Crop Profile for Celery in Florida

General Production Information

- Florida ranks second nationally in celery production. Although the National Agricultural Statistics Service no longer collects data on celery production in Florida, the state's celery acreage has consistently been the second highest, after California, even accounting for recent reductions in Florida acreage. In 1997, Florida's celery acreage accounted for 15 percent of the total U.S. acreage, and between 1990 and 1994, Florida's acreage ranged between 20 and 24 percent of the national celery acreage (1-5).

- In 1997, there were 12 celery-producing farms in Florida, with a total of 4,115 acres. Celery acreage has dropped from 8,259 acres (on 14 farms) in 1992 (1). At one time Florida's second largest vegetable commodity, celery has continued to drop in acreage, with current production on slightly less than 3,000 acres (6,7).

- Between 1980 and 1992, production of celery in Florida ranged from nearly 285 million pounds to over 485 million pounds (8). In 1992, the last year for which data were collected on celery production in Florida, 8,000 acres were planted and 7,600 acres were harvested, with total production of 315.4 million pounds. Average yield for Florida celery in that year was 41,500 pounds per acre, and the crop had a total value of $39.1 million (9). Cash receipts from Florida celery production totaled $58.7 million in 1993, while the total in 1994 was $21.6 million and in 1995 was $8.3 million (10).

- Nearly the entire Florida crop of celery is produced for the fresh market, as full stalks or celery hearts. Several hundred acres are produced for canned celery, as well as prepared as fresh celery sticks and fresh diced and crescent celery (6).

- Total costs for celery production in the Everglades area of Florida were $4,580 per acre in 1993-94. Operating costs (growing costs) represented 36 percent of the total, and harvest and marketing costs represented 46 percent. The cost of insecticides was $334 per acre (7.3 percent of total costs), the cost of herbicides was $58 per acre (1.3 percent of total costs) and the cost of fungicides was $162 per acre (3.5 percent of total costs). The cost of pesticides therefore represented 12 percent of the total costs and 34 percent of the total growing costs. Additionally, machinery costs for a boom sprayer and herbicide sprayer totaled $39 per acre (0.9 percent of total costs), costs for aerial spraying totaled $82 per acre (1.8 percent of total costs) and those of scouting totaled $22 per acre (0.5 percent of total). Altogether, pest management costs represented 42.4 percent of the cost of growing the crop in the seedbed and field and 15.2 percent of the total production costs (11).
The first commercial planting of celery in Florida was in the Sanford area, in 1897. Presently, the only celery-producing region in Florida is the Everglades region (around the southern tip of Lake Okeechobee in Palm Beach County) (12,13).

### Production Practices

Celery is a biennial plant, which produces vegetative growth (the edible stalks, or petioles) during the first year and seed stalks during the second year. It is harvested about 90 days after transplanting, but if the plant were left to grow for the second year and were exposed to low temperatures, it would produce a longer stem and a seed head (14).

Celery in Florida is grown on organic, muck soils. Soil preparation is more important in celery than in most other crops. Fields in which celery is to be planted are plowed, disked and leveled, then alternately flooded and dried during the summer months to manage nematodes, soil-borne diseases and insects. After flooding, the fields are plowed, disked and leveled again, followed by a sub-soiling mole-draining operation to aid in sub-surface irrigation, and finally, the fields are fertilized before planting (14,15).

Among vegetables on Florida's organic soils, celery is the most heavily fertilized. Fertilizers are applied to at or near 100 percent of celery acreage in the state. During the years in which chemical usage data have been collected for celery in Florida, between 33 and 45 pounds of nitrogen per acre have been applied an average of 3 times per year, with total usage ranging from 622,000 to 962,000 pounds annually. Phosphate has been applied from 1.5 to 2 times each year, at an average rate ranging from 105 to 127 pounds per acre and an average annual state total ranging from 1.15 to 1.86 million pounds of phosphate. Celery growers in Florida have applied potash at an average rate ranging from 135 to 286 pounds per acre, an average of 2 to 3 times each year, totaling between 2.45 and 4.97 million pounds annually (3-5,12).

Celery requires a long, cool growing season and is sensitive to both high and low temperatures. The optimum temperature for growth is between 60 and 70° (15.6 to 21.1°), with a maximum monthly average of 70 to 75° (21.1 to 23.9°). Under high temperatures and moist conditions, the crop is more susceptible to disease and insect damage, as well as physiological problems. If temperatures drop below 50° (10°) for 10 to 14 days when plants are young, bolting may occur, during which the plant enters the seed-producing stage of the second year during its first year. If that occurs, growth slows and initiation of flower stalks occurs prematurely as the plant approaches marketable size, leaving a stalk with no commercial value. The temperature requirements of celery limit commercial production in the winter months to California, Florida and south Texas. In addition, timing of planting is essential for producing healthy transplants and bringing the crop to harvest without slowing its growth, which can result in poor market quality (12,14).
Celery is usually planted in south Florida between October and March. When grown in other parts of the state, it is planted in north Florida between August and February and in central Florida between September and March. Among the varieties common in the state are Floribelle-M9, Florida Slobolt-M68-29-5, June Belle and Florida 683. Most seedlings for transplant are grown outdoors in raised beds under shadecloth. Celery seeds are pressed on the soil surface of the bed and kept moistened. After 3 months in the seedbed, celery is transplanted to the field, using mechanical transplanters, where it remains for an additional three months. Plants are set at 18 to 40 inches (46 to 102 cm) between rows and 6 to 12 inches (15 to 30 cm) between plants, giving a plant population under closest spacing of 58,080 per acre (12,14-16).

One hundred percent of celery acreage in Florida is irrigated. Celery has similar water requirements to carrots during the rapid growth stage and somewhat less need for water during the final growth stages. The plant is sensitive to a fluctuating supply of water because of its shallow roots, but excessive water at the roots can also slow growth. The crop therefore requires more frequent irrigation. Overhead sprinklers are used to irrigate celery in Florida only following transplanting. Once transplants have recovered from the shock, irrigation is limited to sub-surface infiltration. All celery in Florida is grown where the producer can regulate the sub-surface water table by manipulating a series of ditches and canals. The canals within this sub-surface irrigation system also allow for rapid drainage after heavy rains (1,12,14,15).

Celery in Florida is harvested from early December to late May. Once celery reaches marketable size, it must be harvested within 6 to 8 days or reduction in quality will make it unmarketable. Celery growers therefore schedule planting so that a uniform quantity of celery is ready to harvest every week (14,17).

Most celery in Florida is harvested by hand, where crews cut, trim, size, wash and pack the crop in the field. Outer petioles (stalks) are removed, the celery is trimmed to a uniform length, which is usually 14 or 15 inches (36 to 38 cm), and it is packed into cartons or crates. After leaving the field, the packed celery is taken to a cooling facility, where it is hydrocooled and then packed onto refrigerated trucks and transported to the market. Celery that will be used as sticks, diced, or crescents may be machine harvested. It is taken to a packinghouse, where it is washed and processed. After cooling, it is loaded onto trucks for transport (12,14).

The most common unit in which shipments are recorded for celery is the crate, which has a billing weight of 60 pounds and an actual net weight that can range from 55 to 75 pounds. Celery is sized by the number of dozen or half dozen stalks fitting into the standard packing crate, with a smaller sizing therefore given to larger celery. Trimmings and outer petioles are often used for processing, in soups, juices and convenience dinners. When the large outer stalks are stripped to sell the remainder as celery hearts, the outer stalks are processed. Much of Florida's celery production, that which is sized at 4 or 6 dozen stalks per box or smaller, is sold as hearts. The hearts are washed thoroughly, stripped of suckers, leaves and damaged petioles, cut to 8 to 10 inches (20 to 25 cm) in length, and packaged in polyethylene bags, with 2 to 3 hearts per bag. Any celery sold for processing is washed and cut up before leaving for the processor. Fresh celery is primarily sold to retailer-wholesalers, terminal market brokers, wholesale
The most important insect and related pests of celery in Florida are serpentine leafminers (*Liriomyza trifolii*) and a worm complex, consisting of armyworms [mainly beet armyworm (*Spodoptera exigua*) and to a lesser extent fall armyworm (*Spodoptera frugiperda*) and southern armyworm (*Spodoptera eridania*), cutworms [mainly granulate cutworm (*Feltia subterranea*) and occasionally black cutworm (*Agrotis ipsilon*)], and occasionally cabbage looper (*Trichoplusia ni*) and the green celeryworm (*Platysenta sutor*). Wireworms [corn wireworm (*Melanotus communis*), southern potato wireworm (*Conoderus falli*) and tobacco wireworm (*Conoderus vespertinus*), aphids [mainly green peach aphid (*Myzus persicae*) and melon aphid (*Aphis gossypii*) and occasionally green citrus aphid (*Aphis citricola*) and rice root aphid (*Rhopalosiphum rufiabdominalis*)] and twospotted spider mites (*Tetranychus urticae*) are minor or occasional pests. The celery leafftier, celery webworm, saltmarsh caterpillar, celery and soybean loopers, celery caterpillar, banded cucumber beetle, aster leafhopper, tarnished plant bug, garden flea hopper, potato flea beetle, southern green stink bug, silverleaf and sweet potato whiteflies, and onion and tobacco thrips may occasionally be seen on celery, but currently are not economically damaging. Snails were a minor pest on celery in the previous production region of central Florida. Losses from all insects and mites on celery in Florida have been estimated at approximately 14 percent (18-25).

**AMERICAN SERPENTINE LEAFMINER:** (*Liriomyza trifolii*). The serpentine leafminer *Liriomyza trifolii* has historically been one of the most serious pests of celery in Florida (18,19). Its host range is very broad, including many vegetable crops and weeds. Vegetable hosts, in addition to celery, include spinach (*Spinacia oleraceae*), lettuce (*Lactuca sativa*), muskmelon (*Cucumis melo*), cucumber (*Cucumis sativus*), pumpkin (*Cucurbita pepo*), okra (*Hibiscus esculentatus*), pepper (*Capsicum* sp.), tomato (*Lycopersicon esculentum*), eggplant (*Solanum melongena*), potato (*Solanum tuberosum*), and carrot (*Daucus carota var. sativa*). Weed species serving as hosts to the serpentine leafminer in Florida include lambsquarters (*Chenopodium album*), cocklebur (*Xanthium* sp.), black nightshade (*Solanum nigrum*), Spanish needle (*Bidens pilosa*), hairy galinsoga (*Galinsoga ciliata*), and sowthistle (*Sonchus* spp.) (26,27).

Leafminer attack on celery can result in early senescence of outer petioles, longer time to maturity, and a reduction in yield, although celery plants in south Florida have been shown to withstand substantial leafminer damage without a reduction in growth or yield. Of greater concern to celery growers is the effect of leafminer feeding on cosmetic quality. Celery plants with insect damage on more than 2 petioles receive a lower grade, according to USDA standards. Protecting celery plants from leafminer damage during the last month of the growing season has been shown to be the key to preventing cosmetic damage to celery in south Florida. During the first two months after transplanting, leafminer populations below 60 pupae per 20 leaflets held for 7 days is acceptable. However, during the final month in the field, leafminer densities as low as 3 pupae per 20 leaflets can result in a significant loss in
Adult leafminers feed at flowers. In addition, adult females puncture celery leaves with their ovipositors (egg-laying organs) and feed on the plant juices that accumulate at the feeding puncture. Males cannot puncture the leaf, so they feed after females have left. The female inserts an egg between the upper and lower epidermis (leaf surface), and the larva feeds within the leaf. As the larva feeds, it moves throughout the leaf from within, creating a mine in an irregular line (serpentine mine). The mine increases in diameter as the larva grows and consumes greater amounts of leaf tissue. When fully grown, the larva cuts through the upper leaf surface and leaves the leaf to pupate, falling between the petioles or onto the soil. The larva usually exits the leaf during the morning hours and becomes a pupa by mid-afternoon. After completing the pupal stage, the leafminer emerges from the soil or plant debris as an adult (28).

Although leafminers are more abundant during the middle and late part of the season, they can be a problem at any time (20). The time required for *L. trifolii* to complete its development on celery in the laboratory has been shown to vary from 14 days at 35° (95°) to 64 days at 15° (59°). Survival of pupae is very low at 35C, however, and reduced egg laying occurs at 15C. Optimum temperature for survival and egg laying has been demonstrated to be 30° (86°). Based on these studies of survival and egg laying at different temperatures, *L. trifolii* is expected to experience maximum population growth between May and October in central Florida (when average air temperatures are at least 25° or 77°), lower population growth during March, April and November (when average air temperature is about 20° or 54°), and virtually no population growth from December to January (when average air temperature is about 15° or 59°) (30). Temperatures in south Florida, where celery is now produced exclusively, are higher, allowing for leafminer population growth through most of the year.

**BEET ARMYWORM** (*Spodoptera exigua*)

Armyworms are the principal component of a worm complex that affects nearly all crops in south Florida and is one of the greatest insect problems of celery in the state. The worm complex, which also includes cutworms and occasionally cabbage loopers, among others, appears each year first in south Florida and then moves northward. The most important of the armyworms on celery is the beet armyworm, which also feeds on many cultivated and wild plants, including corn, pepper, tomato, potato, onion, pea, sunflower, citrus, soybean and tobacco, as well as plantain and lambsquarters (19,20,31).

The beet armyworm lives in the adult (moth) stage for four to ten days. Each female can lay about 600 eggs (in clusters or egg masses of about 80) within a week, and the eggs hatch in two to three days. Upon emerging, the larvae spin webs around themselves to feed first on the egg mass and later on the plant. The larvae, which at first feed in groups under the silk webbing and later feed alone and cease to produce webs, continue to feed for between one and three weeks. They then construct a loose cocoon with soil and leaf parts, within which they pupate. The adult moth emerges from the cocoon approximately one week later. Since the beet armyworm has a short life cycle (four to five weeks) and survives the winter in south Florida, many generations can occur each year. The long growing season in south Florida and the wide host range of this insect allow it to maintain an active presence all year round.
in that region, providing a reservoir for yearly migration into north Florida and the southeastern U.S. Pheromone trap data collected in south Florida indicate that beet armyworm adults are usually most prevalent during the months of May and June, although they are collected in all months (31,32).

**GRANULATE CUTWORM** (*Feltia subterranea*).
Cutworms are another part of the worm complex that attacks celery every year in Florida. Although the black cutworm (*Agrotis ipsilon*) may be present, the granulate cutworm is a greater problem in celery in Florida (18-20). These cutworms attack many field and other vegetable crops, including beans, crucifers, cucurbits, corn, cowpea, lettuce, onion, pea, pepper, potato, spinach, sweet potato and tomato. Cutworm larvae become active in the spring, hiding within the soil during the day and feeding on young plants at night. They can cut off plant stems near soil level, and they feed on the leaves, chewing into the developing petioles of celery. Cutworm larvae continue to feed until mature (about three to four weeks), then pupate within the soil. After two to four weeks, the adult moths emerge and the adult females begin to lay clusters of eggs during the night on the lower surface of host plant leaves. Eggs hatch within three to five days, and young larvae feed on the leaves, retreating to the base of the plants as they get older (23,31).

**CABBAGE LOOPER** (*Trichoplusia ni*).
The cabbage looper occasionally forms part of the worm complex on celery in Florida (20). It has a broad host range, including cabbage and related crucifers, lettuce, celery, parsley, tomato, potato, spinach, soybean and cotton. In Florida, cabbage loopers overwinter as pupae. In the spring, when the adult moths emerge, each female deposits 275 to 350 eggs on host plant leaves. Within several days, the larvae (caterpillars) emerge and begin to feed. After feeding for two to four weeks, they pupate within cocoons on the leaves. Within two weeks, the adult moths emerge. Several generations of the cabbage looper occur each year in Florida. In south Florida, pheromone trapping data shows adult populations to be highest during the late spring and summer months, and in some years in the late fall (31,32).

**WIREWORMS** (Family Elateridae)
Wireworms can damage celery in south Florida, but they are generally not a problem, as long as growers are able to practice off-season flooding, which effectively controls them (20). The hard, slender wireworms, which are the immature stage (larvae) of click beetles, can be found throughout the root zone, feeding on underground plant parts. Symptoms of wireworm attack may include a sudden reduction in plant stand. Injury from wireworms can also leave the plant more susceptible to secondary infection from soil-borne plant pathogens. Whether chemical or cultural, control of wireworms must be preventive (33).

The corn wireworm, *Melanotus communis*, is the most damaging wireworm on celery and other vegetable crops grown on the organic, muck soils of south Florida (23). Attacking mainly corn and small grains, it also feeds on the roots, seeds and tubers of many flower and vegetable crops. The life cycle of this wireworm may last from three to six years. Adults deposit eggs on the roots of grass hosts in May or June, and emerging larvae feed and develop throughout the summer, then overwinter in the soil during the first year. Most remain as larvae for five years and pupate within cells in the soil during the summer of the 6th year. Adults emerge in about 18 days and feed on pollen. The following May or June, they
become active and deposit eggs (31).

The southern potato wireworm (*Conoderus falli*) prefers potato tubers but will also damage most crops, including celery, sweet potatoes, carrots, and corn roots, as well as low-lying fruit of strawberries, cantaloupes, watermelons and tomatoes. On crops in which it damages roots, the wireworm chews holes, with a single root sometimes having more than ten holes. The southern potato wireworm has developed resistance to chlorinated hydrocarbons and organophosphate insecticides (31).

**APHIDS** (Family Aphididae)

Aphids are usually a minor pest on celery in Florida, but they may be of concern because of their role as virus vectors. To manage them, growers try to use compounds that preserve beneficials (predators and parasites) when possible, but they resort to methomyl when there is a large aphid outbreak. The most important aphids in Florida celery are the green peach aphid (*Myzus persicae*) and the melon aphid (*Aphis gossypii*). The green citrus aphid (*Aphis spiraecola*) may also colonize celery in Florida. An aphid pest newly introduced to Florida, *Hyadaphis coriandri*, may potentially colonize celery. Primarily a pest of coriander and other Umbelliferous herbs, it has the potential to become a serious pest if it becomes established in crop areas. At present, infestations have been confined to residential areas, with citations over a wide area in Orlando and one confirmed infestation in Tampa (20,22,34).

Aphids feed by inserting their needle-like mouthparts into plant tissue and sucking up plant juices. In addition to depleting the plant of nutrients, they can inject toxins that produce abnormal plant growth. While feeding, they also excrete large amounts of a sweet, sticky liquid called honeydew, on which black sooty mold often grows. Throughout Florida, aphid populations are exclusively female and are able to reproduce abundantly. The immature nymphs feed as well, and within just a few days they mature and begin producing more young. As a result of this rapid reproduction, aphid populations can increase dramatically. When populations are high, winged aphids are produced, which fly to new plants. Despite the potential for rapid increase in population, control of aphids is not difficult. Since they remain on the exterior of the plant and do not lay eggs, all stages are susceptible. When applying insecticides, complete coverage is necessary, since aphids tend to be more numerous on the underside of leaves and in protected areas of the plant. In addition, there are several natural enemies that help to maintain aphid populations at low levels (33).

The green peach aphid (*Myzus persicae*), in addition to feeding on celery, also colonizes a wide range of plants, including cabbage and related crucifers, parsley, turnip, lettuce, chard, endive, tomato, potato, pepper, beets, spinach, and mustard greens. It is one of the most important aphid virus vectors and can transmit over 100 plant viruses, including those that affect celery in Florida (cucumber mosaic virus and celery mosaic virus). The green peach aphid has developed resistance to a great number of insecticides (31,34,35).

The melon aphid (*Aphis gossypii*) is also a vector of both celery viruses in Florida. It has a broad host range as well and can colonize beans, cowpea, citrus, cucurbits, eggplant, peppers, potato, tomato, spinach, okra, beets, cotton, and many ornamental plants, as well as having many weed hosts. Many
overlapping generations occur each year (31,34,35).

**TWOSPOTTED SPIDER MITE** (*Tetranychus urticae*)

Twospotted spider mites are a minor and occasional pest of celery in Florida. They are more of a problem later in the season, when their presence on the harvested product is undesirable. They are known to have over 180 host plants, including at least 100 crop plants. Symptoms of spider mite damage begin with a bronzed appearance on leaves and include yellow and reddish-brown blotches on both leaf surfaces. Under severe infestations, paling and dropping of leaves may occur. Spider mites are nearly microscopic, but a powdery appearance on leaves from their molted skins indicates their presence. In addition, twospotted spider mites spin silken webs on leaf surfaces. They feed by piercing the leaf surface (epidermis) with their long, slender mouthparts and withdrawing plant sap (23,31,33).

Hot, dry weather speeds spider mite development, and populations may increase rapidly under optimum conditions. Each female may produce up to 19 eggs per day and a total of up to 100 eggs. The larvae hatch after 6 to 19 days and begin to feed. Mites experience a resting period after the larval stage, then pass through two nymphal stages, with another resting period after each one. Maturity into adults may take as few as five days or as many as 20 days, depending on the temperature. The age structure of the population should be determined when considering the use of chemical controls. When many nymphs are present, the population is probably increasing, whereas if many adults are present, particularly males, it is probably declining. In addition, if a miticide is used, a second application is necessary in Florida between five and seven days after the first. The second application kills the mites that as eggs escaped the first application. Timing is critical to prevent those mites from maturing and laying eggs (31,33).

**Chemical Control:**

Cyromazine (Trigard), abamectin (Agri-Mek), B.t. (*Bacillus thuringiensis*), and permethrin (Ambush/Pounce) are the insecticides used most often in Florida celery production. Methomyl (Lannate), acephate (Orthene), and thiodicarb (Larvin) are applied occasionally. Azadirachtin (Neemix), azinphos-methyl (Guthion), carbaryl (Sevin), diazinon (D.z.n./AG-500/Spectracide), dimethoate (Dimethoate/Dimate), endosulfan (Thiodan), malathion (Cythion), naled (Dibrom), oxamyl (Vydate), insecticidal oils (Sun Spray), insecticidal soap (M-Pede/Safer Soap), pyrethrins plus piperonyl butoxide (Pyrenone) and pyrethrins plus rotenone (Pyrellin) are also available for use on celery in Florida (3-5,15,20,21,36).

- **CYROMAZINE** (Trigard). Cyromazine is a triazine insecticide that works as an insect growth regulator. It is one of the two principal insecticides applied to celery for the management of leafminers. Cyromazine, which has no effect on the adult leafminer, is applied as a foliar spray. The median price of cyromazine is $188.00 per pound of active ingredient, and the average cost per application in 1994 was approximately $24 per acre (3,37). Cyromazine may be applied up to 7 days before harvest (PHI=7 days), and the restricted entry interval (REI) under the Worker Protection Standard is 12 hours.

During the years in which usage data have been collected, cyromazine has been applied to a range of 94 to 100 percent of celery acreage in Florida, an average number of 4 to 6.5 times per
year. Average application rates have ranged from 0.13 to 0.16 pounds of active ingredient per acre, and total statewide annual usage has ranged from 3,600 to 7,400 pounds of active ingredient (3-5).

- **ABAMECTIN** (Agri-Mek). Abamectin is a fermentation product composed of two avermectins derived from the soil bacterium *Streptomyces avermitilis*. Florida celery growers apply this miticide/insecticide as a foliar spray to manage *Liriomyza* leafminers and twospotted spider mites. The median price of abamectin is $6,156.00 per pound of active ingredient, and the average cost per per acre at each application, with average annual number of applications ranging from 1.8 to 4.7. Percentage of acres treated has ranged from 46 to 98, and total annual usage in the state has ranged from 100 to 300 pounds of active ingredient (3-5).

- **B.T.** (*Bacillus thuringiensis*) (Agree/Cutlass/Condor/Dipel/Javelin/Mattch/MUPII/Xentari/Crymax). B.t. is a soil bacterium that produces spores and crystalline bodies acting as a stomach poison to the insects that consume it. *B.t. kurstaki* and *B.t. aizawai* are the strains of the bacterium toxic to the lepidopterous larvae against which celery growers apply this biological pesticide. Although Florida celery growers primarily use B.t. to manage armyworms, it is also effective against cabbage loopers, saltmarsh caterpillars, celeryworms and webworms. The median price of B.t. is $140.16 per pound of active ingredient (37). B.t. may be applied up to the day of harvest (PHI=0), and the restricted entry interval (REI) under the Worker Protection Standard is 4 hours.

During the years in which usage data have been collected, B.t. was applied to a range of 60 to 100 percent of celery acreage. Average number of applications during the crop year has ranged from 3.0 to 5.4. Rates and statewide totals are unavailable, because the amount of active ingredient is not comparable among products (3-5).

- **PERMETHRIN** (Ambush/Pounce). Permethrin is a broad-spectrum synthetic pyrethroid insecticide used by Florida celery growers primarily for the management of armyworms, cabbage loopers, and black and granulate cutworms, although it can also be used to manage vegetable leafminers, green cloverworm, and leafhoppers. The median price of permethrin is between $54.76 and $65.94 per pound of active ingredient, and the average cost per application in 1994 was approximately $10 per acre (3,37). Permethrin may be applied up to 1 day before harvest (PHI=1 day), and the restricted entry interval (REI) under the Worker Protection Standard is 12 hours.

During the years in which usage data have been collected, Florida celery growers applied permethrin at an average rate ranging from 0.16 to 0.20 pounds of active ingredient per acre at each application, with average annual number of applications ranging from 1.4 to 4.6. Percentage of acres treated has ranged from 39 to 80, and total annual usage in the state has ranged from 600 to 6,700 pounds of active ingredient (3-5).

- **METHOMYL** (Lannate). Methomyl is a broad-spectrum carbamate insecticide and acaricide
used occasionally in Florida celery production for the management of armyworms, cabbage loopers, variegated cutworms and the aster leafhopper. The median price of methomyl is $20.21 per pound of active ingredient, and the average cost per application in 1994 was approximately $11 per acre (3,37). Methomyl may be applied up to 7 days before harvest (PHI=7 days), and the restricted entry interval (REI) under the Worker Protection Standard is 48 hours.

Methomyl was used during 2 of the 3 years in which usage data have been collected on celery in Florida. When used, a range of 1,400 to 7,600 pounds of active ingredient has been applied statewide to a range of 28 to 54 percent of celery acreage. Average rate of application has ranged from 0.57 to 0.88 pounds of active ingredient per acre, and average number of applications has ranged from 1.3 to 1.9 (3-5).

- **ACEPHATE** (Orthene). Acephate is an organophosphate insecticide used in the management of beet and fall armyworm, green peach aphid, and cabbage loopers. The median price of acephate is $14.00 per pound of active ingredient, and the average cost per application in 1994 was approximately $14 per acre (3,37). Acephate may be applied up to 21 days before harvest (PHI=21 days), and the restricted entry interval (REI) under the Worker Protection Standard is 24 hours.

In 1994, acephate was applied an average of 1.8 times to 66 percent of the state's celery acreage, at an average rate of 0.98 pounds of active ingredient per acre. Statewide usage totaled 8,500 pounds of active ingredient (3-5).

**Chemical Alternatives:**
Emamectin benzoate (Proclaim) is a recently registered, semi-synthetic insecticide derived from the avermectin B1 fermentation product. It has been tested in Florida for the management of lepidopterous pests of celery, among others. Emamectin benzoate provides long residual activity against caterpillars by entering the leaf cuticle. In addition, residues on the leaf surface photodegrade rapidly, resulting in short residual activity against predators and parasites of the pests. It is therefore compatible with Integrated Pest Management programs. When applied full season to celery in 1994 efficacy trials in Zellwood, emamectin benzoate provided greater control of beet armyworm than methomyl or *Bacillus thuringiensis* subsp. *azawai*, resulting in higher celery yields than celery treated with either of the other two products or the untreated control (38).

**Use of Chemicals in IPM Programs:**
Celery growers in Florida are aware of the importance of beneficial insects and try to use chemicals that are least damaging to natural populations of beneficials. For leafminers, they apply primarily cyromazine and abamectin, and for lepidopteran larvae (worm complex) they apply *Bacillus thuringiensis* when possible, in an effort to minimize adverse effects on natural enemies, especially in the seedbed (20).

For several years, the Everglades Research and Education Center at Belle Glade, Florida has been monitoring moth activity of several lepidopterous pests through the use of pheromone traps. Data is
maintained on beet armyworm activity throughout the year and is available to growers and scouts to aid in forecasting populations of these pests. Populations of the cabbage looper were also monitored for several years, although that insect is not currently included in the trapping program (32).

Use of Chemicals in Resistance Management Programs:
Reductions in effectiveness of insecticides used to control the leafminer *Liriomyza trifolii* have been reported since the 1950's, and the resistance problem has severely limited options for management of the leafminer. Parathion, diazinon, naled, azinphos-methyl, dimethoate, and oxamyl had all lost effectiveness against the leafminer by the late 1970's. By 1976, no insecticide labeled for use on celery was able to control leafminer populations in Florida, and after permethrin was made available in 1978, it became ineffective within two years. Effective chemical control for the leafminer in Florida was not available until 1982, with the introduction of cyromazine. However, by 1989, cyromazine resistance in the leafminer had been confirmed in the Everglades area. The leafminer strain resistant to cyromazine was found not to be resistant to abamectin. Beginning in 1990, Section 18 exemptions were granted for the use of abamectin on celery in Florida within a controlled insecticide rotation to manage resistance (39,40).

A program was developed for celery growers to manage cyromazine resistance in *Liriomyza trifolii* by following several insecticide management and crop management guidelines. Within the program guidelines, 1.) the number of insecticide applications was to be limited by using thresholds to determine the need for sprays; 2.) early control was to be maximized by beginning the spray program with abamectin; 3.) each two sprays of abamectin were to be rotated with two sprays of cyromazine; 4.) each crop cycle was to be completed with two sprays of abamectin to minimize the number of adults leaving the soil after the harvest; and 5.) the use of pyrethroids (specifically permethrin and esfenvalerate) was to be avoided to minimize the effects on natural enemy populations. Furthermore, the transfer of cyromazine-resistant leafminers from seedling beds to the field was to be minimized by not using cyromazine in seedbeds and by not growing seedlings close to field production areas. Finally, the program recommended not using cyromazine during the summer months, when celery acreage in the field is low, in order to allow for immigration and reproduction of leafminers susceptible to the insecticide (39).

Although some celery growers continued to use cyromazine in seedbeds, they followed the most important recommendations involving rotational sprays. Abamectin is now labeled for use on celery, and growers continue to alternate cyromazine with abamectin, despite the large difference in cost, in an effort to manage resistance in the leafminer. This alternation of the two insecticides is the most important aspect of the resistance management program, and it is ensured by label restrictions against applying either insecticide in more than two consecutive applications (19,20). Despite active resistance management by celery growers, there has been some resistance to both cyromazine and abamectin building in leafminer populations (25).

Cultural Control:
Flooding celery fields for at least one month in the summer is an effective control for wireworms. Celery growers in south Florida regularly practice summer flooding as a means of managing not only soil
insects, but nematodes and diseases as well (20,33).

Celery growers in previous production areas in central Florida practiced ditchbank sanitation, not only to maintain efficiency of irrigation systems, but to minimize damage from snails, which could attack several rows adjacent to ditchbanks when weeds were present in the ditchbanks. Controlling weeds adjacent to celery fields also aids in reducing aphid populations (25).

**Biological Control:**

**Leafminers.** Hymenopterous parasitoids that have been collected from *Liriomyza trifolii* on celery include *Opius dimidiatus, Diglyphus intermedius, Chrysonotomyia* sp., *Diglyphus pulchripes, Mirzagrammosoma lineaticeps, Closterocerus cinctipennis, Chrysocharis* spp., *Derostenus agromyzae, Derostenus variipes, Achrysocharella formosa, Halticoptera patellana,* and *Halticoptera circulus.* The most common parasitoids of leafminers on celery in Florida are *O. dimidiatus, D. intermedius,* and *Chrysonotomyia* sp., which are able to parasitize greater than 90 percent of active mines in unsprayed celery or nearby weeds. However, percentage of parasitism can vary greatly, depending on population levels, crop age, cropping season, location, pesticide treatments, and spray drift. Populations of these parasites are able to increase at least as fast as the leafminer populations (23,26,27,41).

The importance of natural control of the serpentine leafminer by parasites and the disruption of that control by the use of insecticides highly toxic to the parasites has been recognized for decades. Leafminers did not become a problem on celery in Florida until the use of chlorinated hydrocarbons in the 1950's killed the parasites with little effect on the leafminers, thereby increasing leafminer populations considerably. Researchers at that time recognized that parasite populations could be maintained by the adequate management of less toxic insecticides with short residual activity. Furthermore, the insect's habit of mining within the leaf as a larva allows it to escape contact with insecticides during a significant part of its life cycle. Therefore, any chemical control of leafminer populations requires the simultaneous preservation of parasite populations, and celery growers in Florida have been attempting to preserve leafminer natural enemies for two decades. In addition to choosing less toxic insecticides targeting leafminers, growers also manage caterpillars (armyworms, cutworms, loopers) with leafminer management in mind. For example, they choose *Bacillus thuringiensis* when possible to manage caterpillars instead of methomyl, which knocks down populations of leafminer parasites (40). Celery growers make a particular effort to maintain high populations of beneficials in the seedbed so that they go out to the field with the transplants (20).

**Beet armyworm.** Chemical control of the beet armyworm can be difficult, particularly when it reduces populations of the pest's predators and parasites, many of which are present in Florida. Natural enemies of the beet armyworm observed in Florida include *Apanteles marginiventris* (Cress.), *Apanteles* sp., *Euplectrus platypenae* How., *Apanteles autographae* Mues., *Podisus maculiventris* Say, *Podisus mucronatus* Uhler, *Zelus bilobus* Say, *Sinea* sp., *Calosoma sayi* DeJean, *Polistes* spps., *Erethemis simplicicolis* Say, *Xysticus triguttatus* (Keys), *Phidippus audax* (Hentz), *Agelaius phoeniceus floridanus* Maynard, *Sturnella magna argutula* Bangs, *Cassidix mexicanus* (Gmelin), and *Bubulcus ibis* L. (23). However, there are few beet armyworm natural enemies that can by themselves effectively manage
populations on commercial crops, so conservation of natural enemies must be carried out in concert with other management strategies (31).


Aphids. Several common predators of aphids can aid in reducing aphid populations, including adults and larvae of ladybird beetles and larvae of lacewings and syrphid flies (31).

Diseases

The most important diseases affecting celery in Florida are early blight (caused by *Cercospora apii*), bacterial blight and brown stem (caused by *Pseudomonas cichorii*), and Rhizoctonia stalk rot (caused by *Rhizoctonia solani*). Pink rot (caused by *Sclerotinia sclerotiorum*), late blight (caused by *Septoria apii*), and southern blight (caused by *Sclerotinia rolfsii*) are occasionally a problem. Damping-off (caused by *Rhizoctonia*, *Pythium*, *Fusarium* and *Sclerotinia* spp.), cucumber mosaic (caused by cucumber mosaic virus), red root (caused by *Fusarium* and *Pythium* spp.) and celery mosaic (caused by celery mosaic virus) are minor diseases on celery in the state. Alternaria leaf spot (caused by *Alternaria* sp.), gray mold (caused by *Botrytis cinerea*), anthracnose (caused by *Colletotrichum* sp.), bacterial soft rot (caused by *Erwinia carotovora*), and Fusarium yellows (caused by *Fusarium oxysporum* f. sp. *apii*) have all been reported on the crop in Florida as well. Losses due to plant pathogens in Florida celery have been estimated at approximately 17 percent (20,24,42,43).

**EARLY BLIGHT** (caused by *Cercospora apii*)

Early blight is the most important disease of celery in Florida, appearing yearly and affecting all acreage in the state. It affects plants both in the seedbed and in the field. Symptoms first appear as small, circular spots on the leaves or petiole. The spots enlarge rapidly and can combine to form a large, blighted area over entire leaflets or stalks. Spores develop in the center of the spots, becoming numerous under humid conditions. Lesions may therefore appear gray in the center, and in addition, large chlorotic areas may surround them. Florida's high relative humidity, long dew periods and high temperatures present ideal environmental conditions for development of the disease. Spore production primarily occurs at night when temperatures are in the range of 58 to 86° (14.4 to 30°) for at least ten hours and relative humidity is near 100 percent. Most spores disperse on the wind during the morning hours, as the relative humidity declines. Once spores land on appropriate plants, disease symptoms appear within 12 to 14 days of spore germination and penetration of the plant tissue. Growers primarily apply chlorothalonil, propiconazole, and EBDC compounds to manage early blight. Since many air-borne spores are released during the harvest of celery, any fields within one-half mile downwind should be protected with a fungicide during
the harvest operation (20,42-45).

**BACTERIAL BLIGHT** (caused by *Pseudomonas cichorii*)

Bacterial blight is also one of the principal diseases of celery in Florida. It more commonly affects the crop while in the seedbed, but occasionally it can cause extensive damage to celery in the field. Damage tends to be greatest in seedbed production for fall and early winter crops of celery in Florida. The close proximity of seedlings and the environmental conditions in the seedbed at that time (hot and rainy weather) contribute to rapid development of the disease. Bacterial blight lesions are very similar to lesions caused by the early blight fungus (*Cercospora apii*), but are smaller, with a deeper red color and have a more water-soaked appearance. The margin of the lesion produced is also clearer than that of early blight, and chlorosis occurs more slowly. The disease is favored by warm and humid conditions and is difficult to control when rains are frequent. The bacteria can be spread from plant to plant by rain, irrigation, or on machinery and people. Symptoms appear within days of the bacteria entering a plant's tissue through natural openings or wounds. A preventive spray program aids in management of bacterial blight, and growers principally utilize copper compounds in preventive sprays. However, strains tolerant to copper fungicides have been reported in south Florida. Also, streptomycin resistance in the bacteria is still widespread despite very limited use in the Everglades area over the past two decades (16,20,42,43,45).

**BROWN STEM** (caused by *P. cichorii*)

Brown stem is a petiole necrosis of celery that has been seen in the Everglades Agricultural Area of Florida for nearly 50 years. The pathogen that causes brown stem is the same as that causing bacterial blight. Unlike bacterial blight, which is present every year, brown stem is more sporadic, appearing approximately every five or six years. When it does occur, however, it can be severely damaging to the celery crop. The worst outbreak occurred during the 1992-93 winter season in the Everglades area, resulting in estimated losses to celery producers of $5 million. During that outbreak, the disease was found in 100 percent of surveyed celery fields, and the average incidence was approximately five percent (46).

Brown stem causes more curling and stalk rot than bacterial blight. The principal symptom of brown stem is a brown discoloration over the entire petiole. Although brown streaks may be seen along the whole petiole, the base of the stalk receives the greatest amount of damage. Symptoms intensify closer to harvest, as the plant approaches maturity. The reason for the sporadic nature of the disease is unknown, and the link between outbreaks of brown stem and specific weather conditions is still under investigation (43,46).

**LATE BLIGHT** (caused by *Septoria apii*)

Late blight is only occasionally a problem in the Everglades area, but it has been severe in other celery producing areas in Florida, where all celery acreage may be affected. The disease is favored by cool, wet conditions, including temperatures of 50 to 81° (10 to 27°). The principal symptom of late blight is the appearance of lesions containing small black fruiting bodies (pycnidia). The spores produced within the pycnidia can be dispersed by rain, machinery, or people, but infected seed is the primary source of inoculum. The pycnidia become non-viable after two years, and celery growers manage the disease well
by using seed that is older than two years. Outbreaks may occur when seed is in short supply and green seed must be used. When the disease becomes a problem, growers apply EBDC compounds (maneb) (20,42,43,45).

**RHIZOCTONIA STALK ROT** (caused by *Rhizoctonia solani*)
Rhizoctonia stalk rot can be a significant problem for celery growers in Florida, particularly under warm and wet conditions. The stalks at the base of the plant develop sunken, red lesions as a result of infection by the stalk rot pathogen. When infection is severe, extreme stripping of the stalks may be necessary. Rhizoctonia rot can develop over a broad range of soil conditions, including a range of soil temperatures, soil pH, soil type, soil moisture, and fertilizer level. Celery transplant beds are presently flooded and fumigated with methyl bromide to manage both Rhizoctonia rot and nematodes (20,42,43,47).

**PINK ROT** (caused by *Sclerotinia sclerotiorum*)
Pink rot is not a problem every year in Florida, only becoming serious on occasion. Under conditions of drought when growers are unable to flood fields in the summer, populations of the fungus can build up in the soil, resulting in an outbreak during the celery growing season. When outbreaks occur, celery plants in the field can suddenly wilt and collapse. Plant tissue near the soil line usually develops a soft, watery decay, which appears pink and becomes covered with the white, cottony mycelium (body mass) of the fungus. Small black resting bodies (sclerotia) of the fungus develop within the white covering of the rotting plant tissue. The fungus survives from season to season in the form of these sclerotia, which serve as the source of inoculum for initial infection. The pathogen is favored by cool, moist weather. Conditions of high humidity with dew formation and temperatures ranging from 60 to 70° (15 to 21°) are optimal for disease development (42,43,48).

**CELERY MOSAIC** (caused by celery mosaic virus, CeMV)
Celery mosaic virus, a minor disease in Florida celery, was formerly called western celery mosaic virus. It is confined to plants in the celery family (Umbelliferae), and in addition to celery, mockbishopweed (*Ptilimorium capillaceum*) and wild cherry (*Apium leptophyllum*) are host plants. The disease causes foliage to mottle (producing light and dark green areas together on the leaf) and become distorted and twisted. Plants may also become stunted. Although leafminers have been shown to transmit the virus, aphids are the principal vector, spreading the disease from volunteer celery or weeds in the family Umbelliferae that serve as hosts. Both celery mosaic virus and cucumber mosaic virus are transmitted by aphids in a stylet-borne, nonpersistence manner, meaning that an aphid can pick up virus particles on its mouthparts (stylet) from an infected plant and transfer them to a healthy plant without the virus circulating through the aphid's body. There is no delay time from when the aphid acquires the virus to when it transmits it, and the aphid is able to transmit the virus for only a short period of time. This type of transmission can occur within seconds, and insecticides are therefore ineffective in preventing virus spread (34,42,49).

**CUCUMBER MOSAIC** (caused by cucumber mosaic virus, CMV)
Cucumber mosaic virus is worldwide in distribution and has a wide host range, including plants in ten
families in Florida. Celery, cucumber, squash, cantaloupe, tomatoes and pepper have been the principal crops affected. The most important source plant for the virus in Florida is a weed, creeping dayflower (*Commelina* spp.), which is commonly found in ditchbanks, non-crop areas, and moist fields with organic soils, where celery is grown. The virus concentration is low in this host, but the weed's closeness to celery fields and its attractiveness to aphids increase the chances of its spread to celery (34,42,49).

Symptoms of cucumber mosaic can range from a mild mosaic to severe deformation and stunting of the plant. The disease also causes a stalk pitting. Although mechanical transmission through plant sap can spread the virus within the field, the primary means of transmission is by aphids, in a nonpersistent manner, as discussed above. The most common aphid vectors of celery mosaic and cucumber mosaic virus in Florida are the green peach aphid (*Myzus persicae*) and the cotton aphid (*Aphis gossypii*) (34,42,49).

**Chemical Control:**
The most frequently used fungicides on celery in Florida are chlorothalonil (Bravo/Terranil/Echo/Daconil), copper hydroxide (Kocide/Champion/Champ/Blue Shield/Nu-Cop), and maneb (Maneb). Propiconazole (Tilt), benomyl (Benlate), and streptomycin (Agri-Mycin) are used occasionally. Mefenoxam (Ridomil Gold), DCNA (Botran), chloropicrin (Chlor-O-Pic/Picfume), metam sodium (Vapam), and 1,3-dichloropropene (Telone II) are also available for use on celery in Florida (3-5,15,20,36,42,43).

- **CHLOROTHALONIL** (Bravo/Terranil/Echo/Daconil). Chlorothalonil is a broad-spectrum nitrile fungicide used by celery growers in seedbeds and post-transplant for the management of Cercospora (early) blight, Septoria (late) blight, and basal stalk rot (*Rhizoctonia solani*). It is the principal fungicide used by Florida celery growers for early blight (43). The median price of chlorothalonil is $8.61 per pound of active ingredient, and the average price per application in 1994 was approximately $9.75 per acre (3,37). Chlorothalonil may be applied up to 7 days before harvest (PHI=7 days), and the restricted entry interval (REI) under the Worker Protection Standard is 48 hours.

  During the years in which usage data have been collected, chlorothalonil has been applied to a range of 98 to 100 percent of celery acreage in Florida, an average number of 11.5 to 22.4 times per year. Average application rates have ranged from 1.07 to 1.14 pounds of active ingredient per acre, and total statewide annual usage has ranged from 119,200 to 196,100 pounds of active ingredient (3-5).

- **COPPER HYDROXIDE** (Kocide/Champion/ChampBlue Shield/Nu-Cop). Copper hydroxide is used in the management of bacterial blight, especially during transplant production. Copper hydroxide may be applied up to 2 days before harvest (PHI=2 days), and the restricted entry interval (REI) under the Worker Protection Standard is 24 hours.

  During the years in which usage data have been collected, copper hydroxide has been applied to a
range of 22 to 35 percent of celery acreage in Florida, an average number of 3.1 to 20.4 times per year. Average application rates have ranged from 0.48 to 0.68 pounds of active ingredient per acre, and total statewide annual usage has ranged from 6,700 to 24,600 pounds of active ingredient (3-5). Strains of bacterial blight tolerant to copper fungicides have been reported in south Florida (16).

- **PROPICONAZOLE** (Tilt). Propiconazole is used occasionally in the management of early blight (Cercospora) and late blight (Septoria). It is applied when disease pressure is high (43). The median price of propiconazole is $95.83 per pound of active ingredient, and the average cost per application in 1994 was approximately $11 per acre (3,37). Propiconazole may be applied up to 14 days before harvest (PHI=14 days), and the restricted entry interval (REI) under the Worker Protection Standard is 24 hours.

Propiconazole was used during 2 of the 3 years in which usage data have been collected on celery in Florida. When used, 300 pounds of active ingredient have been applied statewide to a range of 26 to 27 percent of celery acreage. The average application rate has ranged from 0.14 to 0.17 pounds of active ingredient per acre, and the average number of applications has ranged from 1.1 to 1.5 (3-5).

- **BENOMYL** (Benlate). Benomyl is a systemic, benzimidazole fungicide used occasionally in Florida celery production for the management of early and late blight (50). The median price of benomyl is $31.00 per pound of active ingredient, and the average cost per application in 1992 was approximately $7.75 per acre (4,37). Benomyl may be applied up to 7 days before harvest (PHI=7 days), and the restricted entry interval (REI) under the Worker Protection Standard is 24 hours. Resistance of *Cercospora apii* to the benzimidazole class of fungicides has been seen in south Florida for a number of years, and strains resistant to benomyl and an alternative in the same class, thiophanate-methyl, are known to exist (44).

In 1992, benomyl was applied an average of 1.9 times to 31 percent of the state's celery acreage, at an average rate of 0.25 pounds of active ingredient per acre and total usage of 1,200 pounds of active ingredient (3-5).

**Use of Chemicals in IPM Programs:**
Disease forecasting systems for early blight are available in the Everglades production area (42). Growers scout their fields all spring for early and late blight and apply chemical controls only as needed (20).

**Cultural Control:**
There is no completely effective cultural management for bacterial blight, which is difficult to control once it gets into the seedbed (43). Damage from bacterial blight and brown stem may be reduced somewhat by planting seed at least one-year old, avoiding the application of foliar nitrogen and the over-fertilization of soil-applied nitrogen during conditions favorable to the bacteria, and avoiding worker and
farm equipment contact with wet plants (42). There are also resistant varieties available, but overall the choice of celery varieties is limited (20).

Planting only disease-free transplants can reduce the incidence of early blight. There are also celery varieties that are less susceptible to the disease, such as Early Belle and June Belle. Late blight can be avoided by using three-year old seed (42).

Pink rot is primarily managed by flooding the soil during the summer months, continuously or off and on during six weeks, which reduces the number of viable sclerotia available for infection. Seedbeds in which celery transplants are to be grown are also flooded before seeding, with the same effect. Additional cultural controls for pink rot include rotating with a non-susceptible crop such as sweet corn, and burying sclerotia and plant debris by turning the soil 6 to 8 inches (15 to 20 cm) deep (42,43,48).

Rhizoctonia stalk rot can be managed by following a series of steps, the majority of which aim to maximize seedling growth and health, thereby reducing the time that young plants are susceptible to the disease. These steps include using only healthy and disease-free seed and transplants, avoiding deep setting of transplants, planting when soil temperature allows for rapid germination, using crop rotation when possible, minimizing plant debris left on the soil surface during land preparation, controlling soil insects and nematodes that can weaken the plant, avoiding over seeding and transplanting too closely, and avoiding moving soil onto the stems during cultivation operations (42,47).

Isolation of celery fields, maintainence of a celery-free planting period every year, adequate management of aphid vectors, and elimination of weeds around seedbeds can help to reduce the incidence of celery mosaic. Since the main source of infection is within the celery crop, the most important management tactics are preventing the spread from one season to another and starting with healthy transplants. Cucumber mosaic, on the other hand, is usually spread from the dayflower weed host, and transmission to celery from aphid buildup on ditchbank weeds can be prevented by adequate ditchbank sanitation, particularly during aphid movements in the late fall and late spring (34,42,49).

**Nematodes**

Plant-parasitic nematodes are microscopic roundworms, found in soils, which primarily attack plant roots. General symptoms of nematode damage include stunting, premature wilting, leaf yellowing and related symptoms characteristic of nutrient deficiencies. Stunting and poor stand development tend to occur in patches throughout the field as a result of the irregular distribution of nematodes within the soil. Root-knot nematodes are the main nematode pest of celery on muck soils and are therefore the principal nematode celery pest in Florida. On sandy soils, where there is presently no celery production, the most important nematode pests are sting, root-knot, awl and stubby-root nematodes. Losses in Florida celery due to nematodes have been estimated at approximately ten percent (24,51,52).
ROOT-KNOT NEMATODES (*Meloidogyne* spp.)
Root-knot nematodes enter the host plant root as immatures and settle within to feed. At the feeding site, their secretions cause the surrounding plant cells to enlarge, producing the characteristic galls associated with root-knot attack. In addition to expending the plant's resources, the gall tissue is more susceptible to secondary infections such as root rots. Within the root, the female continues to feed, molting several times before developing into a swollen, pear-shaped adult. The adult may live in the host plant for several months, laying hundreds to several thousand eggs that are released into the soil. Low temperatures or very dry soil conditions can cause eggs to hatch more slowly (52,53).

STING NEMATODES (*Belonolaimus longicaudatus*)
Sting nematodes are ectoparasites, remaining outside the plant root and feeding superficially at or near the root tip. Damage from sting nematode feeding inhibits root elongation and causes roots to form tight mats and appear swollen, resulting in a "stubby root" or "coarse root" appearance. Under severe infestations, new root growth is killed in a way that resembles fertilizer salt burn. Sting nematodes are especially damaging to seedlings and transplants, although celery is able to recover from early damage better than some other crops (52-54).

STUBBY-ROOT NEMATODES (*Trichodorus* spp.)
Stubby-root nematodes also feed externally on the root surface and remain in the soil throughout their life cycle. The primary effect on roots from stubby-root nematode feeding is to stop root growth at the tip. Their feeding may also cause abnormal growth of lateral roots and increased production of branch roots. In combination with the cessation of root tip growth, the result can be a short, stubby root system with swollen root branches. In Florida, stubby-root nematodes are found mainly in sandy soils, but also occur in muck soils. The principal crops injured by this nematode in Florida include beets, corn, celery, cabbage, cauliflower, chayote and several grasses. Populations of stubby-root nematodes can build up quickly in the presence of a suitable host and can likewise decrease quickly when a host is no longer available (53,54).

AWL NEMATODES (*Dolichodorus* spp.)
Awl nematodes also feed superficially from the outside of the plant root, inhibiting root elongation. Awl nematodes are similar to the sting nematodes in appearance, habits, and the symptoms of injury on the plant resulting from their feeding. Awl nematodes have historically caused considerable damage to celery grown around Sanford, Florida (53,54).

Chemical Control:
Celery growers in Florida are currently using methyl bromide in the seedbed to control nematodes. Oxamyl (Vydate) and 1,3-dichloropropene (Telone II and Telone 17) are also available for use on celery in Florida. However, once celery is transplanted to the field, growers do not practice chemical nematode management (20,51).

Cultural Control:
The principal means of managing nematode populations in Florida celery is by flooding, before both the
seedbed and field production stages. During the hottest months of the year, fields that are out of production are surrounded by dikes and flooded, which kills nematodes by oxygen starvation. Between four and 12 weeks of flooded conditions are necessary, and alternating periods of flooded and drained conditions works best. Flooding, which is an effective alternative to the use of methyl bromide during transplant production in seedbeds, is the exclusive method of nematode management in production fields. Celery planted in the early fall on muck soils that have not been flooded may experience severe damage from nematodes. Flooding can only be practiced on the organic, muck soils of south Florida, and it is therefore not an option for celery growers in other parts of the state (20,51,55).

**Biological Control:**
Biological control of plant parasitic nematodes is in the research stage and is still years away from providing effective control for commercial vegetable production (52).

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**Weeds**

Weeds compete with the crop plant for moisture, nutrients, light and space and can interfere with harvest operations. Additionally, many weed species serve as alternate hosts for common celery pests such as leafminers, armyworms, loopers, and aphids, as well as plant pathogens and nematodes. Since weeds can also provide shelter and food for natural enemies of celery pests, weed management strategies should adequately address the positive and negative role of weeds in and around the celery field (24).

Adequate management of weeds in celery is particularly important early in crop growth. Weed competition during the first four weeks after transplanting may cause reductions in harvest quality grades of up to 40 percent (56). The most important weed pests in Florida celery production are yellow and purple nutsedge (*Cyperus esculentus* and *C. rotundus*), amaranth (*Amaranthus* spp.), purslane (*Portulacca oleracea*), and various grasses, particularly large crabgrass (*Digitaria sanguinalis*), goosegrass (*Eleusine indica*), and barnyardgrass (*Echinochloa crus-galli*). Spreading dayflower (*Commelina diffusa*), Florida pellitory (*Parietaria floridana*), lambsquarters (*Chenopodium album*), tall water hemp (*Acnida cannabinus*), yellowcress (*Rorippa* sp.), mock bishopweed (*Ptlimnium capillaceum*), common ragweed (*Ambrosia artemisiifolia*), eclipta (*Eclipta alba*), and cudweed (*Gnaphalium* spp.) can also be severe (20,24,57).

**NUTSEDGE** (*Cyperus* spp.)
Yellow nutsedge (*C. esculentus*) and purple nutsedge (*C. rotundus*) constitute the greatest weed problem in Florida celery. Both of these perennial sedges are found in disturbed habitats throughout Florida and the southeast U.S. Yellow nutsedge may produce some seed but reproduces primarily by rhizomes and tubers. The first plant develops rhizomes, which end in bulbs or tubers that produce new plants. Tuber production is favored by low nitrogen levels and high temperatures (27 to 33C, or 80 to 91F). It is tolerant of high soil moisture but is intolerant of shade. Purple nutsedge is also able to reproduce from...
tubers when conditions are harsh, making it difficult to control. Unlike the rhizomes of yellow nutsedge, purple nutsedge rhizomes growing off the first plant produce new plants in a series ("tuber-chains"). The plant also reproduces by seed to a limited degree. Although purple nutsedge is also intolerant of shade, it is able to survive a wide range of environmental conditions, growing well in nearly all soil types and over a range of soil moisture, soil pH, and elevation. It is also able to survive extremely high temperatures (58,59).

**AMARANTH** (*Amaranthus* spp.)
Amaranths (pigweeds) are broadleaf summer annuals with erect stems that can grow to 2 meters (6.5 feet) tall. Several species of amaranth may be present in Florida, but the most problematic in celery are spiny amaranth (*A. spinosus*), smooth pigweed (*A. hybridus*), and livid amaranth (*A. lividus*). Amaranths or pigweeds reproduce solely by seed, producing very small, dark seeds. Smooth pigweeds flower from July to November and spiny amaranth flowers from June to October. They prefer open areas with bright sunlight (59-61).

**PURSLANE** (*Portulaca oleracea*)
Purslane is a broadleaf summer annual with a taproot and multiple branched stems that often form large mats. It reproduces by seed, flowering from August to October. Being resistant to drought, it is difficult to kill (59,60).

**BARNYARD GRASS** (*Echinochloa crusgalli*)
Barnyard grass is a summer annual grass that can reach 2 to 4.5 feet (0.6 to 1.4 m) tall. The plant has shallow, fibrous roots, and roots at the lower nodes, sometimes forming large clumps. Barnyard grass reproduces only by seed (59).

**Chemical Control:**
The most commonly used herbicides on celery in Florida are prometryn (Caparol), sethoxydim (Poast), and thiobencarb (Bolero). Linuron (Lorox/Linex) and glyphosate (Roundup) are used occasionally. Bensulide (Prefar), pelargonic acid (Scythe), and trifluralin (Treflan/Trilin) are also available for use on celery in Florida, although bensulide and trifluralin are only used on mineral soils (3-5,15,61). A Special Local Need [24(c)] Registration has recently been granted for preemergence use of metolachlor (Dual Magnum Herbicide) in Florida-produced celery (62).

- **PROMETRYN** (Caparol). Florida celery growers most commonly use the selective triazine herbicide prometryn in the management of emerged annual grasses and broadleaf weeds. It is broadcast on celery seedbeds post-emergence of celery seedlings (when two to five true leaves are present) and is also applied in the field between two and six weeks after transplanting celery and before weeds have reached 2 inches (5 cm) in height (20,56). The projected approximate price of prometryn in Florida during 1999 is $9.14 per pound of active ingredient, and the average cost per application in 1994 was approximately $7.75 per acre (3,63). The restricted entry interval (REI) of prometryn under the Worker Protection Standard is 12 hours.
During the years in which usage data have been collected in Florida, prometryn has been applied to a range of 66 to 87 percent of the state's celery acreage. The average application rate has ranged from 0.36 to 0.92 pounds of active ingredient per treated acre, and the average number of applications per year has ranged from 1.0 to 1.8. Total annual usage has ranged from 4,500 to 7,300 pounds of active ingredient (3-5).

- **THIOBENCARB** (Bolero). Thiobencarb is also among the most commonly used herbicides in Florida celery production. It is used to manage emerging annual weeds, and celery growers in Florida use it principally for such annuals as purslane and barnyard grass. A single application of thiobencarb is made after transplanting celery, but before emergence of weeds. Thiobencarb is most effective if applied to moist soil and watered into the soil within 24 hours of application (15,20,56). The projected approximate price of this herbicide in Florida during 1999 is $6.23 per pound of active ingredient (63). Thiobencarb may be applied up to 70 days before harvest (PHI=70 days), but it is typically applied within ten days of transplanting (80 to 90 days before harvest). Current usage data are not available for thiobencarb.

- **SETHOXYDIM** (Poast). Sethoxydim is a selective cyclohexene post-emergence herbicide used in the management of annual and perennial grass weeds. The projected approximate price of sethoxydim in Florida during 1999 is $105.05 per pound of active ingredient, and the average cost per application in 1994 was approximately $27 per acre (3,63). Under a recent Special Local Need [24(c)] Registration recently granted for Florida celery, the preharvest interval of sethoxydim has been reduced from 30 days to 14 days in Florida-produced celery (62). The restricted entry interval (REI) of sethoxydim under the Worker Protection Standard is 12 hours.

During the years in which usage data have been collected, Florida celery growers applied sethoxydim at an average rate ranging from 0.16 to 0.26 pounds of active ingredient per treated acre at each application, with average annual number of applications ranging from 1.0 to 1.7. Percentage of acres receiving applications has ranged from 7 to 66, and total annual usage in the state has ranged from 200 to 1,300 pounds of active ingredient (3-5).

- **LINURON** (Lorox/Linex). Linuron is a substituted urea, post-emergence herbicide occasionally used for the management of annual and perennial broadleaf and grassy weeds. It is applied after celery is transplanted but before it is 8 inches in height. Linuron is not to be applied when temperatures exceed 85° (29°) (56). The projected approximate price of linuron in Florida during 1999 is $13.20 per pound of active ingredient, and the average cost per application in 1994 was approximately $11 per acre (3,63). The restricted entry interval (REI) of linuron under the Worker Protection Standard is 24 hours.

In 1994, celery growers applied linuron 1 time each to 14 percent of the state's celery acreage, at an average rate of 0.88 pounds of active ingredient per treated acre and total usage of 900 pounds of active ingredient (3-5).
• **GLYPHOSATE** (Roundup). Glyphosate is a broad-spectrum systemic phosphoric acid herbicide used occasionally in the management of annual and perennial grasses, sedges and broad-leaved weeds. Applications are made pre-plant, and no residual weed control is provided (56). The projected approximate price of glyphosate in Florida during 1999 is $12.56 per pound of active ingredient (63). Glyphosate may be applied up to 8 weeks before harvest (PHI= 8 weeks), and the restricted entry interval (REI) under the Worker Protection Standard is 12 hours.

In 1990, celery growers applied glyphosate an average of 1 time to 29 percent of the state's celery acreage, at an average rate of 0.81 pounds of active ingredient per treated acre and total usage of 2,100 pounds of active ingredient (3-5).

**Cultural Control:**
Weeds in celery can be effectively managed with cultivation. However, celery roots can be easily damaged by close cultivation, and the quality of the celery harvested may therefore be decreased if the roots are pruned during either mechanical cultivation or hand hoeing (56).

**Biological Control:**
Although presently there are no commercially available products for the management of weeds in celery, potential biocontrol agents have been identified in Florida for all of the major weeds in the crop. A patent has been secured for the fungus *Phomopsis amaranthicola*, which is being tested as a bioherbicide to control amaranth weeds. The fungus causes a leaf and stem blight on *Amaranthus* species plants. Another fungus, *Dactylaria higginsii*, is under investigation for its potential role in reducing the competitive ability of nutsedges, for use in an integrated management program. Finally, the fungus *Dichotomophthora portulacae* is being tested in tomato and pepper crops in Florida for its ability to manage common purslane (64).

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