

Crop Profile for Bok Choy in Arizona

Prepared: October, 2001



General Production Information

- **Family:** Brassicaceae (Cruciferae)
- **Scientific name:** *Brassica rapa* sp. *chinensis* L. (*Brassica chinensis* L., *Brassica campestris* L. or *Brassica sinensis* L.)
- **Edible portions:** leaves and petioles, consumed raw or cooked.
- **Use:** fresh vegetable.
- **Alternate names**¹: Baak Choi, Bok Choi, Bok Choy Chinese Cabbage, Canton Pak Choy, Celery Cabbage, Celery Mustard, Chinese Cabbage Bok Choy, Chinese Chard, Chinese Mustard Cabbage, Chinese Savoy, Chongee, Japanese White Celery Mustard, Joi Choy, Lei Choy, Mustard Cabbage, Osaka-Na, Pai Tsai White Stalk, Pak Choy, Pak Choy Sum, Paksoi, Pak Toy, Paktsoi, Shanghai, Spoon Cabbage, Taisai, Tak Tsai, Tatsoi and White Mustard Cabbage.

Production Regions



- An average of 138 acres/year of bok choy was grown per year between 1995 and 1999^{2,3}
- An average of 109,520 cartons/year of bok choy was harvested between 1995 and 1999^{2,3}
- Bok choy had an average yearly value of 480 thousand dollars between 1995 and 1999^{2,3}
- Bok choy is produced in Maricopa and Yuma Counties
- Land preparation and growing expenses for bok choy are approximately \$1.30/carton⁶
- Harvest and post harvest expenses for bok choy are approximately \$2.15/carton⁶

Cultural Practices

General Information^{5, 8, 30}: In the state of Arizona, bok choy is grown in the fall and winter. Planting begins the end of August and is usually complete by November. During the bok choy growing season, temperatures in Arizona may range from 30°F to 90°F. Bok choy is relatively hardy but temperatures rising above 75 °F can cause tip burn and temperatures below 55 °F can initiate flowering. The daylength is also important for proper bok choy growth. Short days promote

vegetative growth, while long days promote flowering. Bok choy grows best in fertile, well-drained, soil with good water retention. In Arizona, bok choy is grown on soils that range from a sandy loam to a clay loam, with a pH from 7.5 to 8.0.

Cultivars/Varieties⁷: In Arizona, 'Joi Choy' is the most commonly grown variety of bok choy. This variety has been used for a very long time and is chosen because it produces nice dark green leaves with a very white petiole. Joi Choy is very tolerant of the wide range of temperatures that occur during the bok choy growing season.

Production Practices^{5, 8, 9, 30}: Prior to planting the field may be deeply tilled, disced, land planed, the beds are prepared and the field is then pre-irrigated. Sprinkle irrigation is often used to establish seedlings. A preplant herbicide may be applied prior to bed formation. If a pre-plant fungicide, such as mefenoxam, is utilized it is usually applied after bed formation but prior to planting.

Bok choy is direct seeded a ¼ to ½ an inch deep into beds with 40" centers. There are two rows of bok choy per bed, and the plants within the rows are spaced from 6" to 12" apart.

A minimum of 1" of water a week should be applied to the crop, in Arizona furrow irrigation is the most common method used. The crop is cultivated two to three times during production. Bok choy has a shallow root system so cultivations must be shallow. Side dressing fertilizer is added two or three times, as necessary, increasing the amount of field cultivation.

Harvesting Procedures: From time of seeding, bok choy requires from 40 to 80 days to reach maturity¹. Harvesting begins in December and is usually completed by March⁸. Bok choy is harvested by hand by cutting the heads off just above the soil surface⁸. All damaged leaves and remaining roots are removed⁵. Bok choy is packed with 18 or 24 heads into wooden crates¹⁰.

In order to meet Arizona standards, a minimum of 90% of shipped bok choy must be free from insect injury, worms, mold, decay or other serious damage or defects that would affect appearance or shipping quality¹¹. Bok choy can be stored for approximately 3 weeks at 32 °F (0 °C) and 95-100% humidity⁵.

Insect Pests

(8, 9, 12, 13, 14, 15, 16, 17, 18, 19, 20)

Hymenoptera

Harvester Ant (*Pogomyrmex rugosus*)

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

Sampling and Treatment Thresholds: University of Arizona experts suggest that a field should be treated at the first signs of damage¹⁷.

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

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

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

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

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

Coleoptera

Striped flea beetle (*Phyllotreta striolata*)

Potato flea beetle (*Epitrix cucumeris*)

Western black flea beetle (*Phyllotreta pusilla*)

Western striped flea beetle (*Phyllotreta ramosa*)

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

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

Sampling and Treatment Thresholds: Flea beetles often migrate from surrounding production areas and Sudan grass. Fields should be monitored weekly for flea beetles and damage. Experts at the University of Arizona recommend treating prior to head formation when there is 1 beetle per 50 plants¹⁶. After head formation, treatment should occur when there is 1 beetle per 25 plants¹⁶.

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

Chemical Control: Methomyl, diazinon and pyrethroids such as lambda-cyhalothrin, permethrin and cypermethrin are frequently used treatments for the control of flea beetles. Methomyl is foliar applied; diazinon and pyrethroids can be foliar applied or chemigated. Chlorpyrifos also has some activity against flea beetles. Diazinon and pyrethroids applied by chemigation have the added benefit of 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. Bok choy fields should be disced under immediately following the final harvest to kill any larvae pupating in the soil. It is also important that Sudan grass is plowed under within a week of the final harvest, as this crop often harbors flea beetles.

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

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

Darkling Beetle (*Blapstinus* sp.)
Rove Beetle (*Staphylinids* sp.)

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

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

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

Sampling and Treatment Thresholds: Nighttime is the best time to monitor a field for darkling beetles; this is when they are the most active. During the day they tend to hide in the soil or debris. The beetles often migrate from nearby cotton and alfalfa fields or weedy areas. According to University of Arizona guidelines, bok choy should be treated when beetle populations are high or there is a threat of migration into the field. Bok choy plants that have 5 to 6 leaves are usually not at risk for beetle attack¹⁶.

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

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

Cultural Control: It is important to control weeds in the field, and surrounding the field, that can act as hosts for darkling and rove beetles. Ditches filled with water around the field's perimeter can deter beetle migration into the field. However, if beetles are already in the field, this method is of little value. 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 or neem oil to control darkling and rove beetles.

Orthoptera

Cricket (*Gryllus* sp.)

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

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

Sampling and Treatment Thresholds: Crickets are difficult to monitor for during the day, as they tend to hide. One can check underneath irrigation pipes; however, a visual inspection of damage is usually sufficient to give an estimate of cricket activity. Fields planted near cotton or Sudan grass should be closely monitored. Experts at the University of Arizona recommend that a field should be treated when cricket damage is high or there is a threat of cricket migration into the field¹⁷.

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

Chemical Control: Baits such as, permethrin and carbaryl, can be used to control cricket populations. Baits are usually placed at the field borders to target crickets migrating into the field. Methomyl, diazinon and pyrethroids such as cypermethrin and permethrin are the most commonly 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 disced immediately following harvest, this will help control cricket populations.

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

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

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

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

Sampling and Treatment Thresholds: University of Arizona experts suggest that fields should be treated as soon as grasshoppers begin to cause damage to the crop¹⁷.

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

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

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

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

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

Diptera

Cabbage maggot (*Delia radicum*)

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

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

Sampling and Treatment Thresholds: Purple and yellow sticky traps are a good method for monitoring the presence of adult flies. Methods to monitor for the presence of maggots are still experimental. One method suggests marking a 5" circle around the base of the plant¹². The soil within the circle is dug up to a depth of 1", placed in a water-filled container and then mixed. When the soil settles to the bottom of the container, any eggs present will float to the surface. If there are more than 25 eggs present in the sample, the field should be treated¹². Maggot populations tend to be localized in small areas within a field, thus it is important to take many random samples throughout the field. It is also important to monitor the crop stand for plants that are wilting or chlorotic. These plants, as well as the surrounding soil, should be uprooted and inspected for damaged roots, maggots and pupae. University of Arizona experts recommend treating bok choy as soon as maggots cause damage to the crop¹⁷. When conditions are favorable for cabbage maggots, such as a cool spring, wet soil and high soil organic matter, one should treat the field prior to planting.

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

Chemical Control: Insecticide treatment is more effective when applied before seeding because cabbage maggots are a stand establishment pest. Treatments after the crop has been planted are usually ineffective. A pre-plant spray can be applied to the soil or a band of insecticide can be applied over the seed row during planting. Diazinon is the most commonly used chemistry for controlling cabbage maggots. If maggot infestations do not occur until the plant is mature, the crop can likely tolerate the pressure.

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

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

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

Leafminers (*Liriomyza* sp.)

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

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

Sampling and Treatment Thresholds: It is important that the crop is monitored regularly for leaf mines, larvae and adult flies. The cotyledons and first true leaves are the first to be mined. Mining is more visible on the undersurface of the leaf; thus both leaf surfaces must be viewed. Presence of leafminer parasites and parasitized mines should also be determined. Yellow sticky traps are a good method for measuring leafminer migration into a field, as well as, determining which species are present. It is important to accurately identify which species are present, because insecticide resistance has been documented for *Liriomyza trifolii*. University of Arizona guidelines recommend that prior to head formation, bok choy should be treated when populations have reached 1 active mine per leaf¹⁶. After head formation, treatment should occur when populations reach 1 mine per leaf per 25 bok choy plants¹⁶.

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: Spinosad, diazinon and pyrethroids such as permethrin are the commonly used chemistries to control *L. sativae* adults. Permethrin is ineffective against leafminer larvae. Neither diazinon nor permethrin are effective against *L. trifolii*. Spinosad is used for the control of the larvae and adults of both *L. sativae* and *L. trifolii*. Spinosad is the only chemistry available that controls *L. trifolii*. Insecticide resistance has been noted in *L. trifolii* populations, thus there is a need for a 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 bok choy field. A field that has a leafminer infestation should be disced immediately following harvest.

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

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

Lepidoptera

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

Black Cutworm (*Agrotis ipsilon*)
Variegated Cutworm (*Peridroma saucia*)
Granulate Cutworm (*Agrotis subterranea*)

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

Cutworm populations are heaviest during the fall and frequently occur in fields that were previously planted with alfalfa or pasture. Seedlings are the most significantly impacted by cutworm attack. Newly hatched larvae feed on the leaves temporarily, but then drop to the soil surface and burrow underground. The larvae emerge at night and feed on the bok choy. The cutworm attacks bok choy 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 bok choy 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. Bok choy that is contaminated by cutworms or damaged by cutworm feeding is unmarketable.

Sampling and Treatment Thresholds: Prior to planting, the field, field borders and adjoining fields should be monitored for cutworms. Pheromone traps can be used to monitor for the presence of cutworms in a field. Once seedlings have emerged, fields should be scouted twice a week. If an area of several wilted or cut off plants is discovered, the surrounding soil should be dug into and searched for cutworms. Cutworms are nocturnal; therefore it is easiest to scout for them on the soil surface during the evening. Cutworms are often not noticed until crop damage has become severe. According to University of Arizona guidelines a field should be treated as soon as stand loss begins¹⁶.

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 bok choy emergence. These baits should be placed in the areas where cutworms have been found in previous years. Cutworms often occur at the field borders or in isolated areas within the field. Sometimes spot and edge treatments are sufficient to control cutworm populations. Spinosad, chlorpyrifos, and pyrethroids such as cypermethrin are the most routinely used methods for controlling cutworm populations. These larvae, however, are often controlled when the crop is sprayed for stand establishment pests. Cutworms usually do not get an opportunity to establish a population.

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

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

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

Saltmarsh Caterpillar (*Estigmene acrea*)

The adult saltmarsh caterpillar moth has white forewings that are covered with black spots; the hindwings are yellow. The female moth lays groups of 20 or more eggs on the leaf surface. The young larvae are yellow-brown in color and covered in long, dark black and red hairs. Older larvae may also 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 caterpillars feed on seedlings and can skeletonize older plants. The larvae often feed in groups on older plants. If populations are high, they can decimate an entire seedling stand.

Sampling and Treatment Thresholds: Counts of saltmarsh caterpillars should be included with the total Lepidoptera count. According to University of Arizona experts, fields should be treated at the first signs of damage¹⁷.

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 the most commonly utilized treatments for controlling saltmarsh caterpillars. Methomyl, pyrethroids and chlorpyrifos are all contact insecticides that are foliar applied. Spinosad is a translaminar insecticide that must be consumed or tread upon to kill the larvae. Tebufenozide is an insect stomach poison that must be consumed to be effective.

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

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

Alternative Control: *Bacillus thuringiensis* may be used to control saltmarsh caterpillars. A concern when using *B. thuringiensis* is its tendency to break down when exposed to UV light and heat. Usually it is sprayed at night to allow the longest period of efficacy.

Diamondback Moth (*Plutella xylostella*)

Diamondback moth populations peak in March and April and again in June through August. If conditions are favorable, this moth can have from four to six generations a year. Diamondback moths can be particularly damaging to bok choy.

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 larvae attack all stages of plant growth but their damage is most significant during the seedling stage and at harvest. Larvae attack the growing points on young plants, stunting growth and decreasing yield. The larvae will also chew small holes, mostly on the underside of mature leaves, on mature plants. Bok choy heads that are contaminated by larvae or larvae frass or damaged by larvae feeding are unmarketable.

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 disced, as the larvae will migrate from such fields. The University of Arizona recommends that prior to head formation, bok choy should be treated when there is 1 larva per 50 plants¹⁶. Once the bok choy head has formed, the crop can tolerate 1 larva per 100 plants¹⁶. All other lepidopterous larvae that are noted should be included in this total.

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

Chemical Control: Methomyl, spinosad and pyrethroids such as permethrin and cypermethrin are the most frequently utilized chemistries for the control of diamondback moths. *Plutella* resistance to insecticides has been reported and is a concern in bok choy production.

Cultural Control: Fields should be disced immediately following harvest in order to kill larvae and pupae in the soil 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*)



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.

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 its name. Loopers can have from 3 to 5 generations in one year.

Looper populations are usually highest in the fall and can cause extensive damage to bok choy. Loopers will attack all stages of plant growth. Excessive feeding on seedlings can stunt growth or

even kill plants. The larvae feed on the lower leaf surface, chewing ragged holes into the leaf. Sometimes loopers will bore into the base of the bok choy head and feed within the head. Bok choy that has been damaged by looper feeding or that is contaminated with larvae or larvae frass is unmarketable.

Sampling and Treatment Thresholds: Once bok choy has germinated, fields should be monitored twice a week. The lower leaf surface should be checked for larvae and eggs, especially on damaged leaves. When populations are noted to be increasing, fields should be monitored more frequently. Pheromone traps are useful for measuring the migration of moths into crop fields. The presence of parasitized and virus-killed loopers should also be noted. The University of Arizona recommends that prior to head formation bok choy should be treated when populations have reached 1 larva per 50 plants¹⁶. After head formation, bok choy can tolerate 1 larva per 100 plants¹⁶. All other lepidopterous larvae that are noted should be included in this total.

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

Chemical Control: Spinosad, tebufenozide, chlorpyrifos and pyrethroids such as permethrin and cypermethrin are the commonly utilized chemistries 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.

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

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

Beet Armyworm (*Spodoptera exigua*)

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

The beet armyworm is a key pest that affects bok choy 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 traveling between plants. A single armyworm can attack several plants. Armyworm feeding can skeletonize leaves and consume entire seedlings. Sometimes an armyworm bores from underneath into a bok choy head and feeds on the newly formed leaves. Often this damage is not noticed until the bok choy is harvested. Bok choy heads that have been damaged by armyworm feeding are unmarketable.

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

Sampling and Treatment Thresholds: Weeds surrounding the field should be monitored for larvae and eggs prior to crop emergence. If population levels are high in surrounding weeds, the crop should be monitored very closely. Pheromone traps can be used to monitor for the presence of beet armyworms in a field. After germination, fields should be monitored twice a week. According to University of Arizona guidelines, prior to head formation bok choy should be treated when populations reach 1 larva per 50 plants¹⁶. Once the head has formed, bok choy can tolerate 1 larva per 100 plants¹⁶. All other lepidopterous larvae that are noted should be included in this total.

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

Chemical Control: Spinosad, 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 by alternating chemistries.

Cultural Control: Weeds growing within the field or surrounding the field should be removed, as armyworms can build up in these areas. When 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 disced immediately following harvest to kill larvae pupating in the soil.

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

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

Corn earworm (bollworm) (*Helicoverpa zea*)
Tobacco budworm (*Heliothis virescens*)

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

Budworm and earworm populations peak during the fall. These larvae attack all stages of plant growth and can be very destructive to bok choy stands. The larvae are cannibalistic, eating larvae of their own species and of other lepidopterous species, thus they tend to be feed alone. These

larvae are capable of killing entire stands of seedlings. In older plants, the larvae chew holes into the leaves and the midrib. Sometimes the larvae will bore into the bok choy head and attack the growing point of the plant, often killing the growing tip. Once inside the head it is difficult to control larvae with pesticides. Often this damage is not noticed until the bok choy is harvested. Damage to the bok choy head results in an unmarketable plant.

Sampling and Treatment Thresholds: Field monitoring should begin immediately following seed germination. Pheromone traps can be used to monitor for the presence of tobacco budworms and corn earworms. Earworms and budworms migrate from corn and cotton fields, thus it is important to carefully monitor field edges that border these fields. If eggs are discovered, it should be determined if they have hatched, are about to hatch or have been parasitized. The bok choy should also be checked for larvae and feeding damage. It is important to correctly identify which larvae are present, as resistance in tobacco budworms has been reported. Experts at the University of Arizona recommend that bok choy should be treated before head formation when populations reach 1 larva per 50 plants¹⁶. After head formation the crop can tolerate 1 larva per 100 plants¹⁶. 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. (big-eyed bugs). These insects are often able to reduce earworm and budworm populations. Care must be taken with insecticide treatment, as it can decrease the populations of beneficial insects. Nuclear polyhedrosis virus, a naturally occurring pathogen, also helps control populations.

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

Cultural Control: Delaying planting until after cotton defoliation will decrease larvae migration into bok choy fields. However, due to market demands it is not always feasible to delay planting. Fields that are planted next to cotton fields require close monitoring. Fields should be disced 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 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 many hairs giving the larvae a velvety appearance.

The imported cabbageworm larvae feed on the inner and outer leaves of the bok choy head, chewing large irregular-shaped holes into the leaves. Larvae sometimes bore into the center of the head and feed. When young plants are attacked, the larvae can stunt or kill the plants. Older plants can tolerate more larvae feeding than the young plants but any damage to the leaves will

render the bok choy head unmarketable. The larvae feed for 2 to 3 weeks and then attach themselves to the stem or leaf on the plant or a near by object to pupate. Contamination of the head with larvae or larvae frass or damage to the leaves is 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. Experts at the University of Arizona recommend that prior to head formation, bok choy should be treated when there is 1 larva per 50 plants¹⁶. Once the bok choy head has formed, the crop can tolerate 4 larvae per 100 plants¹⁶. Imported cabbageworm counts should be included in the lepidopterous complex.

Biological Control: There are many natural enemies to the imported cabbageworm including; *Pteromalus puparum*, *Apanteles glomeratus*, *Microplitis plutella* and the tachinid fly. There are also some viral and bacterial diseases that will attack cabbageworms.

Chemical Control: Spinosad, chlorpyrifos and pyrethroids such as permethrin and cypermethrin are the most commonly used chemistries for the control of 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 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.

1999 Insecticide Use to Control Lepidoptera Larvae on Arizona Grown Bok Choy

Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	Total # of Acres	% of Acres Treated	# of Reports**	(# of reports)			
							By Air	AW***	L	Unspecified larvae
<i>Bacillus thuringiensis</i>	0.05	0.339	1.05	12	12%	2	1	0	0	2
Cypermethrin	0.05	0.077	0.10	77.5	76%	12	5	2	1	10
Lambdacyhalothrin	0.02	0.027	0.03	30.4	30%	15	2	0	0	15
Methomyl (carbamate)	0.23	0.720	0.90	21.4	21%	7	6	7	2	0
Permethrin	0.05	0.149	0.20	13	13%	6	0	0	0	6
Spinosad	0.023	0.078	0.156	112.7	110%	18	11	6	3	10

AW=armyworm
 L=loopers
 OP=Organophosphate

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

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

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

Homoptera

APHIDS (syn. "plant lice")

Green Peach Aphid (*Myzus persicae*)

Potato Aphid (*Macrosiphum euphorbiae*)

Turnip Aphid (*Lipaphis erysimi*)

Cabbage Aphid (*Brevicoryne brassicae*)



There are four different species of aphid that are pests to cabbage: 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 are similar 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 bok choy. 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 producing live young; this allows the population to increase rapidly. Under ideal conditions aphids have as many as 21 generations in one year. When populations become too large or food is scarce, aphids produce winged offspring that can migrate to new hosts.

The majority of aphid damage occurs during the final heading stage of bok choy. Extreme aphid feeding can deplete a plant of enough phloem sap to reduce the plant's vigor or even kill the plant.

In addition, as an aphid feeds it excretes phloem sap ("honeydew") onto the plant's surface. This provides an ideal environment for sooty mold infection, which inhibits photosynthesis. Aphid feeding can cause the leaves to become deformed and the head to be distorted. Another concern is the viruses that green peach aphids can transmit such as; alfalfa mosaic virus, lettuce mosaic virus and beet western yellows virus. Aphids are most damaging, however, as a contaminant; their presence in a bok choy head will make the head unmarketable.

Sampling and Treatment Thresholds: To control aphid infestations, it is essential to monitor fields frequently and prevent the growth of large populations. These pests migrate into crop fields and reproduce rapidly, quickly infecting a crop. Beginning in January, fields should be monitored no less than twice a week. Yellow waterpan traps are useful for measuring aphid movement into the field. In infested fields, aphids tend to occur in clusters within the field, thus it is important to randomly sample the field. Experts at the University of Arizona recommend that prior to head formation, treatment should begin when populations reach 1 aphid per 10 plants¹⁶. After head formation, bok choy should be treated when aphid colonization begins¹⁶

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

Chemical Control: A pre-plant application of imidacloprid is the most common method used to control aphids. Imidacloprid 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 necessary. When foliar insecticides are used, the timing of application is critical. Dimethoate and imidacloprid are the most frequently used foliar-applied treatments. The initial foliar-applied treatment should occur once wingless aphids begin to migrate into a crop field. To ensure that the harvested bok choy is not contaminated with aphids, it might be necessary to use repeated applications. Aphids often hide within the protected areas of the bok choy head making insecticide treatment difficult. If aphids only occur at the field borders or in isolated areas, border or spot applications might be sufficient to control populations. Insecticide chemistries should be alternated for good resistance management.

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

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

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

WHITEFLIES

Sweetpotato whitefly (*Bemisia tabaci*)

Silverleaf whitefly (*Bemisia argentifolii*)

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

The adult whitefly is minute (1/16" in length) and has a white powder covering its body and wings.

The female whitefly lays small, oval, yellow eggs on the undersurface of young leaves. The eggs become darker in color prior to hatching. The hatched whitefly (nymph) travels about the plant until it finds a desirable minor vein to feed from 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. Bok choy planted downwind from these crops are particularly susceptible. Whitefly feeding removes essential salts, vitamins and amino acids required by the bok choy plant for proper growth. This feeding results in, reduces plant vigor, decreased head size and can delay harvest if not controlled at an early stage. As with aphids, the phloem sap that whiteflies excrete onto the bok choy's surface creates an ideal environment for sooty mold infection. Whiteflies also contaminate the harvested bok choy, making it unmarketable. Still a concern is the whitefly's ability to transmit viruses.

Sampling and Treatment Thresholds: The best way to prevent a whitefly infestation is to inhibit initial colonization. Whitefly counts should be performed early in the morning when the insects are the least active. Once whiteflies become active they are difficult to count. During the mid-morning, fields should be monitored for swarms of migrating whiteflies. According to University of Arizona guidelines, if a soil-applied insecticide is not used, crops should be treated when populations reach 5 adults per leaf¹⁶

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

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

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 infestation. However, delay of planting is not always a feasible option. Whiteflies build up in weeds, especially cheeseweed (*Malva parviflora*), thus it is important to control weeds in the field and surrounding the field. Crop debris should be plowed under immediately following harvest to prevent whitefly build up and migration to other fields.

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

Alternative Control: Organic produce growers use; neem oil soap, neem emulsion, pyrethrin, 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 surrounding weedy areas, unirrigated pastures and mustard, alfalfa, onion and wheat fields.

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

Thrips feeding results in wrinkled and deformed leaves, damaged heads and stunted growth. Feeding can also cause brown scarring; extreme damage causes leaves to dry and fall off the plant. Black dust (thrips feces) on the leaves distinguishes this damage from wind burn or sand burn. Thrips present in harvested bok choy are considered a contaminant. Although thrips can cause crop damage, they are also an important mite predator. In some instances, the beneficial control that thrips provide for mite populations is greater than the damage they cause the crop. Bok choy that has been damaged by thrips or that is contaminated by thrips is not marketable.

Sampling and Treatment Thresholds: Sticky traps are also a good monitor of thrips migration into a field. When inspecting for thrips, the folded plant tissue and bok choy heads must be carefully examined, as this is where thrips hide. It is estimated that for every 3 to 5 thrips observed there are three times as many undiscovered. The University of Arizona recommends that prior to head formation, bok choy should be treated when populations reach 1 thrips per 10 plants¹⁶. After head formation, the crop should be treated when the population reaches 1 thrips per 25 plants¹⁶.

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

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

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

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

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

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

<i>Bacillus thuringiensis</i>	0.05	0.339	1.05	12	12%	2	1	0	2	0	0
Cypermethrin	0.05	0.077	0.10	77.5	76%	12	5	0	13	0	1
Diazinon (OP)	0.25	0.4	4.00	1	1%	1	1	1	0	0	0
Lambdacyhalothrin	0.02	0.027	0.03	30.4	30%	15	2	0	15	0	0
Methomyl (carbamate)	0.23	0.720	0.90	21.4	21%	7	6	0	9	1	1
Permethrin	0.05	0.149	0.20	13	13%	6	0	0	6	0	0
Spinosad	0.023	0.078	0.156	112.7	110%	18	11	0	19	0	0

Aph=aphids

Lep=lepidoptera larvae

SE=stand establishment insects = maggots, ants, crickets, flea beetles, darkling beetles, grasshoppers

WF=whitefly

OP=organophosphate

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

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

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

Weeds

(4, 12, 13, 15, 26, 30, 31)

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 bok choy. Weed control is the most important during the first 30 days of plant establishment, after this period bok choy is better able to compete with weeds. As well, the canopy created by the bok choy stand, shades the underlying soil and inhibits the germination of weed seeds. The planting date can also give bok choy the advantage. Fields planted when summer weeds are dying back but before winter weeds have begun to germinate have decreased weed competition. Due to market windows, however, it is not always feasible to delay planting. It is essential that weeds be destroyed before they flower and produce seed. One plant can produce hundreds or thousands of seeds depending on the species of weed.

The summer broadleaf weeds commonly found in Arizona between the months of August and October are pigweed (*Amaranthus* sp.), purslane (*Portulaca oleracea*), lambsquarters (*Chenopodium album*) and groundcherry (*Physalis wrightii*). Common summer grasses include; barnyardgrass (*Echinochloa crusgalli*), junglerice (*Echinochloa colonum*), cup grass (*Eriochloa* sp.) and sprangletop (*Leptochloa* sp.). The winter broadleaf weeds found in Arizona between the months of November and March are black mustard (*Brassica nigra*), wild radish (*Raphanus*

sativus), knotweed (*Polygonum* sp.), annual yellow sweet clover (*Melilotus indicus*), shepherdspurse (*Capsella bursa-pastoris*), London rocket (*Sisymbrium irio*), cheeseweed (*Malva parviflora*), sowthistle (*Sonchus oleraceus*), prickly lettuce (*Lactuca serriola*), lambsquarters (*Chenopodium album*) and nettleleaf goosefoot (*Chenopodium murale*). Common winter grasses include; canarygrass (*Phalaris minor*), annual blue grass (*Poa annua*), wild oats (*Avena fatua*) and wild barley (*Hordeum* sp.).

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

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

Chemical Control: Chemical control of weeds is difficult as many of the weeds are in the same family as bok choy (Brassicaceae). It is challenging to adequately control weeds while ensuring crop safety. It is important to correctly identify the weed species, as different weeds have different chemical tolerances. Most postemergence herbicides do not have a wide range of weed control and are especially poor at controlling cruciferous weeds such as wild mustard and shepherdspurse. Preemergence herbicides are more effective for the control of weeds in a crucifer crop field. Another option is to use a non-selective herbicide such as glyphosate to sanitize the field prior to bok choy 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 sprayed. Irrigation is required to activate bensulide, usually 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 grasses. In addition, oxyfluorfen is only registered for use on a fallow field and the plant back restriction is 120 days, which makes this option impractical. DCPA will control many of the small-seeded broadleaf and grass weeds. This is a surface applied, preemergence herbicide. 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 bok choy 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: Bok choy should be encouraged to grow quickly and establish the stand, which will allow increase the ability of bok choy to out compete any weeds present in the field. Precise planting, a regular water supply and appropriate fertilization will help increase the ability of bok choy to compete.

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

competition. However, due to market demands this control method is not always feasible.

Another method to control weeds is to till the field, form beds and irrigate prior to planting. This will encourage the germination of the weed seeds. The field can then be sprayed with a nonselective herbicide or rotary-hoed to eliminate the weeds. After the weeds have been destroyed, the bok choy is planted. Disking will eliminate germinated weeds but also exposes new weed seeds that can germinate and infest the field.

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

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

1999 Herbicide Usage on Bok Choy Grown in Arizona

Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	Acres	% Acres	Reports**	By Air	Broadleaf***	Unspecified
Bensulide (OP)	5	3.64	6	61.6	60%	16	0	2	14

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

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

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

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

ARIZONA PESTICIDE USE REPORTING

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

Commercial applicators licensed through the state must submit Arizona

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

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

Section 18 active ingredients should have 100% reporting. There were no section 18s active in Arizona for bok choy in the 1999 growing season.

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

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

Diseases

FUNGAL DISEASES

(4, 8, 9, 12, 15, 21, 22, 25, 26, 27)

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

In Arizona, damping-off is occasionally observed in bok choy fields. Damping-off is a soil borne 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 is a fumigant registered for use on both *Pythium* and *Rhizoctonia* induced damping-off; however, this method is very costly and generally not considered a viable option. Mefenoxam is the only other chemical method available for controlling *Pythium*-induced damping-off. This fungicides work best when used as a preventative treatment, being applied before disease becomes apparent. Usually mefenoxam is applied in a band over the seed row, either pre-plant incorporated or preemergence. There are no other chemistries registered for controlling *Rhizoctonia*-induced damping-off. There are no registered seed treatments in Arizona for controlling damping-off of bok choy. Most growers, however, do not treat for damping-off, as this disease is not currently a large threat to bok choy in Arizona.

Cultural Control: All residues from the previous crop should be plowed under and completely decomposed before planting bok choy. It is best to plant when the soil is warm, as this will speed

germination and allow the crop to quickly reach a resistant stage of growth. Overhead or sprinkler irrigation are the best methods for promoting rapid germination. It is important to manage water and avoid over saturating the field. Fields should be properly drained and low spots should be eliminated to avoid water accumulation. 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 bok choy. Downy mildew thrives in cool, humid weather, such as that which is typical of the winter growing season in western Arizona. This weather promotes spore formation and spore dispersal, as well as, plant infection. A wet leaf surface is required for spore germination. *P. parasitica* infects bok choy plants through their leaves and the fungus grows between the leaf's cells. When conditions are favorable, disease can spread rapidly. The fungus also produces resting spores, which can survive in the soil or crop residue until the following season *P. parasitica* is spread by; wind, rain and infected seed.

Plant infection begins with the growth of gray-white fungi on the lower leaf surface. Damage occurs on both leaf surfaces, beginning with chlorotic lesions that later turn purple and eventually brown. Young leaves sometimes dry and drop off, while older leaves generally remain on the plant and develop a papery texture. Downy mildew can decimate large numbers of seedlings. Severe infections of mature bok choy can result in decreased photosynthesis, stunted plants and reduced yield. Damage to the stem and head leaves the plant susceptible to secondary infections. Often downy mildew is not noticed until the bok choy head is cut open. Any damage to the bok choy head, however, results in an unmarketable product. Downy mildew can also damage bok choy that is in transit.

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

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

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

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

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

Sclerotinia Rot (*Sclerotinia minor*, *Sclerotinia sclerotiorum*)

In Arizona, *Sclerotinia* is normally not a concern in bok choy fields. Sclerotinia rot, also known as

white mold, is caused by two species of soil-borne fungi. *Sclerotinia minor* infects only those plant parts that are in contact with the ground. *Sclerotinia sclerotiorum* will also 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 bok choy's head, stem and leaves with white cottony mold. Eventually the infected tissue turns brown, becomes watery and decays. As sclerotinia rot persists, the leaves will drop off and the bok choy plant will weaken and collapse.

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

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

Chemical Control: Metam sodium is a fumigant registered for use on *Sclerotinia*; however, this method of control is very costly and generally not considered a viable option. Benomyl can also be used to control *Sclerotinia*.

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

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

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

Alternaria Leafspot (*Alternaria brassicae*)

Alternaria is rarely reported on bok choy in Arizona. *Alternaria* leafspot, also known as *alternaria* blight, typically occurs during a wet winter. Spores can survive in weed hosts and plant debris. The fungal spores are wind and rain dispersed and require free water for germination to occur.

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

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

Chemical Control: Maneb is the most commonly used method for controlling *alternaria* leaf spot. This fungicide is foliar applied and is most effective when applied as a protectant before the onset of disease.

Cultural Control: *Alternaria* can be passed on to the next generation in infected seed, therefore it is important to be certain that seed is disease-free. *Alternaria* also persists in the soil; thus cole crops should not be planted more than once in four years to avoid disease carryover. It is important to clean equipment between uses in different fields, to prevent contamination of an uninfected field. Controlling cruciferous weeds that can act as a disease host will prevent the transmission of

Alternaria from these weeds to bok choy.

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

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

BACTERIAL DISEASES **(8, 9, 11, 14, 21, 22, 23, 24, 25, 26)**

Black Rot (*Xanthomonas campestris*)

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

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

Chemical Control: There are no fungicides currently available to control black rot in bok choy fields in Arizona.

Cultural Control: Planting only certified disease-free seed will help reduce the risk of black rot. If the seed is infected, it can be treated with hot water, which will reduce infection but also reduces the germination percentage of the seed. 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, which can act as hosts for black rot. Irrigation should be performed with care, to avoid over watering the crop. It is very important to ensure that tillage and plow equipment is sanitized between uses on different fields, this will prevent the spread of bacterium. 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 bok choy. Bacterial soft rot does occur in the field, but is more common during post-harvest storage. Infection often occurs on bok choy that is stored at warm temperatures, or if heat is allowed to accumulate in the storage containers. This disease is capable of destroying an entire lot of bok choy.

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 architecture of the bok choy head also contributes to bacterial

infection. The crevices formed by the leaf bases are capable of holding water creating an ideal environment for bacterial growth. The initial sign of infection is water soaked spots on the plant. Once inside bok choy the bacterium spreads rapidly. The bacterium dissolves the middle lamella that holds cells together and causes the inner contents of the cell to shrink. The infected portions of the plant can develop a brown color and the wet rot is accompanied by a foul odor.

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

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

Chemical Control: There are no methods for the direct chemical control of *Erwinia*; however, insecticides can help control the insects that damage bok choy 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: Bok choy should be handled carefully to avoid bruising and wounding that will leave the plant susceptible to infection. Plants must be thoroughly cleaned and stored at a low temperature, typically 40 °F. It is important to keep the storage facility free of soft rot bacteria by immediately destroying any infected plants and maintaining a clean facility.

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

*** There is no data available for the 1999 fungicide usage on bok choy grown in Arizona**

VIRAL DISEASES (12, 27, 28)

Generally speaking, viral diseases are not a common occurrence in cole crops grown during Arizona's winters. Cabbage mosaic and turnip mosaic viruses have been observed in bok choy stands but their occurrences are rare. These viral diseases cause the bok choy'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 cabbage aphids are both capable of transmitting viral diseases.

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

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

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

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

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

ABIOTIC DISEASES (12)

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

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

Although bok choy is relatively tolerant of cold temperatures, the leaves can sometimes be damaged by low temperatures. If only the outer leaves that are damaged, they can be removed and have little effect on the crop value. This damage can also leave the plant susceptible to secondary infections.

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

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

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

Nematodes

Various species (12, 13, 15, 29)

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

The female nematode lays her eggs on 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: *Stienernema carpocapsae*, a species of parasitic nematode, can be used to control 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 of a threat in bok choy fields to warrant the expense of a chemical treatment. If treatment is necessary, fumigants are often used. 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 discing will speed decay. If this is not done prior to fumigation, the fumigant cannot 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 can be used to control 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. The soil temperature, soil moisture and the rate used, affects the interval between application and planting. 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 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 bok choy receives the appropriate amount of fertilizer and water to reduce plant stress, thus reducing their susceptibility to nematodes. Crop debris should be plowed under immediately following harvest, especially when the crop was infested with 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

(12, 13)

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

Contacts

Judy K. Brown, Associate Professor

Phone: (520) 621-1402, Email jbrown@ag.arizona.edu

Lin Evans, Pest Control Advisor

Phone: (602) 390-4722, Email: levans4918@aol.com

Michael E. Matheron, Plant Pathologist

Phone: (520) 726-0458, Email: matheron@ag.arizona.edu

Jeff Nigh, Pest Control Advisor

Phone: (520) 580-0404, Email bugnigh@aol.com

Mary W. Olsen, Associate Extension Plant Pathologist,

Phone: (520) 626-2681, Email molsen@ag.arizona.edu

John C. Palumbo, Associate Research Scientist, Entomologist

Phone: (520) 782-3836, Email: jpalumbo@ag.arizona.edu

Kai Umeda, Area Extension Agent, Vegetable Crops

Phone: (602) 470-8086, Email: kumeda@ag.arizona.edu

Research by:

Emily V. Dimson
Research Assistant
Western Growers Association
2450 W. Osborn, Suite 1
Phoenix, Arizona 85015
(602) 266-6149

Data provided by:

Ken Agnew
Research Specialist
Pesticide Information and Training Office
University of Arizona
1109 E. Helen St.
Tucson, AZ 85719
(520) 621-4013

ACKNOWLEDGMENTS

- Judy K. Brown, University of Arizona, Tucson, Arizona.
- Mike Didier Select Seed of Arizona Inc., Yuma, Arizona.
- Arnott Duncan Sunfresh Farms, Goodyear, Arizona.
- Lin Evans, Lin Evans Enterprises Inc., Phoenix, Arizona.
- Joe Grencevicz Arizona Department of Agriculture, Phoenix, Arizona.
- Clare Jervis, Arizona Agriculture Statistics Service, Phoenix, Arizona.
- John Kovatch, Select Seed of Arizona Inc., Yuma, Arizona.
- Joel Lehman, Arizona Agriculture Statistics Service, Phoenix, Arizona.
- Shauna Long, Rousseau Farming Company, Tolleson, Arizona.
- Mike Matheron, University of Arizona, Yuma, Arizona.
- Michael A. McClure, University of Arizona, Tucson, Arizona.
- Jeff Nigh, Colorado River Consulting, Yuma, Arizona.
- James Nowlin, Arizona Department of Agriculture, Phoenix, Arizona.
- Mary W. Olsen, University of Arizona, Tucson, Arizona.
- John Palumbo, University of Arizona, Yuma, Arizona.
- Scott Rasmussen, University of Arizona, Tucson, Arizona.
- Doug Schaeffer, Pacific International Marketing, Phoenix, Arizona.
- Will Sherman, Arizona Agriculture Statistics Service, Phoenix, Arizona.
- Bruce Williams, Amigo Farms Inc., Roll, Arizona.
- Kai Umeda, University of Arizona, Phoenix, Arizona.

Crop Photos are courtesy of Dr. Michael J. Brown

Insect Photos are courtesy of the University of Arizona.

References

1. Markle G.M., Baron J.J., and Schneider B.A. (1998) Food and feed crops of the United States, 2nd Edition, Meister Publishing Co., Ohio.

2. Arizona Agricultural Statistics Service. (2000) 1998 Arizona Agricultural Statistic.
3. National Agricultural Statistics Service (1999) 1997 Census of Agriculture
4. Peirce L.C. (1987) Vegetables. Characteristics, production and marketing. John Wiley and Sons, New York.
5. Myers C. (1991) Specialty and minor crops handbook, 1st Edition, The small farm center, University of California, Publication 3346.
6. The sources of production, harvest and post-harvest costs have been withheld to protect the privacy of individual operations.
7. Personal communication with John Kovatch and Mike Didier, Select Seed of Arizona Inc., Yuma, Arizona.
8. Personal communication with Lin Evans, Lin Evans Enterprises Inc., Phoenix, Arizona.
9. Personal communication with Jeff Nigh, Colorado River Consulting, Yuma, Arizona.
10. Personal communication with Joe Grencevicz, Field Supervisor, Arizona Department of Agriculture, Phoenix, Arizona.
11. Citrus, Fruit and Vegetable Standardization (1999) Arizona Department of Agriculture Title 3 Rules, 1999 Edition, Chapter 4, Article 7.
12. University of California, division of agriculture and natural resources. (1992) Integrated pest management for cole crops and lettuce, Publication 3307.
13. Arizona Crop Protection Association (1991) Arizona Agricultural Pest Control Advisors Study Guide. Arizona Crop Protection Association, Phoenix, Arizona
14. Kerns D.L., Palumbo J.C. and Byrne D.N. (1995) Insect pest management guidelines for cole crops, cucurbits, lettuce and leafy greens vegetables. University of Arizona, Cooperative Extension Publication.
15. University of California (2000) UC IPM Online, University of California statewide integrated pest management project. <http://www.ipm.ucdavis.edu/>
16. University of Arizona (1999) Insect Pests of Leafy Vegetables, Cole Crops and Melons in Arizona. <http://Ag.Arizona.Edu/aes/yac/veginfo/bracken.htm>
17. Personal communication with John Palumbo, Associate Research Scientist, University of Arizona, Yuma, Arizona.
18. Palumbo J.C. (1999) Management of aphids and thrips on leafy vegetables. 1998 Vegetable Report: University of Arizona, College of Agriculture, series P-115. http://ag.arizona.edu/pubs/crops/az1101/az1101_2.html
19. Palumbo J., Kerns D., Mullis C. and Reyes F. (1999) Implementation of a pest monitoring network for vegetable growers in Yuma County. 1999 Vegetable Report. University of Arizona, College of Agriculture, series P-117. http://ag.arizona.edu/pubs/crops/az1143/az1143_35.pdf
20. Knowles T.C. (1998) Beet Armyworm. University of Arizona, Cooperative Extension. Extension Bulletin AZ1047. <http://ag.arizona.edu/pubs/insects/az1047.pdf>
21. University of Arizona, Extension Plant Pathology (1999) Diseases of cole crops in Arizona. <http://Ag.Arizona.Edu/PLP/plpext/diseases/vegetables/cole/cole.html>
22. Personal communication with Mike Matheron, Plant Pathologist, University of Arizona, Yuma, Arizona.
23. Streets R.B. Sr (1969) Diseases of the cultivated plants of the Southwest. The University of Arizona Press, Tucson, Arizona.
24. Chupp C. and Sherf A.F. (1960) Vegetable diseases and their control. The Ronald Press Company, New York, New York.
25. Ryder E.J (1979) Leafy Salad Vegetables. AVI Publishing Company Inc, Westport, Connecticut.
26. Hodges L. and Neild R.E. (1992) Culture of cole crops. University of Nebraska Extension Publications, Publication #G1084.
27. Personal communication with Mary W. Olsen, Associate Extension Plant Pathologist, University of Arizona, Tucson, Arizona.
28. Personal communication with Judy K. Brown, Associate Professor, University of Arizona, Tucson, Arizona.
29. Personal communication with Michael A. McClure, Professor, University of Arizona, Tucson, Arizona.

30. Personal communication with Kai Umeda, Area Extension Agent, University of Arizona, Phoenix, Arizona.
31. Umeda, Kai (2000) Weed control in cole crops. University of Arizona, Cooperative Extension Publication. IPM series No. 15. <http://ag.arizona.edu/pubs/crops/az1197.pdf>