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Florida Crop/Pest Management Profile: Cabbage[1]

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Production Facts

- As of 2003, Florida ranks fourth nationally in the production of fresh market cabbage, accounting for approximately eleven percent of U.S. cabbage production. The state ranks sixth in terms of harvested acres, accounting for approximately ten percent of national cabbage acreage. Florida ranks fourth in terms of cabbage yield and crop value. Florida's crop contributes eight percent to the total national value of fresh market cabbage (USDA/NASS, 2004).
- In 2001, cabbage was Florida's tenth ranking vegetable crop in terms of value and eighth in terms of acreage (FASS, 2003).
- In 2003, Florida growers planted 7,800 acres of fresh market cabbage and harvested 7,500 acres. Average yield was 32,000 pounds per acre, and total production was 243 million pounds. The value of Florida's cabbage crop in that year was $0.10 per pound, with a total value of $24.3 million. Total value of Florida's cabbage crop over the past decade has ranged from $17.2 million in 1994-95 to $42.3 million in 1992-93 (FASS, 2004; USDA/NASS, 2004).
- Florida's production of cabbage is exclusively for the fresh market. The higher quality cabbage obtained during the late fall, winter, and early spring months in Florida allows the state to ship fresh cabbage to areas of the U.S. that are unable to produce cabbage during that part of the year (Sargent,1999).
- Production costs have been estimated for cabbage in the Hastings area (northeast Florida). Total production costs during 1996-97 were estimated at $2,507 per acre. Of that total, $1,147 represented harvest and marketing costs, while pre-harvest operating costs totaled $1,359. Fungicide expenses totaled $30.96 per acre, while herbicides cost $26.75 per acre, insecticide costs were $113.52 per acre, and the cost of nematicides totaled $30.26 per acre. Growers also spent an average of $8 per acre on the use of boom sprayers. Total cost of pesticide applications excluding labor represented 15

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percent of pre-harvest operating costs and 8 percent of total production costs (Smith et al., 1999)

Production Regions

The Hastings area in northeast Florida (Flagler and St. Johns Counties) is the principal cabbage producing region in the state, representing 25 percent of the state's cabbage growers and 50 percent of the cabbage acreage. Manatee County, in west-central Florida, is another important cabbage producing county, accounting for 6 percent of the growers and 18 percent of the acreage. Remaining cabbage production is found throughout the state (USDA/NASS, 1998).

Production Practices

Cabbage is a cool season crop that grows at a temperature range of 32 to 77°F (0 to 25°C), with an optimum temperature range of 59 to 68°F (15 to 20°C). In Florida, the crop is grown on mineral, sand, and muck soils, although most production is on sandy soils. Although it can grow on a range of soil types, cabbage is sensitive to soil acidity, preferring a pH of 6.5. The disease club root can become a problem when cabbage is grown in soils with pH over 7.0 (Leibee, 1996).

Nearly all of the cabbage grown in Florida consists of hybrid varieties of green cabbage, with red varieties constituting less than one percent of production. Examples of green varieties grown in the state include Atlantis, Augusta, Bravo, Cheers, Emblem, Gideon, Gloria, Isalco, Rio Verde, Royal Vantage, and Solid Blue 790. Cardinal and Red Rookie are red varieties planted in Florida (Maynard et al., 2003).

Primary planting dates for cabbage in Florida may range from August to March. Planting in north Florida usually occurs between August and February, in central Florida between September and February, and in south Florida between September and January (FASS, 2003b; Maynard et al., 2003).

Seeds are planted at a distance of 20 to 40 inches (51 to 102 cm) between rows and 9 to 16 inches (23 to 41 cm) between plants, giving a plant population of 29,403 per acre at the closest spacing. When the crop is seeded in double rows in each bed, there are 15 to 24 inches (38 to 61 cm) between rows and 10 to 12 inches (25 to 30 cm) within rows centered on beds of 40 to 60 inches (102 to 152 cm). Seeds are planted at a depth of 0.25 to 0.5 inches (0.6 to 1.3 cm). Between 85 and 110 days are required from seed to maturity and between 70 and 90 days from transplanting to maturity, depending on the variety (Maynard et al., 2003).

Direct seeding of cabbage on sandy soils tends to lead to poor germination. In addition, broadleaf weed management is more difficult when the crop is direct-seeded. As a result, approximately 90 percent of Florida's cabbage crop is transplanted. Many transplants are grown outside in open beds. Bare-root plants are taken from beds in the field, or container-grown plugs are brought in from greenhouses. Growers in Florida have access to container-grown cabbage transplants throughout the year, and the use of container-grown rather than bare-root transplants has been on the rise. Most cabbage in Florida is planted using mechanical transplanters (Leibee, 1996).

The cabbage crop requires about one inch of water each week, and supplying water in even amounts throughout the season prevents cracking of the heads. Irrigation use during the winter months varies throughout the state. The crop in southern Florida may use 0.10 inches per day (2700 gallons/acre/day), while in north Florida the average may be 0.06 inches per day (1600 gallons/acre/day). In 1997, 86 percent of cabbage producing farms and 99 percent of the state's cabbage acreage was irrigated. Seepage-type irrigation is the most commonly used irrigation on Florida cabbage. Sub-surface irrigation is used on sandy soils with a high water table. Drip irrigation is also common, particularly on deeper sands (Maynard et al., 2003; USDA/NASS, 1998).

Cabbage uses high amounts of nitrogen and potassium. During the years in which usage data have been collected, 100 percent of cabbage acreage in Florida has received an average of 2.7 to 3.7 applications of nitrogen annually. An average range of 52 to 97 pounds of nitrogen per acre has been used at each application, with a statewide annual total ranging from 1,481,000 to 2,984,000 pounds. An average range of 30 to 52 pounds per acre of phosphate has been applied an average of 1.7 to 2.6 times annually to between 98 and 100 percent of the state's cabbage acreage, with total annual usage ranging from 592,000 to 1,276,000 pounds. Potash has also been applied an average of 2.1 to 2.8 times per year to 100 percent of Florida s cabbage acreage. An average range of 73 to 126 pounds of potash per acre has been used at each application, and a total of 1,561,000 to 2,948,000 pounds has been used annually (USDA/NASS, 1991; USDA/NASS, 1993; USDA/NASS, 1995; USDA/NASS, 1997; USDA/NASS, 1999).

Cabbage in Florida is usually harvested between October 25 and June 15, with the most active harvest period between January 1 and April 15 (FASS, 2004). Grading is often done in the field. Usually, about three or four of the green wrapper leaves are left on each head at harvest unless they are damaged by worms. The wrapper leaves help to protect the head during harvest and shipment (Sargent, 1999).

Since ninety percent of Florida cabbage growers set transplants, there are no thinning activities. Workers either stock the transplanting machine or set transplants by hand. A transplanting crew can set approximately eight acres per day. Larger contract growers purchase hybrid seed which assures all cabbage is of equal size when the one picking occurs. Truck farmers generally pick two or three times. There is no mechanical harvest. A group of approximately 10 people work with one wagon and hand harvest the cabbage. This group can cover between four and seven acres per day, and generally work bare-handed (Leibee, 2004; Stall, 2004).

Most often, cabbage is packed into crates or cartons directly in the field, without washing. Only occasionally it is put into bags and then onto pallets. Cabbage in Florida is shipped under refrigeration, but it is usually not rapidly pre-cooled. Some cabbage is forced-air cooled, usually on a leased trailer. In this case, the boxed cabbage is put directly from the field into the trailer for one to two hours to be cooled and then loaded onto another refrigerated trailer for distribution. However, the price of cabbage sometimes drops so low that it becomes uneconomical to cool the crop before shipment (Sargent, 1999). Nearly all of Florida's out-of-state cabbage shipments go the markets in the eastern portion of the U.S.

Since cabbage is easily bruised, care must be taken in handling during harvest and shipment. Pre-cooling cabbage helps to minimize damage, as do harvesting during the cooler part of the day and avoiding rough handling. Exposure to very small quantities of ethylene can also produce damage in cabbage, particularly yellowing and shedding of outer leaves. Cabbage should therefore not be stored together with ethylene-producing fruits and vegetables. Fresh cabbage has a maximum storage life of three to six weeks when kept at about 32°F (0°C) with 90 to 95 percent relative humidity (Sargent, 1999).

Insect/Mite Management

Insect/Mite Pests

Insects constitute the principal pest group on cabbage in Florida. The greatest insect problem for growers in the state is the diamondback moth (*Plutella xylostella*). Cabbage looper (*Trichoplusia ni*) is also considered a major pest, although it has been less of a problem over the past decade. Insect pests that have been considered major in the past and are only occasionally a problem now include aphids, beet armyworm (*Spodoptera exigua*), cabbage webworm (*Hellula rogatalis*), imported cabbageworm (*Artogeia rapae*), cutworms, and mole crickets. All of the minor pests on cabbage in Florida have the potential to become major pests, since they are currently being controlled by treatments for diamondback moth. Silverleaf whitefly (*Bemesia argentifolii*) and vegetable leafminer (*Liriomyza trifolii*) are more significant in southern Florida, where they are considered major and minor pests, respectively (Hayslip et al., 1953; Webb, 2003).

Additional insect pests that may occasionally cause minor damage to cabbage in Florida include southern armyworm (*Spodoptera eridania*), yellow-striped armyworm (*Spodoptera ornithogalli*), fall armyworm (*Spodoptera frugiperda*), blister beetles (*Epicauta* spp. and Macrobasis unicolor), cabbage budworm (Hellula *phidilealis)*, corn earworm (*Helicoverpa zea*), cross-striped cabbageworm (*Evergestis rimosalis*), flea beetles (*Phyllotreta* spp.), grasshoppers, gulf white butterfly (*Ascia monuste*), harlequin bug (*Murgantia histrionica*), horned squash bug (*Anasa armigera*), onion thrips (*Thrips tabaci*), saltmarsh caterpillar (*Estigmene acrea*), southern cabbageworm (*Pontia protodice*), southern green stinkbug (*Nezara viridula*), spotted cucumber beetle (*Diabrotica undecimpunctata howardi*), tarnished plant bug (*Lygus lineolaris*), vegetable weevil (*Listroderes costirostris obliquus*), and yellow-margined leaf beetle (*Microtheca ochroloma*) (Leibee, 1996; Webb, 2003).

Diamondback Moth (*Plutella xylostella*). Diamondback moth became the principal pest on cabbage in Florida in the 1980s, and it remains one of the most serious problems for the state's cabbage growers, occurring annually (Leibee, 1996; Webb, 2003). Plants at all stages of growth may be attacked. The moth lays its eggs on the lower surface of leaves in groups of two to three. In approximately one day the eggs hatch, and the larvae begin to feed on the leaves. Feeding results in many small holes that grow larger as the larvae increase in size. Often, feeding does not go through the entire leaf, leaving a thin layer of the leaf epidermis. In addition to the leaves, diamondback moth larvae can attack the developing cabbage heads, producing shallow tunnels on the tops of the heads. The resulting damage deforms the heads and leaves entry points for decay pathogens (Hayslip et al., 1953).

The larval stage can range from ten days to a month, depending on temperature. Diamondback moth larvae slow their feeding at temperatures below 50°F (10°C), and population growth is most rapid at temperatures greater than 80°F (26.7°C). The pupal stage is passed within a transparent, loose cocoon, which is usually attached to the underside of leaves. Within about one to two weeks of entering the pupal stage, the moths emerge (Hayslip et al., 1953).

In southern Florida, diamondback moth is most abundant from December to February or March and can attack at any time during the crop cycle. By the end of May, moth counts in pheromone traps fall to near zero. Moth counts may rise in mid-fall through early winter, but activity is limited during that time. Populations build on winter weeds, such as wild mustard, before moving into winter and early spring cabbage plantings. From mid-winter through the spring, when it is a serious pest, diamondback moth may cause losses of up to 70 percent in the absence of control (Nuessly et al., 1999).

Cabbage Looper (*Trichoplusia ni*). Cabbage looper is also one of the most important annual pests for Florida cabbage growers. It is less of a problem in southern Florida, where it is considered a minor pest. In that part of the state, pheromone trap data show that adult populations tend to be highest during the late spring and summer months, and in some years in the late fall (Nuessly et al., 1999). Cabbage looper does not enter diapause and cannot survive prolonged cold weather. The insect remains active and reproduces throughout the winter months only in the southern part of Florida (south of Orlando) (Capinera, 1999a). In central Florida, cabbage looper populations peak during early fall and again during late spring (Leibee, 1996). In general, cabbage looper is more of a problem on Florida cabbage during the fall than during the winter or spring months.

Cabbage looper larvae damage plants by chewing holes in leaves. Smaller larvae remain on the lower leaf surface, while larger larvae produce larger holes throughout the leaf. In addition to feeding on the wrapper leaves, cabbage loopers may bore into the developing head. Some defoliation can be tolerated before head formation, but feeding damage and excrement left behind on heads make cabbage unmarketable. Cabbage with damage confined to wrapper leaves is marketable but with reduced value. Control has been shown to be justified in Texas when population densities reach 0.3 larvae per plant (Capinera, 1999a). In Florida, an action threshold of 0.1 medium to large cabbage looper larvae per plant was developed for cabbage (Hayslip et al., 1953; Leibee, 1996).

Eggs are deposited singly or in small clusters on either leaf surface, although more are found on the lower leaf surface. Each female moth can produce 300 to 600 eggs during the approximately 10 to 12 days it is alive. After the eggs hatch, additional larvae move to the lower leaf surface to feed. Two to four weeks after hatching, the mature larva forms a thin cocoon on the lower leaf surface, or in plant debris or soil. The pupal stage lasts approximately two weeks. Total time required for development from egg to adult can be as little as 18 days at 21°C (69.8°F) and 25 days at 32°C (89.6°F) (Hayslip et al., 1953; Leibee, 1996; Capinera 1999a).

Aphids [turnip aphid (*Hyadaphis erysimi*), green peach aphid (*Myzus persicae*), cabbage aphid (*Brevicoryne brassicae*)]. Turnip aphid and green peach aphid are the most important aphids on cabbage in Florida. Green peach aphid is a vector of turnip mosaic virus in Florida (Webb, 2003).

Although cabbage aphid may attack the crop at any stage, green peach aphid attacks cabbage mainly before heading begins. Aphids suck plant juices with their piercing-sucking mouthparts, resulting in yellowing and curling of the leaves. The plant, particularly when attacked as a seedling, may be stunted or die as a result of aphid feeding. Aphids can be protected from insecticide sprays within the curled leaves or inside the cupped leaves of headed plants (Hayslip et al., 1953).

Beet Armyworm (*Spodoptera exigua*). Beet armyworm is a sporadic pest on Florida cabbage, and it is usually kept under damaging levels by controls targeted to diamondback moth. Beet armyworm populations in southern Florida are highest from late March through mid-June, with a smaller population rise from mid-August through October. Population rise in the late summer and fall is thought to be related to beet armyworm activity on late summer weeds, while the population increase in the spring coincides with the leafy vegetable production season in southern Florida (Nuessly et al., 1999).

The beet armyworm has a wide host range, and in addition to cabbage it attacks such vegetables as asparagus, bean, beet, broccoli, cauliflower, celery, chickpea, corn, cowpea, eggplant, lettuce, onion, pea, pepper, potato, radish, spinach, sweet potato, tomato, and turnip, and such field crops as alfalfa, corn, cotton, peanut, safflower, sorghum, soybean, and tobacco. Many weeds also serve as hosts, including lambsquarters (*Chenopodium album*), pigweeds (*Amaranthus* spp.), purslane (*Portulaca* sp.), parthenium (*Parthenium* sp.), and mullein (*Verbascum* sp.). Larvae feed on both foliage and fruit of host plants. On cabbage, beet armyworm larvae consume greater amounts of leaf tissue than the diamondback moth but not as much as the cabbage looper. An action threshold of 0.3 beet armyworm larvae per plant has been used for cabbage in Texas. Since adults can readily invade a field from nearby crops or weeds, monitoring the crop twice a week for beet armyworm presence and damage is recommended (Capinera 1999b).

The insect is active during the entire year in southern Florida, from which it migrates annually into north Florida and the southeastern U.S. (Nuessly et al. 1999). Females can lay up to 600 eggs each, usually in groups of about 100. Eggs are laid on the underside of lower leaves and are covered with fuzzy, white scales. Under warm conditions, eggs hatch within two to three days. The larvae feed from one to three weeks, in groups when younger and scattered on the plant when larger. When full-grown, larvae pupate in the soil, within a cocoon constructed from sand and bits of soil. Within about a week in warm temperatures, the adult emerges (Sorenson et al., 1983; Capinera, 1999b).

Cabbage Webworm (*Hellula rogatalis*). Like beet armyworm, cabbage webworm is seen sporadically and is controlled by treatments for diamondback moth. It is more of a problem in southern Florida. The pest can attack cabbage both in seedbeds and in the field (Hayslip et al., 1953).

Cabbage webworm eggs are usually laid in the buds of the plant. Upon hatching, the larvae feed on the underside of the leaves in the bud area, producing small holes. The larvae cover themselves with webs, which become covered with dirt and excrement. Larger larvae can burrow into buds, stems, and leaves. The insect may feed on the growing point, which prevents head formation, and the plant may appear lopsided. When fully grown, larvae pupate in the buds, on the sides of stems, or on the surface of the soil (Hayslip et al., 1953).

Imported Cabbageworm (*Artogeia rapae*). Another minor pest, imported cabbageworm produces large holes in leaves and may attack the head near maturity, leaving damage similar to that of diamondback moth (Workman, 1983). Feeding by imported cabbageworm results in large, irregular holes in the leaves and the outer layers of the head (Hayslip et al., 1953).

Female moths can lay several hundred eggs each within a cabbage field, attaching them to the underside of leaves. The egg stage lasts about one week, and the emerging caterpillars feed on the underside of the leaves. After about two weeks, the larvae attach themselves with silk to a support and pupate. The moths emerge in about one to two weeks (Hayslip et al., 1953).

Cutworms black cutworm (*Agrotis ipsilon*) and granulate cutworm (Feltia subterranea). Cutworms are stout, gray caterpillars with a greasy appearance. They are active at night, feeding on the stems and leaves of cabbage and other plants. During the day, they take refuge in the soil at the base of the plants. Recently transplanted cabbage is particularly susceptible to attack by cutworms, which can cut thin-stemmed plants off at or slightly below the soil surface. They can also cut out large holes from leaves touching the soil surface (Hayslip et al., 1953). Several plants in a row are usually affected, and the cutworm often pulls into a protected area of the soil the end of the leaf on which it is feeding (Workman, 1983). Cutworms can also eat into heading cabbage and may remain within the head during the day. Overall, while some damage to leaves and heads occurs, greatest losses from cutworm damage are the result of reduced stands (Hayslip et al., 1953).

The black cutworm is one of the most destructive of the cutworms and attacks a wide range of plants. Although cutworm larvae can migrate into a field from adjacent areas, most migration occurs by adults flying into the field. The moth deposits eggs in groups of one to 30 on leaves or stems near ground level. The egg stage lasts from 5 to 15 days, the larval stage lasts from three to four weeks, and the pupal stage takes 12 to 36 days. At high temperatures, when development is more rapid, the life cycle can be completed in six or seven weeks. The life cycle of the granulate cutworm is similar to that of the black cutworm (Hayslip et al., 1953).

Mole Crickets (*Scapteriscus* spp. and *Neocurtilla hexadactyla*). Mole crickets are a problem in cabbage seedbeds, where they produce raised tunnels on the soil surface. Although they do not feed on the plant, their tunneling may cause cabbage seedlings to fall over (Workman, 1983). Their enlarged front legs are adapted for burrowing, and they can also damage newly-transplanted cabbage plants by burrowing around them, resulting in drying out of the soil and roots. Mole crickets spend their entire life cycle in the soil and are nocturnal, becoming active at night and remaining in their tunnels during the day. Greatest damage occurs during warm, moist weather (Hayslip et al., 1953).

Silverleaf Whitefly (*Bemisia argentifolii*). Silverleaf whitefly, previously known as strain B of the sweetpotato whitefly, is a common pest on cabbage in southern Florida. However, it does not severely damage the crop. Under heavy infestations, when the outer leaves become covered with whiteflies, the leaves are removed at harvest.

Adult females produce an average of 160 eggs each, depositing them on the lower surface of host plant leaves. The first nymphal (immature) stage, the crawler stage, attaches itself to the leaf near the empty egg case. The whitefly passes through three more sedentary nymphal stages, appearing like transparent scales, before molting to the adult stage. Whiteflies feed by sucking the plant's sap through their needle-like, piercing-sucking mouthparts. Like aphids, they extract large amounts of the plant's sap (phloem), excreting the excess liquid as honeydew, upon which sooty mold can grow (Johnson et al., 1996; Norman et al., n.d.).

With a host range of over 500 species of plants, the silverleaf whitefly has been observed to reproduce on at least 15 crops and 20 weed species in Florida. Whitefly populations commonly peak on the state s crops at the time of harvest, as the whitefly migrates from crop to crop throughout the year. In southern Florida, populations build on fall vegetables and move directly to overlapping spring crops. In west-central Florida, numbers of whitefly adults trapped in cabbage fields have been found to be highest from November until April or May. Cabbage is thought to serve as a winter reservoir for whiteflies colonizing spring plantings of tomatoes and other vegetable crops in the southwest region of the state. Over the summer fallow period, whitefly populations are low, because during that time whiteflies are limited to weeds, such as water primrose, hairy indigo, and spurge. Weeds are poor hosts to the whitefly and usually harbor many natural enemies that reduce populations further during that time (Schuster et al., 1992; Stansly, 1995; Norman et al. n.d.).

Chemical Control

In 2002, Florida growers applied insecticides totaling 6,100 pounds of active ingredient to 100 percent of the state s cabbage acreage. During the years in which usage data have been collected, between 95 and 100 percent of cabbage acreage has been treated with insecticides each year, with total annual usage ranging from 6,100 to 55,200 pounds of active ingredient. The most commonly used insecticides on Florida cabbage are *Bacillus thuringiensis* (B.t.) and spinosad. In fact, B.t. was the only insecticide with published use values for Florida cabbage in 2002. Other chemicals used in Florida for cabbage in 2002 were: bifenthrin, carbaryl, chlorpyrifos, dimethoate, emamectin benzoate, endosulfan, esfenvalerate, fenamiphos, imidacloprid, indoxacarb, lambda-cyhalothrin, malathion, methomyl, permethrin, thiodicarb, tebufenozide, and dried frementation solubles of Myrothecium verrucaria. Other insecticidal materials registered for use in Florida cabbage as of 2003 were: azadirachtin, azinphos-methyl, Beauveria bassiana, cryolite, cypermethrin (beta or zeta), diazinon, disulfoton, ethoprop, fenpropathrin, insecticidal soaps, insecticidal oils, methoxyfenozide, methyl parathion, naled, oxydemeton-methyl, polyhedrosis viruses for corn earworm and beet armyworm, pymetrozine, pyrethrins, rotenone, and sulfur.

Bacillus thuringiensis. The biopesticide Bacillus thuringiensis (B.t.) is the most important insect management tool for Florida cabbage growers, who use it every year in the management of diamondback moth and other lepidopteran larvae. B.t. is a naturally occurring soil bacterium that produces spores and crystalline bodies that act as stomach poison to the insects that consume it. The most common formulations are highly specific for lepidopterous larvae (caterpillars) and therefore do not harm beneficial organisms. However, it is most effective against smaller larvae. The median price of B.t. is $160.00 per pound of active ingredient (Helena, 2003). B.t. may be applied up to the day of harvest (PHI=0 days), and the restricted entry interval (REI) under the Worker Protection Standard is 4 hours.

In 2002, Florida growers applied B.t. to 88 percent of their cabbage acreage, an average of 4.3 times. During the years in which usage data have been collected, cabbage growers in Florida have applied B.t. to between 76 and 96 percent of their cabbage acreage, making an average of 4.3 to 7.6 applications per year. Information on average rate and total pounds of active ingredient applied is not available, because amounts of active ingredient are not comparable among products (USDA/NASS, 1991; USDA/NASS, 1993; USDA/NASS, 1995; USDA/NASS, 1997; USDA/NASS, 1999, USDA/NASS 2001; USDA/NASS 2003).

Spinosad. Spinosad is a reduced risk broad-spectrum insecticide derived from fermentation of the naturally occurring soil bacterium Saccharpolyspora spinosa. Since its registration it has become one of the most important insecticides for Florida cabbage growers (Eger et al., 1998). It controls many lepidopterous larvae, dipteran leafminers, and thrips. It is used by Florida cabbage growers primarily in the management of diamondback moth and cabbage looper but also controls imported cabbageworm and armyworms. Spinosad has low activity against most beneficial insects and is therefore useful in IPM programs. Spinosad may be applied up to 1 day before harvest (PHI=1 day), and the restricted entry interval (REI) under the Worker Protection Standard is 4 hours. For purposes of resistance management, a maximum of six diamondback moth treatments may be made per year (since this is a lower rate than the maximum of 0.16 lb ai/A). Additionally, no more than three consecutive treatments may be made within a period of 30 days, followed by a 30 day period free of spinosad. The maximum amount that can be used per crop is 0.45 lb ai/A. The median price of spinosad is $262.50 per pound of active ingredient, and the approximate cost per maximum labeled application (0.16 lb ai/A) is $42.00 per acre (Helena, 2003).

Spinosad use was not published for 2002. In 2000, Florida growers applied an average of 0.06 pounds of active ingredient per acre at each application to 58 percent of their cabbage acreage, an average of 2.0 times. Total usage was 600 pounds of active ingredient. (USDA/NASS, 2001; USDA/NASS, 2003).

Chemical Alternatives

Emamectin benzoate 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 cabbage, showing a high level of efficacy against diamondback moth and cabbage looper larvae. It also controls beet armyworm, cabbage webworm, imported cabbageworm, and fall armyworm. Once ingested by the caterpillar, it paralyzes the pest, which rapidly ceases to eat, and death results within four days. 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 (Eckel et al., 1996; Jansson et al., 1997).

Other new active ingredients registered for use in cabbage include pymetrozine and methoxyfenozide. Pymetrozine has novel selective antifeeding activity on homopteran insects such as aphids and whiteflies. Methoxfenozide joins the other diacylhydrazine insecticide tebufenozide as selective compounds which interfere with the molting process of lepidopteran larvae, especially looper. These selective materials, such as emamectin benzoate and tebufenozide, are being employed in Florida cabbage production. They complement products with similar selectivities to provide alternate rotational chemistries.

Use of Insecticides in IPM Programs

Action thresholds for caterpillar pests of cabbage were developed in Florida and Georgia during the 1970s and 1980s to reduce the number of insecticide sprays on cabbage. Until then, growers had been spraying based on a fixed schedule of once or twice weekly. Early thresholds, based on the number of larvae present, were shown to greatly reduce insecticide sprays and still produce marketable cabbage. Several thresholds based on visual damage ratings and percent of plants with new damage were developed and found to be as effective as counts of larvae, which are more time consuming. However, thresholds based on new damage tended to result in more insecticide applications. All thresholds were shown to be less effective when an atypical pest was present or a particular pest was present in very high numbers (Leibee et al., 1984; Leibee, 1996).

An IPM program for management of diamondback moth in cabbage has been under development in Florida for several years. The program consists of a combination of strategies, including the use of B.t. insecticides, biological control (parasitoid releases), trap crops, and pheromone treatments for mating disruption (Hu et al., 1998).

Use of Insecticides in Resistance Management Programs

Insecticide resistance in the control of cabbage insects in Florida has been a problem for more than 40 years. Diamondback moth is an agricultural pest that has demonstrated the ability to quickly become resistance to insecticides. From the 1940s through the 1970s, growers applied DDT, toxaphene, parathion, methoxychlor, mevinphos, endosulfan, naled, methomyl, and methamidophos to cabbage for control of the complex of cabbage caterpillars. Cabbage looper resistance to DDT, parathion, and toxaphene was documented in 1957, and populations resistant to methomyl were found in the early 1980s. When the pyrethroids became available in the early 1980s, growers switched to permethrin and fenvalerate to control cabbage looper and diamondback moth, which had become more difficult to control with the earlier insecticides. Permethrin and fenvalerate effectively controlled those pests until resistance began to be seen in the mid-1980's. Within a few years, growers were experiencing difficulty in controlling diamondback moth with those insecticides. Populations of diamondback moth taken from central Florida in 1987 were found to be resistant to fenvalerate and methomyl but susceptible to chlorpyrifos, acephate, endosulfan, and thiodicarb. By the early 1990s, thiodicarb had also become less effective (Leibee et al., 1992a; Leibee et al., 1992b; Leibee et al., 1995; Leibee, 1996).

After pyrethroids and carbamates became less effective during the late 1980s, growers again modified their insecticide usage, this time switching to several organophosphates, endosulfan, and Bacillus thuringiensis kurstaki. None of these was completely effective, and resistance to B.t. kurstaki was confirmed in Florida in the early 1990s. Growers then switched to the newly introduced Bacillus thuringiensis aizawai-based insecticides, which offered a greater degree of control of diamondback moth. In addition, reductions in use of pyrethroids has resulted in greater natural control due to the return of parasites. Diamondback moth populations also appeared to develop greater susceptibility to B.t. kurstaki, which growers were able to begin using again. However, resistance has apparently been developing to B.t. aizawai (Leibee et al., 1995; Leibee 1996).

Resistance in diamondback moth populations in Florida has been attributed largely to the frequent use over time of single insecticides or classes of insecticides, as well as to the nearly continuous production of cabbage in isolated areas. During the 1980s, cabbage producers in Florida began to harvest later in the spring and transplant earlier in the summer, reducing the previous crucifer-free period that had existed between June and September. At the same time, container grown transplants began to be produced during the summer months, giving diamondback moth continuous access to crucifers. The principal transplant producers have operated in the main field production areas, allowing easy movement of insect pests from fields to transplant houses at the end of the spring season and back to production fields at the start of the fall season. The development of insecticide resistance, coupled with the loss of natural enemies as a consequence of insecticide treatments for cabbage looper control, contributed to an increase in diamondback moth populations in Florida during the 1980's, at which time it became a major pest on cabbage. Intensive use of insecticides during the 1980's, coupled with the increasing use of infested transplants and resulting greater insect pest problems, are thought to have contributed to the high degree of insecticide resistance found among cabbage pests in Florida (Leibee et al., 1995; Leibee 1996).

A number of recommendations were made several years ago to limit the development of greater resistance problems in diamondback moth in Florida. Those included: 1) avoiding the production of cabbage during the warmest months, when B.t.-based insecticides are least effective and insect problems are greatest; 2) destruction of crop residues to avoid pest movement into new plantings; 3) using pest-free transplants; 4) inspecting the crop frequently, beginning at the seedling stage, and using action thresholds to minimize insecticide applications; 5) using pheromone traps to monitor adult activity and time insecticide applications; 6) using B.t. kurstaki and B.t. aizawai as the main insecticides to control diamondback moth, with rotations of the two to reduce resistance selection; and 7) avoiding the use of carbamates and eliminating the use of pyrethroids (Leibee et al., 1995).

Cultural Control

Mating disruption with sex pheromones has been shown to be effective in reducing diamondback moth and cabbage looper populations in Florida cabbage. In field trials in northeast Florida, treatment of cabbage fields with sex pheromones controlled diamondback moth populations for most of the cabbage season, minimizing the need for pesticide sprays. Although the effect of pheromone treatment on larval counts of cabbage looper was not evaluated because cabbage looper larvae were not present in sufficiently high numbers, mating suppression was confirmed. The use of pheromones is considered a promising management tactic should cabbage looper populations increase considerably (Mitchell et al., 1997a).

The use of a trap crop, a plant more attractive to the insect pest that lures it from the more valuable crop, has also been investigated in Florida for management of diamondback moth in cabbage. In preliminary studies, collard plants, when planted between rows of cabbage, were shown to have potential as a trap crop for diamondback moth. Collards also play an important role in maintaining populations of the natural enemy Diadegma insulare (Mitchell et al., 1997b). Planting collards around the perimeters of cabbage fields has been shown more recently in northeast Florida to reduce pesticide sprays for diamondback moth on cabbage by 75 to 100 percent over cabbage fields treated with conventional insecticides, producing equivalent quantity and quality of cabbage (Weaver, 1999).

Another cultural control for cabbage looper moths is the use of row covers, which can prevent cabbage looper moths from laying their eggs on the plants. However, the use of row covers is not always economically feasible (Capinera, 1999a). Cutworm damage can be reduced by plowing under weeds at least one month prior to planting (Hayslip et al., 1953).

Biological Control

Cabbage growers in Florida depend upon the microbial insecticide Bacillus thuringiensis for management of diamondback moth and cabbage looper, among other caterpillar pests. Several other natural control agents are effective in reducing pest population densities in cabbage. A nuclear polyhedrosis virus (NPV) can naturally reduce populations of cabbage looper in some years. Larvae consuming the virus inclusion bodies usually die within five to seven days, after becoming blotchy, then creamy white and swollen, and eventually limp. The virus is spread from the disintegrated bodies of infected larvae, a process aided by rainfall. Cabbage looper mortality from NPV therefore tends to be greater during years of greater rainfall. Although shown to be effective, the Trichoplusia ni NPV has a narrow host range, and consequently it has not been commercialized (Capinera 1999a). Another nuclear polyhedrosis virus that is highly specific to beet armyworm is considered to be the most important natural mortality factor for beet armyworm larvae (Capinera 1999b). A polyhedrosis virus is commercially available for corn earworm as well.

Other natural mortality agents of cabbage looper include tachinid parasitoids such as Voria ruralis, which attacks medium or large larvae, wasp parasitoids such as Trichogramma spp., which parasitize looper eggs, and predators such as the earwig Labidura riparia, which has been observed feeding on cabbage looper larvae and pupae in Florida crucifer fields. Bird predation of cabbage looper has also been observed in fields in Florida. Mass release of Trichogramma spp. has been studied in several crops and found to be effective in crucifers, but it has not been used by Florida cabbage growers (Leibee, 1996; Capinera, 1999a).

The parasitic wasp Cotesia plutellae was imported and released in Florida in 1990, and since then it has been released into cabbage fields in the state sporadically, but it has not been shown to be established. Effects on diamondback moth populations of inundative releases of C. plutellae have been evaluated in cabbage fields in northeast Florida. While the release rates used in the latest study (about 3,082 per hectare over the season) were not considered to provide sufficient economic control of the pest, such releases in combination with other IPM tactics (trap crops, pheromones for mating disruption, and use of B.t. insecticides) may prove effective. Parasitism by C. plutellae was also shown to be complementary to the natural parasitism occurring from the native Diadegma insulare (Leibee, 1996; Mitchell et al., 1997c; Mitchell et al., 1999).

Diamondback moth populations in Florida have also been observed to suffer a high parasitism rate by Trichogramma sp. and to be affected by several pathogens, including Zoophthora spp. (Leibee, 1996). Additional natural enemies of cabbage pests reported in Florida include the parasites Meteorus vulgaris, a braconid wasp that has been found attacking granulate cutworm and fall armyworm in the Everglades area, the encyrtid wasp Copidosoma truncatellum, a parasite of the cabbage looper, the ichneumonid wasp Horogenes insularis, which attacks diamondback moth and cabbage looper, the braconid wasp Diatretus rapae, which parasitizes cabbage and turnip aphids, and the tachinid flies Archytas piliventris and Eucelatoria rubentis, which attack armyworms and cutworms. Predators of cabbage insects reported in Florida include the pentatomid bugs Podisus maculiventris and Podisus mucronatus, which feed on cabbage loopers and imported cabbageworms, and the reduviid bug Zelus bilobus, which also attacks cabbage loopers and imported cabbageworms. Other predaceous bugs include the pentatomids Stiretrus anchorago and Euthyrhynchus floridanus, and the reduviids Arilus cristatus and Sinea diadema. In addition, ground beetles of the genus Calosoma have played a role in biological control of cabbage pests. The native species C. scrutator and C. sayi frequently feed on cutworms and armyworms. Finally, the ladybird beetles Cycloneda sanguinea immaculata, Hippodamia convergens, Ceratomegilla fuscilabris floridanus, Scymnus collaris, Scymnus terminatus, Exochomus marginipennis, Psyllobora sp., and Coccinella novemnotata are all aphid feeders found in Florida (Hayslip et al., 1953).

Disease Management

Disease Pathogens

Diseases are less of a problem than insect pests for cabbage growers in Florida, and most of the diseases affecting cabbage are sporadic. Nevertheless, in most years cabbage growers must contend with the presence of at least one major disease. The most significant diseases on cabbage in Florida are black rot (caused by *Xanthomonas campestris*), sclerotinose (caused by *Sclerotinia sclerotiorum*), downy mildew (caused by *Peronospora parasitica*), and Alternaria leaf spot (caused by *Alternaria* spp.). Other diseases that occasionally affect cabbage in Florida include bacterial leaf spot (caused by *Pseudomonas cichorii*), damping-off (caused by *Fusarium* and *Pythium* spp.), turnip mosaic (caused by turnip mosaic virus), wirestem (caused by *Rhizoctonia solani*), and yellows (caused by F*usarium oxysporum f. conglutinans*). White rust of foliage (caused by *Albugo candida)* and powdery mildew (caused by *Erisyphe polygoni*) are minor diseases on cabbage in Florida. A condition, characterized by tiny black specks on the foliage the week after harvest, has an unknown origin. Finally, brown heart, caused by boron deficiency, and tipburn, caused by potassium deficiency, are additional minor problems (Kucharek, 2004).

Black Rot (caused by *Xanthomonas campestris pv campestris*). Black rot is also called black spot or black leg. It is the most serious disease of cabbage in Florida and is most common when cabbage transplants are grown outdoors. It can occur at any time of the year, and it is difficult to control once it gets into a field. Resulting losses of up to ten percent are seen annually. In addition to cabbage, black rot attacks other cole crops, including broccoli, cauliflower, kale, kohlrabi, Brussels sprouts, rutabaga, turnip, collards, radish, mustard, and water cress. It also attacks cruciferous weeds such as wild radish, pepper grass, and shepherds purse (Kucharek et al., 2000a)

The bacteria causing black rot enter through injuries or natural openings on the leaves. Mechanical injury during transplanting, particularly that resulting in wounds on the root system, is an ideal entry mechanism for the pathogen. Cracks in the tissue of older roots also offer an entry point, particularly when the soil is saturated with water. Injury from insect feeding is a minor source of entry. A more virulent strain of the bacteria, which is present in Florida, is more likely to enter plants through stomatal openings in the leaves (Kucharek et al., 2000a).

Symptoms may not appear on leaves until up to 43 days after infection. Early symptoms of black rot include stunting, yellowing of the leaves, and blackening of the veins. A yellow, “V” shaped area may be produced at the ends of leaves. As the bacteria move down the leaf veins and into the plant s vascular system, the disease becomes systemic, as bacteria move within the vascular system to healthy leaves. Both leaf veins and vascular tissue become darkened, and leaves wilt and necrose. Plants are later dwarfed and produce one-sided heads (Kucharek et al., 2000a).

Plants at any growth stage can be infected by black rot. The disease is seed-borne, and plants from infected seeds die quickly after germination. When young seedlings are infected, the plants do not produce heads, and heads from plants infected later will deteriorate after harvest. In addition to being spread on seeds, the bacteria are spread by rain, irrigation, and any movement on water in the field. The disease is most severe under warm and wet conditions. The bacteria, which can survive in undecomposed debris of crucifer plants, can grow at temperatures ranging from 40 to 97°F (4 to 36°C), although optimum temperature for its growth is between 80 and 86°F (27 to 30°C). After plants are infected, symptom expression is greatest at temperatures between 68 and 82°F (20 to 28°C) (Kucharek et al. 2000a).

Sclerotinose (caused by *Sclerotinia sclerotiorum*). Sclerotinose, also called Sclerotinia watery rot or watery soft rot, is another of the important cabbage diseases in Florida, but it does not occur each year. Its sporadic occurrence coincides with the simultaneous presence of cool and damp conditions. Optimum conditions for rapid disease development include temperatures from 60 to 70°F (15 to 21°C) and high humidity with dew formation (Pohronezny et al., 1994).

The disease is first seen on leaves and stems close to the ground. Small, water-soaked spots appear and enlarge, accompanied by a growth of white mycelium (the body of the fungus). As the disease develops, the fungus grows upward on the plant, often spreading over the head and creating a soft, dark, water-soaked mass on the leaves. Within this mass, many small, black sclerotia (resting structures) are produced. The sclerotia, which are characteristic of diseases caused by S. sclerotiorum, are the fungus survival mechanism from season to season. Sclerotia may form on the surface of the head as the disease progresses and the fungus invades the whole plant. Plants with heavily infected stems will wilt and fall over, eventually dying. Sclerotinose often follows cold conditions or other types of plant injury (Kucharek, 2004).

Sclerotinia watery rot was a major disease in the Hastings area in the 1940s and 1950s, declining in importance during the 1960s and 1970s. At that time, the disease was observed after hard freezes that damaged the cabbage plants at the soil line, where the fungus would enter the injured stem. Sclerotia were found to be the source of inoculum for such infections. After falling to the ground and being incorporated into the soil during disking and bedding operations, the sclerotia produce fruiting bodies (apothecia) in the presence of at least ten days of high soil moisture. The fruiting bodies produce spores that are carried by air currents to infect injured or dying cabbage tissue. From there, the infection can spread slowly by plant-to-plant contact. The fungus can also attack the plant from the soil without forming fruiting bodies and resulting spores. In that case, leaves in direct contact with the soil are infected, or infection occurs at the soil line. Infection resulting from spore dispersal can occur on all plant parts (Weingartner, 1981).

Downy Mildew (caused by *Peronospora parasitica)*. Downy mildew occurs in most years on cabbage in Florida, but losses are minimal (about 2 percent), because growers effectively control the disease with chemical management. Fungicides are the principal means of control of downy mildew by Florida cabbage growers, and the use of non-systemic fungicides is recommended. Strains of the fungus resistant to systemic fungicides develop more rapidly (Kucharek, 2000b).

The fungus causing downy mildew of cabbage also attacks other crucifers, such as cauliflower, collards, Chinese cabbage, Brussels sprouts, broccoli, kale, and kohlrabi (McRitchie, 1973). The first symptoms of downy mildew are the formation of black specks and yellow-brown spots on the upper leaf surface, accompanied by the development of a fluffy mold growth on the lower surface. Young leaves may fall off when infected, and on older leaves, the spots may coalesce, producing large, sunken, tan spots. The disease can attack young seedlings or plants that have already headed. On older cabbage plants, the disease produces dark, sunken spots, which may appear purplish, on the head or wrapper leaves. Downy mildew infection of older plants may leave them susceptible to sclerotinose-causing bacteria (Kucharek, 2000b).

Disease development can be extremely rapid, affecting an entire field within three to four days under favorable conditions (cool, moist weather). Although spore production can occur at temperatures ranging from 39 to 85°F (4 to 29°C), optimum temperatures are between 53 and 61°F (12 to 16°C). Germination and penetration of the spores is most rapid at temperatures between 42 and 61°F (6 to 16°C) and can occur at any temperature between 39 and 75°F (4 and 24°C). At temperatures around 75°F (24°C), symptoms occur within three to four days of infection. When temperatures are suitable, disease development progresses more rapidly under wetter conditions (Kucharek, 2000b).

The fungus that causes downy mildew can be spread by infected transplants or windblown spores produced in the lesions on the lower leaf surface of infected plants. Another type of spore, functioning as a survival spore, is produced within infected plant tissue during crop senescence and may serve as a source of inoculum for later crops. However, the role of the survival spores in disease spread is considered minimal. The extent to which weeds serve as a source of inoculum is presently unclear (Kucharek 2000b).

Alternaria Leaf Spot (caused by *Alternaria spp*.). Alternaria leaf spot can also be a major disease on Florida cabbage in the years in which it occurs. It tends to be more of a problem in northern Florida than in southern Florida. The fungus can be seedborne, being carried in the seed in the form of mycelium or on the outside of the seed in the form of spores. Alternaria spp. seedling infections are not common in Florida. However, when they occur, infected seeds can experience pre-emergent or post-emergent seedling blight. Stem lesions at the seedling stage, if not killing the plant outright, will result in inferior produce size (Kucharek, 2000c).

The leaf spots produced by Alternaria spp. are much more common in Florida. Initial symptoms of Alternaria leaf spot include small, dark spots on the leaves, on which a target spot can be seen as they enlarge. Older spots, which enlarge to 2 to 3 inches (5 to 7.5 cm) may be black, brown, or tan. The presence of a yellow halo around brown lesions on the edges of leaves can be used to distinguish Alternaria leaf blight from black rot. However, yellow halos are not always produced around leaf lesions. As disease development continues, leaves may yellow and die. Concentric bands or a solid mass of fuzzy dark green-to-black growth within leaf spots develop as a result of spore production. Spores are usually produced at night and released during the day, but during prolonged periods of overcast weather, spores may be produced continuously. Optimum temperatures for spore production are between 75 and 82°F (24 to 28°C), and under favorable temperature conditions for penetration and germination, new spores can be produced within seven to ten days of infection (Kucharek, 2000c).

In addition to being produced within leafspots, spores can be produced on crop debris. The fungus may possibly be able to survive on cruciferous weeds as well. Number of infections and lesion size increases substantially with longer periods of leaf wetting, as a result of prolonged dew periods or frequent rains (Kucharek, 2000c).

Bacterial Leaf Spot (caused by *Pseudomonas cichorii*). Bacterial leaf spot is only occasionally a problem on cabbage in Florida. The disease produces small, slightly sunken, gray-to-dark brown spots that may appear as target spots (concentric rings). It occurs principally on the wrapper leaves, but it may affect internal leaves when conditions are favorable. Overhead irrigation and poor field drainage favor disease development (Kucharek, 2004).

Damping-off (caused by *Fusarium* and *Pythium spp*.). Damping-off occurs in transplant seedbeds. Plants either fail to emerge, or in the case of post-emergence damping-off, a water-soaked lesion develops on the stem at or just below the soil surface. The seedling later wilts, falls over, and then dies (Kucharek, 2004).

Turnip Mosaic (caused by turnip mosaic virus). Turnip mosaic, also called black ringspot, occasionally affects cabbage in Florida. The disease, which is transmitted by aphids, also affects other crucifers, beets, spinach, and tobacco, among others. Symptoms appear on infected plants when the temperature is between 75 and 85°F (23.9 to 29.4°C). Leaves become mottled, and plants appear stunted. Mosaic symptoms develop first on the underside of leaves. As the tissue in the dark green spots dies, a ring spot pattern develops. Heads from plants that did not appear to be infected in the field may develop symptoms in post-harvest storage (Kucharek, 2004).

Wirestem (caused by *Rhizoctonia solani*). Wirestem is also an occasional problem for Florida cabbage growers. The causal fungus can attack roots, stems, and leaves. In some cases, a seedling's outer stem will shrivel, turn dark, and become tough. Under appropriate weather conditions, such seedlings can recover. However, if the fungus continues to grow up the stem, bottom rot and head rot may develop (Kucharek, 2004).

Yellows (caused by *Fusarium oxysporum f. conglutinans*). Yellows is another of the occasional diseases seen by Florida cabbage growers. The disease is first seen in the lower leaves, with the appearance of a yellow-green color. Yellowing of the tissue may move upward to the top leaves. Yellowed tissue turns brown and premature shedding of the leaves occurs. Vascular tissue in the leaves and stems is blackened. Sometimes, only one side of the plant is infected, in which case the plant curls and bends (Kucharek, 2004).

Chemical Control

In 2002, Florida growers applied fungicides totaling 27,700 pounds of active ingredient to 99 percent of the state s cabbage acreage. During the years in which usage data have been collected, between 73 and 99 percent of cabbage acreage has been treated with fungicides each year, with total annual usage ranging from 27,700 to 84,600 pounds of active ingredient. The most commonly used fungicides on Florida cabbage are chlorothalonil, copper hydroxide, and maneb. In fact, chlorothalonil was the only fungicide with published use values for Florida cabbage in 2002. Other fungicidal materials registered for use in Florida cabbage as of 2003 were: other copper compounds, fosetyl-Al, hydrogen peroxide, mefenoxam, phosphoric acid compounds, PCNB, and sulfur.

Chlorothalonil. Chlorothalonil is a broad-spectrum, chloronitrile fungicide used in the management of Alternaria leaf spot and downy mildew. The median price of chlorothalonil is $10.32 per pound of active ingredient, and the approximate cost per maximum application (1.13 lb ai/A) is $11.66 per acre (DPRA, 2001; Syngenta, 2003). 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 12 hours. The minimum retreatment period is seven days and there is a seasonal maximum of 12 lb ai/A.

In 2002, Florida growers applied an average of 0.91 pounds of active ingredient per acre at each application to 54 percent of their cabbage acreage, an average of 5.7 times. Total usage was 22,700 pounds of active ingredient. During the years in which usage data have been collected, cabbage growers in Florida have applied chlorothalonil at an average rate ranging from 0.80 to 1.42 pounds of active ingredient per acre at each application, to between 39 and 94 percent of their cabbage acreage. Growers have made an average number of applications ranging from 4.6 to 5.7 each year, totaling between 22,700 and 56,300 pounds of active ingredient annually (USDA/NASS, 1991; USDA/NASS, 1993; USDA/NASS, 1995; USDA/NASS, 1997; USDA/NASS, 1999; USDA/NASS, 2001; USDA/NASS, 2003).

Maneb. Maneb is an ethylene bisdithiocarbamate (EBDC) fungicide, also used in the management of Alternaria leaf spot and downy mildew. The median price of maneb is $3.67 per pound of active ingredient, and the approximate cost per maximum application (1.5 lb ai/A) is $5.51 per acre (DPRA, 2001; Cerexagri, 2001). Maneb 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. A maximum of 9.6 pounds of active ingredient per acre per season may be applied.

In 2000, Florida growers applied an average of 0.84 pounds of active ingredient of maneb per acre at each application to 12 percent of their cabbage acreage, an average of 3.4 times each. Total usage was 2,700 pounds of active ingredient. During the years in which usage data have been collected, cabbage growers in Florida have applied maneb at an average rate ranging from 0.68 to 1.28 pounds of active ingredient per acre at each application, to between 12 and 41 percent of their cabbage acreage. Growers have made an average number of applications ranging from 3.3 to 7.7 each year, totaling between 2,700 and 26,500 pounds of active ingredient annually (USDA/NASS, 1991; USDA/NASS, 1993; USDA/NASS, 1995; USDA/NASS, 1997; USDA/NASS, 1999, USDA/NASS, 2001; USDA/NASS, 2003).

Copper Hydroxide. Florida cabbage growers use copper hydroxide in the management of black rot, Alternaria leaf spot, and downy mildew. The restricted entry interval (REI) of copper hydroxide under the Worker Protection Standard is 24 hours. The median price of copper hydroxide is $3.25 per pound of active ingredient, and the approximate cost per maximum application (1.5 lb ai/A) is $4.88 per acre (DPRA, 2001; Griffin, 2001).

In 2000, Florida growers applied an average of 0.68 pounds of active ingredient of copper hydroxide per acre at each application to 19 percent of their cabbage acreage, an average of 3.0 times. Total usage was 3,200 pounds of active ingredient. During the years in which usage data have been collected, cabbage growers in Florida have applied copper hydroxide at an average rate ranging from 0.32 to 0.89 pounds of active ingredient per acre at each application, to between 5 and 20 percent of their cabbage acreage. Growers have made an average number of applications ranging from 1.9 to 3.0 each year, totaling between 200 and 3,200 pounds of active ingredient annually (USDA/NASS, 1991; USDA/NASS, 1993; USDA/NASS, 1995; USDA/NASS, 1997; USDA/NASS, 1999, USDA/NASS, 2001; USDA/NASS, 2003).

Cultural Control

Black rot can be spread by infected seeds or during transplant production. Although resistant varieties are available, the most effective management is adequate sanitation while producing transplants. Cabbage growers can buy certified transplants as well as seeds that have been certified as being free of black rot. Hot water treatment [soaking at 122°F (50°C) for 30 to 35 minutes] of cabbage seeds regardless of the source is an essential management tactic that effectively controls black rot. Specific practices during transplant production include the use of clean flats and disease free seed, destruction of diseased plants and residue after the harvest, avoiding the movement of contaminated soil, fumigation or rotation of transplant beds, irrigation from a well and not from an open ditch, elimination of cruciferous weeds, raising transplant beds for adequate drainage, avoiding handling of plants while wet, and avoiding placing transplant beds within one-quarter mile of crucifer production fields. In addition, transplants should not be wetted down before transplanting, since black rot spreads most easily under moist conditions (Kucharek et al., 2004).

While the use of clean planting material is the key cultural control for black rot, most growers also stay out of the fields as much as possible during wet conditions, to avoid spreading the disease. Additional cultural practices, all of which should be followed together, include planting in fields that have not been in crucifer production for 12 months, plowing down crucifer fields just after harvest, and thoroughly cleaning all equipment and tools prior to use in the field or transplant bed (Kucharek et al., 2000a; Kucharek, 2004).

The best cultural control for sclerotinose, as well as most other diseases, is wider plant and row spacing, which cuts down on long dew periods. However, to maximize yield, most growers do not increase spacing as a disease management practice. Additional recommendations for cultural control of sclerotinose include rotating with a crop that is not susceptible to Sclerotinia (e.g., sweet corn), turning the soil at least six inches when plowing, avoiding the use of overhead irrigation, and where possible, flooding completely or intermittently for six weeks during the summer (Kucharek, 2004).

Destruction or burial of old plant beds and residues in harvested fields aids in managing Alternaria leaf spot and downy mildew. Elimination of cruciferous crops and weeds around seedbeds, rotation with non-cruciferous crops, and the use of disease-free seeds and transplants also aid in managing those diseases. Turnip mosaic can be managed by eliminating the weed hosts of the virus, particularly mustard type weeds, both in the seedbed and in the field. Early control of aphids, especially in seedbeds, is the other key to reducing virus incidence. Cultural controls for wirestem include crop rotation, both for seedbeds and fields, providing adequate drainage, cultivating as soon as possible after heavy rains to aerate and dry the soil, and avoiding planting in crop debris or a green manure crop that has recently been incorporated. For yellows, disease-free transplants should be used, and the only available control once soil has been infested is the use of resistant varieties (Kucharek, 2000c; Kucharek, 2004).

Post-Harvest Decays and Their Management

Excessive trimming of wrapper leaves may cause the more susceptible inner leaves to wilt. In addition to contributing to wilting, cuts or breaks can provide an entry site for disease pathogens. The post-harvest decays watery soft rot, bacterial soft rot, gray mold rot, Alternaria leaf spot, and black leaf speck can all affect cabbage during the post-harvest period (Sargent 1999).

Nematode Management

Nematode Pests

Plant-parasitic nematodes are microscopic roundworms found in soils. They 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, sting, stubby root, and awl nematodes are all important pests of crucifers, and in local areas of central Florida cyst nematode is a serious pest (Noling 1999; Noling 2002).

Root-Knot Nematodes (*Meloidogyne* spp.). Many cruciferous plants are hosts to common species of root-knot nematodes. In greenhouse tests, moderate levels of root galling and egg masses were seen to occur on cabbage plants infested with three species of root-knot nematodes (M. javanica, M. incognita races 1 and 3, and M. arenaria) (McSorley et al., 1995).

Root-knot nematodes enter the host plant root as second stage juveniles and settle within the root to establish a feeding site. At the feeding site, secretions from the nematode cause the surrounding plant cells to enlarge and multiply, producing the characteristic galls associated with root-knot attack. As more nematodes enter the root and feeding continues, the galls fuse to form large tumors on the roots. Within the root, the developing female molts 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. Root deformation and injury caused by root-knot nematodes reduce root area and interfere with water and nutrient uptake. Resulting symptoms include stunting, wilting, chlorosis, and yield loss. In addition to expending the plant s resources, the gall tissue is more susceptible to secondary infections such as root rots (Stokes, 1972; Dunn et al., 2001; Noling, 1999).

Sting Nematodes (*Belonalaimus longicaudatus*). Cabbage in Florida often experiences severe yield losses due to sting nematodes (White et al., 1992). Sting nematodes are ectoparasites, remaining outside the plant root and feeding superficially at or near the root tip. Affected root tips turn yellow and later necrotic, with cavities forming and the root tip swelling slightly. 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 (Christie, 1959; Esser, 1976; Noling, 1999, Dunn et al., 2001).

Sting nematodes are especially damaging to seedlings and transplants. Death of transplants on highly infested sites can leave gaps of missing plants or patches of plants lacking vigor. In northern Florida, sting nematodes are most abundant in April and May. Sting nematodes prefer sandy soils (with 84 to 94 percent sand) and are most abundant in the upper 12 inches (30 cm). Optimum soil temperature for this nematode is between 77 and 90°F (25 and 32°C), and optimum soil moisture is about 7 percent (Christie, 1959; Esser, 1976; Noling 1999, Dunn et al., 2001).

Stubby Root Nematodes (*Trichodorus* spp., *Paratrichodorus* spp.). Stubby-root nematodes feed externally on the root surface and remain in the soil throughout their life cycle. They mainly feed at the tip of the growing root, which stops root elongation. The result can be a short, stubby root system with swollen root branches. Their feeding may also cause abnormal growth of lateral roots and increased production of branch roots. In Florida, stubby-root nematodes are found mainly in sandy or sandy loam soils, but also occur in muck soils. In addition to cabbage, the principal crops injured by this nematode in Florida include beets, corn, celery, 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 (Christie, 1959; MacGowan, 1983; Dunn et al., 2001).

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 (Christie, 1959; Dunn et al., 2001).

Chemical Control

Ethoprop, fenamiphos, methyl bromide, metam, and 1,3-dichloropropene are the nematicides registered for use on cabbage in Florida and the latter three have reportedly been used in either 2000 or 2002. Both methyl bromide and fenamiphos have planned phaseouts of 2005 and 2007, respectively, and no critical use exemption for methyl bromide use was submitted for cabbage. The biological material Myrothecium verrucaria was reportedly used in Florida in 2002. Usage values have not been reported for Florida cabbage production in either 2000 or 2002.

Cultural Control

The use of pest-free transplants is the most important cultural control for nematodes on cabbage. Transplants should be produced in sterile growing medium or in soil that has been fumigated (Noling, 2002).

Some resistance to sting nematodes has been found in several cabbage varieties tested in Florida. However, the use of nematode resistance alone has not been found to be economically adequate (White et al., 1992).

Weed Management

Weed Pests

Weeds can reduce yields of cabbage by competing for nutrients, water, and light. Managing weeds early in the season is particularly important to maintain vigor and yield of the crop. Since cabbage is largely a winter crop, many of the weed species are winter annuals. Wild radish is a major weed in Florida cabbage fields. Cutleaf evening primrose and Carolina geranium may also be present. In the early spring or late fall, there may be problems with summer annuals like amaranth, lambsquarters, and Pennsylvania smartweed, among others (Stall, 2003).

Wild Radish (*Raphanus raphanistrum*). Wild radish is a winter annual that dies when hot weather begins, although some plants can live for a whole year in Florida. It can reach 1 meter (3.28 feet) in height. The stems, which have prickly hairs when the plant is younger, become smooth as the plant matures. The plant has one to several branches, and the leaves are hairy, with deep, rounded lobes. Wild radish germinates rapidly. The plant is often confused with wild mustard (Brassica kaber), but wild mustard is not found as a weed in Florida crops (Hall et al., 1991a).

The effect of wild radish presence on cabbage yield depends on when during the season the competition occurs. For example, during the warmer part of the spring and fall, the presence of up to 16 wild radish plants per meter (3.28 feet) of cabbage row will not reduce cabbage yields. However, the presence of only one wild radish plant per meter will significantly reduce cabbage yields during the cooler part of the season (Stall, 2003). In general, wild radish is a poor competitor with cabbage during the spring planting season (Steed et al., 1998).

Cutleaf Evening Primrose (*Oenothera laciniata*). Cutleaf evening primrose is an annual plant with hairy stems that branch at the base. Its long, narrow leaves are deeply cut near the base (Miller et al., 1975).

Carolina Geranium (*Geranium carolinianum*). Carolina geranium is a winter annual with smooth, reddish stems that branch widely at the base (Miller et al., 1975). Its many branches form a circular growth from the center of the plant, and it may rise to 0.6 m (2 feet) tall from a tap root (Hall et al., 1991b).

Amaranth (*Amaranthus* spp.). Amaranths (pigweeds) are summer annual broadleaf weeds with erect stems that can grow to 2 meters (6.5 feet) tall. Several species of amaranth are present in Florida, the most important being smooth pigweed (Amaranthus hybridus), spiny amaranth (A. spinosus), 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 (Lorenzi et al., 1987).

Lamb's-Quarters (*Chenopodium album*). Lamb's-quarters is an erect, summer annual that grows to 2 meters (6.5 feet) tall. It grows well on all soil types and over a range of soil pH values (Hall et al., 1991c).

Pennsylvania Smartweed (*Polygonum pennsylvanicum*). Pennsylvania smartweed is a summer annual with smooth, branching stems and smooth, pointed leaves. It grows from 1 to 4 feet (0.3 to 1.2 meters) tall (Miller et al., 1975).

Chemical Control

In 2002, Florida growers applied herbicides totaling 7,200 pounds of active ingredient to 89 percent of the state's cabbage acreage. During the years in which usage data have been collected, between 69 and 89 percent of Florida's cabbage acreage has been treated with herbicides each year, with total annual usage ranging from 6,000 to 13,000 pounds of active ingredient. Historically, the most commonly reported herbicides used on cabbage in Florida are trifluralin, metolachlor, and napropamide, but others include DCPA, glyphosate, oxyfluorfen, sethoxydim, and paraquat (USDA/NASS, 1991; USDA/NASS, 1993; USDA/NASS, 1995; USDA/NASS, 1997; USDA/NASS, 1999; USDA/NASS, 2001; USDA/NASS, 2003). Bensulide, pelargonic acid, and clethodim are also available for use on cabbage.

Cultural Control

Cultural weed management practices include crop rotation, cover cropping, high density planting, mulching, cultivation, and flooding. Cabbage growers in northern Florida tend to cultivate more than those in southern Florida, who utilize herbicides to a greater extent (Stall, 2003).

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