Crop Profile for Broccoli in Arizona

Prepared: November, 2001

Note: this profile contains information pertaining to broccoli grown for the fresh and processed markets only. Broccoli grown for seed is grown in a different manner and experiences different pest pressures; thus it deserves a separate profile to adequately describe its production.

Family: Brassicaceae (syn: Cruciferae)

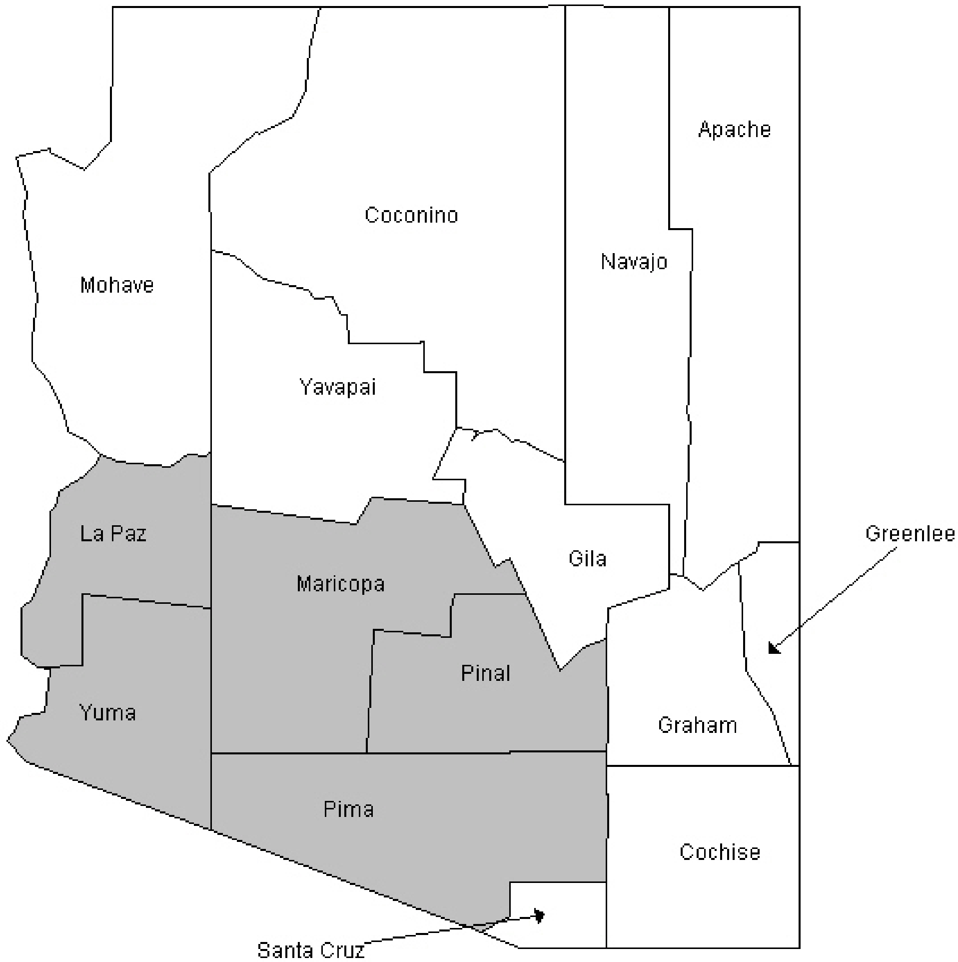
Scientific name: *Brassica oleracea* var. *italica* Plenck

Edible portions: flower head and stem subtending flower stalk; consumed raw or cooked.

Use: fresh and frozen vegetable.

Alternate names: Asparagus Broccoli, Brecoles, Broccolini, Brocoli, Calabrese, Cape Broccoli, Cavolo Broccoli, Heading Broccoli, Italian Broccoli, Purple Cauliflower, Sprouting Broccoli, Winter Broccoli.

General Production Information



- In 1998, Arizona ranked 2nd in the United States for broccoli production, producing approximately 7.5% of the nation's broccoli[2, 3].
- An average of 10,900 acres/year of broccoli was harvested between the growing seasons of 1994/5 and 1998/9[2].
- An average of 72,810 tons of broccoli was produced between the growing seasons of 1994/5 and 1998/9[2].
- Broccoli production had an average yearly value of 45 million dollars between 1994/5 and 1998/9[2].
- Broccoli is produced in La Paz, Maricopa, Pima, Pinal and Yuma Counties. Yuma County accounts for approximately 70% of the broccoli production[2]. Maricopa and Pinal counties, combined, account for 25% of the broccoli production[2].
- Land preparation and growing expenses for broccoli are approximately $3.25/carton[5].
- Harvest and post harvest expenses for broccoli are approximately $3.95/carton[5]. Crowns cost an additional $0.25-0.50 to harvest; florets cost an additional $0.50-0.75 to harvest[5].

Cultural Practices

General Information[7, 26, 32]: In the state of Arizona, broccoli is grown in the fall, winter and spring. Planting can begin as early as the middle of August and is usually completed by the beginning of December. Temperatures during the broccoli-growing season can range between 30 °F to 90 °F. Broccoli can be grown in a wide range of soil types but grows best in well-drained soil. In Arizona, the soils used for broccoli production range from a sandy loam to a clay loam, with a pH of 7.5-8.0.

Cultivars/Varieties[6]: In Arizona, the variety of broccoli chosen is dependent on the timing of planting and the county it is grown in. The climate in Yuma County and Maricopa County can be quite different; evenings in Yuma County are much warmer than in Maricopa County. Broccoli grown in Maricopa County is occasionally exposed to frost.

Planting periods in Maricopa are divided into; Fall, Mid-Winter and Spring. For fall plantings the most commonly chosen varieties are: 'Major", 'Ninja', and 'Captain'. These varieties are chosen because they can withstand the high temperatures that commonly occur in August and September. Ninja is popular because it has excellent crown quality. Major and Captain are popular because they are versatile and hardy, being able to withstand a wide range of temperatures. Both varieties can either be bunched or cut for crowns. The most common varieties for mid-winter plantings are: 'Everest', 'Liberty', 'Greenbelt' and 'Heritage'. Greenbelt is a popular variety and has been grown for a long time. This variety creates excellent bunches and excellent crown cuts. Many growers prefer this variety because of its versatility, this allows the grower to harvest broccoli according to consumer demand (bunches versus crowns). Liberty and Heritage are both new varieties that have the potential to replace Greenbelt. They both produce a crop that can be cut for good quality bunches or crowns. Everest is popular because it matures quickly. This variety is harvested for bunches. The most common varieties for spring plantings are; 'Marathon', 'Triathlon' and 'Greenbelt'. Greenbelt is popular for spring plantings because it can withstand the temperature changes from winter to spring (cool to warm) as well as the change in day length. Triathlon is excellent for late-planted broccoli and produces high quality crowns. Marathon is an older variety that matures slowly and produces good bunches or crowns.

In Yuma County planting periods are divided into; Fall, Transition, Mid-Winter and Spring. Captain and Major are planted during the Fall period. Everest, Coronado and Nomad are planted during the Transition period. Liberty and Greenbelt are grown during the Mid-Winter period. During the spring period, Marathon, Heritage and Triathlon are planted. These varieties have the same characteristics as previously described.

Production Practices[4, 6, 7, 26, 32]: Prior to planting, the field is deeply tilled, disked, then land-planed and bordered. The field is then pre-irrigated, allowed to dry, disked again and then furrowed to form the beds. Sometimes the field is land-planed again before bed formation. A preplant incorporated herbicide may be applied before the beds are formed. If a pre-plant fungicide, such as mefenoxam, is utilized it is usually applied after bed formation but prior to planting.

Most broccoli is directly seeded at ¼ to ½ an inch deep into beds with 40" centers; however, a small proportion of broccoli is transplanted. There are two rows per bed and plants are spaced 7" apart within the row. If a preemergence herbicide is utilized it is often sprayed behind the planter. Sprinkle irrigation is sometimes utilized to establish transplants or promote seed germination, as well as, work any applied herbicides into the soil.

Fields are cultivated two or three times during the production of broccoli. The roots of broccoli grow close to the soil's surface; thus cultivations must be shallow. Fields are side-dressed with fertilizer two or three times, depending on necessity. Broccoli is especially sensitive to boron, manganese, magnesium and molybdenum deficiencies. Nutrient supply is especially important during the development of flower heads. Furrow irrigation is the most common method for providing water to the broccoli crop. Broccoli grown for processing is grown in the same manner as broccoli grown for the fresh market.

Harvesting Procedures: From the time of seeding, broccoli requires between 60 to 100 days to mature, depending on which variety of broccoli is grown[1]. Harvesting of broccoli, which is performed manually, begins in mid-November and is usually completed by the beginning of April[7]. If insects are still colonizing the crop, an insecticide will be applied as close to harvest as the pre-harvest interval will allow. The flower head and 3 to 6 inches of the subtending stem are cut from the plant[1]. The central stalk produces the first head that can be harvested. Once this is removed, additional flower heads will be produced laterally. If conditions are ideal, broccoli will continue to produce lateral flower heads for several weeks[1]. Flower heads should be harvested while the buds are still small, condensed and dark green[1, 4]. Broccoli that is harvested after the buds have begun to open will have a 'woody' texture[4].

Broccoli is packaged as heads, crowns, florets and spears. Broccoli harvested for the fresh market is cut, trimmed, cleaned and packed in the field and then shipped to the cooler. Ice is then injected into the cartons to preserve the broccoli's freshness. Broccoli heads are tied into bunches of two or three and packed into cartons. Depending on the size of the heads, 14 or 18 bunches are packed into wax cardboard boxes. Crowns are packed loose into 20lb cartons. Spears are also packed loose in 20lb cartons. Florets are packaged in 3lb bags with 4 bags per carton or packed loose in an 18lb carton[8].

Broccoli that is to be processed is packed into bulk bins and shipped to the packinghouse. In the packinghouse broccoli is, inspected for defects, trimmed, washed with mildly chlorinated water and then packaged.

In order to meet Arizona standards, all packed broccoli must be free from mold, decay and serious damage. No more than 5%, by count, of a bunch of broccoli in any container or lot can have mold or decay. No more than 15%, by count, of broccoli in any container or lot can fail to meet Arizona standards[9]. Broccoli is stored and transported under crushed ice to preserve freshness[4].

Insect Pests

(7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19)

Hymenoptera

Harvester Ant (*Pogomyrmex rugosus*)

Ants are not a frequent pest in Arizona; 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 ant hill. Ants generally do not cause damage to the mature broccoli plant. Ants can also be a pest to people working the field by swarming people and inflicting painful bites.

Sampling and Treatment Thresholds: University of Arizona experts suggest that a field should be treated at the first signs of damage[15].

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 ant hill. 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 to control ant populations within the crop field.

Cultural Control: Surrounding the field with a water-filled ditch can help control ant migration into the field. This method, however, is not always feasible because the ants are often already in the field

Post-Harvest Control: There are no effective methods for 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 ant hill to kill populations inside.

Coleoptera

Striped Flea Beetle (*Phyllotreta striolata*)

Potato Flea Beetle (*Epitrix cucumeris*)

Western Black Flea Beetle (*P. pusilla*)

Western Striped Flea Beetle (*P. 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 hind legs allow them to jump great distances.

In Arizona, flea beetles are particularly damaging to cole crops. The female flea beetle lays her eggs in the soil, on leaves, or within holes and crevices in the broccoli plant. Depending on the species, the larvae feed on the leaves or the roots of the broccoli plant. The adult beetles will also feed on the broccoli 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 flea beetle feeding damages the broccoli head, the plant is 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. University of Arizona guidelines suggest that prior to head formation fields should be treated when there is 1 beetle per 50 plants[14]. Once the head has formed, broccoli does not normally require treatment unless populations are extremely dense[14].

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, permethrin and cypermethrin are the most commonly utilized treatments for the control of flea beetles. Methomyl is foliar applied; diazinon and pyrethroids can be foliar applied or chemigated. Chlorpyrifos also has some activity against flea beetles. Diazinon and pyrethroids applied by chemigation have the added benefit of also targeting crickets, grasshoppers and lepidopterous larvae.

Cultural Control: It is important to control volunteer plants and weeds in and around the field that 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. Broccoli fields should be disked immediately following final harvest. It is 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 have a shiny appearance and lack clubbed antennae. It should be noted that the predaceous ground beetle is a beneficial insect because it feeds on lepidopterous larvae 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 broccoli 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 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 a broccoli field should be treated when beetle populations are high or there is a threat of migration into the field[14]. Broccoli plants that have 5 to 6 leaves are usually not at risk for beetle attack[14].

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

Chemical Control: Methomyl, diazinon, chlorpyrifos and pyrethroids such as permethrin and cypermethrin are routinely used treatments for the control 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 will deter beetle migration into the field. This method, however, is ineffective if there are beetles already in the field. Placing baits around the perimeter of the field may also be used for the control of beetles migrating into 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: Rotenone and neem oil are used by some growers 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 cricket feeding occurs at night; during the day crickets hide in the soil, weeds, ditches and under irrigation pipes. Crickets attack broccoli seedlings as they emerge from the soil. If cricket populations are high enough, they can completely decimate an entire crop.

Cricket populations build up in cotton fields, Sudan grass and desert flora. At the end of the summer, crickets move into broccoli fields. Fields that use over-head sprinkler irrigation encourage inhabitance by creating an ideal environment for crickets; 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. The

University of Arizona suggests that a field should be treated when cricket damage is high or there is a threat of cricket migration into the field[14].

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 such as cypermethrin and permethrin are the most commonly utilized treatments for controlling cricket populations. These insecticides can be ground applied or applied by chemigation. 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 broccoli 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 that chew holes into leaves. In most years, grasshopper populations are so small their damage is insignificant.

Sampling and Treatment Thresholds: University of Arizona experts suggest that fields should be treated as soon as grasshoppers begin causing damage to the crop[15].

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

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

Cultural Control: If grasshopper populations are decimating a field, replanting may be 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

Cabbage Maggot (*Delia radicum*)

The adult fly is dark gray in color and is about half the size of the common housefly. The female fly lays her eggs in the soil surrounding the broccoli stem. When the eggs hatch, small white maggots emerge and begin feeding on the broccoli’s roots. Some maggots will bore into the taproot. After 3 to 5 weeks of feeding, the maggots pupate and 2 to 3 weeks later adult flies emerge from the soil. Cabbage maggots have two to three generations per year.

In Arizona cabbage maggots rarely a pose a threat to broccoli stands, unless the crop was planted late and the spring is cool and wet. Cabbage maggot feeding on broccoli seedlings causes roots to become weak and rotten. This damage leads to stunting, wilting and yellowing of plants. Feeding on roots also creates lesions that leave the plant susceptible to pathogens that cause diseases such as bacterial soft rot. Mature, established plants are more tolerant of maggot feeding than young seedlings.

Sampling and Treatment Thresholds: Purple and yellow sticky traps are a good method for monitoring the presence of adult flies. Methods to monitor for the presence of maggots are still experimental. One method suggests marking a 5" circle around the base of the plant[10]. The soil within the circle is dug up to a depth of 1", placed in a water-filled container and then mixed. When the soil settles to the bottom of the container, any eggs present will float to the surface. If there are more than 25 eggs present in the sample, the field should be treated[10]. Maggot populations tend to be localized in small areas within a field, thus it is important to take many random samples within the field. It is also important to monitor the crop stand for plants that are wilting or chlorotic. These plants, as well as the surrounding soil, should be uprooted and inspected for damaged roots, maggots and pupae. University of Arizona experts suggest that broccoli should be treated as soon as maggots cause damage to the crop[15].

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

Chemical Control: When conditions are favorable for cabbage maggots, such as a cool spring, wet soil and high soil organic matter, one should treat the field prior to planting. Insecticide treatment is more effective when applied before seeding because cabbage maggots are a stand establishment pest. Treatments after the crop has been planted are usually ineffective. A pre-plant spray can be applied to the soil or a band of insecticide can be applied over the seed row during planting. Diazinon is the most commonly used chemistry for controlling cabbage maggots. If maggot infestations do not occur until the plant is mature, the crop can likely tolerate the pressure.

Cultural Control: Seeds that are promoted to germinate and grow rapidly will quickly outgrow maggot infestations. Adult female flies prefer to lay their eggs in moisture gradients that occur in seed rows. Utilizing a drag chain behind the planter will eliminate this gradient. It is important to disk the field a minimum of two weeks before planting; this will deter females from ovipositing eggs in the soil. When several rows of maggot infested plants occur, it is often more economical to replant rather than treat the field. A field that has a maggot infestation should be disked immediately following harvest.

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

Alternative Control: Some growers use *Bacillus thuringiensis* to control cabbage maggot populations.

Leafminers

(*Liriomyza* sp.)

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, feed on the mesophyll tissue and do not emerge until they pupate. Leafminers usually pupate in the soil, although sometimes they will pupate on the leaf surface. 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.

Leafminers rarely affect broccoli stands, unless photosynthesis is inhibited, because the leaves are not the marketed portions of the crop. A broccoli plant can usually outgrow a leafminer infection, unless the infection is severe and occurs during the seedling stage.

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*. According to University of Arizona guidelines, prior to head formation broccoli should be treated when populations have reached 1 active mine per leaf[14]. After head formation, treatment should occur when populations reach 3 mines per leaf per 25 broccoli plants[14].

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 both *L. sativae* and *L. trifolii*. Spinosad is the only chemistry available that provides control for *L. trifolii*. Insecticide resistance has been noted in *L. trifolii* populations, thus there is a need for a 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 broccoli 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 = diamondback moth, loopers, beet armyworm, corn earworm, tobacco budworm and imported cabbageworm.

Black Cutworm (*Agrotis ipsilon*)

Variegated Cutworm (*Peridroma saucia*)

Granulate Cutworm (*Agrotis subterranea*)

The threat of cutworms in Arizona is sporadic, and appears to increase in response to environmental conditions such as warm temperatures. The adult moth has gray-brown fore wings with irregular markings; the hind wings 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 have the most significant impact on seedlings. 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 broccoli plants. The cutworm attacks broccoli 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 broccoli 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. Cutworms frequently occur in fields that were previously planted with alfalfa or pasture.

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 for 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 on the soil surface during the evening. 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[14].

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 broccoli 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, chlorpyrifos, and pyrethroids such as cypermethrin are the most routinely used chemistries for controlling cutworm populations. The 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 in close proximity to alfalfa fields are especially prone to cutworm infestation, and should be carefully monitored. Cutworms tend to reoccur in the same area of a field and in the same fields. It is important to control weeds, that can act as hosts to cutworms, in 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 and yellow hindwings. 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 may develop yellow stripes down the sides of their bodies. 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 not normally a cole crop pest. The larvae, however, will migrate from surrounding host fields. The saltmarsh caterpillar feeds on seedlings and can skeletonize older plants. The larvae tend to feed in groups on older plants. If populations are high, they can decimate an entire seedling stand.

Sampling and Treatment Thresholds: According to University of Arizona experts, fields should be treated at the first signs of damage[15].

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 broccoli field[14]. Methomyl, spinosad, tebufenozide, chlorpyrifos and pyrethroids such as permethrin and cypermethrin 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 broccoli 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 can 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. One important consideration when using *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.

Diamondback Moth (*Plutella xylostella*)

The adult diamondback moth is small, slender and gray-brown in color. The name 'diamondback' is derived from the appearance of three diamonds when the male species folds its wings. The female moth lays small eggs on the underside of the leaf. Typically the eggs are laid separately, but occasionally can be found in small groups of two or three. The larvae are about a 1/3 of an inch long, pale yellow-green and covered with fine bristles. A v-shape is formed by the spreading prolegs on the last segment of the caterpillar. When startled, the larvae will writhe around or quickly drop from the leaf on a silken line. Diamondback moth populations peak in March and April and again in June and August. If conditions are favorable, this moth can have four to six generations a year.

Diamondback moth larvae attack all stages of plant growth but their damage is most significant during the seedling stage and at harvest. Broccoli can be particularly hard hit by diamondback moth populations. Larvae attack the growing points on young plants, stunting growth and decreasing yield. The larvae chew small holes, mostly on the underside of mature leaves, on mature plants. The larvae of the diamondback moth penetrate broccoli heads, damaging the head as well as contaminating it.

Sampling and Treatment Thresholds: Fields should be monitored during; the seedling stage, crop thinning and prior to heading. Fields should also be checked if an adjacent field has recently been harvested or been disked, as the larvae will migrate from such fields. The University of Arizona recommends that prior to head formation; broccoli should be treated when there is 1 larva per 50 plants[14]. Once the broccoli head has formed, the crop can tolerate 4 larvae per 25 plants[14]. All other larvae in the lepidopterous complex should be included in this count.

Biological Control: The ichneumonid wasp (*Diadegma insularis*) will commonly parasitize *Plutella* cocoons. *Trichogramma pretiosum* is a less common parasite that attacks diamondback moth eggs. Lacewing larvae and ladybug larvae (syn: ant lions) can also be used to control small diamondback larvae. Care must be used when spraying insecticides as they can harm populations of beneficial insects. These beneficial insects usually do not provide complete control of diamondback moth populations.

Chemical Control: Methomyl, thiodicarb, spinosad and pyrethroids such as permethrin and cypermethrin are the most frequently utilized chemistries for the control of diamondback moths larvae. There is a new chemistry available, indoxacarb, that will also help control diamondback moth larvae. *Plutella* resistance to insecticides has been reported and is a concern in broccoli production.

Cultural Control: Fields should be disked immediately following harvest in order to kill larvae and pupae and prevent moth migration to adjacent crops.

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

Alternative Control: *Bacillus thuringiensis* (Bt) can be used to control diamondback moth larvae. A consideration when using *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. Diatomaceous earth can be used to control diamondback larvae. Neem oil soap, neem emulsion, and rotenone are less effective choices for the control of larvae.

Cabbage Looper (*Trichoplusia ni*)

Alfalfa Looper (*Autographa californica*)

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 hind wings 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.

Looper populations are usually highest in the fall and can cause extensive damage to broccoli. Loopers will attack all stages of plant growth. These larvae feed on the lower leaf surface, chewing ragged holes into the leaf. Excessive feeding on seedlings can stunt growth or even kill plants. Broccoli that has been damaged by looper feeding or that is contaminated with larvae or larvae frass is unmarketable.

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.

Sampling and Treatment Thresholds: Once broccoli 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 begin to increase, 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 head formation broccoli should be treated when populations have reached 1 larva per 50 plants[14]. After head formation, broccoli can tolerate 4 larvae per 25 plants[14]. All other larvae in the lepidopterous complex should be included in this count.

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 the 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, chlorpyrifos and pyrethroids such as permethrin and cypermethrin are the commonly utilized chemistries for controlling looper populations. All are foliar applied insecticides. Indoxacarb is a new insecticide available that will also provide control for cabbage loopers. 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. Fields should be plowed immediately following harvest to kill larvae and remove host material.

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 the most effective if applied when eggs are hatching and larvae small. 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 will not affect beneficial predators and parasites. Diatomaceous earth, neem oil soap, neem emulsion and rotenone are other methods for the alternative control of cabbage loopers.

Beet Armyworm (*Spodoptera exigua*)

The forewings of the adult moth are gray-brown in color 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 cole crops. The larvae have a broad stripe on each side of the body and light-colored stripes on the back. A black dot is located above the second true leg and a white dot at the center of each spiracle. The mature larvae pupate in the soil.

The beet armyworm is a key pest that affects broccoli production in Arizona. Armyworm populations are heaviest in broccoli stands during the fall. The larvae 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 young armyworms will die while travelling between plants. Armyworm feeding can skeletonize leaves and consume entire seedlings. A single armyworm can attack several plants. Broccoli heads that have been damaged by armyworm feeding are unmarketable.

Beet armyworm populations are the most active between the months of July and November. In the fall, beet armyworms often migrate from surrounding cotton and alfalfa fields to vegetable crops. Armyworms also feed on weeds including; redroot pigweed (*Amaranthus* sp.) 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, broccoli should be treated prior to head formation when populations reach 1 larva per 50 plants[14].

Once the flowering head has formed, broccoli can tolerate 4 larvae per 25 plants[14]. All other larvae in the lepidopterous complex should be included in this count.

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

Chemical Control: Spinosad, chlorpyrifos, tebufenozide and pyrethroids such as permethrin and cypermethrin 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 and surrounding the field should be controlled, as armyworms can build up in these areas. When seeding, 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 larvae pupating in the soil.

Post-Harvest Control: There are no effective methods for the post-harvest control of beet 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 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 vary in color 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 broccoli stands. The larvae of these two species are cannibalistic, eating larvae of their own species and of other lepidopterous species, thus they tend to feed alone. Budworms and earworms are capable of killing entire stands of seedlings. In older plants, the larvae chew holes into the leaves and also attack the growing point of the plant, often killing the growing tip. Damage to the broccoli head will result 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 fields. If eggs are discovered, it should be determined if they have hatched, are about to hatch or have been parasitized. The broccoli should be checked for larvae and feeding damage. It is important to correctly identify which larvae is present, as resistance in tobacco budworms has been reported. The University of Arizona recommends that prior to broccoli head formation, the crop requires treatment when populations reach 1 larva per 50 plants[14]. After head formation the crop can tolerate 4 larvae per 25 plants[14]. 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 these 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 and corn earworms is mid-afternoon, this is when the larvae are the most active. Spinosad, chlorpyrifos and pyrethroids such as permethrin and cypermethrin are often used for controlling earworms and budworms.

Cultural Control: Fields that are planted next to cotton fields require close monitoring. Delaying planting until after cotton defoliation will decrease larvae migration into broccoli fields, however due to market demands it is not always possible to delay planting. Fields should disked under 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.

Imported Cabbageworm (*Pieris rapae*)

The imported cabbageworm is not a common pest in Arizona, but damage caused by this pest has been recorded. The adult cabbageworm moth, called the cabbage butterfly, is white-yellow in color and has black spots on the upper surface of its wings. The female moth lays rocket-shaped eggs on the lower leaf surface. The larvae are green in color with a faint yellow or orange stripe down its back and broken stripes down the sides of its body. The larvae's body is covered with numerous hairs giving the larvae a velvety appearance.

The imported cabbageworm chews large, irregular holes into the leaves. When young plants are attacked, the larvae can stunt or kill the plants. Older plants can tolerate more larvae feeding than the young plants can. The larvae feed for 2 to 3 weeks and then attach themselves to the stem or leaf on the plant or a near by object to pupate. The presence of the larvae and larvae frass within the broccoli head and damage to the head will render the plant unmarketable.

Sampling and Treatment Thresholds: The field should be randomly checked for areas of damaged plants. Cabbage loopers, however, cause the same sort of damage as the cabbageworm. Thus it is important to also check for eggs, larvae and moths to positively identify the larvae species causing the damage. The University of Arizona recommends that prior to head formation, broccoli should be treated when there is 1 larva per 50 plants[14]. Once the broccoli head has formed, the crop can tolerate 4 larvae per 25 plants[14]. All other larvae in the lepidopterous complex should be included in this count.

Biological Control: There are many natural enemies to the imported cabbageworm including; *Pteromalus puparum*, *Apanteles glomeratus*, *Microplitis plutell*a and the tachinid fly (*Voria ruralis*). There are also some viral and bacterial diseases that will attack cabbageworms. Insecticides should be sprayed with caution as they can harm beneficial insects.

Chemical Control: Spinosad, chlorpyrifos and pyrethroids such as permethrin and cypermethrin are often used for controlling imported cabbageworms. There is a new chemistry available, indoxacarb, that will also provide control for imported cabbage worms.

Cultural Control: Weeds growing within the field and surrounding the field can act as hosts to cabbageworms and thus must be controlled. Fields should be plowed after harvest to eliminate any larvae that may be pupating in the soil. Sanitation of equipment is important to prevent the contamination of uninfected fields.

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

Alternative Control: *Bacillus thuringiensis* (Bt) can be used to control cabbageworms and will not harm beneficial predaceous and parasitic insects. Bt is most effective when sprayed on young larvae. One concern when spraying Bt is its tendency to break down when exposed to UV light and heat. Spraying at night will allow for a longer period of efficacy.

1999 Insecticide Usage to Control Lepidoptera Larvae on Arizona Grown Broccoli

Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	Total # of Acres	% Acres treated	# of Reports**	(# of reports)							
							By Air	AW***	TBW	CE	CW	DBM	ICW	L
Bifenthrin	0.03	0.054	0.10	1010	8%	25	20	18	0	13	0	0	0	10
Bacillus thuringiensis	0.05	0.194	1.05	1319	11%	26	22	11	0	7	0	1	1	23
Chlorpyrifos (**OP**)	n/a	0.787	2.25	5966	48%	195	175	178	1	16	4	3	0	92
Cypermethrin	0.05	0.082	0.10	2894	23%	121	79	78	1	33	12	2	0	36
Diazinon (**OP**)	0.25	0.533	4.00	705	6%	21	16	7	0	1	3	2	3	6
Dimethoate (**OP**)	0.25	0.406	0.50	20	0%	2	2	0	0	0	0	0	0	2
Endosulfan	0.75	0.763	1.00	695	6%	18	17	6	0	0	0	1	0	15
Esfenvalerate	0.02	0.040	0.05	3282	26%	113	87	79	0	1	0	1	3	65
Imidacloprid	0.16	0.123	0.38	458	4%	8	5	5	0	0	0	0	0	5
Lambdacyhalothrin	0.02	0.025	0.03	5444	44%	118	80	91	0	2	3	6	0	95
Malathion (**OP**)	0.63	1.990	2.50	114	1%	5	5	0	0	1	1	0	0	3
Methomyl (**carbamate**)	0.23	0.658	0.90	1212	10%	43	36	20	0	0	0	3	3	27
Oxydemeton-methyl (**OP**)	0.38	0.411	0.50	103	1%	3	3	0	0	0	0	1	0	2
Permethrin	0.05	0.127	0.10	2437	20%	71	42	52	0	5	0	6	0	46
Pyrethrins	n/a	0.006	n/a	638	5%	10	10	9	0	0	0	3	0	10
Spinosad	0.023	0.073	0.156	5123	41%	136	65	87	0	3	1	20	2	69
Tebufenozide	0.09	0.114	0.12	3480	28%	91	21	82	0	13	2	0	0	33
Thiodicarb (**carbamate, B1/B2**)	0.40	0.575	1.00	864	7%	19	15	13	0	0	0	0	1	7

AW - armyworm
TBW - tobacco budworm
CE - corn earworm
CW - cutworm
DBM - diamondback moth
ICW - imported cabbageworm
L - loopers
OP - organophosphate

*Application rates are pounds of active ingredient 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 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*)

Turnip Aphid (*Lipaphis erysimim*)

Cabbage Aphid (*Brevicoryne brassicae*)

There are four different species of aphid tha t are pests to broccoli: green peach aphids, potato aphids, turnip aphids and cabbage 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. The cabbage aphid is gray-green and covered with a waxy 'bloom' giving the insect a gray-white appearance. Some refer to this aphid as the 'gray aphid'. Cabbage aphids colonize the young leaves and flowering structures of broccoli. Cabbage aphids are the most common species of aphid found on cole crops. The turnip aphid is similar in appearance to the cabbage aphid but is not covered with a waxy 'bloom'. These aphids form small colonies on 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 that produce live young; this allows the population to increase rapidly. When conditions are ideal, aphids have as many as 21 generations in one year. When populations become too large or food is scarce, aphids produce winged offspring that are capable of migrating to new hosts.

The majority of aphid damage occurs during the final heading stage of broccoli. 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. Another concern are 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; their presence in a broccoli head will make the head unmarketable.

Sampling and Treatment Thresholds: 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. Aphids usually appear first at the upwind field border and those borders that are adjacent to fields of cruciferous weeds and crops. In infested fields, aphids tend to occur in clusters within the field, thus it is important to randomly sample the field. The following is the University of Arizona's recommendations for aphid control; prior to broccoli head formation treatment should begin when populations reach 1 aphid per 10 plants[14]. After head formation, broccoli should be treated when aphid colonization begins[14].

Biological Control: Parasitoids and predators that attack aphids are available; however, they are usually unable to completely control aphid populations. Lady beetle larvae (syn: ant lions), lacewing larvae, syriphid fly larvae, aphid parasites are some of the insects used to control aphids. These beneficial insects, however, can also become contaminants of broccoli heads. Spraying of insecticides should be performed with caution as it can also eliminate beneficial insects.

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. Endosulfan, oxydemeton-methyl, dimethoate and imidacloprid are the most frequently used foliar-applied treatments. The initial treatment should occur once aphids begin to migrate into a crop field. To ensure that the harvested broccoli is not contaminated with aphids, it might be necessary to use repeated applications. Aphids often hide within the broccoli's flower heads making insecticide contact difficult. If aphids only occur at the field borders or in isolated areas, border or spot applications may be sufficient to control populations. Insecticide chemistries should be alternated for good 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: Some growers use; insecticidal 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 considered a primary pest 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 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 darken in color prior to hatching. The immature whitefly (nymph) travels about the plant until it finds a desirable minor vein to feed from. The nymph 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. Broccoli planted downwind from these plants are particularly susceptible. Whitefly feeding removes essential salts, vitamins and amino acids required by the broccoli plant for proper growth. This feeding results in; reduced plant vigor, decreased head size and can delay harvest if not controlled at an early stage. As with aphids, the phloem sap that whiteflies excrete onto the broccoli's surface creates an ideal environment for sooty mold infection. Whiteflies also contaminate the harvested broccoli head, 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[14].

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, such as imidacloprid, is often applied. If broccoli is planted after whitefly populations have declined, foliar-applied insecticides can be used as necessary. Imidacloprid, endosulfan, oxydemeton-methyl and dimethoate are the most commonly used foliar insecticides. Tank-mixing insecticides helps control whiteflies, as well as, preventing the development 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.

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 decrease whitefly infestations. However, delaying 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: Some growers use; neem oil soap, neem emulsion, pyrethrins, insecticidal 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 mustard, alfalfa, onion and wheat fields, surrounding weedy areas and unirrigated pastures.

Thrips species are small (1/20-1/25 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 is 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 wrinkles and deforms leaves, damages heads and stunts 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 wind burn or sand burn. Thrips present in harvested broccoli are considered a contaminant.

Sampling and Treatment Thresholds: Sticky traps are a good way to monitor for thrips migration into a field. When inspecting for thrips, the folded plant tissue and broccoli heads must be carefully examined, as this is where thrips prefer to hide. It is estimated that for every 3 to 5 thrips observed there are three times as many that are undiscovered. The University of Arizona recommends that prior to head formation, broccoli should be treated when populations reach 1 thrips per 10 plants[14]. After head formation, the crop should be treated when the population reaches 1 thrips per 25 plants[14].

Biological Control: Lacewing larvae, ladybug larvae (syn: ant lions) and the minute pirate bug can be 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 effect the degree of control. The more mature a plant is the more folds and crevices it has for thrips to hide in and avoid insecticide contact.

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. Dimethoate, 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 and protruding eyes. 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.

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 broccoli fields.

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

Sampling and Treatment Thresholds: The University of Arizona suggests that before the formation of the broccoli head, a stand does not require treatment until populations reach 10 contaminant insects per 50 plants[14]. Once the head is formed, broccoli should be treated when populations reach one contaminant insect per 25 plants[14].

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 broccoli, chemical control is not normally required until head formation begins. Growers typically spray as close to harvest as possible. Dimethoate, methomyl, chlorpyrifos, 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 contaminant insects, in the field and surrounding the field. Alfalfa should not be cut until the broccoli field has been harvested, this will prevent insect migration into the broccoli 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 Broccoli Grown in Arizona

							(# of reports)							
Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	Total # of Acres	% Acres Treated	# of Reports**	By Air	Aph.***	Con.	LM	Lep.	SE	Thp.	Un.
WESTERN														
Allium sativum	n/a	0.148	n/a	14	0%	1	1	2	0	0	0	0	0	0
Bifenthrin	0.03	0.057	0.10	1107	14%	32	26	4	0	0	41	4	0	0
Bacillus thuringiensis	0.05	0.225	1.05	965	12%	20	17	0	0	0	33	0	0	0
Chlorpyrifos (**OP**)	n/a	0.789	2.25	6258	78%	203	183	4	2	0	306	47	0	2
Cypermethrin	0.05	0.082	0.10	3242	41%	135	89	10	4	0	168	32	2	0
Diazinon (**OP**)	0.25	0.745	4.00	2055	26%	58	21	15	0	2	20	37	0	1
Dimethoate (**OP**)	0.25	0.406	0.50	20	0%	2	2	2	0	0	2	0	0	0
Endosulfan	0.75	0.792	1.00	802	10%	35	34	39	2	0	16	2	1	0
Esfenvalerate	0.02	0.040	0.05	2971	37%	133	100	2	0	0	147	73	0	1
Imidacloprid	0.16	0.189	0.38	2662	33%	59	14	31	8	0	3	5	1	0
Lambdacyhalothrin	0.02	0.025	0.03	5055	63%	115	75	6	1	1	182	3	3	1
Malathion (**OP**)	0.63	1.785	2.50	632	8%	23	23	27	10	0	5	0	0	0
Methomyl (**carbamate**)	0.23	0.682	0.90	743	9%	34	27	0	0	0	46	1	1	0
Oxydemeton-methyl (**OP**)	0.38	0.456	0.50	293	4%	12	12	17	0	0	3	0	0	0
Permethrin	0.05	0.123	0.10	2717	34%	85	45	3	0	0	104	9	0	15
Spinosad	0.023	0.072	0.156	4382	55%	125	52	2	0	0	164	1	2	0
Sulfur	2.40	3.476	8.00	28	0%	2	2	0	3	0	131	3	0	0
Tebufenozide	0.09	0.114	0.12	3525	44%	93	21	0	0	0	5	0	0	0
Thiodicarb (**carbamate**, **B1/B2**)	0.40	0.665	1.00	86	1%	5	1	0	0	0	0	0	0	0
CENTRAL														
Bacillus thuringiensis	0.05	0.122	1.05	384	9%	7	6	0	0	0	10	0	0	0
Carbaryl (**carbamate**)	1.00	1.50	2.00	63	1%	2	2	0	0	0	0	3	0	0
Cypermethrin	0.05	0.095	0.10	64	1%	3	3	1	0	0	6	0	1	0
Diazinon (**OP**)	0.25	0.483	4.00	513	12%	11	11	4	0	0	6	5	0	0

Dimethoate (**OP**)	0.25	0.222	0.50	79	2%	2	2	0	0	0	0	1	0	0
Endosulfan	0.75	0.716	1.00	477	11%	9	9	0	0	0	6	2	0	0
Esfenvalerate	0.02	0.040	0.05	784	18%	13	13	0	0	0	23	2	0	0
Imidacloprid	0.16	0.122	0.38	424	10%	7	5	0	0	0	10	5	0	0
Lambdacyhalothrin	0.02	0.026	0.03	736	17%	11	11	0	0	0	19	5	0	0
Methomyl (**carbamate**)	0.23	0.580	0.90	613	14%	14	13	0	0	0	20	3	0	0
Permethrin	0.05	0.088	0.10	213	5%	6	5		0	0	5		1	0
Pyrethrins	n/a	0.006	n/a	638	15%	10	10	1	0	0	22	6	1	0
Spinosad	0.023	0.082	0.156	947	22%	15	15	1	0	0	27	6	1	0
Sulfur	2.40	2.40	8.00	58	1%	1	1	0	0	0	1	0	0	0
Thiodicarb (**carbamate, B1/B2**)	0.40	0.543	1.00	778	18%	14	14	2	0	0	21	0	0	0

Aph. - aphids
Con. - contaminant = lygus, chinch bug, leaf hoppers, alfalfa hoppers
LM - leafminer
Lep. - lepidoptera larvae
SE - stand establishment insects = maggots, ants, crickets, flea beetles, darkling beetles, grasshoppers
Thp. - Thrips
Un - known
OP - organophosphate

*Application rates are pounds of active ingredient 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, 10, 13, 20, 21, 22, 25, 26, 28)

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

In Arizona, damping-off is occasionally observed in broccoli 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. Seedlings that are attacked by *Rhizoctonia* but continue to grow will develop wirestem, which is discussed in detail further on in this document.

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 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 fungicides work 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. PCNB is the only other registered chemical treatment for controlling *Rhizoctonia*-induced damping-off. PCNB should also be used in a prophylactic manner. Typically, PCNB is applied during planting. There are no registered seed treatments in Arizona for controlling damping-off of broccoli. Most growers, however, do not treat for damping-off as this disease is not currently a large threat to broccoli in Arizona.

Cultural Control: All residues from the previous crop should be plowed under and completely decomposed before planting broccoli. 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 very important to manage water application 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.

Downy Mildew (*Peronospora parasitica*)

Of the potential fungal diseases, downy mildew poses the largest threat to the production of broccoli in Arizona. Downy mildew thrives in mild, humid weather, such as that which is typical of the winter growing season in western Arizona. This weather promotes spore formation and spore dispersal, as well as, plant infection. A wet surface is required for spore germination. *P. parasitica* infects broccoli through its leaves and then grows between the leaf's cells. When conditions are favorable, the pathogen can spread rapidly. The fungus also produces resting spores, which can survive in the soil or crop residue until the following season. *P. parasitica* is spread by; wind, rain, infected seed and infected transplants.

Plant infection begins with the growth of gray-white fungi on the lower leaf surface. Damage occurs on both leaf surfaces, beginning with chlorotic lesions that later turn purple and eventually brown. Young leaves sometimes dry and drop off, while older leaves generally remain on the plant and develop a papery texture. Downy mildew can decimate large numbers of seedlings. Severe infections of mature broccoli can result in decreased photosynthesis, stunted plants and reduced yield. Downy mildew is a systemic disease that results in darkened areas and/or black streaks in the stem and floral tissue. This damage to the stem and head, leaves the plant susceptible to secondary infections. If damage only occurs on the leaves of broccoli the losses are less severe as the leaves are not part of the consumable crop. Any damage to the broccoli head and stem, however, results in an unmarketable product.

Biological Control: There are no biological methods for controlling downy mildew.

Chemical Control: Mefenoxam, fosetyl-aluminum, maneb and copper-based fungicides are the most commonly used methods for chemically controlling downy mildew. Maneb is a popular choice because it is inexpensive. Downy mildew is best controlled when treatment is used as a preventative measure, rather than waiting for the onset of disease symptoms. If there is heavy rain and/or mild temperatures, one can anticipate downy mildew. If environmental conditions remain favorable for disease development, multiple applications may be required. Mefenoxam and fosetyl-aluminum are systemic treatments; copper fungicides and maneb are protectants. It is important to alternate fungicides or apply fungicide mixtures to ensure proper resistance management. A mix of mefenoxam and chlorothalonil is sometimes used for resistance management. Chlorothalonil on its own will provide some control of downy mildew.

Cultural Control: Cruciferous weeds that can act as a host for downy mildew must be controlled. It is important to rotate to a non-cole crop the subsequent year. Overhead irrigation should be avoided, as this aids in the spread of *P. parasitica*. Fields should be plowed under following harvest to promote the decomposition of infected plant debris.

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

Alternative Control: Some growers use milk and hydrogen peroxide to control downy mildew. Spreading compost on the soil is also used for the control pathogens.

Phytophthora Stem and Root Rot (*Phytophthora* sp.)

In Arizona, *Phytophthora* is rarely observed in broccoli stands. *Phytophthora* infection is usually the result of poor water drainage in the field. *Phytophthora* is a soil-borne fungus that infects the roots and stem near the soil surface. The fungus infects the inner cortical tissue of the plant, creating cankers in the tissue. The canker increases in size until it eventually girdles the stem. The first visual sign of infection is when the edges of leaves develop a red/purple color. This begins at the bottom of the plant on the older leaves, and will spread up the plant infecting the younger leaves. This necrosis spreads inwards on the leaf until the entire leaf dies. As the canker on the stem increases in size the broccoli wilts and ultimately dies. Contaminated water and contaminated soil spread *Phytophthora*.

Biological Control: There are no available methods for the biological control of *Phytophthora*.

Chemical Control: Metam sodium and metam-potassium are fumigants registered for use on *Phytophthora*; however, these methods are a very costly method of control and generally not considered a viable option. Mefenoxam is the only other available chemistry for the control of *Phytophthora*. This is a systemic fungicide that is applied preemergence or pre-plant incorporated. Mefenoxam is the most effective when applied as a preventative treatment before the onset of disease.

Cultural Control: Planting broccoli on high beds, with good soil drainage prevents the soil from remaining saturated for too long. This fungus thrives in a wet environment, thus it is important to irrigate only as required and avoid saturating the field. However, drought stress will also leave broccoli susceptible to *Phytophthora*, so it is important to ensure the crop receives an adequate supply of water.

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

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

Wirestem (*Rhizoctonia* sp.)

Wirestem is occasionally observed in Arizona broccoli fields. Rhizoctonia attacks seedlings and young plants. As described previously, newly germinated seedlings infected by *Rhizoctonia* will display damping-off symptoms

Infection begins on the broccoli stem near the soil level. Warm soil temperatures promote *Rhizoctonia* infection. The fungus enters the plant and infects the primary cortex of the stem. The initial sign of infection is a constricted site on the stem. This area can range from a small pinpoint spot or can be up to an inch in length. Eventually the broccoli plant, without breaking, will collapse under its own weight becoming bent and twisted, hence the name 'wirestem'.

Biological Control: There are no available methods for the biological control of *Rhizoctonia*.

Chemical Control: Metam sodium and metam-potassium are fumigants registered for use on *Rhizoctonia*; however, these methods are a very costly method of control and generally not considered a viable option. The only other chemistry registered in Arizona to control wirestem is PCNB. PCNB should be applied during or immediately after seeding.

Cultural Control: Cole crops should not be planted more frequently than once every four years, this will reduce disease carryover between cropping seasons.

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

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

Alternaria Leafspot (*Alternaria brassicae*)

Alternaria leafspot, also known as alternaria blight, is rarely reported on broccoli in Arizona. Typically this disease occurs during a wet winter. Spores can survive in weed hosts and plant debris for long periods of time. The fungal spores are wind and rain dispersed and require this free water for germination to occur.

Symptoms begin as a small dark spot on the leaf. As the disease progresses, concentric rings will develop around the spot creating a bulls-eye pattern. Eventually, velvety, brown spore-bearing growths develop within the spots. If left untreated, alternaria leafspot will eventually defoliate a plant. Spots may also appear on the broccoli head, causing the curd to brown and rendering it unmarketable. *Alternaria* spores can survive for long periods of time on plant debris or within infected seeds.

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

Chemical Control: Maneb and chlorothalonil are the commonly used methods for controlling alternaria leaf spot. These fungicides are foliar applied and are most effective when applied as a protectant before the onset of disease. Copper fungicides are also labeled for controlling *Alternaria*.

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 cole crops should not be planted more than once in four years to avoid disease carryover. It is important to clean equipment between uses in different fields, to prevent contamination of an uninfected field. Controlling cruciferous weeds that can act as a disease host will prevent the transmission of *Alternaria* from these weeds to broccoli.

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

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

Sclerotinia Rot (*Sclerotinia minor, Sclerotinia sclerotiorum*)

In Arizona, *Sclerotinia* is rarely a concern in broccoli fields grown for the fresh market. This disease is more of a threat when broccoli is grown for seed. 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 those parts of the plant that are in contact with the ground. *Sclerotinia sclerotiorum* will infect plant parts in contact with the soil, but in addition produces air-borne spores that can infect the upper leaves and flower heads. The first sign of infection is the covering of the broccoli's head, stem and leaves 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 broccoli 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. sclerotiorum* 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*.

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

Chemical Control: Metam sodium is a fumigant that is registered for use on Sclerotinia; however, this method of control is very costly and generally not considered a viable option.

Cultural Control: Fields should be irrigated with care, as wet conditions favor this fungus. 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*.

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

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

BACTERIAL DISEASES

(4, 7, 10, 13, 21, 22, 23, 24, 25, 26, 27)

Black Rot (*Xanthomonas campestris*)

Black rot is occasionally observed in Arizona broccoli fields. This bacterium normally only occurs when the weather is warm and humid; however, it can be introduced into Arizona crops from infected seed or transplants. Animals and humans can also spread *Xanthomonas*. The bacterium spreads rapidly when there is unusually high rainfall or if overhead irrigation is used. *X. campestris* enters the plant through the leaf margin or insect wounds.

The initial symptoms of black rot are yellow-orange v-shaped lesions that occur along the leaf margins. As the disease progresses, these lesions dry out and the leaves are shed from the plant. Black rot damages the plant's vascular system, giving it characteristic black veins. This disease can become systemic, in which case these black veins are also be observed in the main stem. Black rot is sometimes deceiving by not expressing symptoms in cool temperatures, rather only developing small, brown spots that resemble symptoms of other bacterial diseases. Prolonged infection can cause plant stunting, wilting and even death of plants. *X. campestris* survives in crop debris, infected weeds and infected seed.

Biological Control: There are no available methods for the biological control of black rot.

Chemical Control: Copper-based fungicides are the only registered fungicide in Arizona for the chemical control of black rot. These fungicides are the most effective when applied preventively before the onset of disease. Copper-based fungicides are contact fungicides.

Cultural Control: Planting only seed and transplants that are certified to be disease-free will help reduce the risk of black rot. If the seed is infected, it can be treated with hot water, which will reduce infection but also reduces the germination percentage of the seed. Cole crops should not be planted in the same field more than once every four years; this reduces the risk of disease carryover between crops. As well, it is important to control weeds, especially cruciferous weeds, and volunteer plants that can act as hosts for black rot. One must be careful when clipping or mowing transplants before planting as this will spread the pathogen. Irrigation should be performed with care, to avoid over watering the crop. Fields should be deeply plowed after harvest to kill bacterium and speed the decay of plant debris.

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

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

Bacterial Soft Rot (*Erwinia* sp.)

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

Open wounds on the plant provide an entry for the bacterium. A plant that was infected with downy mildew or black rot or that was damaged by freezing or insects is particularly susceptible to bacterial soft rot. The architecture of the broccoli head also contributes to bacterial infection. The crevices formed by the immature flower buds are capable of holding water, creating an ideal environment for bacterial growth. The initial sign of infection is water soaked spots on the plant. Once inside broccoli 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 develop a brown color and the wet rot is accompanied by a foul odor.

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

Biological Control: 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 broccoli leaving it susceptible to bacterial infection.

Cultural Control: Crops should be cultivated carefully, to prevent damage to the plant that could provide an entry way 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: Broccoli should be handled carefully to avoid bruising and wounding that will leave the plant susceptible to infection. Plants must be thoroughly cleaned with a chlorine wash 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.

1999 Fungicide Usage on Broccoli Grown in Arizona

Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	Total # of Acres	% Acres Treated	# of Reports**	(# of reports)				
							By Air	*Alternaria****	*Sclerotinia*.	Downy mildew	Unidentified Fungus
WESTERN AZ											
Chlorothalonil (**B1/B2**)	1.12	0.956	1.40	38	0%	4	3	1	0	4	0
Copper hydroxide	0.33	1.000	2.00	20	0%	1	1	1	0	1	0
Fosetyl-Al	1.60	2.080	4.00	562	7%	30	29	14	1	29	1
Iprodione	1.00	1.00	1.00	32	0%	2	2	1	1	2	0
Maneb (**B1/B2**)	1.12	1.150	1.50	2213	28%	84	58	23	0	76	0
Mefenoxam	0.25	0.109	0.50	308	4%	12	7	0	0	11	0
Sulfur	2.25	3.476	8.00	28	0%	2	2	1	0	2	0
CENTRAL AZ											
Sulfur	2.25	2.40	8.00	58	1%	1	1	0	0	1	0

*Application rates are pounds of active ingredient 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 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.

VIRAL DISEASES

(10, 28, 29)

Generally speaking, viral diseases are not a common occurrence in cole crops grown during Arizona’s winters. Cauliflower mosaic and turnip mosaic viruses can occur in broccoli stands but their occurrences are rare. These viral diseases cause the broccoli’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 and whiteflies are both capable of transmitting viral diseases.

Biological Control: There are no biological control 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 in controlling virus transmissions because it only requires a few vectors 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 virus 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.

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

(10)

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

Brown bud in broccoli is thought to be related to calcium nutrition and rapid growth, and is often associated with warm weather. The disease causes the flower buds to turn brown prior to maturity. There are some cultivars available that are more resistant to brown bud than others.

Hollow stem is related to rapid growth. High temperatures combined with high levels of nitrogen, large stem diameters, wide plant spacing and boron deficiencies cause broccoli to grow quickly. This disease causes the inner tissue of the stem, the pith, to crack and collapse often leaving the inner stem hollow. When hollow stem is caused by a boron deficiency, the cracked tissue is also dark in color. The best way to avoid hollow stem is to maintain an adequate nutrient availability and prevent rapid stem growth.

Although broccoli is relatively tolerant of cold temperatures, cold temperatures can damage the head of the broccoli. The damage that occurs can leave the plant susceptible to secondary infections, such as bacterial soft rot.

Strong winds that carry sand can abrade the leaves and make them susceptible to secondary infections. When the leaves heal, they become thickened and discolored. These symptoms can be misidentified as pathogen injury. Wind can also severely damage seedlings, pinching the stem and collapsing the plants.

High salt concentrations in the soil can be injurious to broccoli. Symptoms include; stunted plants, thickened dark leaves, yellowing or burning of the leaf margin and orange, rough roots. Salt can also inhibit seed germination.

Nutrient deficiencies will cause 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.

Nematodes

(Various species)

(10, 11, 13, 30)

Nematodes are not a major pest of broccoli in Arizona. Due to the cool soil temperature, nematodes are relatively inactive during the winter months that vegetable crops are grown. Cool soil temperatures also slows the nematode's life cycle. If broccoli is grown when weather is warmer nematodes can pose a threat. The root knot nematode's life cycle can be as short as 18 days when conditions are favorable.

The female nematode lays her eggs on the plant and on the soil. Larvae hatch from the eggs and pass through three larval stages before becoming sexually mature adults. The hatched larvae enter the roots, and travel between and through the cells to the differentiating vascular tissue. Nematodes feed through a needle-like stylet that is inserted into the plant cell. Digestive enzymes are secreted, through the stylet, into the cell to predigest the contents. The nematode then sucks out the cell's contents. As the nematode feeds, its salivary secretions cause the enlargement of surrounding cells, creating galls. Nematode damage often results in infection by *Rhizoctonia* and other fungi. Nematode feeding causes stunting, wilting, yield reduction, discoloration of leaves, poor top growth, reduced root system, rotting roots and root galls.

Sampling and Treatment Thresholds: Scouting should begin far enough in advance of planting to allow a pre-plant treatment if an infestation is discovered. When scouting for nematodes one should observe the roots and look for; gelatinous masses of eggs exuding from smaller roots and galls. Galls should be cut open and investigated for the presence of eggs, larvae and adult nematodes. Nematode infestations will often occur in isolated areas within the field. Areas where plants show symptoms should be specifically checked but random sampling should also be performed. The threshold at which a field should be treated is undetermined: however, when populations occur in soils that are sandy, sandy loam, loamy sand, or when populations are large the field should be treated. If infestations are in localized areas, spot fumigation can be used to reduce cost.

Biological Control: Some growers use *Stienernema carpocapsae*, a species of parasitic nematode, to decrease nematode pest populations. This species of nematode does not directly attack root knot nematodes but does compete with them. Some growers have had success decreasing nematode populations with this method, but the results are inconsistent. *Myrothecium verrucaria* has also been used with some success. *M. verrucaria* can be applied pre-plant, at planting or post-planting, but should not be applied directly to the foliage and must be incorporated.

Chemical Control: Chemical applications to a field are incapable of eradicating a nematode population; they will only reduce the population. Nematodes, however, are rarely a large enough threat in broccoli fields to warrant the expense of a chemical treatment. If a field is treated, fumigants are commonly used to treat for nematodes. The soil, however, must be properly prepared by plowing under all crop residues and allowing it to completely decompose. Decomposition can take as long as a month, but additional plowing or disking will speed decay. If this is not done prior to fumigation, the fumigant can not properly penetrate the debris and large soil clods and cannot kill the nematodes. The field must be at 50% capacity and the soil temperature should range between 50-80°F for fumigation to be the most successful. The amount of time that must lapse between fumigation and planting varies depending on the product used and the species of nematode present.

1,3 –dichloropropene is a popular choice for nematode control because it is inexpensive and will also control some fungal diseases. This chemical must be used 1 to 2 weeks prior to planting due to its phytotoxicity. Metam-sodium is a fumigant that is also effective at controlling nematode populations and has the added benefit of also controlling some species of weeds and some fungal diseases. Metam-sodium, however, is considerably more expensive than 1,3 –dichloropropene and is phytotoxic. Tarping is sometimes used when applying metam-sodium to prevent gas escape from the soil.

Cultural Control: Rotation to non-susceptible crops will help reduce nematode populations. It is important when planting a non-susceptible crop to control weeds that can act as a nematode host. Summer fallowing and disking the soil during this fallow period can be used to reduce nematode populations, but it is a costly method of control. Any equipment that is used in an infested field should be carefully cleaned before being used in another field. It is important that the broccoli receives the appropriate amount of fertilizer and water to reduce plant stress, thus reducing their susceptibility to nematodes.

Post-Harvest Control: There are no effective methods of post-harvest control of nematodes.

Alternative Control: Chicken manure can be used to control nematode populations. The efficacy of other types of manure is questionable.

Vertebrates

(10, 11)

Birds can be very destructive of crops. Horned larks, blackbirds, 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 broccoli 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 are known to damage irrigation ditches and canals as well as feed on broccoli seedlings. These pests can be controlled by; fumigation, trapping and poisoning. It is best to poison squirrels in their burrows to prevent the poisoning of predatory birds. There are several species of mice that can be pests of vegetable crops and they can be controlled by weed control, repellents and occasionally with poisoning. Wood rats sometimes 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 that infest fields can cause economic damage. 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 broccoli, but are protected by Arizona State laws.

Weeds

(4, 10, 11, 13, 26, 31, 32, 33, 34)

Weeds are a threat to the cultivation of any crop. They compete with the crop for sunlight, water and nutrients. Control of weeds, especially cruciferous weeds, is fundamental for pest management. Weeds may host a variety of diseases and pests that can be transmitted to broccoli. Weed control is the most important during the first 30 days of plant establishment, after this period broccoli is better able to compete with weeds. As well, the canopy created by the broccoli stand, shades the underlying soil and inhibits the germination of weed seeds. The planting date can also give broccoli the advantage. Fields planted when summer weeds are dying back, but before winter weeds have begun to germinated, have decreased weed competition. It is essential that weeds are destroyed before they flower and produce seed. One plant can produce hundreds or thousands of seeds, depending on the species of weed.

The summer broadleaf weeds found between the months of August and October in Arizona include; pigweed (*Amaranthus* sp.), purslane (*Portulaca oleracea*), lambsquarters (*Chenopodium album*) and groundcherry (*Physalis wrightii*). Common summer grasses include; cupgrass (Eriochloa sp.), barnyardgrass (*Echinochloa crusgalli*), junglerice (*Echinochloa colonum*) and sprangletop (*Leptochloa* sp.). The winter broadleaf weeds 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*), prickly lettuce (*Lactuca serriola*), knotweed (*Polygonum* sp.), annual yellow sweet clover (*Melilotus indicus)*, lambsquarters (*Chenopodium album*) 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.).

Sampling and Treatment Thresholds: 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.

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

Chemical Control: Chemical control of weeds is difficult as many of the weeds are in the same family as broccoli (Brassicaceae). 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 shepherdspurse. Preemergence herbicides are more effective for the control of weeds in a crucifer crop field. Another option is to use a non-selective herbicide such as glyphosate to sanitize the field prior to broccoli emergence.

Trifluralin and bensulide are the most commonly used preemergence grass herbicides. Bensulide is usually sprayed behind the planter in a band over the seed row; however, it can also be broadcast spayed. Irrigation is required to activate besulide; usually sprinkler irrigation is utilized. This herbicide is effective against grass weeds and will also control some small-seeded broadleaf weeds. Trifluralin is usually broadcast sprayed prior to planting and must be mechanically incorporated. This herbicide is effective on grass weeds, and has efficacy against some small-seeded broadleaf weeds. Trifluralin usually gives better broadleaf weed control than bensulide. Oxyfluorfen is an effective preemergence broadleaf herbicide but has little effect on grass weeds. In addition, oxyfluorfen is only registered for use on transplanted broccoli. It can be used on a fallow field but the plant back restriction is 120 days which makes this option impractical. DCPA will control many of the small-seeded broadleaf and grass weeds. This is a surface applied, preemergence herbicide that requires irrigation to activate the chemical. Sethoxydim is the only available postemergence herbicide. This herbicide can be broadcast sprayed or spot treated. It 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 broccoli if not applied correctly and carefully. Injury may result from spray drift, residue in the soil from a 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: Broccoli should be encouraged to grow quickly and establish the stand, which will allow increase the ability of broccoli to out compete any weeds present in the field. Precise planting, a regular water supply and appropriate fertilization will help increase the ability of broccoli to compete with weeds.

Purchasing seed that is guaranteed to be weed-free will help prevent the introduction of new weed species to a field. 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. Weed seed can also be spread by contaminated irrigation water from canals, reservoirs and sumps. 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 favor wet conditions. The planting date can give broccoli an advantage over weeds. Fields have decreased weed competition when summer weeds are declining but before winter weeds begin to germinate; however, due to market demand it is not always possible to delay planting.

Another method 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 nonselective herbicide or rotary hoed to eliminate the weeds. After the weeds have been destroyed, the broccoli is planted. Disking will eliminate germinated weeds but it will also expose new weeds seeds allowing them to germinate.

Cultivation and hoeing can be used to control weeds but should be done with care due to the shallow root system of broccoli. Rows and beds must be carefully planted and the cultivation equipment must be carefully aligned. Cultivating tools can be arranged to push 1" of soil to the base of the broccoli plant, creating a mulch and preventing weed germination. This can only be performed; however, when the broccoli is large enough not to be buried.

Rotating to a non-crucifer crop will allow the use of herbicides that are more effective for the control of crucifer weeds. Crop rotation 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 Broccoli Grown in Arizona

Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	Total # of	% Acres	(# of reports)				
						Reports**	By Air	Broadleaf***	Unspecified*	Grass

					Treated	Acres				
WESTERN AZ										
Bensulide (**OP**)	5.00	3.305	6.00	5522	69%	117	1	90	30	3
DCPA	4.50	5.240	10.50	922	12%	47	0	1	37	1
Glyphosate	0.25	1.50	5.00	72	1%	2	1	0	1	1
Napropamide	1.00	0.500	2.00	9	0%	1	0	1	0	0
Oxyfluorfen	0.25	0.300	0.50	229	3%	12	0	17	1	0
Sethoxydim	0.10	0.207	0.30	159	2%	5	0	0	0	5
Trifluralin	0.50	0.587	0.75	3365	42%	91	0	2	40	44
CENTRAL AZ										
Bensulide (**OP**)	5.00	5.500	6.00	40	1%	2	1	0	1	0
Sethoxydim	0.10	0.282	0.30	13	0%	1	1	0	0	1
Trifluralin	0.50	0.466	0.75	445	10%	7	1	0	7	0

OP = organophosphate

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 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 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 were no section 18s active in Arizona for broccoli 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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