Celery Production in Arizona

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Family: Apiaceae (Umbelliferae)

Scientific name: *Apium graveolens* var. *dulce* (Mill.) Pers.

Edible portions: leaf stalks (petioles), leaf blades, seed, raw or cooked

Use: fresh vegetable, seed is used as a condiment

Alternative names: Apio, Celery Seed, Quin Cai and Stalk Celery.

General Production Information

- In 1997, Arizona produced 3.5% of the nations celery[2, 3].
- Between the years of 1994/95 and 1998/99, Arizona produced approximately 610 acres of celery[2].
- An average of 477,571 cartons/year of celery was produced between 1994/95 and 1998/99[2].
- Celery production had an average yearly value of 3 million dollars between 1995 and 1999.
- Celery is grown in Maricopa, Pinal and Yuma Counties.
- Land preparation and growing expenses for celery are approximately $3.65/carton[5].
- Harvest and post harvest expenses for celery are approximately $4.40/carton[5].

Cultural Practices

General Information[4, 7, 8]: In Arizona, celery is a grown during the fall and the winter months. Most celery is transplanted in September, although transplanting can continue through December. The temperature in Arizona during the months that celery is grown ranges from 30°F to 90°F. Prolonged temperatures below 50 °F will induce celery to flower; prolonged temperatures below freezing will cause serious damage (see Abiotic Diseases section). In Arizona, celery is grown on soils that range from a dry loam to a sandy loam with a pH of 7.5-8.0.

Cultivars/Varieties[6]: The most common variety of celery grown in Arizona is ‘Tall Utah 52-70R Improved’. This is an old variety that has been grown for many years. Another popular variety is ‘Coquistador’. This variety has nice straight petioles, with good green color and nice tops. This variety is bolting tolerant and is well suited for desert production.

Production Practices[4, 7, 8]: Prior to planting, the field is deeply tilled, disced, land planed, the beds are formed and then the field is pre-irrigated. A preplant herbicide may be applied prior to bed formation. If a pre-plant fungicide, such as mefenoxam, is utilized it is usually applied after bed formation but prior to planting.

The majority of celery is transplanted; celery seed is very difficult to germinate and is slow to establish. Celery is transplanted in September and is grown in beds with 40" centers. There are two rows per bed and plants are spaced 10" apart within the rows.

Some trials have been performed to evaluate growing celery in beds with 80" centers. The celery field is minimally cultivated, usually only once or twice in a season.

Celery has a very shallow root system and thus requires regular irrigation. This consistent irrigation is important to allow celery to develop the desired crispness, succulence and flavor. An irregular water supply can cause the celery stem to crack. In Arizona, drip irrigation is usually used for celery production; furrow irrigation can also be used. If furrow irrigation is used, a small amount of fertilizer is sometimes added to the furrow water. Sprinkler irrigation can be used, but can cause issues with foliar Diseases.

Harvesting Procedures: From the time of transplanting, celery requires 3 to 4 months to mature[1]. Harvesting of celery begins in November and usually completed by January, although it sometimes continues through April[7]. The outer stalks are often coarse or blemished, and are removed before the celery is packaged. Celery is hand harvested. The celery is cleaned and cut to a specified uniform length and then packaged with 18, 24 or 32 heads per cardboard or wooden box[1, 7, 9]. Celery hearts, stalks with the upper stem portion and leaves removed, are packaged with either 12 or 18 heads per carton[10]. Celery for processing is shipped in bulk to the processing plant. At the distribution center, celery is cooled either by forced air or hydrocooling. If cooled to 32 °F and 95% relative humidity, celery can be stored from 2 to 4 weeks[4]. However, celery absorbs odors from other commodities, such as apples and onions, thus they should not be stored in close proximity[11].

To meet Arizona standards, all celery that is packed or offered for sale must be fairly well developed and free from serious damage [10]. No more than 5%, by count, of the celery is allowed to have any one defect. No more than 10%, by count, of any container or lot can fail to meet Arizona standards[10].

Insects and Mites

(7, 8, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21)

Hymenoptera

Harvester Ant (*Pogomyrmex rugosus*)

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

Sampling and Treatment Thresholds: University of Arizona experts suggest that a field should be treated at the first signs of damage[18].

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

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

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

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

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

Coleoptera

Striped flea beetle (*Phyllotreta striolata*)
Potato flea beetle (*Epitrix cucumeris*)

Western black flea beetle (*Phyllotreta pusilla*)
Western striped flea beetle (*Phyllotreta ramosa*)

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

Flea beetles can cause damage to celery during the initial seedling stages. The female flea beetle lays her eggs in the soil, on leaves, or within holes and crevices in the celery plant. Depending on the species, the larvae feed on the leaves or the roots of the celery plant. The adult beetles will also feed on the celery 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. However, if the celery leaves or petioles 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 plants[17]. After head formation, treatment should occur when there is 1 beetle per 25 plants[17].

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

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

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

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

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

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

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

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

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

Sampling and Treatment Thresholds: Nighttime is the best time to monitor a field for darkling beetles; this is when they are the most active. During the day they tend to hide in the soil or debris. These beetles often migrate from nearby cotton and alfalfa fields or weedy areas. According to University of Arizona guidelines, celery should be treated when beetle populations are high or there is a threat of migration into the field[17]. Celery plants that have 5 to 6 leaves are usually not at risk for beetle attack[17].

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

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

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

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

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

Orthoptera

Cricket (*Gryllus* sp.)

Crickets are rarely a problem in Arizona but dense populations are capable of destroying an entire crop. Crickets are ½ to 1" in length, and brown-black in color. Most feeding occurs at night; during the day crickets hide in the soil, weeds, ditches and under irrigation pipes. Crickets attack celery 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 celery fields at the end of the summer. Fields that use over-head sprinkler irrigation encourage inhabitance by creating an ideal environment for crickets because female crickets lay their eggs in damp soil.

Sampling and Treatment Thresholds: Crickets are difficult to monitor for during the day, as they tend to hide. One can check underneath irrigation pipes; however, a visual inspection of damage is usually sufficient to give an estimate of cricket activity. Fields planted near cotton or Sudan grass should be closely monitored. Experts at the University of Arizona recommend that a field should be treated when cricket damage is high or there is a threat of cricket migration into the field[18].

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

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

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

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

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

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

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

Sampling and Treatment Thresholds: University of Arizona experts suggest that fields should be treated as soon as grasshoppers begin to cause damage to the crop[18].

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

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

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

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

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

Diptera

Leafminers
(*Liriomyza* sp.)

Leafminers are the biggest threat to celery Production in Arizona. Adult leafminers are small, shiny, black flies with a yellow triangular marking on the thorax. The adult female leafminer oviposits her eggs within the leaf tissue. Male and female flies feed at these puncture sites. The larvae hatch inside the leaf tissue and feed on the mesophyll tissue; they do not emerge until they pupate. Leafminers usually pupate in the soil, although sometimes they will pupate between the 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 celery must be completely damage free as this is part of the consumed portion of the crop. If a celery head is damaged by leafmining, or contaminated by leafminer pupae, the plant is unmarketable.

Sampling and Treatment Thresholds: It is important that the crop is monitored regularly for leaf mines, larvae and adult flies. The cotyledons and first true leaves are the first to be mined. Mining is more visible on the undersurface of the leaf; thus both leaf surfaces must be viewed. Presence of leafminer parasites and parasitized mines should also be determined. Yellow sticky traps are a good method for measuring leafminer migration into a field, as well as, determining which species are present. It is important to accurately identify which species are present, because insecticide resistance has been documented for *Liriomyza trifolii*. University of Arizona guidelines recommend that prior to head formation, celery should be treated when populations have reached 1 active mine per leaf[17]. After head formation, treatment should occur when populations reach 1 mine per leaf per 25 celery plants[17].

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

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

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

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

Lepidoptera

Lepidopterous complex = diamondback moth, loopers and beet armyworm.

Cabbage Looper (*Trichoplusia ni*)
Alfalfa Looper (*Autographa californica*)

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

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

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

Sampling and Treatment Thresholds: Once celery 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 celery should be treated when populations have reached 1 larva per 50 plants[17]. After head formation, celery can tolerate 1 larva per 100 plants[17]. All other lepidopterous larvae that are noted should be included in this total.

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

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

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

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

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

Beet Armyworm (*Spodoptera exigua*)

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

Armyworms can cause damage to celery grown in Arizona. Armyworm populations are heaviest during the fall and the larvae will attack all stages of plant growth. Young larvae feed in groups near their hatching site. As the beet armyworm feeds, it spins a web over its feeding site. Mature armyworms become more migratory and move to new plants. Many armyworms will die while traveling between plants. Armyworm feeding can skeletonize leaves and consume entire seedlings. A single armyworm can attack several plants. Celery stalks or leaves 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.), lambsquarters (*Chenopodium album*) and nettleleaf goosefoot (*Chenopodium murale*).

Sampling and Treatment Thresholds: Weeds surrounding the field should be monitored for larvae and eggs prior to crop emergence. If population levels are high in surrounding weeds, the crop should be monitored very carefully following emergence.

Pheromone traps can be used to monitor for the presence of beet armyworms in a field. After germination, fields should be monitored twice a week. According to University of Arizona guidelines, prior to head formation celery should be treated when populations reach 1 larva per 50 plants[17]. Once the flowering head has formed, celery can tolerate 1 larva per 100 plants[17]. All other lepidopterous larvae that are noted should be included in this total.

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

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

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

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

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

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 rarely cause damage to celery grown in Arizona.

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. Celery 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 disked, as the larvae will migrate from such fields. The University of Arizona recommends that prior to head formation, celery should be treated when there is 1 larva per 50 plants[17]. Once the celery head has formed, the crop can tolerate 1 larva per 100 plants[17]. 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 are the most frequently utilized chemistries for the control of diamondback moths. *Plutella* resistance to insecticides has been reported and is a concern in celery production.

Cultural Control: Fields should be disked 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.

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

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

Budworm and earworm populations peak during the fall. These larvae attack all stages of plant growth and but are rarely a threat to celery grown in Arizona. 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. Once inside the head it is difficult to control larvae with pesticides. Often damage is not noticed until the celery is harvested. Damage to the celery head results in an unmarketable plant.

Sampling and Treatment Thresholds: Field monitoring should begin immediately following transplanting. Pheromone traps can be used to monitor for the presence of tobacco budworms and corn earworms. Earworms and budworms migrate from corn and cotton fields, thus it is important to carefully monitor field edges that border these crops. If eggs are discovered, it should be determined if they have hatched, are about to hatch or have been parasitized. The celery 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 celery should be treated before head formation when populations reach 1 larva per 50 plants[17]. After head formation the crop can tolerate 1 larva per 100 plants[17]. All other larvae in the lepidopterous complex should be included in this count.

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

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

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

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

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

1999 Insecticide Use to Control Lepidoptera Larvae on Celery Grown in Western, Arizona

							(# of reports)				
Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	# of Acres	% of Acres Treated	# of Reports**	By Air	AW	L	CE	DM
Acephate (**OP**)	0.5	0.83	1	79	2%	3	0	2	1	0	0
Endosulfan	0.5	1.00	1	41.4	1%	2	0	1	1	0	0

Methomyl (**carbamate**)	0.225	0.70	0.9	883.5	25%	28	16	26	11	1	0
Oxamyl (**carbamate**)	0.5	0.54	1	58.7	2%	3	0	3	1	0	0
Permethrin	0.05	0.17	0.2	1206.5	34%	36	23	36	13	2	0
Spinosad	0.023	0.07	0.156	736.6	20%	19	7	17	4	1	1
Tebufenozide	0.09	0.11	0.12	95.4	3%	2	0	2	1	0	0

AW armyworm

L loopers

CE corn earworm

DM diamondback moth

OP organophosphate

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

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

Aphids are the most significant pest of celery grown in Arizona. There are three main species of aphid that are pests to celery: green peach aphids, potato aphids and cowpea aphids. These aphids may or may not have wings. Green peach aphids are light green, red or pink in color. They are found feeding on the lower surface of mature leaves and will quickly colonize younger leaves as the population increases. Potato aphids have a similar appearance to green peach aphids but are larger and form small colonies on the lower surface of new leaves. Cowpea aphids are a more recently introduced species of aphid found in Arizona. Their population has been increasing over the past few years. The cowpea aphid has a shiny black body and white bands on its legs.

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

Aphids can be very destructive to celery. The majority of aphid damage occurs during the final heading stage of celery. 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 celery head to be distorted. Another concern are the viruses that green peach aphids can transmit such as; cucumber mosaic virus and the western celery mosaic virus. Aphids are most damaging, however, as a contaminant; their presence in a celery 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 celery head formation, treatment should begin when populations reach 1 aphid per 10 plants[17]. After head formation, celery should be treated when aphid colonization begins[17].

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, syriphid fly larva, aphid parasites are some of the insects used to control aphids. Spraying of insecticides should be performed with caution as it can eliminate beneficial insects. These beneficial insects, however, can also become contaminants of the celery head.

Chemical Control: A pre-plant application of imidacloprid is the most common method used to control aphids. This insecticide has the added benefit of long-term residual control. However, this prophylactic approach to control is expensive and is applied with the assumption that the crop will receive aphid pressure. Many growers will choose to wait and apply a foliar insecticide. When foliar insecticides are used, the timing of application is critical. Endosulfan and dimethoate are most commonly used foliar-applied insecticides. The initial foliar-applied treatment should occur once wingless aphids begin to migrate into a crop field. To ensure that the harvested celery is not contaminated with aphids, it might be necessary to use repeated applications. Aphids often hide within the protected areas of the celery 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.

Imidacloprid and oxydemeton-methyl are commonly used foliar-applied insecticides, however these chemistries are not registered for use on celery grown in Arizona. A greater diversity of insecticides is necessary to allow proper resistance management.

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

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

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

WHITEFLIES

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

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

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

Whitefly infestations are usually the heaviest during the fall. Colonization of the crop can begin immediately following germination, beginning with whiteflies feeding on the cotyledons. Whiteflies migrate from cotton, melon and squash fields, as well as, from weed hosts. Celery planted downwind from these crops are particularly susceptible. Whitefly feeding removes essential salts, vitamins and amino acids required by celery 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 celery's surface creates an ideal environment for sooty mold infection. Whiteflies also contaminate harvested celery, making it unmarketable. Still a concern is the whitefly's ability to transmit viruses.

Sampling and Treatment Thresholds: The best way to prevent a whitefly infestation is to inhibit initial colonization. Whitefly counts should be performed early in the morning when the insects are the least active. Once whiteflies become active they are difficult to count. During the mid-morning, fields should be monitored for swarms of migrating whiteflies. According to University of Arizona guidelines, if a soil-applied insecticide is not used, crops should be treated when populations reach 5 adults per leaf[17]

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 celery is planted after whitefly populations have declined, foliar applied insecticides can be used as necessary. Endosulfan 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 to decrease whitefly infestation. However, delay of planting is not always a feasible option. Whiteflies build up in weeds, especially cheeseweed (*Malva parviflora*), thus it is important to control weeds in the field and surrounding the field. Crop debris should be plowed under immediately following harvest to prevent whitefly build up and migration to other fields.

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

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

Thysanoptera

THRIPS

Western Flower Thrips (*Frankliniella occidentalis)*
Onion Thrips (*Thrips tabaci*)

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

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

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

Sampling and Treatment Thresholds: Sticky traps are a good method for monitoring thrips migration into a field. When inspecting for thrips, the folded plant tissue and celery heads must be carefully examined, as this is where thrips prefer to hide. It is estimated that for every 3 to 5 thrips observed there are three times as many undiscovered. The University of Arizona recommends that prior to head formation, celery should be treated when populations reach 1 thrips per 10 plants[17]. After head formation, the crop should be treated when the population reaches 1 thrips per 25 plants[17].

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

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

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

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

Other Contaminants (syn. "Trash Bugs")

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

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

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

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

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

Sampling and Treatment Thresholds: The University of Arizona suggests that before the formation of the celery head, a stand does not require treatment until populations reach 10 contaminant insects per 50 plants[17]. Once the head is formed, celery should be treated when populations reach 1 contaminant insect per 25 plants[17].

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

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

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

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

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

1999 Insecticide Usage on Celery Grown in Western Arizona

Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	# of Acres	% of Acres Treated	# of Reports**	(# of reports)						
							By Air	Aph.	Con.	LM	Lep.	Thp.	WF
Acephate (**carbamate**)	0.5	0.81	1	80	2%	4	0	4	0	0	3	0	0
Endosulfan	0.5	0.94	1	59.4	2%	3	1	3	0	0	2	1	0
Methomyl (**carbamate**)	0.225	0.71	0.9	1024.7	28%	31	18	9	0	2	38	2	1
Oxamyl (**OP**)	0.5	0.54	1	58.7	2%	3	0	0	0	3	4	0	0
Permethrin	0.05	0.17	0.2	1297.7	36%	37	23	7	1	4	51	0	1
Spinosad	0.023	0.07	0.156	764.1	21%	20	7	4	1	2	23	0	0
Tebufenozide	0.09	0.11	0.12	95.4	3%	2	0	1	0	0	3	0	0

Aph.	aphids
Con.	contaminant = lygus, chinch bug, leaf hoppers, alfalfa hoppers
LM	leafminer
Lep.	lepidoptera larvae
Thp.	thrips
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 from product labels.

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

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Diseases

Fungal Diseases

(4, 7, 8, 12, 16, 22, 23, 24, 27, 28)

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

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

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

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

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

Cultural Control: All residues from the previous crop should be plowed under and completely decomposed before planting celery. 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. Transplants should be inspected for healthy, white roots. It is important to avoid stressing the crop, as this will make it more susceptible to damping-off.

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

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

Pink Rot (*Sclerotinia* sp.)

Pink rot can cause significant damage to celery production. *Sclerotinia* thrives when the winter growing season is cool and wet.

The soil-borne fungus Sclerotinia sp. causes pink rot, also known as crown rot or petiole rot. In younger seedlings, *Sclerotinia* can cause damping-off symptoms. In older plants the fungus attacks the lower portion of the celery stalks and causes the watery rot of the lower portion of the head. Disease can cause the celery heads to wilt and collapse due to the soft rot of the lower petiole tissue. The rot can develop a pinkish color, hence the name pink rot. A white cottony mold will eventually develop over the damaged tissue.

The fungus produces large, black sclerotia in the plant tissue and on the soil surface. The sclerotia and the mycelium can survive for a long time in the soil, especially when the weather is dry. The sclerotia are spread by contaminated equipment, soil and plant tissue. Some species of *Sclerotinia*
also produces sexual spores that are wind dispersed. Sclerotia germinate on the soil and then infect the plant.

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

Chemical Control: Metam sodium and metam-potassium are fumigants registered for use on *Sclerotinia*; however, these methods are very costly and generally not considered a viable option. Chlorothalonil is the only other chemistry registered for controlling *Sclerotinia*. Pink rot is best controlled when fungicides are used as protectants rather than waiting for the onset of disease. Chlorothalonil is a foliar-applied fungicide.

Cultural Control: Fields should be irrigated with care, as wet conditions favor *Sclerotinia*. Weed control in and around the field is essential to eliminate potential hosts for *Sclerotinia*. It important to rotate to resistant crops, such as corn or beets, this 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*. Flooding the field will help rot some of the dormant sclerotia.

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. *Bacillus subtilis* is also registered for controlling *Sclerotinia* on celery grown in Arizona.

Early Blight (*Cercospora apii*)

Early blight is not as common in Arizona as late blight. High temperatures combined with high humidity will promote disease development. *Cercospora apii*
can persist in the field refuse and within the seed. Splashing water, such as that from rain or overhead irrigation, and wind will spread *Cercospora*.

As the disease develops, chlorotic spots will appear on the leaves of celery. These spots will increase in size and will gradually darken and develop a gray fuzzy growth in the center. This growth should not be confused with the distinct, black fruiting bodies that develop in the lesions causes by late blight. The celery stalk will also develop chlorotic spots; the spots on the stalk are usually more elongated. The lesions may grow so large that they cover an entire celery stalk. Eventually the chlorotic spots become dry and papery and may even split or crack. Damage to the stalks or leaves of celery will result in an unmarketable plant.

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

Chemical Control: Benomyl and chlorothalonil are the most commonly used fungicides to control *Cercospora.* Copper, propiconazole and azoxystrobin are also registered for use on celery grown in Arizona. Early blight is best controlled if fungicides are used as protectants rather than waiting for the onset of disease.

Cultural Control: Treating infected seed with hot water can be used to control disease; however, it will also reduce the germination percentage of the seed. Only certified disease-free transplants should be planted. Tolerant celery varieties are available and can help reduce infection. When a field is harvest it will spread the fungal spores. It is very important that nearby fields that are not harvested are treated with a fungicide to protect them from the introduction of spores.

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

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

Late Blight (*Septoria apiicola*)

Late blight often occurs in transplants grown in the greenhouse. This disease can result in weak transplants that do not fare well once planted in the field. If field conditions are favorable for *Septoria,* late blight can result in crop loss. Moderate temperatures with a high humidity favor disease development. The fungus can persist in the field refuse and within the seeds. Splashing water, from irrigation or rain, and infected seed will spread the fungus.

Celery that is infected with *Septoria*
will develop small, chlorotic spots on the stalk and leaves. Eventually, black fruiting bodies will develop within the center of these spots. These lesions will continue to increase in size and may grow together. As disease progresses, the spots will become dry and papery. Any damage to the stalk or leaves of celery results in an unmarketable plant.

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

Chemical Control: Transplants should be treated with a fungicide to prevent *Septoria* introduction into the field. Benomyl and chlorothalonil are the most commonly used fungicides to control *Septoria.* Copper, propiconazole and azoxystrobin are also registered for use on celery grown in Arizona. Late blight is best controlled if fungicides are used as protectants rather than waiting for the onset of disease.

Cultural Control: Only certified disease-free seed should be used. Infected seed can be treated with hot water; however, this will reduce the germination percentage. Transplants should always be disease free to prevent the introduction of *Septoria* into the field. After harvest the field should be plowed under. Crop rotation is important to prevent disease carryover. Equipment should always be cleaned before use in another field. Overhead irrigation should be avoided, as this will aid in the spread of the *Septoria*.

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

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

Fusarium yellows (*Fusarium oxysporum* f.sp. *apii*)

Fusarium
is a soilborne fungus that can cause significant damage to celery and reduce crop yields. Seedlings attacked by thus disease will

exhibit slow growth and could eventually die. In older plants, *Fusarium* attacks the vascular system of celery.

Older plants that are infected develop a dull color and will eventually yellow and will exhibit stunted growth. Chlorosis develops between the vascular strands and the vascular tissue develops a reddish-brown color. The roots may also develop a dark brown color and show some watery rot. As disease progresses the celery plant may collapse due to the rotting of the stalks. Damage caused by this disease will leave the plant susceptible to bacterial soft rot.

Fusarium is spread in infected soil and plant tissue, on equipment and on field workers.

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

Chemical Control: There are no fungicides registered for use on celery grown in Arizona that will control *Fusarium* that causes fusarium yellows.

Cultural Control: Once introduced to a field *Fusarium*
persists indefinitely, thus crop rotations have little value. Equipment should be thoroughly cleaned before use in other fields to avoid spreading the fungus. The best mode of action against this fungal disease is to plant resistant varieties of celery.

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

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

Basal Stalk Rot (*Rhizoctonia solani*)

The soil-borne fungus *Rhizoctonia* causes basal stalk rot, also known as crater rot. *Rhizoctonia* thrives in warm, wet weather and produces sclerotia that are capable of surviving in the soil for long periods of time. The sclerotia germinate in the soil and infect the celery plant through open stomata or damaged tissue. Infection begins in those petioles that are in contact with the soil and then the fungus moves to inner, healthy leaves. The initial sign of infection is the development of sunken, red-brown spots on the underside of the lower stalks. Infection can occur in the early seedling stages but advanced symptoms usually do no occur until the final heading stage. The brown spots increase in size; rotting the bottom portion of the radicchio plant. White-brown mycelia grow within these lesions. Sometimes, fungal infection is not noticed until the head is harvested. Damage caused by *Rhizoctonia* can leave the plant susceptible to *Erwinia* sp. (bacterial soft rot). If not controlled, celery will eventually be covered in a brown, slimly rot and collapse.

Biological Control: There are no biological methods for controlling bottom rot.

Chemical Control: Metam sodium and metam-potassium are fumigants registered for the control of *Rhizoctonia*; however, these methods are very costly and generally not considered a viable option. Chlorothalonil is the only other fungicide registered to control basal stalk rot, caused by *Rhizoctonia*, in celery grown in Arizona. This is a foliar applied fungicide that is the most effective when applied as a protectant.

Cultural Control: Only certified disease-free transplants should be used. It is important not to over irrigate fields, as this will encourage Rhizoctonia infection. It is also best not to rotate from alfalfa into celery; as alfalfa tends to harbor *Rhizoctonia*. Deep plowing will bury sclerotia and promote their decay.

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

Alternative Control: Spreading compost on the soil is sometimes used to control pathogens. Another method used by some growers is to apply large amounts of nutritional sulfur on the soil to promote the vigor of the plant.

Bacterial Diseases

(7, 8, 16, 22, 25, 26)

Bacterial Soft Rot (*Erwinia* sp.)

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

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

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

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 celery 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: Celery 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.

Viral Diseases

(13, 27, 28, 29)

Generally speaking, viral Diseases are not a common occurrence for celery grown in Arizona. Celery is susceptible to some mosaic viruses, such as western celery virus and cucumber mosaic virus, but their occurrences are rare. Mosaic viruses cause the celery's leaves to develop a yellow/light green/dark green mottled appearance. Necrotic areas can also develop. Western mosaic virus will also cause the leaves to twist and cup. Other viral Diseases may result in pitted stalks and discolored vascular strands. When infection is severe and occurs early in plant development, it can decrease plant vigor. Any damage to the celery stalk or leaves results in an unmarketable product. Green peach aphids are capable of transmitting some of the viral Diseases that affect celery production.

A phytoplasma organism, not a virus, causes aster yellows. However, its symptoms are similar to those of a virus thus is it often grouped with viral Diseases. Disease symptoms include plant stunting and yellowing of tissues. The petioles can become twisted and curved; in mature plants the petioles also become brittle and crack. If disease progresses the inner petioles will develop a brown rot. This disease can be distinguished from fusarium yellows because it does not develop brown vascular tissue. Aster yellows is spread by leafhoppers.

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

Chemical Control: Neither viruses nor aster yellows can be chemically controlled. The insects that spread viruses and aster yellows, however, can be controlled (e.g. aphids, leafhoppers). This method of control, however, is inefficient because it only requires a few insects to spread disease.

Cultural Control: Only planting disease-free seed and resistant cultivars will help control viral infections. Controlling weeds that can serve as hosts for 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 or aster yellows.

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

1999 Fungicide Usage on Celery Grown in Western, Arizona

							(# of reports)					
Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	# of Acres	% of Acres Treated	# of Reports**	By Air	Early Blight	Late Blight	Leaf Spot	Sclerotinia
Benomyl	0.13	0.25	0.25	108	3%	5	0	3	2	1	2

Chlorothalonil (**B1/B2**)	0.75	2.10	2.25	108	3%	5	0	4	1	1	1
Dicloran	1.5	1.46	1.5	233.3	6%	4	0	2	2	0	4
Neem Oil	0	1.19	0	32	1%	1	1	2	2	0	4
Propiconazole	0.11	0.11	0.11	233.3	6%	4	0	0	0	0	0

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

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

Vertebrate Pests

(13, 14)

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

Abiotic Diseases

(4, 13, 27)

There are a number of Abiotic Diseases that celery can suffer from that can affect the crop yield and often have symptoms similar to those caused by pathogens or insect pests. If the celery stalks or leaves are damaged by any Abiotic disease the plant will be unmarketable.

Celery is very intolerant of cold and frost. When celery is damaged by frost injury, the outer edges of the leaves will brown and dry out. Freezing or cold injury can cause the stem to crack and become ‘pithy’. This damage will leave the plant susceptible to secondary infections. In addition, if the leaves or the stem of celery are damaged or scarred they are unmarketable.

Celery that is deficient in calcium can develop blackheart. Blackheart is usually caused when there is an increase in temperature or available nitrogen. It is thought that this change causes a sudden increase in growth. When there is a lack of calcium to meet this sudden increase in demand, celery experiences a calcium deficiency. Symptoms occur in the heart of the celery plant. The inner leaves develop brown water-soaked areas; eventually the entire heart can dry out and become black in color. Some have found that adding calcium, such as $CaNO_3$ or $CaCl_2$, directly to the celery heart will help control this disease. A consistent water supply and adequate fertilization will also help prevent blackheart.

Celery that experiences a boron deficiency can develop what is known as ‘brown checking’ or ‘cracked stem’. Excessive nitrogen or potassium will accentuate this disease. The inner surfaces of the leaves and petioles turn necrotic and brown and the stem may develop cracks. Damaged celery is susceptible to bacterial soft rot. Some have found that applying boron, such as sodium borate, directly to the plant will help relieve this disease. Planting resistant varieties will also help control cracked stem.

Chlorosis is a disease observed in plants that have a magnesium deficiency. An increased amount of calcium within the plant increases the plants susceptibility to chlorosis. Plants that have an inability to properly uptake and metabolize magnesium will develop chlorosis. Planting resistant cultivars and/or using soil applied high-magnesium lime or foliar-applied magnesium, such as magnesium sulfate, will help control chlorosis.

Other nutrient deficiencies can also cause celery damage. Nutrient deficiency damage often results in stunted plants, chlorosis and leaf spotting. Nitrogen, phosphorus and molybdenum are some of the other common element deficiencies that 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.

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

High salt concentrations in the soil can be injurious to celery. 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.

Weeds

(4, 13, 14, 16, 31)

Weeds are a threat to the cultivation of any crop. They compete with the crop for sunlight, water and nutrients. Control of weeds is fundamental for pest management. Weeds may host a variety of Diseases and pests that can be transmitted to celery. Weed control is the most important during the first 30 days of plant establishment, after this period celery is better able to compete with weeds. As well, the canopy created by the celery stand, shades the underlying soil and inhibits the germination of weed seeds. The planting date can give celery the competitive 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 are destroyed before they flower and produce seed. One plant can produce hundreds or thousands of seeds depending on the weed species.

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

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

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

<u>Chemical Control</u>: It is challenging to adequately control weeds while ensuring crop safety. It is important to correctly identify the weed species, as different weeds have different chemical tolerances. Most postemergence herbicides do not have a wide range of weed control; preemergence herbicides are often more effective for the control of weeds. Another option is to use a non-selective herbicide such as glyphosate to sanitize the field prior to celery transplanting.

Bensulide is registered as a pretransplant grass herbicide for use on celery grown in Arizona. Bensulide is usually sprayed in a band over the seedling row; however, it can also be broadcast spayed or chemigated. Irrigation is required to activate this chemistry; sprinkler irrigation is often utilized. This herbicide is effective against grass weeds and will also control some small-seeded broadleaf weeds. Trifluralin is usually broadcast sprayed prior to transplanting 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. Linuron is another registered post-transplant herbicide. It is labeled to control both grass and broadleaf weeds. Prometryne is a post-transplant herbicide that can be used to control annual broadleafs and some grass weeds.

Oxyfluorfen and clethodim can be used on fallow land. Oxyfluorfen is an effective preemergence broadleaf herbicide but has little effect on grasses. It has a plant back restriction is 120 days, which makes this option impractical. Clethodim controls annual and perennial grasses but has no activity against broadleafs.

Sethoxydim is the only available postemergence herbicides. Sethoxydim has good grass control but has no efficacy against broadleaf weeds.

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

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

Purchasing seed that is guaranteed to be weed-free will help prevent the introduction of new weed species into a field. It is also important to maintain field sanitation by always cleaning equipment used in one field before it is used in another and ensuring that any manure that is used is weed seed free. Contaminated irrigation water from canals, reservoirs and 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 used to control weeds is to till the field, form beds and irrigate prior to planting. This will encourage the germination of the weed seeds. The field can then be sprayed with a nonspecific herbicide or rotary hoed to kill the weeds. After the weeds have been destroyed, the celery is planted. Disking will eliminate germinated weeds but will also expose new weed seed that may germinate and cause a second flush of weeds.

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

Crop rotation will allow the use of different herbicides that may have better efficacies on the weeds present in the field. 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 Celery Grown in Western Arizona

Active Ingredient	Label Min.*	Avg. Rate*	Label Max.*	# of Acres	% of Acres Treated	# of Reports**	(# of reports)			
							By Air	Broadleaf	Unspecified	Grass
Bensulide (**OP**)	5	4.36	6	106.5	3%	12	0	2	0	10
Prometryn	0.8	1.54	2	157.2	4%	7	0	0	3	0
Sethoxydim	0.1	0.28	0.3	91.4	3%	1	0	0	0	1
Trifluralin	0.5	2.77	1	85	2%	3	0	0	3	0

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 from product labels.

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

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

Arizona Pesticide Use Reporting

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

Commercial applicators licensed through the state must submit Arizona Department of Agriculture Form 1080 Pesticide Use Reports for all applications. The use of commercial applicators varies across crops. Aerial application is always performed by commercial applicators.

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

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

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

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

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