles are a ¼" in length, or smaller, have a shiny, dark black-brown body and very short elytra that cover the wings. These beetles are frequently confused with winged ants and termites.

Darkling and rove beetles are most damaging during seedling establishment, digging planted seeds out of the soil. They will also feed on parsley seedlings, girdling plants at the soil surface. Sometimes these beetles feed on the leaves of older plants. Darkling and rove beetles, however, are normally not a threat to mature plants unless their populations are high.

Sampling and Treatment Thresholds: Nighttime is the best time to monitor a field for darkling beetles; this is when they are the most active. During the day they tend to hide in the soil or debris. These beetles often migrate from nearby cotton and alfalfa fields or weedy areas. According to University of Arizona guidelines, parsley should be treated when beetle populations are high or there is a threat of migration into the field[15]. Parsley plants that have 5 to 6 leaves are usually not at risk for beetle attack[15].

Biological Control: There are no effective methods for the biological control of rove and darkling beetles.

Chemical Control: Placing baits around the perimeter of the field will provide some control when beetles migrate into the field. Methomyl, diazinon and pyrethroids are routinely used for the treatment of rove beetle and darkling beetle populations. Diazinon and pyrethroids can be chemigated through the sprinkler system or foliar applied. These two active ingredients will also help control cricket, grasshopper and lepidopterous larvae populations.

Cultural Control: It is important to control weeds in the field, and surrounding the field, that can act as hosts for darkling and rove beetles. Ditches filled with water around the field's perimeter can deter beetle migration into the field. This method, however, is ineffective if there are beetles already in the field. Fields should be deeply plowed to reduce soil organic matter and beetle reproduction.

Post-Harvest Control: There are no post-harvest control methods for rove beetles or darkling beetles.

Alternative Control: Some growers use rotenone and neem oil to control darkling and rove beetles.

Orthoptera

Cricket (*Gryllus* sp.)

Crickets are rarely a problem in Arizona but dense populations are capable of destroying an entire crop. Crickets are ½ to 1" in length, and brown-black in color. Most feeding occurs at night; during the day crickets hide in the soil, weeds, ditches and under irrigation pipes. Crickets attack parsley seedlings as they emerge from the soil.

Cricket populations build up in cotton fields, Sudan grass and desert flora and then move from these fields into parsley fields at the end of the summer. Fields that use over-head sprinkler irrigation encourage inhabitance by creating an ideal environment for crickets because female crickets lay their eggs in damp soil.

Sampling and Treatment Thresholds: Crickets are difficult to monitor for during the day, as they tend to hide. One can check underneath irrigation pipes; however, a visual inspection of damage is usually sufficient to give an estimate of cricket activity. Fields planted near cotton or Sudan grass should be closely monitored. Experts at the University of Arizona recommend that a field should be treated when cricket damage is high or there is a threat of cricket migration into the field[16].

Biological Control: There are no effective methods for biologically controlling cricket populations.

Chemical Control: Baits such as, permethrin and carbaryl, can be used to control cricket populations. Baits are usually placed at the field borders to target crickets migrating into the field. Methomyl, diazinon and pyrethroids are the most commonly used chemistries for controlling cricket populations. These insecticides can be ground applied or chemigated. Spraying, rather than using baits, has the added benefit of also targeting lepidopterous pests.

Cultural Control: Fields should be disked immediately following harvest; this will help control cricket populations.

Post-Harvest Control: There are no effective methods for the post-harvest control of crickets.

Alternative Control: Some growers use rotenone to control cricket populations.

Spur-throated grasshopper (*Schistocerca* sp.)

Desert (Migratory) Grasshopper (*Melanoplus sanguinipes*)

In Arizona, grasshoppers are usually not a threat to parsley stands. Occasionally, sometimes after a heavy rain, the grasshopper population can 'explode'. In these years grasshoppers move from the desert into produce fields and can decimate entire crops. Due to their ability to fly, it is difficult to prevent the migration of grasshoppers into a field. There have been such outbreaks in previous years in Arizona; however, they are rare. Grasshoppers are foliage feeders and will chew holes into leaves. In most years, grasshopper populations are so small their damage is insignificant. Often the grasshoppers are merely seeking shade in the field.

Sampling and Treatment Thresholds: University of Arizona experts suggest that fields should be treated as soon as grasshoppers begin to cause damage to the crop[16].

Biological Control: A predaceous protozoon, *Nosema locustae*, can be used to control grasshopper populations.

Chemical Control: If grasshopper populations are large, chemical control is usually the only option. Chemical control of these insects can be difficult. Pyrethroids, such as lambdacyhalothrin have been used in the past with some success.

Cultural Control: If grasshopper populations are decimating a field, replanting is often the only option.

Post-Harvest Control: There are no effective methods for the post-harvest control of grasshoppers.

Alternative Control: Some growers use rotenone to control grasshopper populations.

Diptera

Leafminers

(*Liriomyza* sp.)

Leafminers can cause damage to parsley grown in Arizona, but typically are not a large threat. Adult leafminers are small, shiny, black flies with a yellow triangular marking on the thorax. The adult female leafminer oviposits her eggs within the leaf tissue. Male and female flies feed at these puncture sites. The larvae hatch inside the leaf tissue and feed on the mesophyll tissue; they do not emerge until they pupate. Leafminers usually pupate in the soil, although sometimes they will pupate between the parsley leaves. These larvae often die and rot within the parsley plant, providing a substrate for pathogen infection. When conditions are favorable, leafminers can complete a life cycle as quickly as 3 weeks.

As larvae feed on the mesophyll tissue, they create extensive tunneling within the leaf. The width of these tunnels increases as the larvae grow. These mines cause direct damage by decreasing photosynthesis; as well, the puncture wounds provide an entryway for pathogenic infection. Leafminers are usually considered to be a secondary pest. The leaves of parsley must be completely damage free as this is the consumed portion of the crop. If the parsley leaves are damaged by leafmining, or contaminated by leafminer pupae, the plant is unmarketable.

Sampling and Treatment Thresholds: It is important that the crop is monitored regularly for leaf mines, larvae and adult flies. The cotyledons and first true leaves are the first to be mined. Mining is more visible on the undersurface of the leaf; thus both leaf surfaces must be viewed. Presence of leafminer parasites and parasitized mines should also be determined. Yellow sticky traps are a good method for measuring leafminer migration into a field, as well as, determining which species are present. It is important to accurately identify which species are present, because insecticide resistance has been documented for *Liriomyza trifolii*. University of Arizona guidelines recommend that prior to leaf formation, parsley should be treated when populations have reached 1 active mine per leaf[15]. After leaf formation, treatment should occur when populations reach 1 mine per leaf per 25 parsley plants[15].

Biological Control: *Diglyphus* and *Chrysocharis* genera of parasitic wasp are sometimes utilized to control leafminer populations. Insecticides used to control noxious pests should be used with care because they can eliminate parasitic wasps causing a leafminer outbreak.

Chemical Control: Diazinon and pyrethroids such as permethrin are commonly used chemistries to control *L. sativae* adults. Permethrin is ineffective against leafminer larvae. Neither diazinon nor permethrin are effective against *L. trifolii*. Spinosad is used for the control of the larvae and adults of both *L. sativae* and *L. trifolii*. Spinosad is the only chemistry available that controls *L. trifolii*. Insecticide resistance has been noted in *L. trifolii* populations, thus there is a need for a greater diversity of insecticides to allow resistance management.

Cultural Control: It is best to avoid planting near cotton, alfalfa and other host fields, because leafminers will migrate from these fields into the parsley field. A field that has a leafminer infestation should be disked immediately following harvest.

Post-Harvest Control: There are no effective methods for the post-harvest control of leafminers.

Alternative Control: Some growers use insecticidal soaps to control leafminer populations.

Lepidoptera

Lepidopterous complex = loopers, beet armyworm, corn earworm and tobacco budworm.

Black Cutworm (*Agrotis ipsilon*)

Variegated Cutworm (*Peridroma saucia*)

Granulate Cutworm (*Agrotis subterranea*)

The threat of cutworms in Arizona is sporadic, and appears to vary in response to environmental conditions such as warm temperatures. The adult moth has gray-brown forewings with irregular markings; the hindwings are lighter in color. The female moth lays her eggs on the leaves and stem near the soil surface.

Cutworm populations are heaviest during the fall and frequently occur in fields that were previously planted with alfalfa or pasture. Seedlings are the most significantly impacted by cutworm attack. Newly hatched larvae feed on the leaves temporarily, but then drop to the soil surface and burrow underground. The larvae emerge at night and feed on the parsley. The cutworm attacks parsley by cutting the stem at, or just below the soil surface. A single cutworm is capable of damaging several plants in one evening and a large population can destroy an entire parsley stand. When cutworms have been active, one might observe several wilted or cut off plants in a row. A stand that has recently been thinned is especially sensitive to cutworm attack. Parsley that is contaminated by cutworms or damaged by cutworm feeding is unmarketable.

Sampling and Treatment Thresholds: Prior to planting, the field, field borders and adjoining fields should be monitored for cutworms. Pheromone traps can be used to monitor the presence of cutworms in a field. Once seedlings have emerged, fields should be scouted twice a week. If an area of several wilted or cut off plants is discovered, the surrounding soil should be dug into and searched for cutworms. Cutworms are nocturnal; therefore it is easiest to scout for them, during the evening, on the soil surface. Cutworms are often not noticed until crop damage has become severe. According to University of Arizona guidelines, a field should be treated as soon as soon as stand loss begins[15].

Biological Control: There are some natural enemies to the cutworm, however they do not provide adequate control.

Chemical Control: Baits can be used to control cutworms but are more effective when used prior to parsley emergence. These baits should be placed in the areas where cutworms have been found in previous years. Cutworms often occur at the field borders or in isolated areas within the field. Sometimes spot and edge treatments are sufficient to control cutworm populations. Spinosad and pyrethroids are the most routinely used methods for controlling cutworm populations. These larvae, however, are often controlled when the crop is sprayed for stand establishment pests.

Cutworms usually do not get an opportunity to establish a population.

Cultural Control: Fields that are in close proximity to alfalfa fields are especially prone to cutworm infestation, and should be carefully monitored. Cutworms tend to reoccur in the same areas of a field and in the same fields. It is important to control weeds that can act as hosts to cutworms in the field and surrounding the field. The field should be plowed a minimum of two weeks prior to planting, in order to kill cutworms, hosts and food sources.

Post-Harvest Control: There are no effective methods for the post-harvest control of cutworms.

Alternative Control: Some growers use *Bacillus thuringiensis* (Bt) for the control of cutworms. It is best to spray Bt in the dark because it is UV light and heat sensitive. Spraying at night will give the longest period of efficacy.

Saltmarsh Caterpillar (*Estigmene acrea*)

The adult saltmarsh caterpillar moth has white forewings that are covered with black spots; the hindwings are yellow. The female moth lays groups of 20 or more eggs on the leaf surface. The young larvae are yellow-brown in color and covered in long, dark black and red hairs. Older larvae sometimes develop yellow stripes down the sides of their bodies and red and black hairs. These caterpillars are sometimes referred to as ‘wooly bear caterpillars’.

Saltmarsh caterpillar populations are heaviest in the fall. These larvae are more common in cotton, alfalfa, bean and sugarbeet fields and are not normally a pest to parsley. The larvae, however, will migrate from surrounding host fields. The saltmarsh caterpillars feed on seedlings and can skeletonize older plants. The larvae often feed in groups on older plants and if populations are high, they can decimate an entire seedling stand.

Sampling and Treatment Thresholds: Counts of saltmarsh caterpillars should be included with the total Lepidoptera count. According to University of Arizona experts, fields should be treated at the first signs of damage[16].

Biological Control: There are no effective methods for the biological control of saltmarsh caterpillars.

Chemical Control: Field edges should be sprayed when saltmarsh caterpillars begin to migrate into the parsley field[15]. Methomyl, spinosad, tebufenozide and pyrethroids are the most commonly utilized treatments for controlling saltmarsh caterpillars. Methomyl, pyrethroids and chlorpyrifos are all contact insecticides that are foliar applied. Spinosad is a translaminar insecticide that must be consumed or tread upon to kill the larvae. Tebufenozide is an insect stomach poison that must be consumed to be effective.

Cultural Control: The simplest way to control saltmarsh caterpillars is to prevent their migration into a field. Monitoring any surrounding cotton and alfalfa fields prior to parsley emergence will help assess the degree of risk for the crop. Saltmarsh caterpillars do not like to cross physical barriers. A 6" high aluminum foil strip or irrigation pipes that the larvae cannot crawl under will provide a barrier to the field. These barriers can also be used to herd the larvae into cups of oil. A ditch of water containing oil or detergent that surrounds the perimeter of the field can also be used as a barrier. Barriers work well to exclude saltmarsh caterpillars from the field, but will have no useful value if the larvae have already infested the field.

Post-Harvest Control: There are no effective methods for the post-harvest control of saltmarsh caterpillars.

Alternative Control: *Bacillus thuringiensis* may be used to control saltmarsh caterpillars. A problem with the use of *B. thuringiensis* is its tendency to break down when exposed to UV light and heat.

Usually it is sprayed at night to allow the longest period of efficacy.

Cabbage Looper (*Trichoplusia ni*)

Alfalfa Looper (*Autographa californica*)

Loopers are a major pest in the central and southwestern deserts of Arizona. They are present all year, but their populations are highest in the fall when winter vegetables are grown. Loopers occasionally cause damage to parsley grown in Arizona.

Cabbage loopers and alfalfa loopers are very similar in appearance, which makes it difficult to differentiate between the two species. The front wings of the adult looper are mottled gray-brown in color with a silver figure eight in the middle of the wing; the yellow hindwings are yellow. The female moth lays dome-shaped eggs solitarily on the lower surface of older leaves. The larvae are bright green with a white stripe running along both sides of its body. The looper moves by arching its back in a characteristic looping motion, which is also the source of its name. Loopers can have from 3 to 5 generations in one year.

Loopers will attack all stages of plant growth. The larvae feed on the lower leaf surface, chewing ragged holes into the leaf. Excessive feeding on seedlings can stunt growth or even kill plants. Parsley that has been damaged by looper feeding or that is contaminated with larvae or larvae frass is unmarketable.

Sampling and Treatment Thresholds: Once parsley has germinated, fields should be monitored twice a week. The lower leaf surface should be checked for larvae and eggs, especially on damaged leaves. When populations are noted to be increasing, fields should be monitored more frequently. Pheromone traps are useful for measuring the migration of moths into crop fields. The presence of parasitized and virus-killed loopers should also be noted. The University of Arizona recommends that prior to leaf formation parsley should be treated when populations have reached 1 larva per 50 plants[15]. After leaf formation, parsley can tolerate 1 larva per 100 plants[15]. All other lepidopterous larvae that are noted should be included in this total.

Biological Control: There are several species of parasitic wasps, as well as, the tachinid fly (*Voria ruralis*) that will aid in the control of the looper. Care must be taken with insecticide treatment, as it can decrease populations of these beneficial insects. Nuclear polyhedrosis virus is a naturally occurring virus that can assist in the control of loopers when conditions are favorable.

Chemical Control: Spinosad, tebufenozide and pyrethroids are the commonly utilized chemistries for controlling looper populations. All are foliar applied insecticides. Thiodicarb is often tank-mixed with permethrin to provide control of the lepidopterous complex.

Cultural Control: Weeds growing within the field or surrounding the field should be controlled because they can act as hosts for loopers and other lepidopterous insects. Weeds on ditch banks and adjacent fields should be monitored for eggs and larvae during seeding.

Post-Harvest Control: There are no methods for the post-harvest control of loopers.

Alternative Control: *Bacillus thuringiensis* can be used to control looper populations, but is most effective if applied when larvae. One concern when applying *B. thuringiensis* is its tendency to break down when exposed to UV light and heat. Spraying at night will allow the longest period of efficacy. This microbial insecticide will control other lepidopterous insects, with the exception of beet armyworms, and not affect beneficial predators and parasites.

Beet Armyworm (*Spodoptera exigua*)

The forewings of the adult moth are gray-brown with a pale spot on the mid-front margin; the hindwings are white with a dark anterior margin. The female moth lays clumps of light green eggs on the lower leaf surface. The eggs are covered with white scales from the female moth's body, giving the eggs a cottony appearance. The eggs darken prior to hatching. The emergent larvae are olive green and are nearly hairless, which distinguishes them from other lepidopterous larvae that attack parsley. The larvae have a broad stripe on each side of the body and light-colored stripes on their back. A black dot is located above the second true leg and a white dot at the center of each spiracle. Mature larvae pupate in the soil.

Armyworms will occasionally cause damage to parsley grown in Arizona. Armyworm populations are heaviest during the fall and the larvae will attack all stages of plant growth. Young larvae feed in groups near their hatching site. As the beet armyworm feeds, it spins a web over its feeding site. Mature armyworms become more migratory and move to new plants. Many armyworms will die while traveling between plants. Armyworm feeding can skeletonize leaves and consume entire seedlings. A single armyworm can attack several plants. Parsley that has been damaged by armyworm feeding is unmarketable.

Beet armyworm populations are most active during the months of July through November. In the fall, beet armyworms often migrate from surrounding cotton, alfalfa, and other crop fields to vegetable crops. Armyworms also feed on weeds including; redroot pigweed (*Amaranthus* sp.), lambsquarters (*Chenopodium album*) and nettleleaf goosefoot (*Chenopodium murale*).

Sampling and Treatment Thresholds: Weeds surrounding the field should be monitored for larvae and eggs prior to crop emergence. If population levels are high in surrounding weeds, the crop should be monitored very carefully following emergence. Pheromone traps can be used to monitor for the presence of beet armyworms in a field. After germination, fields should be monitored twice a week. According to University of Arizona guidelines, prior to leaf formation parsley should be treated when populations reach 1 larva per 50 plants[15]. Once the leaves have formed, parsley can tolerate 1 larva per 100 plants[15]. All other lepidopterous larvae that are noted should be included in this total.

Biological Control: There are viral pathogens, parasitic wasps and predators that attack the beet armyworm. These beneficials, however, are unable to completely control armyworm populations. Caution must be used when spraying insecticides as they can harm beneficial insects.

Chemical Control: Spinosad, tebufenozide and pyrethroids are the most commonly used insecticides for the control of armyworms. There is also a new insecticide on the market, indoxacarb, which will also provide control for armyworms. The best time to spray with an insecticide is when the larvae are hatching; this allows maximum control of the population. This also provides the opportunity to determine the degree of predator activity and dispersal deaths. Insecticides are more effective when applied at dusk or dawn when the armyworms are the most active. It is important to practice sound resistance management practices by alternating chemistries.

Cultural Control: Weeds growing within the field or surrounding the field should be removed, as armyworms can build up in these areas. When planting, it is important to monitor weeds along the field's borders and on ditch banks for eggs and larvae. Armyworms will also migrate from surrounding cotton and alfalfa fields. Fields should be disked immediately following harvest to kill any larvae pupating in the soil.

Post-Harvest Control: There are no methods for the post harvest control of armyworms.

Alternative Control: Some growers use diatomaceous earth, neem oil soap, neem emulsion and rotenone for the control of beet armyworms. *Bacillus thuringiensis* is registered for controlling beet armyworms but does not provide adequate control.

Corn earworm (bollworm) (*Helicoverpa zea*)

Tobacco budworm (*Heliothis virescens*)

The tobacco budworm and corn earworm occur throughout Arizona but are the most prevalent in central and western parts of the state. The adult corn earworm moth has mottled gray-brown forewings; the hindwings are white with dark spots. The forewings of the tobacco budworm moth are light olive-green with three thin, dark bands; the hindwings are white with a red-brown border. The female moth lays white eggs separately on the plant's leaves. Twenty-four hours after they are laid, the eggs develop a dark band around the top and prior to hatching the eggs darken in color. The larvae of these two species can be a variety of colors and develop stripes down the length of their body. It is difficult to differentiate between the larvae of these two species until they are older. Older larvae can be distinguished by comparing the spines at the base of the abdominal tubercles and by the presence of a tooth in the mandible.

Budworm and earworm populations peak during the fall. These larvae attack all stages of plant growth and can be very destructive to parsley stands. The larvae are cannibalistic, eating larvae of their own species and of other lepidopterous species, thus they tend to be feed alone. These larvae are capable of killing entire stands of seedlings. In older plants, the larvae chew holes into the leaves. Damage to the parsley leaves results in an unmarketable plant.

Sampling and Treatment Thresholds: Field monitoring should begin immediately following seed germination. Pheromone traps can be used to monitor for the presence of tobacco budworms and corn earworms. Earworms and budworms migrate from corn and cotton fields, thus it is important to carefully monitor field edges that border these crops. If eggs are discovered, it should be determined if they have hatched, are about to hatch or have been parasitized. The parsley should also be checked for larvae and feeding damage. It is important to correctly identify which larvae are present, as resistance in tobacco budworms has been reported. Experts at the University of Arizona recommend that parsley should be treated before leaf formation when populations reach 1 larva per 50 plants[15]. After leaf formation the crop can tolerate 1 larva per 100 plants[15]. All other larvae in the lepidopterous complex should be included in this count.

Biological Control: Some parasites and predators of earworms and budworms include; *Trichogramma* sp. (egg parasite), *Hyposoter exiguae* (larval parasite), *Orius* sp. (minute pirate bug) and *Geocoris* sp. (bigeyed bugs). These enemies are often able to reduce earworm and budworm populations. Care must be taken with insecticide treatment, as it can decrease the populations of beneficial insects. Nuclear polyhedrosis virus, a naturally occurring pathogen, also helps control populations.

Chemical Control: Insecticide treatment is more effective at peak hatching, when larvae are still young. Eggs darken just prior to hatching, which gives a good indication when to prepare to spray. This also allows the opportunity to check for the presence of predators and parasites. The best time to treat for tobacco budworms is mid-afternoon, this is when the larvae are the most active. Spinosad and pyrethroids are often used for controlling earworms and budworms.

Cultural Control: Delaying planting until after cotton defoliation will decrease larvae migration into parsley fields. Due to market demands it is not always feasible to delay planting. Fields that are planted next to cotton fields require close monitoring. Fields should disked following harvest to kill any larvae pupating in the soil.

Post-Harvest Control: There are no methods for the post-harvest control of corn earworms or tobacco budworms.

Alternative Control: Methods for the alternative control of budworms and earworms include: diatomaceous earth, neem oil soap, neem emulsion and rotenone.

1999 Insecticide Usage to Control Lepidoptera Larvae on Arizona Grown Parsley

							(# of reports)				
Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	# of Acres	% of Acres Treated	# of Reports**	By Air	AW***	CE	CW	L
Bacillus thuringiensis	0.05	0.43	1.05	8	73%	1	1	1	0	0	1
Diazinon (**OP**)	0.25	0.54	4	8.6	78%	4	2	2	0	4	0
Malathion (**OP**)	1.5	1.60	2	2.5	23%	1	1	1	0	0	0
Methomyl (**carbamate**)	0.45	0.74	0.9	32.7	297%	12	11	12	0	2	0
Permethrin	0.05	0.20	0.2	8	73%	1	1	1	0	0	1
Spinosad	0.023	0.07	0.156	18.5	168%	3	3	3	1	0	2

AW - armyworm
CE - corn earworm
CW - cutworm
L - loopers
OP - organophosphate

*Application rates are pounds of active ingredient (AI) per acre. Average rate is an average of field level rates from the ADA 1080 reports using a NAS conversion table to determine the pounds of AI in pesticide products. Maximum and minimum rates are from product labels.

**the number of reports is the number of unique 1080 forms received with indicated AI. 1080s with multiple AIs are counted for each AI. Acres for multiple AI mixes are separately counted for each AI. % of acres treated is AI acre total divided by planted acres. Only previous year's planted acres is available.

***Up to four target pests are recorded and multiple AI applications are common. No mechanism in the 1080 forms presently exists to link specific AIs to specific target pests. For this reason, all AI/pest counts do not necessarily reflect intended efficacy.

Homoptera

APHIDS (syn. "plant lice")

Green Peach Aphid (*Myzus persicae*)

Potato Aphid (*Macrosiphum euphorbiae*)

Aphids are the most significant pest of parsley grown in Arizona. There are two main species of aphid that are pests to parsley: green peach aphids and potato aphids. These aphids may or may not have wings. Green peach aphids are light green, red or pink in color. They are found feeding on the lower surface of mature leaves and will quickly colonize younger leaves as the population increases. Potato aphids have a similar appearance to green peach aphids but are larger and form small colonies on the lower surface of new leaves.

Aphid populations peak during the months of November and December and again during February and March. Populations consist entirely of asexual reproducing females producing live young; this allows the population to increase rapidly. Under ideal conditions aphids have as many as 21 generations in one year. When populations become too large or food is scarce, aphids produce winged offspring that can migrate to new hosts.

Aphids can be very destructive to parsley. The majority of aphid damage occurs during the final maturing stage of parsley. Extreme aphid feeding can deplete a plant of enough phloem sap to reduce the plant’s vigor or even kill the plant. In addition, as an aphid feeds it excretes phloem sap ("honeydew") onto the plant’s surface. This provides an ideal environment for sooty mold infection, which inhibits photosynthesis. Aphid feeding can cause the leaves to become deformed. Another concern is the viruses that green peach aphids can transmit such as; alfalfa mosaic virus, lettuce mosaic virus and beet western yellows virus. Aphids are most damaging, however, as a contaminant.

<u>Sampling and Treatment Thresholds</u>: To control aphid infestations, it is essential to monitor fields frequently and prevent the growth of large populations. These pests migrate into crop fields and reproduce rapidly, quickly infecting a crop. Beginning in January, fields should be monitored no less than twice a week. Yellow waterpan traps are useful for measuring aphid movement into the field. In infested fields, aphids tend to occur in clusters within the field, thus it is important to randomly sample the field. Experts at the University of Arizona recommend that prior to parsley leaf formation, treatment should begin when populations reach 1 aphid per 10 plants[15]. After leaf formation, parsley should be treated when aphid colonization begins[15].

<u>Biological Control</u>: Parasitoids and predators that attack aphids are available; however, they are usually unable to completely control aphid populations. Lady beetle larvae, lacewing larvae, syriphid fly larva, aphid parasites are some of the insects used to control aphids. Spraying of insecticides should be performed with caution as it can eliminate beneficial insects. These beneficial insects, however, can also become contaminants of parsley.

Chemical Control: A pre-plant application of imidacloprid is the most common method used to control aphids. This insecticide has the added benefit of long-term residual control. However, this prophylactic approach to control is expensive and is applied with the assumption that the crop will receive aphid pressure. Many growers will choose to wait and apply a foliar insecticide. When foliar insecticides are used, the timing of application is critical. Imidacloprid and malathion are the only foliar-applied insecticides that are labeled for use on parsley grown in Arizona. Malathion has little activity against aphids. The initial foliar-applied treatment should occur once wingless aphids begin to migrate into a crop field. To ensure that the harvested parsley is not contaminated with aphids, it might be necessary to use repeated applications. Aphids often hide within the protected areas of the parsley making insecticide treatment difficult. If aphids only occur at the field borders or in isolated areas, border or spot applications might be sufficient to control populations. Insecticide chemistries should be alternated for good resistance management.

Endosulfan, oxydemeton-methyl and dimethoate are often used to control aphids, however these chemistries are not registered on parsley. A greater diversity of insecticides is necessary to allow proper resistance management.

Cultural Control: Aphids tend to build up in weeds, particularly cruciferous weeds and sowthistle (*Sonchus asper*), therefore it is important to control weeds in the field and surrounding the field. Fields should be plowed under immediately following harvest, to eliminate any crop refuse that could host aphids

Post-Harvest Control: There are no methods for the post-harvest control of aphids.

Alternative Control: Organic growers use; insecticidial soaps, neem oil soap, neem emulsion, pyrethrins, rotenone dust, plant growth activators, elemental sulfur, garlic spray and diatomaceous earth to control aphid populations.

WHITEFLIES

Sweetpotato whitefly (*Bemisia tabaci*)

Silverleaf whitefly (*Bemisia argentifolii*)

Historically, whiteflies have not been a primary pest of parsley but have been a concern because of their ability to spread viral pathogens. More recently, whiteflies have become a primary pest feeding on the plant's phloem and are capable of destroying an entire crop.

The adult whitefly is minute (1/16" in length) and has a white powder covering its body and wings. The female whitefly lays small, oval, yellow eggs on the undersurface of young leaves. The eggs become darker in color prior to hatching. The hatched whitefly (nymph) travels about the plant until it finds a desirable minor vein to feed from and does not move from this vein until it is ready to pupate. Whiteflies can have numerous generations in one year.

Whitefly infestations are usually the heaviest during the fall. Colonization of the crop can begin immediately following germination, beginning with whiteflies feeding on the cotyledons. Whiteflies migrate from cotton, melon and squash fields, as well as, from weed hosts. Parsley planted downwind from these crops is particularly susceptible. Whitefly feeding removes essential salts, vitamins and amino acids required by parsley for proper growth. This feeding results in, reduces plant vigor, decreased plant size and can delay harvest if not controlled at an early stage. As with aphids, the phloem sap that whiteflies excrete onto the parsley's surface creates an ideal environment for sooty mold infection. Whiteflies also contaminate harvested parsley, making it unmarketable. Still a concern is the whitefly's ability to transmit viruses.

Sampling and Treatment Thresholds: The best way to prevent a whitefly infestation is to inhibit initial colonization. Whitefly counts should be performed early in the morning when the insects are the least active. Once whiteflies become active they are difficult to count. During the mid-morning, fields should be monitored for swarms of migrating whiteflies. According to University of Arizona guidelines, if a soil-applied insecticide is not used, crops should be treated when populations reach 5 adults per leaf[15]

Biological Control: Parasitoid wasps (*Eretmocerus* sp.) can be used to control whitefly populations, however they only parasitize immature whiteflies. Lacewing larvae and ladybug larvae (syn: ant lions) are also used for the control of whiteflies. These insects are very sensitive to pyrethroids and other insecticides, thus it is important to determine the severity of pest pressure and the activity of beneficial insects before spraying.

Chemical Control: If the crop is planted in August or September when populations are at their greatest, a soil-applied prophylactic-insecticide is commonly used. If parsley is planted after whitefly populations have declined, foliar applied insecticides can be used as necessary. Imidacloprid is a commonly used foliar insecticide. Tank-mixing insecticides helps control whiteflies, as well as, preventing the build up of insecticide resistance. When spraying it is important to achieve complete crop coverage, this will provide the best control of whiteflies. There is a strong dependence on imidacloprid to control whiteflies; this creates concerns of product resistance. As well, whitefly resistance to organophosphates and pyrethroids has been noted in the past, thus resistance management is important.

Endosulfan, oxydemeton-methyl and dimethoate are often used to control whiteflies, however these chemistries are not registered on parsley. A greater diversity of insecticides is necessary to allow proper resistance management.

Cultural Control: Whitefly populations are most active in early September and tend to migrate from defoliated and harvested cotton. Delaying planting until populations have begun to decrease and temperatures are lower will help to decrease whitefly infestation. However, delay of planting is not always a feasible option. Whiteflies build up in weeds, especially cheeseweed (*Malva parviflora*), thus it is important to control weeds in the field and surrounding the field. Crop debris should be plowed under immediately following harvest to prevent whitefly build up and migration to other fields.

Post-Harvest Control: There are no methods for the post-harvest control of whiteflies.

Alternative Control: Organic produce growers use; neem oil soap, neem emulsion, pyrethrin, insecticidial soaps, rotenone, elemental sulfur, garlic spray and diatomaceous earth to control whiteflies.

Thysanoptera

THRIPS

Western Flower Thrips (*Frankliniella occidentalis)*

Onion Thrips (*Thrips tabaci*)

Thrips are present all year, but their populations increase in the early fall and late spring. Thrips spread from surrounding weedy areas, unirrigated pastures and mustard, alfalfa, onion and wheat fields. Currently, thrips only pose a moderate threat to parsley production in Arizona.

Thrips species are minute (1/16 in.), slender and pale yellow-brown in color. The two species are similar in appearance, which can make it difficult to distinguish between them. It is important, however, to identify which species of thrips are present because western flower thrips are more difficult to control. Consulting a specialist is best if one is unsure. Female thrips lay small, white, bean-shaped eggs within the plant tissue. The hatched nymphs are similar in appearance to the adults, but smaller in size and lack wings. Thrips will pupate in the soil, or leaf litter, below the plant.

Thrips feeding results in wrinkled and deformed leaves and stunted growth. Feeding can also cause brown scaring; extreme damage causes leaves to dry and fall off the plant. Black dust (thrips feces) on the leaves distinguishes this damage from windburn or sand burn. Thrips present in harvested parsley are considered a contaminant. Parsley that has been damaged by thrips or that is contaminated by thrips is not marketable.

Sampling and Treatment Thresholds: Sticky traps are a good method for monitoring thrips migration into a field. When inspecting for thrips parsley must be carefully examined for any thrips hiding between the tightly packed parsley leaves. It is estimated that for every 3 to 5 thrips observed there are three times as many undiscovered. The University of Arizona recommends that prior to leaf formation, parsley should be treated when populations reach 1 thrips per 10 plants[15]. After leaf formation, the crop should be treated when the population reaches 1 thrips per 25 plants[15].

Biological Control: Lacewing larvae, ladybug larvae (syn: ant lions) and the minute pirate bug are used to provide control of thrips. Insecticides must be sprayed with care as they can harm these beneficial insects.

Chemical Control: Treatment should begin when thrips populations are still low and when tissue scarring begins. For more effective control, applications should be made during the afternoon because this is when thrips are the most active. Studies have shown that even the most effective insecticides do not decrease thrips populations; they are merely able to maintain the population size. This is important to consider when an application date is being chosen. The number of applications a crop stand requires will vary according to the residual effect of the chemical and the rate of thrips movement into the crop field. The size of the plant and the temperature will also affect the degree of control. The more mature a plant is, the more folds and crevices there are for thrips to hide in and avoid insecticide contact. Insecticide resistance has been observed in western thrips populations, making this species difficult to control.

Pyrethroids such as permethrin and cypermethrin will not control thrips nymphs but will suppress the adults. Pyrethroids should only be used in a tank mix to prevent chemistry tolerance in thrips. Spinosad and methomyl will provide control for nymphs but not adults. Currently there are no insecticides that provide complete control of thrips

Cultural Control: Cultural practices do not effectively control thrips because thrips will rapidly migrate from surrounding vegetation.

Post-Harvest Control: There are no methods for the post-harvest control of thrips.

Alternative Control: Some growers use pyrethrins and elemental sulfur to control thrips.

OTHER CONTAMINANTS (syn. "Trash Bugs")

False Chinch Bug (*Nysius raphanus*) (Hemiptera)

Lygus Bug (*Lygus hesperus*) (Hemiptera)

Three-cornered alfalfa hopper (*Sissistilus festinus*) (Homoptera)

Potato Leafhopper (*Empoasca fabae*) (Homoptera)

The false chinch bug is gray-brown with a narrow, 1/8" long body. The eyes of the false chinch bug protrude from its head. False chinch bugs tend to build up in cruciferous weeds.

The lygus bug varies in color from pale green to yellow-brown with red-brown or black markings. This insect is ¼" long and has a flat back with a triangular marking in the center. These insects are commonly found in cotton, safflower and alfalfa fields, as well as, on weed hosts such as verbena.

The three-cornered alfalfa hopper is approximately a ¼" long with a light-green wedge shaped body. The potato hopper has an elongated body and varies from light green to light brown in color. Both species have well-developed hind legs, allowing them to move quickly. These pests are common in alfalfa and legume fields as well as weed hosts. Leafhoppers are not commonly found in parsley fields.

These contaminants normally do not cause direct damage to parsley, they are more of concern as a contaminant of parsley. Populations of these insects often increase when the growing season experiences high rainfall and the desert vegetation and cruciferous weeds flourish. These insects also build up when parsley is planted near alfalfa.

Sampling and Treatment Thresholds: The University of Arizona suggests that before the formation of the parsley leaves, a stand does not require treatment until populations reach 10 contaminant insects per 50 plants[15]. Once the leaves have formed, parsley should be treated when populations reach 1 contaminant insect per 25 plants[15].

Biological Control: There are no methods for the biological control of contaminant insects.

Chemical Control: Since these insects generally do not cause physical damage to parsley, chemical control is not normally required until leaf formation begins. Growers typically spray as close to harvest as possible, to ensure the parsley is not contaminated. Methomyl, diazinon and pyrethroids such as permethrin and cypermethrin are the most commonly used insecticides for controlling contaminant insects.

Cultural Control: It is important to control weeds that can harbor contaminants, in the field and surrounding the field. Alfalfa should not be cut until the parsley field has been harvested, this will prevent insect migration into the parsley field.

Post-Harvest Control: There are no methods for the post-harvest control of contaminant insects.

Alternative Control: Some growers use neem oil, garlic spray, rotenone and pyrethrins to control contaminant insects.

1999 Insecticide Usage on Parsley Grown in Yuma County, Arizona

Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	# of Acres	% of Acres Treated	# of Reports**	(# of reports) By Air	Aph.	Lep.	SE	WF
Bacillus thuringiensis	0.05	0.43	1.05	8	73%	1	1	0	2	0	0
Diazinon (**OP**)	0.25	0.54	4	8.6	78%	4	2	0	6	0	0
Imidacloprid	0.16	0.24	0.38	2.5	23%	1	0	0	0	0	1
Malathion (**OP**)	1.5	1.60	2	2.5	23%	1	1	1	1	0	0
Methomyl (**carbamate**)	0.45	0.74	0.9	32.7	297%	12	11	1	14	0	0
Permethrin	0.05	0.18	0.2	10	91%	2	1	0	2	1	0

Spinosad	0.023	0.07	0.156	18.5	168%	3	3	0	6	0	0

Aph. - aphids
Lep. - lepidoptera larva
SE - stand establishment insects = maggots, ants, crickets, flea beetles, darkling beetles, grasshoppers
WF - whitefly
OP - organophosphate

Note: there is no available data for the insecticide use in Maricopa county, Arizona.

*Application rates are pounds of active ingredient (AI) per acre. Average rate is an average of field level rates from the ADA 1080 reports using a NAS conversion table to determine the pounds of active ingredient (AI) in pesticide products. Maximum and minimum rates come from product labels.

**The number of reports is the number of unique 1080 forms received with indicated AI. 1080s with multiple AIs are counted as an individual report for each AI. Acres for multiple AI mixes are separately counted for each AI. % of acres treated is AI acre total divided by total planted acres. Only previous year's planted acres is available.

***Up to four target pests are recorded and multiple AI applications are common. No mechanism in the 1080 forms presently exists to link specific AIs to specific target pests. For this reason, all AI/pest counts do not necessarily reflect intended efficacy.

Diseases

FUNGAL DISEASES

(4, 7, 8, 11, 14, 20, 21, 25)

Damping-off (*Pythium* sp., *Rhizoctonia solani*)

In Arizona, damping-off is occasionally observed in parsley fields. Damping-off is a soilborne fungus that attacks germinated seedlings that have not yet emerged or have just emerged. Cool, wet weather promotes infection by most *Pythium* species, where as cool to moderate weather promotes *Rhizoctonia* infection. Fields that have poor drainage, compacted soil and/or high green organic matter are the most susceptible to damping-off. The damping-off fungi will not affect plants that have reached the three to four-leaf stage.

Damage usually occurs at soil level, leaving lesions in the stem tissue. The tissue becomes dark and withered, the weak support causes the seedling to collapse and die. *Pythium* can also attack the seedling's roots, causing them to turn brown and rotten.

Biological Control: *Gliocladium virens* GL-21 is the only biological method available for controlling *Pythium* and *Rhizoctonia* induced damping-off. *G. virens* is a fungus that antagonizes *Pythium* and *Rhizoctonia*. In the greenhouse *G. virens* provides good control of damping-off; in the field the control that *G. virens* provides is variable.

Chemical Control: Metam sodium and metam potassium are fumigants registered for use on both *Pythium* and *Rhizoctonia* induced damping-off; however, these methods are very costly and generally not considered a viable option. Mefenoxam is the only other chemical method available for controlling *Pythium*-induced damping-off. This fungicide works best when used as a preventative treatment, being applied before disease becomes apparent. Usually mefenoxam is applied in a band over the seed row, either pre-plant incorporated or preemergence. Other than the available fumigants, which are very expensive methods of treatment; there are no other chemistries available for controlling *Rhizoctonia* in parsley grown in Arizona. There are no registered seed treatments in Arizona for controlling damping-off of parsley. Most growers, however, do not treat for damping-off as this disease is not currently a large threat to parsley in Arizona.

Cultural Control: All residues from the previous crop should be plowed under and completely decomposed before planting parsley. It is best to plant when the soil is warm, as this will speed germination and allow the crop to quickly reach a resistant stage of growth. Overhead or sprinkler irrigation are the best methods for promoting rapid germination. It is important to manage water and avoid over saturating the field. Fields should be properly drained and low spots should be eliminated to avoid water accumulation. When directly seeding it is important not to plant too deep as this will slow emergence, increasing the seedling's susceptibility to damping-off. If transplants are used they should be inspected for healthy, white roots. It is important to avoid stressing the crop, as this will make it more susceptible to damping-off.

Post-Harvest Control: There are no effective post-harvest measures for the control of damping-off.

Alternative Control: Some growers spread compost on the soil to control pathogens.

Alternaria Leafspot (*Alternaria* sp.)

Alternaria is rarely reported on parsley in Arizona. Alternaria leafspot, also know as alternaria blight, typically occurs during a wet winter.

Symptoms begin as a small dark spot on the leaf and stem of parsley. As the disease progresses, concentric rings will develop around the spot creating a bulls-eye pattern. Eventually, brown, velvety spore-bearing growths develop within the spots. If left untreated, alternaria leafspot will eventually defoliate a plant. *Alternaria* spores can survive for long periods of time on plant debris, weed hosts or within infected seeds. The fungal spores are wind and rain dispersed. The spores require free water for germination to occur.

Biological Control: There are no biological methods for controlling *Alternaria*.

Chemical Control: Azoxystrobin is the only fungicide registered for controlling alternaria leaf spot. These fungicides are foliar applied and are most effective when applied as a protectant before the onset of disease.

Cultural Control: *Alternaria* can be passed on to the next generation in infected seed, therefore it is important to be certain that seed is disease-free. *Alternaria* also persists in the soil; thus it is important to rotate crops to prevent disease carryover. It is important to clean equipment between uses in different fields, to prevent contamination of an uninfected field. Controlling weeds that can act as a disease host will prevent the transmission of *Alternaria* from these weeds to parsley.

Post-Harvest Control: There are no post-harvest methods for controlling *Alternaria*.

Alternative Control: Some organic growers spread compost on the soil to control pathogens. Neem oil is also registered for controlling *Alternaria*.

Sclerotinia Rot (*Sclerotinia minor, Sclerotinia sclerotiorum*)

In Arizona, *Sclerotinia* is normally not a concern in parsley but it has been reported to occur on parsley in the past. Sclerotinia rot thrives when the winter growing season is cool and wet.

Sclerotinia rot, also known as white mold, is caused by two species of soil-borne fungi. *Sclerotinia minor* infects only the parts of the plant that are in contact with the ground. *Sclerotinia sclerotiorum* will also infect those plant parts that are in contact with the soil, but in addition produce air-borne spores that can infect the upper leaves. The first sign of infection is the covering of the parsley with white cottony mold. Eventually the infected tissue turns brown, becomes watery and decays. As sclerotinia rot persists, the leaves will drop off and the parsley plant will weaken and collapse.

The fungus produces large, black sclerotia in the plant tissue and on the soil surface. The sclerotia can survive for a long time in the soil, especially when the weather is dry. The sclerotia of *S. minor* and *S. sclerotinia* are spread by contaminated equipment, soil and plant tissue. *S. sclerotiorum* also produces sexual spores that are spread by wind. Sclerotia germinate on the soil and then infect the plant. Cultural and chemical practices can help control *S. minor*, however, they are not very effective on the air-borne spores of *S. sclerotiorum*.

<u>Biological Control</u>: There are no available methods for the biological control of *Sclerotinia*.

<u>Chemical Control</u>: Metam sodium and metam-potassium are fumigants registered for use on *Sclerotinia*; however, these methods are very costly and generally not considered a viable option. There are no other chemistries registered for the control of *Sclerotinia*.

<u>Cultural Control</u>: Fields should be irrigated with care, as wet conditions favor *Sclerotinia*. Weed control in and around the field is essential to eliminate potential hosts for *Sclerotinia*. It important to rotate to resistant crops, which will prevent the transmission of sclerotinia rot to the next crop. Infected plant debris should be removed from the field. Following harvest, fields must be deeply plowed to bury the sclerotia a minimum of 10 inches and encourage their decay. This will not, however, prevent the introduction of the air-borne spores of *S. sclerotiorum*.

<u>Post-Harvest Control</u>: There are no methods for the post-harvest control of sclerotinia rot.

<u>Alternative Control</u>: Some organic growers spread compost on the soil to control pathogens. *Bacillus subtilis* is also registered for controlling *Sclerotinia*.

BACTERIAL DISEASES

(7, 8, 14, 20, 21, 22, 23)

Bacterial Soft Rot (*Erwinia* sp.)

In Arizona bacterial soft rot is occasionally reported to occur on parsley. Bacterial soft rot can occur in the field, but is most common during post-harvest storage. Infection often occurs on parsley that is stored at warm temperatures, or if heat is allowed to accumulate in the storage containers. This disease attacks the leaves and petioles of parsley and is capable of destroying an entire lot of parsley.

Open wounds on the plant provide an entry for the bacterium. A plant that was damaged by freezing or insects is particularly susceptible to bacterial soft rot. The initial sign of infection is water soaked spots on the plant. Once inside parsley the bacterium spreads rapidly. The bacterium dissolves the middle lamella that holds cells together and causes the inner contents of the cell to shrink. The infected portions of the plant can develop a brown color.

Erwinia is spread by; machinery, insects, rain, irrigation and humans.

<u>Biological Control</u>: There are no available methods for the biological control of bacterial soft rot.

Chemical Control: There are no methods for the direct chemical control of *Erwinia*; however, insecticides can help control the insects that damage parsley leaving it susceptible to bacterial infection.

Cultural Control: Crops should be cultivated carefully, to prevent damage to the plant that could provide an entryway for bacterial infection. It is important to control weeds in and around the field that could act as a host to *Erwinia*.

Post-Harvest Control: Parsley should be handled carefully to avoid bruising and wounding that will leave the plant susceptible to infection. Plants must be thoroughly cleaned and stored at a low temperature, typically 40 °F. It is important to keep the storage facility free of soft rot bacteria by immediately destroying any infected plants and maintaining a clean facility.

Alternative Control: Some growers spread compost on the soil to control pathogens. There are no alternative control methods that can be utilized during post-harvest storage.

Note: there is no available data for the fungicide use in Arizona in 1999.

VIRAL DISEASES

(11, 25, 26)

Generally speaking, viral diseases are not a common occurrence for parsley grown in Arizona. It is susceptible to some mosaic viruses, such as western celery virus, but their occurrences are rare. Mosaic viral diseases cause the parsley's leaves to develop a yellow/light green/dark green mottled appearance. Necrotic areas can also develop. When infection is severe and occurs early in plant development, it can decrease plant vigor. Green peach aphids are capable of transmitting viral diseases.

Biological Control: There are no biological methods for directly controlling viruses, however biological methods can be utilized to control virus vectors, e.g. aphids and whiteflies. Controlling virus vectors, however, is not very effective because it only requires a few insects to spread viral diseases.

Chemical Control: Viruses can not be chemically controlled. The insects that spread viruses, however, can be controlled (e.g. aphids, whiteflies). This method of control, however, is inefficient because it only requires a few insects to spread viral disease.

Cultural Control: Only planting disease-free seed and resistant cultivars will help control viral infections. Controlling weeds that can serve as hosts for viral diseases is crucial. It is also important to avoid stressing the plant, i.e.) supply an adequate amount of water and fertilization. All plant residues should be plowed into the soil and promote their decomposition. This will eliminate the host, thus killing the virus.

Post-Harvest Control: There are no available methods for the post-harvest control of viruses.

Alternative Control: There are no available methods for the alternative control of viruses.

ABIOTIC DISEASES

(11, 24)

There are a number of abiotic diseases that parsley can suffer from that can affect the crop yield and often have symptoms similar to those caused by pathogens or insect pests.

Parsley is very intolerant of cold and frost. When parsley is damaged by frost injury, the outer edges of the leaves will brown and dry out. This damage will leave the plant susceptible to secondary infections. In addition, if the leaves of parsley are damaged or scarred they are unmarketable.

Strong winds carrying sand can abrade the leaves and make them susceptible to secondary infections. When the leaves heal themselves, it results in thickened, discolored areas that can be misidentified as pathogen infection. Wind can also severely damage seedlings, pinching the stem and collapsing them.

High salt concentrations in the soil can be injurious to parsley. Symptoms include; stunted plants, thick, dark leaves, yellowing or burning at the leaf margin and roots that are orange in color and rough in appearance. Salt may also inhibit seed germination.

Nutrient deficiencies will cause parsley damage. Nutrient deficiency damage often results in stunted plants, chlorosis and leaf spotting. Nitrogen, phosphorus and molybdenum are the most common element deficiencies to cause injury. Soil and plant tissue should be sampled regularly to determine if deficiencies are present. It is usually not possible, however, to replenish an element after the stand is established.

Vertebrates

(11, 12)

Birds can be very destructive of crops. Horned larks, black birds, starlings, cowbirds, grackles, crowned sparrows, house sparrows and house finches frequently eat planted seeds and seedlings. Frightening devices (visual and acoustical), trapping, poisoned baits and roost control can be used to control birds. Pocket gophers can be destructive to parsley crops by eating and damaging the roots when they dig their burrows. The mounds that gophers produce while digging their burrows can be damaging to agricultural equipment and can disrupt irrigation furrows. Some methods for controlling gophers include controlling food sources (weeds), fumigation, flooding, trapping and poisoning. Ground squirrels (roundtailed ground squirrel, rock squirrel, Harris ground squirrel) are known to damage irrigation ditches and canals as well as feed on parsley seedlings. These pests can be controlled by fumigation, trapping and poisoning. It is best to poison squirrels in their burrows to prevent poisoning of predatory birds. There are several species of mice that can be pests of vegetable crops; they can be controlled by repellents and occasionally with poisoning. Wood rats occasionally pose a threat to the crop and can be controlled by; exclusion, repellents, trapping, shooting, toxic baits. Raptors, kestrels and burrowing owls are all helpful for the control of rodent populations. Rabbits (black-tailed jackrabbits, desert cottontails) that infest fields and cause economic loss. Rabbits can be controlled by habitat manipulation, exclusion, trapping, predators (dogs, coyotes, bobcats, eagles, hawks etc), repellents and poisons. In Arizona, cottontails are classified as a small game species and state laws must be observed to take this species. Jackrabbits are classified as nongame species, but a hunting license or depredation permit is required to take the species. Elk, whitetail deer and mule deer can cause severe grazing damage to vegetable crops. Deer and elk, however, are classified as game species and require special permits to remove them. Fencing can be used for deer control; frightening devices and repellents provide some control. Feral horses and burros also cause damage to parsley, but are also protected by Arizona State laws.

Weeds

(4, 11, 12, 14, 28)

Weeds are a threat to the cultivation of any crop. They compete with the crop for sunlight, water and nutrients. Control of weeds is fundamental for pest management. Weeds may host a variety of diseases and pests that can be transmitted to parsley. Weed control is the most important during the first 30 days of plant establishment, after this period parsley is better able to compete with weeds. As well, the canopy created by the parsley stand, shades the underlying soil and inhibits the germination of weed seeds. The planting date can also give parsley the advantage. Fields planted when summer weeds are dying back but before winter weeds have begun to germinate have decreased weed competition. Due to market windows, however, it is not always feasible to delay planting. It is essential that weeds be destroyed before they flower and produce seed. One plant can produce hundreds or thousands of seeds depending on the weed species.

The summer broadleaf weeds most commonly found in Arizona between the months of August and October include pigweed (*Amaranthus* sp.), purslane (*Portulaca oleracea*), lambsquarters (*Chenopodium album*) and groundcherry (*Physalis wrightii*). Common summer grasses include; barnyardgrass (*Echinochloa crusgalli*), cupgrass (*Eriochloa* sp.), junglerice (*Echinochloa colonum*) and sprangletop (*Leptochloa* sp.). The winter broadleaf weeds most commonly found in Arizona between the months of November and March include black mustard (*Brassica nigra*), wild *radish (Raphanus sativus*), shepherdspurse *(Capsella bursa-pastoris*), London rocket (*Sisymbrium i*rio), cheeseweed (*Malva parviflora*), sowthistle (*Sonchus oleraceus*), knotweed (*Polygonum* sp.), annual yellow sweet grass (*Melilotus* indicus), prickly lettuce (*Lactuca serriola*) and nettleleaf goosefoot (*Chenopodium murale*). Common winter grasses include; canarygrass (*Phalaris minor*), annual blue grass (*Poa annua*), wild oats (*Avena fatua*) and wild barley (*Hordeum* sp.).

<u>Sampling and Treatment Thresholds</u>: A yearly record should be kept detailing what weed species are observed in each field. This is important because herbicides usually work best on germinating weeds. To choose the appropriate herbicide, one must know what weeds are present before they have germinated.

<u>Biological Control</u>: There are no effective methods available for the biological control of weeds.

<u>Chemical Control</u>: It is challenging to adequately control weeds while ensuring crop safety. It is important to correctly identify the weed species, as different weeds have different chemical tolerances. Most postemergence herbicides do not have a wide range of weed control and are especially poor at controlling cruciferous weeds such as wild mustard and shepherd's purse. Preemergence herbicides are often a more effective form of weed control. Another option is to use a non-selective herbicide such as glyphosate to sanitize the field prior to parsley emergence.

Bensulide is registered as a preemergence grass herbicide for use on parsley grown in Arizona. Bensulide is usually sprayed behind the planter in a band over the seed row; however, it can also be broadcast spayed or chemigated. Irrigation is required to activate this chemistry; sprinkler irrigation is often utilized. This herbicide is effective against grass weeds and will also control some small-seeded broadleaf weeds. Oxyfluorfen is an effective preemergence broadleaf herbicide but has little effect on grasses. In addition, oxyfluorfen is only registered for use on transplanted parsley. It can be used on a fallow field but the plant back restriction is 120 days, which makes this option impractical. There are no other preemergence herbicides registered for use on parsley grown in Arizona.

Sethoxydim is the only available postemergence herbicide. This herbicide has good grass control but has no efficacy against broadleaf weeds. Pelargonic acid can be used for spot treatment on postemergence crops.

Herbicides can cause injury to parsley if not applied correctly and carefully. Injury may result from spray drift, residue in the soil from the previous crop, accidental double application to a row, using the wrong herbicide, or using a rate that is too high. Herbicide injury can cause leaf spotting or yellowing that can be misidentified as pathogen injury or nutrient deficiency. Soil, water or plant tissue test can be used to identify herbicide injury.

Cultural Control: Parsley should be encouraged to grow quickly and establish the stand, which will increase the ability of parsley to out compete any weeds present in the field. Precise planting, a regular water supply and appropriate fertilization will help increase the ability of parsley to compete with weeds.

Purchasing seed that is guaranteed to be weed-free will help prevent the introduction of new weed species into a field. Contaminated irrigation water from canals, reservoirs and sumps can also spread weed seed. It is also important to maintain field sanitation by always cleaning equipment used in one field before it is used in another and ensuring that any manure that is used is weed seed free. Irrigation ditches, field borders and any other uncropped area should be maintained weed-free. A properly leveled field is important to prevent the build up water in isolated areas, especially when utilizing furrow irrigation. This water build up will promote the germination of weeds that are favored by wet conditions.

Delaying planting until the time when summer weeds are declining but before winter weeds begin to germinate will decrease the amount of weed competition. However, due to market demands this control method is not always feasible.

Another method used to control weeds is to till the field, form beds and irrigate prior to planting. This will encourage the germination of the weed seeds. The field can then be sprayed with a nonspecific herbicide or rotary hoed to kill the weeds. After the weeds have been destroyed, the parsley is planted. Disking will eliminate germinated weeds but will also expose new weed seed that may germinate and cause a second flush of weeds.

Cultivation and hoeing can be used to control weeds in a planted field but should be done with care due to the shallow root system of parsley. Rows and beds must be carefully planted and the cultivation equipment must be carefully aligned. Fields should be disked following harvest to eliminate any weeds present and prevent the weeds from flowering and spreading seed.

Crop rotation will allow the use of different herbicides that may be more effective for weed control. Crop rotation also promotes different cultural practices and planting times that will aid in weed control.

Post-Harvest Control: There are no methods for the post-harvest control of weeds.

Alternative Control: There are no alternative methods available for controlling weeds

1999 Herbicide Usage on Parsley Grown in Arizona

Active Ingredient	Label Min.*	Ave. Rate*	Label Max.*	Acres	% Acres	Reports**	SLN	Broadleaf
Bensulide	5	3.0	6	2.5	23%	1	0	1

Note: there is no available data for the herbicide use in Maricopa County, Arizona.

Note: Unspecified typically refers to weeds that were treated at the germination stage or seedling stage with a general weed control.

*Application rates are pounds of active ingredient (AI) per acre. Average rate is an average of field level rates from the ADA 1080 reports using a NAS conversion table to determine the pounds of AI in pesticide products. Maximum and minimum rates come from product labels.

**the number of reports is the number of unique 1080 forms received with indicated AI. 1080s with multiple AIs are counted for each AI. Acres for multiple AI mixes are separately counted for each AI. % of acres treated is AI acre total divided by planted acres. Only the previous year's planted acres is available.

***Up to four target pests are recorded and multiple AI applications are common. No mechanism in the 1080 forms presently exists to link specific AIs to specific target pests. For this reason, all AI/pest counts do not necessarily reflect intended efficacy.

ARIZONA PESTICIDE USE REPORTING

The state of Arizona mandates that records must be kept on all pesticide applications. Submission to the Arizona Department of Agriculture (ADA) of these pesticide use reports (form 1080) is mandated for all commercially applied pesticides, pesticides included on the Department of Environmental Quality Groundwater Protection List (GWPL) and section 18 pesticides.

Commercial applicators licensed through the state must submit Arizona

Department of Agriculture Form 1080 Pesticide Use Reports for all applications. The use of commercial applicators varies across crops. Aerial application is always performed by commercial applicators.

The GWPL is a list of active ingredients determined by the Department of Environmental Quality to potentially threaten Arizona groundwater resources. Enforcement of this list is difficult. Strictly speaking, only specific types of soil application of GWPL active ingredients must be reported. Inclusion on the GWPL should indicate a higher level of reporting but without further research no useful distinctions can be drawn.

Section 18 active ingredients should have 100% reporting. There was no section 18s active in Arizona for parsley grown in the 1999 growing season.

Voluntary reporting does take place. Anecdotal evidence indicates some producers submit records for all applications.

Reported pesticide usage provides a solid lower bound of acres treated and a mean application rate of reported applications. Relative magnitude of reported acres is useful for rough comparison but could reflect a bias among commercial applicators or differing reporting rates as a result of inclusion on the GWPL. Finally, while the quality of data from the ADA 1080 forms has improved dramatically in recent years, there is still the possibility of errors.

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