Crop Profile for Brussels Sprouts in Arizona

Prepared: February, 2001

General Production Information

- Brassicaceae (syn: Cruciferae)
- Scientific name: *Brassica oleracea* var. *gemmifera* Zenker
- Edible portions: axillary buds, consumed raw or cooked.
- Use: fresh and frozen vegetable, potherb.
- Alternative Names: Breton, Col de Bruselas, and Toy Cabbage

Currently in the state of Arizona, only a small acreage of brussels sprouts, less than one acre, is grown. This production occurs in Maricopa county, and the sprouts are primarily grown for direct farm marketing. It has been approximately 25 years since brussels sprouts have been grown at a large-scale commercial level in Arizona. However, there is potential that this crop will be grown at a larger scale in the future.

Cultural Practices

General Information[2, 4, 24]: In Arizona, brussels sprouts are grown during the fall and winter. Planting of brussels sprouts can begin as early as August and is usually completed by late November. Temperatures during the growing season range from 30 °F to 90°F. Prolonged temperatures below 50°F will initiate flowering. Brussels sprouts are grown on soils that range from sandy-loam to clay-loam with a pH of 7.5-8.0.

Cultivars/Varieties: 'Jade Cross' is the most common variety of brussels sprouts grown in Maricopa County[3].

Production Practices[4, 24]: Prior to planting, the field is deeply tilled, disked, land-planed, the beds are prepared and pre-irrigated. Often a fertilizer and a preplant herbicide application is made prior to planting. If a pre-plant fungicide, such as mefenoxam, is utilized it is usually applied after bed formation but prior to planning.

In Arizona, Brussels sprouts are directly seeded, ¼ inch deep, in beds with 40" centers. There is one row of brussels sprouts per bed and the plants are spaced 3-4" apart. Sprinkle irrigation may be used to establish seedlings. The beds are later thinned allowing 24" of space between plants.

In Arizona, furrow irrigation is used for brussels sprouts production. Fields are cultivated two to three times during the production season. In addition, a side dressing of fertilizer is added two or three times, depending on necessity.

Harvesting Procedures: In Arizona, harvesting begins in October and is usually completed by March. At maturity the plants are approximately 2 ½ feet tall. Brussels sprouts are harvested when heads are bright green and firm[2]. Sprouts that are not firm or are off-color will be woody and have an undesirable flavor[2]. Brussels sprouts can be either harvested mechanically or manually. Brussels sprouts packed in the field are packed in 25 lb. Cartons[5]. Brussels sprouts are graded, washed, and packaged, in the field. Most often brussels sprouts are packaged into one-pint packages that are usually overwrapped[5]. These packaged sprouts are packed 12 pints per carton. Brussels sprouts are very delicate; thus they are very difficult to store[2].

In order to meet Arizona standards all brussels sprouts must be fairly well colored, fairly firm, not withered or burst and free from soft decay, seedstems and serious damage[6]**. No more than 5%, by weight, of the brussels sprouts can show any one defect and no more than 10%, by weight, can fail to meet the total Arizona standards[6].**

Insect Pests

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

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 the 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 will not cause damage to the mature brussels sprouts 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[12].

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 is the only chemistry labeled for the control of ants within the brussels sprouts field.

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

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

Alternative Control: Rotenone and pyrethrins are alternative methods 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 large hind legs allow them to jump great distances.

In Arizona, flea beetles are particularly damaging to cole crops. Flea beetles often migrate from surrounding production areas and Sudan grass. The female flea beetle lays her eggs in the soil, on leaves, or within holes and crevices in the brussels sprouts plant. Depending on the species present, the larvae feed on the leaves or the roots of the brussels sprouts plant. The adult beetles will also feed on the brussels sprouts 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 sprout, the plant is unmarketable.

Sampling and Treatment Thresholds: Fields should be monitored weekly for flea beetles and damage. According to University of Arizona guidelines, prior to sprout formation treatment should occur when there is 1 beetle per 50 plants[11]. Once the plant is mature, treatment should occur when there is 1 beetle per 25 plants[11].

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

Cultural Control: It is important to control volunteer plants and weeds, in and around the field, which could act as a host for flea beetles. Crop rotation is important; however, flea beetles have a wide range of hosts so not all crops are suitable for rotation. Brussels sprouts 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 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 a 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 lepidoptera 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 brussels sprouts 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. The beetles often migrate from nearby cotton and alfalfa fields or weedy areas. University of Arizona experts recommend treating a field when beetle populations are high or there is a threat of migration into the field. Brussels sprouts plants that have 5 to 6 leaves are usually not at risk for beetle attack[11].

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

Chemical Control: Methomyl, diazinon, chlorpyrifos and pyrethroids such as permethrin and cypermethrin are all frequently utilized treatments for 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 the beetles are already in the field. Placing baits around the perimeter of the field will also provide some control when beetles migrate 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: Some growers use rotenone and neem oil to control darkling and rove beetles.

Orthoptera

Cricket (*Gryllus* sp.)

Crickets are rarely a problem in Arizona but dense populations are capable of destroying an entire crop. Crickets are ½ - 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 brussels sprouts 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 areas into brussels sprouts fields. Fields that use over-head sprinkler irrigation encourage inhabitance by creating an ideal environment for crickets; 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 should be closely monitored. Experts at the University of Arizona recommend treating a field when cricket damage is high or there is a threat of cricket migration into the field[11].

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

Sampling and Treatment Thresholds: University of Arizona guidelines suggest that a field should be treated at the first signs of damage[12].

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

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

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

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

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

Lepidoptera

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

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 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 are 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 are often found feeding in groups on older plants. If populations are high, they can decimate an entire seedling stand.

Sampling and Treatment Thresholds: Experts at the University of Arizona recommend that field edges should be sprayed when saltmarsh caterpillars begin to migrate into the brussels sprouts field[11].

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

Chemical Control: Methomyl, spinosad, tebufenozide, chlorpyrifos and pyrethroids such as permethrin and cypermethrin are often used 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. Surrounding cotton and alfalfa fields must be monitored prior to brussels sprouts emergence; this 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 suitable 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 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.

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. Cutworms frequently occur in fields that were previously planted with alfalfa or pasture. The adult moth has gray-brown forewings with irregular markings; the hindwings are lighter in color. The female moth lays her eggs on the leaves and stem near the soil surface.

Cutworm populations are heaviest during the fall and most significantly impact 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 brussels sprouts seedlings. The cutworm attacks the seedling 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 brussels sprouts 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.

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 easier 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[11].

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 brussels sprouts 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, methomyl and pyrethroids such as permethrin and cypermethrin are the most commonly 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 that are in close proximity to alfalfa fields are especially prone to cutworm infestation, and should be carefully monitored. Cutworms tend to reoccur in the same area of a field and in the same fields. It is important to control weeds that can act as hosts to cutworms, in the field and surrounding the field. The field should be plowed a minimum of two weeks prior to planting, in order to kill cutworms, hosts and food sources.

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

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

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 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 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 from 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. Brussels sprouts can be particularly hard hit by diamondback moth populations. Larvae attack the growing points of the developing brussels sprouts. The larvae will also chew small holes, mostly on the underside of mature leaves, on mature plants.

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 guidelines suggest, prior to head formation brussels sprouts should be treated when there is 1 larva per 50 plants[11]. Once the sprouts have 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. Care must be used when spraying insecticides as they can harm populations of beneficial insects. These beneficial insects, however, usually will not provide complete control of diamondback moth larvae.

Chemical Control: Methomyl, spinosad and pyrethroids such as permethrin and cypermethrin are the most frequently used chemistries for the control of diamondback moths. *Plutella* resistance to insecticides has been reported and is a concern in brussels sprouts 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 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 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 and can cause extensive damage to brussels sprouts. All stages of plant growth are affected by looper feeding. These larvae feed on the lower leaf surface, chewing ragged holes into the leaf. Loopers will sometimes chew through the outer leaves of the sprouts. Excessive feeding on seedlings can stunt growth or even kill plants. Brussels sprouts that have been damaged by looper feeding or that are contaminated with larvae or larvae frass are unmarketable.

Sampling and Treatment Thresholds: Once brussels sprouts plants have germinated, fields should be monitored twice a week. The lower leaf surface should be checked for larvae and eggs, especially on damaged leaves. When populations are noted to be increasing, fields should be monitored more frequently. Pheromone traps are useful for measuring the migration of moths into crop fields. The presence of parasitized and virus-killed loopers should also be noted. According to University of Arizona guidelines, prior to sprout formation brussels sprouts should be treated when populations have reached 1 larva per 50 plants[11]. After sprout formation, brussels sprouts can tolerate 1 larva per 100 plants[11]. All other lepidoptera 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 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 most commonly used methods for controlling looper populations. All are foliar applied insecticides.

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

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 such as; redroot pigweed (*Amaranthus* sp.), lambsquarters (*Chenopodium album*) and nettleleaf goosefoot (*Chenopodium murale*).

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 their body and light-colored stripes on their back. A black dot is located above the second true leg and a white dot at the center of each spiracle. The mature larvae pupate in the soil.

The beet armyworm is a key pest that affects brussels sprouts Production in Arizona. Armyworm populations are heaviest during the fall and the larvae will attack all stages of plant growth. Young larvae feed in groups near their hatching site. As the beet armyworm feeds, it spins a web over its feeding site. Mature armyworms become more migratory and move to new plants. Many armyworms will die while travelling between plants. Armyworm feeding can skeletonize leaves and consume entire seedlings. A single armyworm can attack several plants. Brussels sprouts that have been damaged by armyworm feeding are unmarketable.

<u>Sampling and Treatment Thresholds</u>: 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 sprout formation brussels sprouts should be treated formation when populations reach 1 larva per 50 plants[11]. Once the sprout has formed, brussels sprouts 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 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.

<u>Chemical Control</u>: Spinosad, chlorpyrifos, tebufenozide and pyrethroids such as permethrin and cypermethrin are the most commonly used insecticides for the control of 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.

<u>Cultural Control</u>: 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.

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

<u>Alternative Control</u>: 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 little 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 can be a variety of colors and develop stripes down the length of their body. It is difficult to differentiate between the larvae of these two species until they are older. Older larvae can be distinguished by comparing the spines at the base of the abdominal tubercles and by the presence of a tooth in the mandible.

Budworm and earworm populations peak during the fall. Earworms and budworms attack all stages of plant growth and can be very destructive to brussels sprouts stands. The larvae are cannibalistic, eating larvae of their own species and of other lepidopterous species, thus they tend to feed alone. These larvae 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 sprouts will result in an unmarketable plant.

<u>Sampling and Treatment Thresholds</u>: 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 crop 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. According to University of Arizona guidelines a crop should be treated prior to sprout formation if populations reach 1 larva per 50 plants[11]. After sprout 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. 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 widely used for treating for 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 brussels sprouts fields. Due to market demand, however, it is not always possible to delay plantingFields should disked following harvest to kill any larvae pupating in the soil.

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

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

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 hairs giving the larvae a velvety appearance.

The imported cabbageworm chews large, irregular shaped 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 a stem or leaf on the plant or a near by object to pupate. Damage to the sprouts will render the crop 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. According to University of Arizona guidelines, prior to sprout formation a brussels sprouts crop should be treated when there is 1 larva per 50 plants[11]. Once the brussels sprouts have 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: 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 the most commonly used methods for controlling imported cabbageworms.

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. A 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.

Diptera

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. A brussels sprouts plant can usually outgrow a leafminer infection, unless the infection is severe and occurs during the seedling stage or if the sprout itself is attacked.

Sampling and Treatment Thresholds: It is important that the crop is monitored regularly for leaf mines, larvae and adult flies. The cotyledons and first true leaves are the first to be mined. Mining is more visible on the undersurface of the leaf; thus both leaf surfaces must be viewed. Presence of leafminer parasites and parasitized mines should also be determined. Yellow sticky traps are a good method for measuring leafminer migration into a field, as well as, determining which species are present. It is important to accurately identify which species are present, because insecticide resistance has been documented for *Liriomyza trifolii*. University of Arizona experts recommend that prior to sprout formation, brussels sprouts should be treated when populations have reached 1 active mine per leaf[11]. After sprout formation, treatment should occur when populations reach 1 mine per leaf per 25 brussels sprouts plants[11].

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 the adults and larvae of *L. sativae* and *L. trifolii*. Spinosad is the only chemistry available that effectively controls *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 brussels sprouts 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.

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 that are pests to brussels sprouts: 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 of brussels sprouts. 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 when brussels sprouts are mature. 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 brussels sprout 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. University of Arizona experts suggest that prior to brussels sprouts formation, treatment should begin when populations reach 1 aphid per 10 plants[11]. After sprout formation, brussels sprouts 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. These beneficial insects, however, can also become contaminants of brussels sprouts. Spraying of insecticides should be performed with caution as it can 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 and imidacloprid are available foliar-applied treatments. The initial treatment should occur once aphids begin to migrate into a crop field. To ensure that aphids do not contaminate the harvested brussels sprouts, it might be necessary to use repeated applications. Aphids often hide within the brussels sprouts 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 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 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. Brussels sprouts planted downwind from these plants are particularly susceptible. Whitefly feeding removes essential salts, vitamins and amino acids required by the brussels sprouts plant for proper growth. This feeding results in; reduced plant vigor, stunting and can delay harvest if not controlled at an early stage. As with aphids, the phloem sap that whiteflies excrete onto the plant's surface creates an ideal environment for sooty mold infection. Whiteflies also contaminate the harvested brussels sprouts, 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. University of Arizona guidelines recommend that if a soil-applied insecticide was not used, crops 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, such as imidacloprid, is often applied. If brussels sprouts are planted after whitefly populations have declined, foliar-applied insecticides can be used as necessary. Imidacloprid and endosulfan 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. 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 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, which is actually thrips feces, on the leaves distinguishes this damage from wind burn or sand burn. Thrips present in harvested brussels sprouts are considered a contaminant.

Sampling and Treatment Thresholds: Sticky traps are a good way to monitor of thrips migration into a field. When inspecting for thrips, the folded plant tissue and brussels sprouts 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. University of Arizona guidelines suggest treating field prior to sprout formation if populations reach 1 thrips per 10 plants[11]. After sprout 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. 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. Insecticide resistance has been observed in western thrips populations, making this species difficult to control.

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

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

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

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

Other Contaminants (syn: 'trash bugs')

False Chinch Bug (*Nysius raphanus*) (Hemiptera)
Lygus Bug (*Lygus hesperus*) (Hemiptera)<
Three-cornered alfalfa hopper (*Sissistilus festinus*) (Homoptera)
Potato Leafhopper (*Empoasca fabae*) (Homoptera)

The false chinch bug is gray-brown with a narrow, 1/8" long body 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, 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 brussels sprouts fields.

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

Sampling and Treatment Thresholds: Experts at the University of Arizona recommend that before the formation of the sprout, a stand does not require treatment until populations reach 10 contaminant insects per 50 plants[11]. Once the head is formed, brussels sprouts 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 brussels sprouts, chemical control is not normally required until head formation begins. Growers typically spray as close to harvest as possible to ensure that the harvest is not contaminated. 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 brussels sprouts field has been harvested, this will prevent insect migration into the brussels sprouts 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 brussels sprouts in Arizona in 2000

ACTIVE INGREDIANT	ANT	FB	DB	CR	GR	LM	SM	CW	DM	L	BAW	HEL	ICW	APH	WF	THR
Acephate **(OP)**									X	X			X	X		
Azadirachtin		X	X		X	X	X	X	X	X	X	X	X	X	X	X
Azinphos-methyl **(OP)**									X	X			X	X		
Bacillus thuringiensis							X	X	X	X	X	X	X			
Bifenthrin		X	X	X			X	X	X	X	X	X	X	X	X	X
Carbaryl **(carbamate)**	X	X	X	X	X			X	X		X	X	X			
Chlorpyrifos **(OP)**		X						X	X		X		X	X		
Cryolite		X						X	X	X		X	X			
Cypermethrin		X	X	X			X	X		X	X	X	X			X
Diazinon **(OP)**				X				X	X				X	X		
Disulfoton **(OP)**		X												X		X
Emamectin Benzoate									X	X	X	X	X			
Endosulfan		X						X	X	X	X		X	X	X	
Fenpropathrin										X			X			
Garlic		X	X				X	X	X	X	X	X	X	X	X	
Imidacloprid		X												X	X	
Lambdacyhalothrin		X			X			X	X	X	X	X	X	X	X	X

Malathion **(OP)**									X	X			X	X		
Methomyl **(carbamate)**								X	X	X			X			
Methyl Parathion **(OP)**		X								X	X		X	X		X
Naled **(OP)**									X	X			X	X		
Neem Oil														X	X	X
Oil						X				X				X	X	X
Oxydemeton-methyl **(OP)**														X		
Permethrin			X	X				X	X	X	X		X	X		X
Potassium salts of Fatty Acids														X	X	X
Pyrethrins	X	X		X			X	X	X	X	X	X	X	X	X	X
Spinosad						X			X	X	X		X			X
Tebufenozide										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
HEL	Corn earworm/Tobacco budworm
APH	Aphids
WF	Whiteflies
THR	Thrips
OP	Organophosphate

Diseases

Fungal Diseases

(2, 7, 10, 16, 17, 20, 21)

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

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

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

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

Chemical Control: Metam sodium and metam-potassium are fumigants registered for use on *Pythium* and *Rhizoctonia* induced damping off; however, these methods are very costly and generally not considered a viable option. There are no other chemistries registered for the control of *Pythium* induced damping-off in brussels sprouts fields. The only other method available for controlling *Rhizoctonia* damping-off is PCNB. PCNB should also be used in a preventative manner. Typically, PCNB is applied during planting. There are no registered seed treatments in Arizona for controlling damping-off of brussels sprouts. Most growers, however, do not treat for damping-off as this disease is not currently a large threat to brussels sprouts in Arizona.

Cultural Control: All residues from the previous crop should be plowed under and completely decomposed before planting brussels sprouts. 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. 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 brussels sprouts 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. 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. *Peronospora 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 brussels sprouts 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. This damage to the stem and sprouts, leaves the plant susceptible to secondary infections. If damage only occurs on the leaves of brussels sprouts the losses are less severe as the leaves are not part of the consumable crop. Damage to the brussels sprouts, however, will result 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, 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 *Peronospora parasitica*. Fields should be plowed 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.

Sclerotinia Rot (*Sclerotinia minor, Sclerotinia sclerotiorum*)

In Arizona, *Sclerotinia*

is rarely a concern in brussels sprouts fields. 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 brussels sprouts, stems 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 plant will weaken and collapse.

The fungi produce 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*.

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

<u>Chemical Control</u>: Metam sodium and metam-potassium are fumigants registered for use on *Sclerotinia*; however, these methods are very costly and generally not considered a viable option. The only other method available in Arizona for the chemical control of sclerotinia rot is benomyl. This fungicide is systemic and will provide good control of both *S. minor* and *S. sclerotiorum*. This fungicide is the most effective when applied prior to the onset of disease.

<u>Cultural Control</u>: 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*.

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

<u>Alternative Control</u>: Some growers spread compost on the soil to control pathogens.

Bacterial Diseases

(2, 7, 10, 16, 17, 18, 19, 20)

Black Rot (*Xanthomonas campestris*)

Black rot is occasionally observed in Arizona brussels sprouts fields. This bacterium normally occurs only when the weather is warm and humid; however, it can be introduced into Arizona crops from infected seed or transplants. *Xanthomonas campestris* spreads rapidly when there is unusually high rainfall or if overhead irrigation is used. Animals and humans can also spread the pathogen. 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.

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

<u>Chemical Control</u>: 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.

<u>Cultural Control</u>: Planting only seed and transplants that are certified to be disease-free will help control 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 volunteer plants and weeds, especially cruciferous weeds that can act as hosts for black rot. One must be careful when clipping or mowing transplants before planting as this will spread *X. campestris*. 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 brussels sprouts. Bacterial soft rot does occur in the field, but is more common during post-harvest storage. Infection often occurs on sprouts that are 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 brussels sprouts.

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

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

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

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

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

Fungicides registered for use on brussels sprouts in Arizona in 2000

Active Ingredient	*Pythium* Damping-off	*Rhizoctonia* Damping-off	Downy Mildew	Sclerotinia Rot	Black Rot
Basic Copper Sulfate			X		
Benomyl **(carbamate)**				X	
Chlorothalonil **(B1/B2)**			X		
Copper			X		X
Copper Hydroxide			X		X
Copper Oxide			X		X
Copper Oxychloride Sulfate			X		X
Copper Tallate			X		
Fosetyl-AL			X		
Gliocladium virens GL-21	X	X			
Maneb **(B1/B2)**			X		
Mefenoxam + Chlorothalonil **(B1/B2)**			X		
PCNB		X	X		

Viral Diseases

(7, 21, 22)

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 brussels sprouts stands but their occurrences are rare. These viral Diseases cause the plant'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 because it only requires a few insects to spread viral Diseases.

Chemical Control: Viruses can not be chemically controlled. The insects that spread viruses, however, can be controlled e.g. aphids, whiteflies. This method of 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 to 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.

Nematodes

(Various species)

(7, 8 10, 23)

Nematodes are not a major pest of brussels sprouts 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 brussels sprouts are 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 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 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 brussels sprouts fields to warrant the expense of a chemical treatment.

Fumigants may be used for reducing populations. 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 brussels sprouts crop 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 for the 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.

Vertebrate Pests

(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 brussels sprouts 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 brussels sprouts 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; 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 brussels sprouts, but are protected by Arizona State laws.

Abiotic Diseases

There are a number of Abiotic Diseases that brussels sprouts can suffer from that affect the crop yield and often have symptoms similar to those caused by pathogens or insect pests.

Tipburn on brussels sprouts occurs when the plant is stressed by a calcium deficiency and lack of water coupled with high soil fertility and high temperatures. Symptoms usually begin when the plant suddenly experiences rapid growth. Symptoms are usually not obvious on the outer leaves of the sprout. If the sprout is cut open, however, the tips of the internal leaves are brown. This leaf damage is also susceptible to secondary infections, including bacterial soft rot. Soil should be sampled regularly to ensure the crop has an adequate calcium supply. It is also important to avoid over applying nitrogen to the soil and the crop should receive a consistent water supply.

Although brussels sprouts is relatively tolerant of cold temperatures, cold temperatures can damage the brussels sprouts. The damage that occurs can leave the plant susceptible to secondary infections.

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

Weeds

(2, 7, 8, 10, 20, 24, 25)

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 brussels sprouts. Weed control is the most important during the first 30 days of plant establishment, after this period brussels sprouts are better able to compete with weeds. As well, the canopy created by the brussels sprouts stand, shades the underlying soil and inhibits the germination of weed seeds. The planting date can also give brussels sprouts the advantage. Fields planted when summer weeds are dying back, but before winter weeds have begun to germinate, have decreased weed competition. However, due to market demands it is not always feasible to delay planting. 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.

The summer broadleaf weeds most commonly 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; barnyardgrass (*Echinochloa crusgalli*), cupgrass (*Eriochloa* sp.), junglerice (*Echinochloa colonum*) and sprangletop (*Leptochloa* sp.). The winter broadleaf weeds most commonly found in Arizona between the months of November and March include black mustard (*Brassica nigra*), wild *radish (Raphanus sativus*), shepherds*purse (Capsella bursa-pastoris*), London rocket (*Sisymbrium i*rio), cheeseweed (*Malva parviflora*), sowthistle (*Sonchus oleraceus*), prickly lettuce (*Lactuca serriola*), annual yellow sweet clover (*Melilotus* indicus), knotweed (Polygonum sp.) 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 brussels sprouts (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 shepherds-purse. 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 brussels sprouts 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 or chemigated. Irrigation is required to activate bensulide; typically sprinkler irrigation is utilized. This herbicide is effective against grass weeds and will also control some small-seeded broadleaf weeds. Trifluralin is usually 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. As well, oxyfluorfen is only registered for use on fallow beds and has a 120 day plant back restriction before brussels sprouts can be seeded. DCPA will control many of the small-seeded broadleaf and grass weeds. This is a surface applied, preemergence herbicide. Sethoxydim is the only available postemergence herbicide. This herbicide has good grass control but has no efficacy against broadleaf weeds. Pelargonic acid can be used for spot treatment on postemergence crops.

Herbicides can cause injury to brussels sprouts 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: Brussels sprouts should be encouraged to grow quickly and establish the stand, which will allow increase the ability of brussels sprouts to out compete any weeds present in the field. Precise planting, a regular water supply and appropriate fertilization will help increase the ability of brussels sprouts to compete.

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

The planting date can give brussels sprouts an advantage over weeds. Fields have decreased competition when planted after the summer weeds have declined but before winter weeds begin to germinate.

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 non-specific herbicide or rotary hoed to kill the weeds. After the weeds have been destroyed, the brussels sprouts are planted. Disking will eliminate germinated weeds but will also expose new weed seed that may germinate and cause a second flush of weeds.

Cultivation and hoeing can be used to control weeds but should be done with care due to the shallow root system of brussels sprouts. Rows and beds must be carefully planted and the cultivation equipment must be carefully aligned.

Rotating to a non-crucifer crop will allow the use of herbicides that are more effective for the control of crucifer 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 available for controlling weeds.

Herbicides registered for use of brussels sprouts in Arizona in 2000

Active Ingredient	Pre-Plant Not Incorporated	Pre-Plant Incorporated	Preemergence	Post-Emergent
Bensulide **(OP)**		X	X	
DCPA	X	X	X	
Glyphosate	X		X	

Metam Sodium **(B1/B2)**		X		
Oxyfluorfen	X			
Paraquat	X			
Pelargonic Acid	X		X	X
Sethoxydim				X
Trifluralin		X		

OP = organophosphate

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