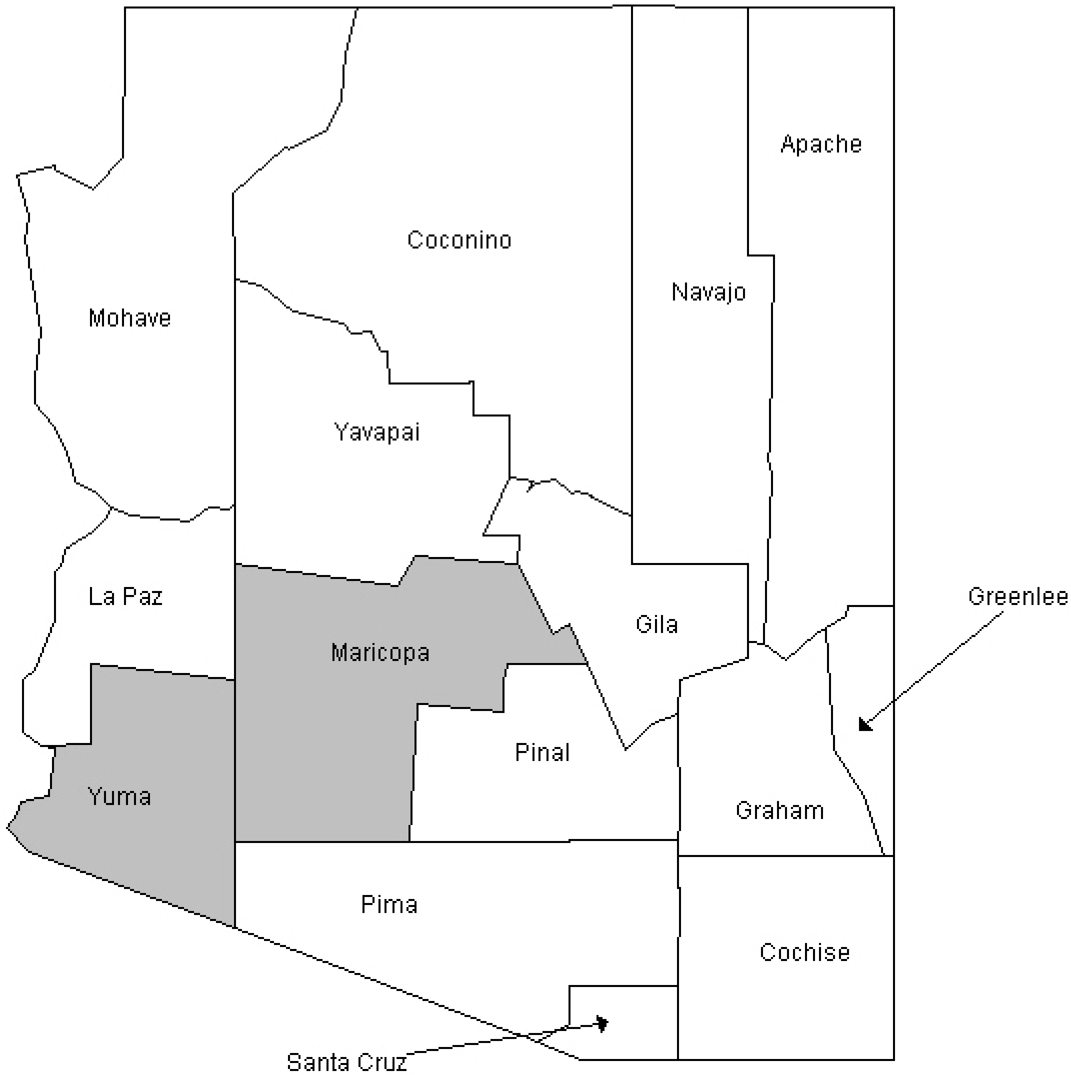
Crop Profile for Arugula in Arizona

Prepared: October, 2001

General Production Information

- **Family**: Brassicaceae (Cruciferae)
- **Scientific name**: *Eruca sativa* Mill (*E. vesicaria* 3(L.) Cav. ssp. sativa (Mill.) Thell.)
- **Edible portions**: young leaves, consumed raw or cooked.
- **Use**: fresh vegetable, in spring mix, potherb, oil from seeds used as flavoring
- **Alternative names**: Arrugula, Garden Rocket, Gargeer, Rocket, Rocket Salad, Roka, Roquette, Rucola, Rugula, Salad Rocket and Tira.
- In 2000, the cost of production was approximately 48¢ per pound of arugula[2].
- In 2000, the cost to mechanically harvest arugula was approximately 12¢ per pound[2].

Production Regions



- Approximately 15 acres of arugula were grown in the state of Arizona during the 1999/2000 growing season[2].
- Arugula is grown in Yuma and Maricopa Counties.

Cultural Practices

General Information[3, 19]: In the state of Arizona, arugula is grown in the fall, winter and spring. Planting usually begins in the middle of October and continues until the middle of February. During the arugula growing season, temperatures may range from 30°F to 90°F. Prolonged warm temperatures will promote flowering and can cause the leaves to acquire an unpleasant flavor. This plant is capable of withstanding a light frost, but if the temperature remains cold the plants can be damaged. In Arizona, arugula is grown on light, sandy loam soil with a pH ranging from 7.5 to 8.0.

Cultivars/Varieties: There is no specific variety of arugula chosen for production in Arizona. The variety is merely referred to as 'arugula'[5].

Production Practices[2, 19]: Prior to planting, the field may be disked several times, it is then deeply plowed using a chisel shank (ripped), disked again and laser leveled. The field is then listed to form the beds and pre-irrigated to promote the germination of weed seeds. Sprinkler irrigation is used to supply the crop with an adequate water supply. Once the weeds have germinated, the field is sprayed with a non-selective herbicide or shallowly cultivated to kill the weeds. The top of the bed is mulched to aerate the soil and the bed top is flattened. If a pre-plant fungicide, such as mefenoxam, is utilized it is usually applied after bed formation but prior to planting.

Early planted arugula is grown on beds with 40" centers, with 9 rows on each bed. Arugula grown later in the season may be grown on 80" beds, with 24 rows per bed. Arugula is directly seeded, ¼ to ½ inch deep, with plants spaced 2" apart within a row. The crop is not thinned. Most arugula is grown for the packaged salad industry and is harvested as 'baby' arugula. These plants can be grown close together because they do not attain a large size. If the arugula is planted too closely together, the leaves that develop are thin, easily damaged and can break down in the packaged salad bag. If sowing is staggered over a number of weeks, it is possible to produce a crop that can be continuously harvested[3]. Once planted, arugula fields are not cultivated.

Harvesting Procedures[2]: Harvesting of arugula begins the middle of November and is usually completed by the beginning of April. Arugula can be harvested either manually or mechanically. Some growers will 'mow' (cut leaves off at soil level) the arugula two or three times during the course of one growing season, allowing one crop to be harvested multiple times. Sometimes the plants are allowed to attain a larger size on the third growth and are used for a brazen mix. Subsequent growths of arugula may change the shape, color and taste of the leaves and therefore the crop is usually only harvested once. Arugula that is harvested for the fresh market is tied into bunches and packed into cartons in the field. Arugula that is for the processed market is shipped in bulk containers to the packing house. In the packing house, the arugula is triple washed, chopped and packaged into packaged salad bags. Arugula may also be packaged with other leafy greens and sold as 'Spring Mix'.

To meet Arizona standards, a minimum of 90%, by either weight or count, of arugula must be free of worms, mold, decay and other serious defects that damage the appearance or the shipping quality of the arugula[6].

Insect Pests

(7, 8, 9, 10, 11, 12, 13, 14, 15)

Arugula is usually harvested when it is in a 'baby' stage, thus, it does not experience many insect pressures. Flea beetles, crickets, grasshoppers, ants, aphids, thrips, leafminers, whiteflies and lepidopterous larvae have been noted as pests to arugula.

Hymenoptera

Harvester Ant (*Pogomyrmex rugosus*)

Ants are not a frequent pest of Arizona crops; however, when they do occur in a field they can be insidious. Harvester ants are 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 arugula 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 guidelines suggest that a field should be treated at the first signs of damage[12].

Biological Control: There are no methods for biologically controlling 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 other ants and the queen. Hydramethylnon, however, can only be used on bare ground, outside borders and ditch banks. Carbaryl baits can be used within the crop field and will provide control of ant populations.

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

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

Alternative Control: Some growers use rotenone or pyrethrin 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 large hind legs allow them to jump great distances.

In Arizona, flea beetles are particularly damaging to vegetable crops.

The female flea beetle lays her eggs in the soil, on leaves, or within holes and crevices in the arugula plant. Depending on the species, the larvae feed on the leaves or the roots of the arugula plant. The adult beetles also feed on the arugula plant; chewing small holes and pits into the underside of the leaf. These insects are the most damaging pests 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 marketed leaves, the plant is unmarketable.

Sampling and Treatment Thresholds: Flea beetles often migrate from surrounding production areas, especially Sudan grass. Fields should be monitored weekly for flea beetles and damage. University of Arizona guidelines suggest that prior to head formation, treatment should occur when there is 1 beetle per 50 plants[11]. Once the head has formed, arugula should be treated when there is 1 flea beetle per 25 plants[11].

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

Chemical Control: Imidacloprid is the only chemistry labeled for controlling flea beetles on arugula. The efficacy of imidacloprid on flea beetles has not been documented.

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

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. Azadirachtin, and pyrethrin are labeled for controlling flea beetles on arugula but only have marginal control of flea beetles. Pyrethrins are photosensitive, breaking down quickly in sunlight thus having a short residual effect. Azadirachtin is slow-acting.

Orthoptera

Cricket (*Gryllus* sp.)

In Arizona, crickets are rarely a problem 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 arugula 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 from these fields into arugula fields. Fields that use over-head sprinkler irrigation encourage inhabitance by creating an ideal environment for crickets because the female cricket lays her 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 needs to 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[11].

Biological Control: There are no methods for biologically controlling crickets.

Chemical Control: Baits can be used to control cricket populations. Baits are usually placed at the field borders to target crickets migrating into the field. The only bait registered for use in arugula fields is permethrin. There are no chemistries labeled for spraying or chemigating an arugula field to control cricket populations

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

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

Alternative Control: Rotenone can be used to control cricket populations. Pyrethrin is also registered for controlling crickets in arugula fields. Pyrethrin, however, breaks down quickly and has only a short residual effect. As well, the control this chemistry provides is weak.

Spur-throated grasshopper (*Schistocerca* sp.)
Desert (Migratory) Grasshopper (*Melanoplus sanguinipes*)

In Arizona, grasshoppers are normally not a threat to arugula stands. Occasionally, after a period of 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 to cause damage to the crop[12].

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

Chemical Control: If the grasshopper population is large, chemical control is usually the only option. However, there are no labeled chemistries for controlling grasshoppers in arugula fields.

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

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

Alternative Control: The only product registered for use on grasshoppers in arugula fields is azadirachtin. This product will only provide marginal control of grasshoppers and is slow acting.

Diptera

Leafminers (*Liriomyza* sp.)

Adult leafminers are small, shiny, black flies with a yellow triangular marking on the thorax. The female leafminer fly oviposits her eggs within the leaf tissue. Male and female flies will feed at the puncture sites. The larvae hatch inside the leaf, 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. Mining damage of the arugula leaves can render the plant unmarketable. These mines also inhibit the plants ability to photosynthesize and the puncture wounds provide an entryway for pathogenic infection. Leafminers will often pupate between the leaves of the arugula head, contaminating the head and making it unmarketable. Rotting pupae within the head can provide an environment for post-harvest pathogens.

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 arugula should be treated when populations have reached 1 active mine per leaf[11]. After head formation, treatment should occur when populations reach 1 mine per 25 arugula plants[11].

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

Chemical Control: Spinosad is used for the control of both *L. sativae* and *L. trifolii*. Spinosad is the only chemistry available that effectively controls *L. trifolii*. Other registered chemistries include;

cryomazine and permethrin. Cyromazine is not a popular choice because of the limited plant-back restrictions. Permethrin provides some control of *L. sativae* adults but has no efficacy against leafminer larvae or *L. trifolii* adults. 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 arugula field. Fields should be plowed under immediately following harvest to reduce leafminer populations.

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

Alternative Control: Some growers use insecticidal soaps to control leafminer populations. Pyrethrins can be used to control *L. sativae*, but is not effective against *L. trifolii*. Azadirachtin is also registered for controlling leafminers but is slow acting.

Lepidoptera

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

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, black and red hairs. Older larvae sometimes 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 pest to arugula. The larvae, however, will migrate from surrounding host fields. The saltmarsh caterpillar feeds on seedlings and can skeletonize the leaves of arugula 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[12].

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 an arugula field[11]. Spinosad, and tebufenozide are the most popular methods of controlling saltmarsh caterpillars. 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 arugula emergence will help assess the degree of risk for the crop. Saltmarsh caterpillars do not like to cross physical barriers. A six-inch high aluminum foil strip or irrigation pipes that the larvae cannot crawl under are will provide a barrier to the field. These barriers can also be used to herd the larvae into cups of oil. A ditch of water containing oil or detergent that surrounds the perimeter of the field can also be used as a barrier. Barriers will work to exclude saltmarsh caterpillars from the field, but have no useful value if the larvae have already infested the field.

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

Alternative Control: *Bacillus thuringiensis* may be used to control saltmarsh caterpillars. An 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. Azadirachtin and pyrethrins are registered for controlling saltmarsh caterpillars in arugula fields. These products, however, only provide a short residual control.

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 through 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. Arugula 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. This leaf damage will render the plant unmarketable. The larvae of the diamondback moth penetrate arugula 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. University of Arizona experts suggest that prior to head formation, arugula should be treated when there is 1 larva per 50 plants[11]. Once the arugula head has formed, the crop can tolerate 1 larva per 100 plants[11]. 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 (ant lions) can also be used to control small diamondback larvae. Insecticides must be used with care as they can decrease the populations of these beneficial insects. These beneficial insects, however, usually do not provide complete control of diamondback moth populations.

Chemical Control: Spinosad is the only chemistry registered for controlling diamondback moths. *Plutella* resistance to insecticides has been reported and is a concern in arugula production. The lack of available insecticides for arugula could create further resistance issues.

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 post-harvest control methods for diamondback moths.

Alternative Control: *Bacillus thuringiensis* can be used to control diamondback moth larvae. A concern 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. Azadirachtin and pyrethrins are also labeled for diamondback moth control in arugula fields. Diatomaceous earth can be used for controlling 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; this 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 hindwings are yellow. The female moth lays dome-shaped eggs solitarily on the lower surface of older leaves. The larvae are bright green with a white stripe running along both sides of its body. The looper moves by arching its back in a characteristic looping motion, which is also the source of the larvae's name. Loopers can have from 3 to 5 generations in one year.

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

<u>Sampling and Treatment Thresholds</u>: Once arugula 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 have begun 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. University of Arizona experts suggest that prior to head formation, arugula should be treated when populations have reached 1 larva per 50 plants[11]. After head formation, arugula can tolerate 1 larva per 100 plants[11]. All other larvae in the lepidopterous complex should be included in this count.

<u>Biological Control</u>: 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, a naturally occurring virus can also assist in the control of loopers when conditions are favorable.

<u>Chemical Control</u>: Spinosad, tebufenozide, permethrin and thiodicarb are all registered for controlling looper populations. All are foliar-applied insecticides.

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

plowed under immediately following harvest to kill larvae and remove any host material.

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

Alternative Control: *Bacillus thuringiensis* can be used to control looper populations, but is 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. Azadirachtin and pyrethrin are also registered for controlling 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 arugula. 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.

Armyworm populations are heaviest in arugula stands during the fall. These 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 the 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, chew on the leaf's midrib and consume entire seedlings. A single armyworm can attack several plants. Arugula leaves 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 crop fields to vegetable crops. Armyworms also feed on weeds including; pigweed (Amaranthus sp.), lambsquarters (*Chenopodium album*) and nettleleaf goosefoot (*Chenopodium murale*).

Sampling and Treatment Thresholds: Weeds surrounding the field should be monitored for larvae and eggs prior to crop emergence. If population levels are high in surrounding weeds, the crop should be monitored very carefully following emergence. Pheromone traps can be used to monitor for the presence of beet armyworms in a field. After germination, fields should be monitored twice a week. According to University of Arizona guidelines, prior to head formation arugula should be treated when populations reach 1 larva per 50 plants[11]. Once the head has formed, arugula can tolerate 1 larva per 100 plants[11]. 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. Care must be taken with insecticide treatment, as it can decrease the populations of these beneficial insects.

Chemical Control: Spinosad, thiodicarb, permethrin and tebufenozide are the registered chemistries available for the control of armyworms in arugula fields. 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 armyworms are the most active. It is important to practice sound resistance management practices by alternating chemistries.

Cultural Control: Weeds growing within the field 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 post-harvest control methods for beet armyworms.

Alternative Control: *Bacillus thuringiensis* is registered for controlling beet armyworms but provides little control. Azadirachtin is also registered but has short residual control. Diatomaceous earth, neem oil soap, neem emulsion and rotenone are used by some growers for the control of beet armyworms.

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 arugula 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, chew on the leaf's midrib and also attack the growing point of the plant, often killing the growing tip. Damage to the arugula leaves renders the plant unmarketable.

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. Arugula should be checked for larvae and feeding damage. It is important to correctly identify which larvae are present, as resistance in tobacco budworms has been reported. The University of Arizona suggests that before arugula head formation, the crop requires treatment when populations reach 1 larva per 50 plants[11]. After head formation the crop can tolerate 1 larva per 100 plants[11]. 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. Nuclear polyhedrosis virus, a naturally occurring pathogen, also helps control populations. Insecticides should be used with care as they can harm beneficial insects.

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 budworms and earworms is mid-afternoon, this is when the larvae are the most active. Permethrin and thiodicarb are the only chemistries registered 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 earworm and budworm migration into arugula fields. Fields should be disked following harvest to kill any larvae pupating in the soil.

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

Alternative Control: Methods for the alternative control of budworm and earworm include; diatomaceous earth, neem oil soap, neem emulsion and rotenone. *Bacillus thuringiensis* and azadirachtin are also registered for earworm and budworm control.

Homoptera

APHIDS (syn. "plant lice")

Green Peach Aphid (*Myzus persicae*)
Potato Aphid (*Macrosiphum euphorbiae*)

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

Aphid populations peak during the months of November and December and again during February and March. Populations consist entirely of asexual reproducing females that produce live young; this allows the population to increase rapidly. Under ideal conditions aphids can 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.

Extreme aphid feeding can deplete a plant of enough phloem sap to reduce the plant's vigor or even kill the plant. Feeding can also distort and curl arugula leaves. 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 an arugula 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. Experts at the University of Arizona suggest that prior to arugula head formation treatment should begin when populations reach 1 aphid per 10 plants[11]. After head formation, arugula should be treated when aphid colonization begins[11].

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. Care must be taken with insecticide treatment, as it can decrease the populations of these beneficial insects. These beneficial insects, however, can also become contaminants of arugula.

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

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 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. Azadirachtin and pyrethrins are also registered for controlling aphids in arugula fields.

WHITEFLIES

Sweetpotato whitefly (*Bemisia tabaci*)
Silverleaf whitefly (*Bemisia argentifolii*)

Historically, whiteflies were not 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. Arugula planted downwind from these plants are particularly susceptible. Whitefly feeding removes essential salts, vitamins and amino acids required by the arugula 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 arugula's leaf surface creates an ideal environment for sooty mold infection. Whiteflies also contaminate the harvested arugula, making it unmarketable. The whitefly's ability to transmit viruses is also still a concern.

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. Experts at the University of Arizona suggest that if a soil-applied insecticide was not used, a crop should be treated when populations reach 5 adults per leaf[11].

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, imidacloprid, is often applied. If arugula is planted after whitefly populations have declined, foliar-applied insecticides can be used as necessary. Imidacloprid can also be used as a foliar insecticide. Tank-mixing insecticides helps control whiteflies, as well as, preventing the build up of insecticide resistance. When spraying it is important to achieve complete crop coverage, this will provide the best control of whiteflies. Imidacloprid is the only chemistry registered to control whiteflies on arugula. There is a strong dependence on imidacloprid to control whiteflies; this creates concerns of product resistance.

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 manage whitefly infestation. This, however, does not always correspond with market windows. 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 produce growers use; neem oil soap, neem emulsion, pyrethrins, azadirachtin, 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 species are small (1/20-1/25 in.), slender and pale yellow-brown in color. The two species are very 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. Thrips are present all year, but their populations increase in the early fall and late spring. Thrips spread from surrounding mustard, alfalfa, onion and wheat fields, weedy areas and unirrigated pastures.

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 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 arugula are considered a contaminant.

Sampling and Treatment Thresholds: Sticky traps are a good method for monitoring of thrips migration into a field. When inspecting for thrips, the folded plant tissue and arugula 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. According to University of Arizona guidelines, arugula should be treated prior to head formation when populations reach 1 thrips per 10 plants[11]. After head formation, the crop should be treated when the population reaches 1 thrips per 25 plants[11].

Biological Control: Lacewing larvae, ladybug larvae (syn: ant lions) and the minute pirate bug can be used to provide control of thrips. Care must be taken with insecticide treatment, as it can decrease the populations of 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. Insecticide resistance has been observed in western flower thrips, making this species difficult to control.

Spinosad is the only chemistry labeled for controlling thrips on arugula. Spinosad will provide control for thrips nymphs but little control for the 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 post-harvest thrips control.

Alternative Control: Pyrethrins and elemental sulfur are used by some organic growers to control thrips. Azadirachtin is also registered for controlling thrips populations but is slow-acting.

OTHER CONTAMINANTS ('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 has a ¼" long, 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 arugula fields.

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

Sampling and Treatment Thresholds: According to University of Arizona guidelines; before the formation of the arugula head a stand does not require treatment until populations reach 10 contaminant insects per 50 plants[11]. Once the head is formed, arugula should be treated when populations reach 1 contaminant insect per 25 plants[11].

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 arugula, chemical control is not normally required until head formation begins. Growers typically spray as close to harvest as possible to ensure an uncontaminated crop. Permethrin is the only effective chemistry available to control contaminant insects in arugula.

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 arugula field has been harvested, this will prevent contaminant insect migration into the arugula 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.

Insecticides registered for use on arugula grown in Arizona in 2000

ACTIVE INGREDIANT	ANT	FB	CR	GR	LM	SM	DM	L	BAW	CE/TB	APH	WF	THR
Azadirachtin		X		X	X	X	X	X	X	X	X	X	X
Bacillus thuringiensis						X	X	X	X	X			
Cryomazine					X								
Imidacloprid		X									X	X	
Malathion **(OP)**											X		
Neem oil											X	X	X
Permethrin			X		X			X	X	X	X		X
Pyrethrins + Piperonyl butoxide	X	X	X			X	X	X	X	X	X	X	X
Pyrethrins + Rotenone					X			X			X	X	X
Spinosad					X		X	X	X				X
Tebufenozide								X	X				
Thiodicarb (**carbamate, B1/B2)**								X	X	X			

ANT - Ants
FB - Flea Beetles
CR - Crickets
GR - Grasshoppers
LM - Leafminer
SM - Saltmarsh caterpillar
DM - Diamondback moth
L - Loopers
BAW - Beet Armyworms
CE/TB - Corn earworm/Tobacco budworm
APH - Aphids
WF - Whiteflies
THR - Thrips
OP - Organophosphate

Diseases

Arugula does not experience many fungal or bacterial disease pressures, due to the short growing period required to obtain a harvestable plant. Most fungal and bacterial diseases that could pose a threat to the arugula plant do not have a chance to develop before the plant is harvested.

FUNGAL DISEASES

(7, 10, 16, 17, 18)

Downy Mildew (*Peronospora parasitica*)

Of the potential fungal diseases, downy mildew poses the largest threat to the production of arugula in Arizona. Downy mildew thrives in cool, 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 arugula through the leaves and then grows between the leaf's cells. When conditions are favorable, disease 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 and infected seed.

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 arugula can result in decreased photosynthesis, stunted plants and reduced yield. Downy mildew is a systemic disease that will spread throughout the arugula plant. Damage to the stem and leaves is susceptible to secondary infections, and any damage to the arugula leaves results in an unmarketable product.

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

Chemical Control: Mefenoxam and fosetyl-aluminum are the only methods for chemically controlling downy mildew. Mefenoxam and fosetyl-aluminum both are systemic treatments. 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 might be required. It is important to alternate fungicides or apply fungicide mixtures to ensure proper resistance management.

Cultural Control: Weeds that can act as a host for downy mildew must be controlled. It is important to rotate crops to allow the use of other chemistries and reduce the risk of disease carryover. 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.

BACTERIAL DISEASES

(7, 10, 16, 17)

Black Rot (*Xanthomonas campestris*)

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

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 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. Damage to arugula’s leaves will make the plant unmarketable.

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

Chemical Control: In Arizona, there are no methods for the chemical control of black rot in arugula.

Cultural Control: Planting only certified disease-free seed 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. Crop rotation should be practiced to reduce the risk of disease carryover between crops. As well, it is important to control weeds and volunteer plants that can act as hosts for black rot. 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.

Fungicides registered for use on arugula grown in Arizona in 2000.

Active Ingredient	Downy Mildew	Black Rot
Fosetyl-Al	X	
Mefenoxam	X	

VIRAL DISEASES

Radish mosaic *comovirus* can occur in arugula but to date, there have been no reported cases of viral diseases occurring in arugula stands in Arizona.

Vertebrates

(7, 8)

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 arugula 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 feeding on arugula 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, 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 arugula, but are protected by Arizona State laws.

Weeds

(4, 7, 8, 10, 19)

Weeds are a threat to the cultivation of any crop. They compete with the crop for sunlight, water and nutrients. Control of weeds is fundamental for pest management because weeds may host a variety of diseases and pests that can be transmitted to arugula. Weeds present at harvest can contaminate harvested arugula, especially when harvested mechanically. Due to the low-growing form of arugula, weeds present at harvest can slow down the harvesting crew that will be forced to search through the weeds for the desired crop. It is essential that weeds are destroyed before they flower and produce seed. One plant can produce hundreds or even thousands of seeds depending on the weed species present.

The summer broadleaf weeds commonly found in Arizona between the months of August and October are pigweed (*Amaranthus* sp.), purslane (*Portulaca oleracea*), lambsquarters (*Chenopodium album*) and groundcherry (*Physalis wrightii*). Common summer grasses include barnyardgrass (*Echinochloa crusgalli*), cupgrass (Eriochloa sp.) junglerice (*Echinochloa colonum*) and sprangletop (*Leptochloa* sp.). The winter broadleaf weeds most commonly found in Arizona between the months of November and March are black mustard (*Brassica nigra*), wild *radish (Raphanus sativus*), shepherds*purse (Capsella bursa-pastoris*), London rocket (*Sisymbrium i*rio), cheeseweed (*Malva parviflora*), sowthistle (*Sonchus oleraceus*), prickly lettuce (*Lactuca serriola*), lambsquarters (*Chenopodium album*) and nettleleaf goosefoot (*Chenopodium murale*). Common winter grasses include canary grass (*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 arugula (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 an arugula field. Another option is to use a non-selective herbicide such as glyphosate to eliminate weeds in the field prior to arugula emergence.

Bensulide is the most commonly used preemergence herbicides. Bensulide is usually sprayed behind the planter in a band over the seed row; however, it can also be broadcast spayed or applied by chemigation. Bensulide requires irrigation to activate the chemical; typically sprinkler irrigation is utilized. This herbicide is effective against grass weeds and will also control some small-seeded broadleaf weeds. Sethoxydim and pelargonic acid are the only available postemergent herbicides. Sethoxydim is applied by broadcast or spot treatment and is often applied with crop oil. This herbicide provides control of grasses but is ineffective against broadleaf weeds. Pelargonic acid is a nonselective contact herbicide that is labeled for use on both grasses and broadleafs. Perlargonic acid has little activity on larger weeds.

Herbicides can cause injury to arugula 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. A soil, water or plant tissue test can be used to identify herbicide injury.

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

Purchasing seed that is guaranteed to be weed-free will help prevent the introduction of new weed species into a field. 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 are favored by wet conditions. The planting date can give arugula 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 used to control weeds is to till the field, form beds and irrigate prior to planting. This will encourage the germination of the weed seeds. The field can then be sprayed with a nonselective herbicide or rotary-hoed to eliminate the weeds. After the weeds have been destroyed, the arugula is planted. While disking will eliminate germinated weeds it can also expose new weeds seeds allowing them to germinate.

Cultivation and hoeing can be used to control weeds in a planted field but is difficult due to the close spacing of arugula plants. Fields should be disked after harvest to eliminate any weeds present and to prevent the weeds from flowering and spreading seed.

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

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

Alternative Control: There are no alternative methods of weed control.

Herbicides registered for use on arugula grown in Arizona in 2000

Active Ingredient	Pre-Plant Not Incorporated	Pre-Plant Incorporated	Preemergence	Postemergence
Bensulide (**OP**)	X	X	X	
Glyphosate	X		X	
Metam-sodium (**B1/B2**)		X		
Paraquat	X			
Pelargonic Acid	X			X
Sethoxydim				X

OP - organophosphate

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