

Florida Crop/Pest Management Profiles: Snap Beans¹

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Production Facts

- Florida is ranked first nationally in the production, acreage and total value of fresh market snap beans (1).
- The state's snap bean crop contributes 43 percent of the U.S. total in terms of production and 51 percent in terms of cash receipts (1,2). During the winter months (January, February and March), Florida produces 100 percent of the fresh market snap beans grown in the U.S. (2).
- In 2000-2001, Florida growers produced 256 million pounds of snap beans, with a value of \$0.54 per pound and a total value of \$138.4 million. Snap beans were planted on 35,000 acres, and 34,000 acres were harvested, yielding an average of 7,530 pounds per acre (3).
- In 1997, there were 283 snap bean producing farms in Florida. Of those farms, 47.3 percent produced snap beans on less than 5 acres, as a group representing 0.6 percent of the state's total snap bean acreage. An additional 21.9 percent maintained between 5 and 49 acres of snap beans (representing 3.4 percent of the state's snap bean acreage), 17 percent planted between 50 and 249 acres (19.8 percent of acreage), 7.4 percent planted between 250 and 499 acres (23.6 percent of acreage), and 6.4 percent planted greater than 500 acres (52.6 percent of acreage) (4).
- During the 2000-2001 season, snap beans ranked 3rd and 4th for harvested acreage and value of production, respectively, for Florida's diverse vegetable commodities. Harvested acreage for snap beans represented 12 percent of the state's total vegetable acreage, while production value represented 8 percent of the total production value for Florida vegetables (5).
- Total production costs in 1996-97 for bush beans in the Dade County area were estimated at \$2,678 per acre. Of that total, \$1,128 represents harvest and marketing costs, and \$894 represents preharvest operating costs. Costs for fungicides totaled \$151.70 per acre, for herbicides totaled \$2.67 per acre, and for insecticides totaled

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\$111.50 per acre. Direct costs for pesticides therefore accounted for 30 percent of preharvest operating costs and for 10 percent of total production costs (6).

- The majority of Florida's snap bean crop is produced for the fresh market, with only a small percentage destined for processing. For example, in 1994, 90 percent of snap bean production in the state was for the fresh market. Production in south Florida is entirely for the fresh market (1,7).

Production Regions

The southeastern region (mainly Miami-Dade and Palm Beach counties) is the principal production region for snap beans in Florida. Miami-Dade County is both a state and national leader in the production of fresh market snap beans. Approximately half of the state's production occurs in Miami-Dade County, in which 57 percent of the state's snap bean acreage and 23 percent of its farms are found. Palm Beach County is second in harvested area, accounting for 14 percent of harvested acres and 5.7 percent of snap bean farms in Florida (2,4).

North-central Florida is another notable region of snap bean production. Alachua County ranks third in acreage of snap beans, representing 6.7 percent of harvested acres and 9.2 percent of farms. Snap bean production in Suwannee County accounts for 5.5 percent of harvested acres and 2.8 percent of farms in the state. The third largest production area is around the northern Tampa Bay region. Manatee County comprises 4 percent of snap bean acreage and 2.5 percent of farms, while Hillsborough County represents 1.7 percent of acreage and 14.8 percent of snap bean farms in the state (4).

Production Practices

Snap beans are planted in Florida between August 15 and April 1, with some variation by region. In north Florida, usual planting dates are from March to April and from August to September. Planting occurs in central Florida from February to April and from August to September, while south Florida snap beans may be planted anytime from September to April. Harvest throughout the state can occur between

October 15 and June 15, with the most active harvest period from November 1 to May 1 (2,9).

Approximately 33 percent of snap bean acreage is harvested during the winter season (January to March), with approximately 44 percent harvested during the spring season (April to May) and 23 percent harvested during the fall season (October to December). No snap bean production occurs during the summer months in Florida (3).

Both bush-type and pole-type snap beans are grown in Florida, the majority being bush-type. Pole-type beans are produced principally in Miami-Dade County, where the most common variety is Dade. Bush-type varieties planted in the state include Benchmark, Fandango, Hialeah, Mirada, Opus, Prosperity, Seville and Sonata. Bush-type snap beans are typically planted at a depth of 1 to 1.5 inches (2.5 to 3.8 cm) and a distance of 18 to 36 inches (46 to 91 cm) between rows and 2 to 4 inches (5 to 10 cm) between plants, generating a population of 172,240 plants per acre. Pole-type snap beans are usually planted 1 to 1.5 inches (2.5 to 3.8 cm) deep, with 36 to 48 inches (91 to 122 cm) between rows and 3 to 5 inches (8 to 13 cm) between plants (58,000 plants per acre). Bush-type snap beans are mature for the first pick in 45-60 days after seeding, while pole-type beans take 50-70 days (8,9).

One-half of the nitrogen and potassium fertilizer is applied at planting, with the rest added later in one or two additional applications (10). In the years in which usage data have been collected, 95 to 100 percent of snap bean acreage in Florida has received an average of 2.4 to 6.7 applications of nitrogen annually. Between 18 and 36 pounds of nitrogen per acre have been used at each application, with a statewide total ranging from 2.2 to 4.2 million pounds. Between 27 and 63 pounds per acre of phosphate have been applied an average of 1.6 to 5.3 times annually to 85 to 99 percent of snap bean acreage, with total usage of 2.4 to 5.2 million pounds. Potash has also been applied an average of 2.4 to 5.7 times per year to 92 to 100 percent of acreage. Between 28 and 59 pounds of potash per acre are used at each application, and a total of 3.0 to 5.8 million pounds have been used annually (11-14).

In 1997, 92 percent of the state's snap bean acreage was irrigated (4). Both sub-surface irrigation through manipulation of the water table and overhead irrigation are utilized (7). Irrigation is particularly important to snap beans during periods of fruit set and pod development.

Worker activities are quite few for snap beans. Since the seeds are mechanically seeded, the only requirement for hand labor is to rogue double plants or reseed holes. For machine harvested beans in Florida (>95 percent of snap beans), which are picked only once, the crop is washed, hydrocooled, and then graded on a conveyor line in a packinghouse. Some growers cool snap beans using a cold water flume. The beans are packed by the bushel in wooden crates or waxed cartons. An alternate method, which is not common, is to hand harvest and field pack the beans in wooden crates, followed by hydrocooling at a packing house. Hand harvested beans are usually picked only when prices are very high, and this picking is followed by a mechanical picking. Hand harvesters generally wear gloves to protect their hands. Although snap beans in Florida were traditionally forced-air cooled, most packers have switched to hydrocooling within the past decade. The beans are packed wet into the shipping container and maintained at 38 to 40°F (3.3 to 4.4°C). Many, but not all, packers use chlorine in the cooling water, which is recommended to prevent pathogen buildup in the water. Once packed, Florida's snap beans are transported on refrigerated trucks, with most out-of-state shipments going to the Northeast, Midwest, and Canada (7,10,15,16).

Insect/Mite Management

Insect/Mite Pests

The silverleaf whitefly is the most damaging insect pest on snap beans in Florida. In south Florida, the melon thrips is also a major pest. Minor insect and related pests include American serpentine and vegetable leafminers, cabbage looper, bean leafroller, southern green stinkbug, southern armyworm, cowpea curculio, banded cucumber beetle, cowpea and black bean aphids, and twospotted spider mite. Bean leafroller and garden fleahopper are major pests in home gardens. Insect and related pests that

occasionally damage snap bean include lesser cornstalk borer, bean leaf beetle, spotted cucumber beetle, striped cucumber beetle, green June beetle, vegetable weevil, whitefringed beetle, armyworm, beet armyworm, soybean looper, bean leaf skeletonizer, green cloverworm, saltmarsh caterpillar, yellow woollybear caterpillar, gray hairstreak caterpillar, potato flea beetle, Mexican bean beetle, green peach aphid, pea aphid, potato leafhopper, broad mite, strawberry mite, tumid mite, leaf-footed bugs, tarnished plant bug, brown stink bug, onespotted stink bug, bean thrips, onion thrips, sweet potato whitefly, greenhouse whitefly, corn earworm, bean weevil, cowpea weevil, pea weevil, and southern cowpea weevil (17-20).

Silverleaf Whitefly (*Bemisia argentifolii*).

Silverleaf whitefly is one of the most important pests of snap beans in Florida, principally because of its role as a vector of bean golden mosaic virus (BGMV). It is particularly damaging in the southern part of the state. It was at first thought to be a strain of the sweet potato whitefly (*Bemisia tabaci*) and referred to as sweet potato whitefly-strain B. Now, it is considered a separate species. The first U.S. outbreak of silverleaf whitefly was recorded in south-central Florida in 1986. Its aggressive establishment and associated insecticide resistance have led to heavy infestations in Florida's vegetable and ornamentals industries since then. This pest's host range is much broader than that of sweet potato whitefly. More than 500 species of plants can be attacked by silverleaf whitefly (21,22).

The whitefly damages the bean plant directly by removing plant sap with its piercing-sucking mouthparts. Feeding damage is produced by both adults and immature nymphs. Feeding can result in stunting and defoliation, as well as the production of honeydew, on which sooty mold can grow. The adults, which feed and mate primarily on the underside of leaves, are most active from mid-morning to mid-afternoon. Able to fly within the crop canopy as well as to complete migratory flights, adults prefer yellow and green objects when settling. Each adult female deposits 50 to 400 eggs on the underside of leaves. Each egg is attached to the leaf by a stalk. Eggs hatch within five to seven days. Only during the first nymphal stage (the crawler) does the

whitefly move on the leaf surface, to select a feeding site. During the remaining nymphal stages (instars), nymphs remain sedentary on the lower leaf surface, nearly covering the leaves during high infestations. During the nymphal period, the whitefly molts four times and then enters the pupal stage, during which two red eyes can be seen. Usually, all stages of the life cycle can be seen together on the plant (21,22).

In addition to causing direct damage to the bean plant, silverleaf whitefly is a vector of bean golden mosaic virus in Florida and possibly tomato yellow leaf curl virus (TYLCV) (9,10). Since small numbers of whiteflies are sufficient to spread the virus, diligent management is essential in areas where geminiviruses such as BGMV are present. Silverleaf whitefly sampling plans have been developed for cotton, but not completely for vegetable crops. Not enough data is available to establish action thresholds for most crops. In addition, as a result of silverleaf whitefly's rapid development of resistance to insecticides, it has become difficult to control with conventional chemical tactics, further complicated by the need for thorough coverage of the lower leaf surface. Research into a number of biological control strategies has been continuing for several years (21,23).

Melon Thrips (*Thrips palmi*). Melon thrips, which was first reported in Miami-Dade County in 1990, is a major pest of snap beans in south Florida. In addition, the insect attacks a wide range of plants, including eggplant, pepper, potato, tobacco, melons, squash, soybean, broad bean, amaranth spinach, and many ornamental species. Infestations can build up quickly and cause severe damage. Both adults and larvae feed in groups on all above-ground plant parts, removing sap with their rasping-sucking mouthparts. Often found in cracks and crevices within the plant, melon thrips feed most frequently on leaves. The thrips have been seen to severely defoliate bean fields in south Florida. Leaves on heavily infested plants develop a silvery or bronzed appearance, and pods may be scarred and deformed. In high enough numbers, melon thrips can kill the plant. The duration of the life cycle is shortest (21 days) between 20 and 25°C (68 to 77°F) and longer at higher or lower temperatures (10,24,25).

Leafminers (*Liriomyza trifolii* and *Liriomyza sativae*). American serpentine leafminer and vegetable leafminer are occasionally major pests in Florida snap beans. Larvae of these small flies damage plants by tunneling between the upper and lower leaf surfaces as they feed on the inner leaf tissue. Although damage can be quite evident, healthy bean plants can tolerate substantial damage without yield loss. Greatest damage occurs to the first two leaves (primary leaves) of young seedlings, before the appearance of the true leaves. In Florida, leafminer generations are continuous for most of the year. Chemical control of leafminers requires careful timing, because the larvae are protected within the leaf tissue. A number of parasitic wasps attack the larval and pupal stages and can maintain leafminer populations below damaging levels in the absence of broad-spectrum pesticide applications. Leafminers have become more severe in areas where vigorous management of silverleaf whitefly is needed (10,18,26,27).

Bean Leafroller (*Urbanus proteus*). Bean leafroller, which is found throughout the state but used to be a prevalent problem in Miami-Dade County, is a minor pest of late summer beans in Florida and a major pest in home gardens. In addition to snap beans, it feeds on other legume crops (including cowpea, lima bean, pea and soybean), as well as non-crop legumes such as wisteria (*Wisteria* spp.), tick trefoil (*Desmodium* spp.), butterfly pea (*Clitoria* spp.) and hog peanut (*Amphicarpa bracteata*). Unable to withstand extended freezing temperatures, bean leafroller breeds throughout the year only in the southern part of the state, often migrating southward in the fall and northward in the spring and summer. In north Florida, it does not appear until about June and becomes most abundant in September and October (10,28).

The bean leafroller's life cycle may be completed in as little as 30 days. Eggs, which are deposited on the lower leaf surface individually or in clusters of two to six, hatch in three to four days. The larvae, which pass through five instars in 15 to 20 days, at first cut a small triangle in the leaf edge and fold it over. This shelter is then lined with silk. The larva leaves the shelter only to feed at night, and when older, folds over a larger section of the leaf or

attaches two leaves together with silk. The mature larva pupates within the sheltered leaf area and remains in the pupal stage for seven to 20 days, after which the adult emerges (28).

Bean plants can tolerate defoliation of up to about 30 percent prior to the blooming stage without yield loss. Based on that, an action threshold for the bean leafroller has been calculated at 140 eggs per plant or 70 first instar larvae per plant (29,30).

Cabbage Looper (*Trichoplusia ni*). Cabbage looper is a minor pest of snap bean in the state. It attacks a variety of crops, including crucifers, lettuce, spinach, beet, pea, celery, parsley, potato and tomato. There are usually three or more generations per year. Cabbage looper eggs are deposited individually on leaf surfaces. Upon hatching, the larvae feed and grow for two to four weeks. The pupal stage, which is spent in a loose cocoon attached to leaves, lasts another two weeks. The adult moth is similar in appearance to cutworm moths. Adults are usually active all winter in peninsular Florida. Chemical control of cabbage loopers is difficult, because of both resistance to many insecticides and the pest's habit of moving quickly to protected areas of the plant after sprays. Therefore, judicious choice of chemicals and thorough coverage of the plant during spraying are necessary when using chemical controls (26,27).

Southern Green Stink Bug (*Nezara viridula*). Southern green stinkbug is an occasional pest of snap beans in Florida, particularly when temperatures are high. It feeds on many plants, including several important crop plants, as well as weeds such as beggarweed, rattlebox, Mexican clover, wild blackberry, and nutsedge. Damage is caused by the removal of plant sap by the insect's piercing-sucking mouthparts and punctures in pods, which can lower the market value of snap beans. All plant parts may be attacked, but the developing pods and actively growing shoots are preferred. (31).

Overwintering as an adult during the coldest months, the insect is most prevalent from October to December and from March to April. Up to four generations per year occur in warmer climates. The life cycle of the southern green stink bug is completed in 65 to 70 days. Three to four weeks after

reaching the adult stage, females deposit one to two masses of 30 to 130 eggs each on the lower surface of leaves. Eggs hatch in five days in the summer and two to three weeks in the late fall or early spring. The nymphs congregate on the lower leaf surface and do not feed until after their first molt, three days later. After an additional 27 days, the final molt to the adult occurs (31).

Economic thresholds for the southern green stink bug have been determined for several crops, including soybeans (36 stink bugs per 100 swings of a net) and cowpea (5000 stink bugs per hectare) (31). On snap beans, a small number of stinkbugs can affect the grade standard, because damage to the pods lowers the quality of product harvested (10).

Cowpea Curculio (*Chalcodermus aeneus*). Cowpea curculio can be a problem in Florida snap bean production in the late spring. Although entire fields can occasionally be damaged during those months, it is not seen at any other time of the year. The host range of the cowpea curculio includes snap beans, peas, soybeans, lima beans, cotton, strawberry, and several leguminous weeds such as vetch, but it prefers black-eyed pea, crowder pea, and long bean (all *Vigna* spp.). The weevils spend the winter months in weeds or crop debris. Upon leaving overwintering sites, adult females puncture bean pods to feed and to lay their eggs in developing seeds. The punctures leave unsightly brown spots on the pods and seeds, requiring growers to apply control measures. Within four to six days, the cowpea curculio larvae hatch and begin to feed on the seeds. After feeding for one to three weeks, they bore exit holes into the sides of the pod and drop to the ground, where they pupate in the soil. About ten days later, the next generation of adults emerges (18,26,32).

Southern Armyworm (*Spodoptera eridania*). Southern armyworm is a minor pest of Florida snap beans. It has a wide host range, including such vegetables as beet, cabbage, carrot, celery, collards, corn, cowpea, eggplant, okra, pepper, potato, rhubarb, sweet potato, and tomato. It also attacks many weeds, particularly spiny amaranth and pokeweed. Southern armyworms overwinter in Florida as larvae or pupae and migrate north each year. Female moths deposit eggs on leaves, in masses

covered with scales, giving them a fuzzy appearance. Eggs hatch in four to six days, and larvae feed for approximately 17 days, then drop to the soil surface to pupate. After another nine to 13 days, the next generation of moths emerges. Up to five generations per year can occur in Florida. Although larvae feed mainly on foliage, they can also damage pods of snap beans (18,26).

Twospotted Spider Mite (*Tetranychus urticae*).

Twospotted spider mite is also a minor pest on snap beans in Florida. It can be found on over 100 cultivated plant and weed species. Mites feed on the lower leaf surface, withdrawing sap from the plant. As a result of feeding damage, foliage becomes silvery, and leaves can eventually die. Pale spots appear on leaves when lightly infested, with leaves drying up under greater mite pressure. As the mites feed on the lower leaf surface, they spin silken webs, which can be abundant during heavy infestations. Under warmer conditions, egg-laying activity increases, and each female can produce up to 100 eggs in total. Larvae hatch from the eggs in three to 19 days and begin to feed. Mites take between five and 20 days to mature into adults, depending on temperature. Many generations occur each year. Development is faster under hot, dry conditions (32).

Mexican Bean Beetle (*Epilachna varivestis*).

Mexican bean beetle, an occasional pest on snap beans in north and central Florida, was first reported in north Florida in 1930 and was present throughout the northern half of the state by 1982. It is one of the few plant-feeding members of the Family Coccinellidae, to which the beneficial ladybird beetles belong. Commonly found throughout the eastern U.S., Mexican bean beetle can feed on many legumes, including snap beans, lima beans, soybeans, cowpea, black-eyed pea, velvet bean, alfalfa, and clover. Snap beans, particularly wax bean varieties, are among its favored hosts. During strong infestations, Mexican bean beetle is capable of completely defoliating snap bean fields. Both adults and larvae feed on snap bean plants, skeletonizing tender foliage (32-34).

Adult Mexican bean beetles overwinter, and in Florida they begin to feed and reproduce on snap beans in the spring. During May and June, they move

over to beggarweed (*Desmodium tortuosum*), a common weed throughout the state. Beggarweed continues to support Mexican bean beetle populations until late fall, when overwintering begins. Upon becoming active in the spring, females feed for one to two weeks before depositing up to 600 eggs (in clusters of 40 to 75) on the underside of bean leaves. After hatching one to two weeks later, the larvae feed together, remaining in groups throughout their development. Feeding on the underside, they skeletonize the leaves. After four molts, larvae pupate on the underside of leaves, stems or pods. The pupal stage lasts five to ten days. Total time from egg to adult averages 30 days. Adults, which find moist, sheltered places to overwinter, are able to fly long distances to find new bean fields (33,34).

Although Mexican bean beetles can feed on leaves, flowers and pods, leaves are most commonly attacked. The most important stage of the insect in terms of damage to the plant is the larval stage. Economic thresholds on bean plants, which vary depending on variety and conditions, have been estimated at 1 to 1.5 larvae per plant. A successful biological control program, discussed below, prevented economically significant infestations from occurring for a number of years. It remains a viable option if Mexican bean beetle becomes a widespread pest in the future (33,34).

Banded Cucumber Beetle (*Diabrotica balteata*). The banded cucumber beetle, another occasional minor pest, is more common in the southern part of the state than in the north, although it can be found throughout Florida. Cucumber beetle adults prefer to feed on leaves of bean and soybean, but they can damage many plants, including such vegetables as cucumber, squash, beet, pea, sweet potato, okra, corn, lettuce, onion, and cabbage. Adult cucumber beetles chew holes out from the upper leaf surface, which can seriously defoliate the plant, and larvae feed on plant roots. The entire life cycle can be completed in 45 days under appropriate conditions. Females lay up to 850 eggs, depositing them in cracks in the soil. Eggs hatch after five to nine days. After 11 to 17 days in the larval stage, cucumber beetles pupate in the soil, and four to six days later, the adult emerges (35).

Cowpea Aphid (*Aphis craccivora*). Aphids, most often cowpea aphid, are a minor pest of Florida snap beans. Distributed worldwide, cowpea aphid colonizes a wide variety of plants, but prefers legumes. Its hosts include alfalfa, apple, carrot, cotton, dandelion, goldenrod, kidney bean, lambsquarters, lettuce, lima bean, pinto bean, peanut, pepperweed, pigweed, red clover, shephardspurse, vetch, wheat, and white and yellow sweet clovers. Young colonies of cowpea aphids can be found on the growing points of the plant, often being attended by ants. Aphids damage bean plants by removing plant juices with their piercing-sucking mouthparts, drying out plant tissue and causing yellowing or wilting when present in large numbers. In Florida, adult female aphids give birth to live female nymphs, which quickly reach reproductive age and continue to reproduce asexually. Populations can therefore increase rapidly under favorable conditions. Many generations are possible each year. Aphid populations are often checked by predation from ladybird beetle adults and larvae, lacewing larvae and syrphid larvae, as well as fungal diseases during periods of high humidity (27,32).

Potato Leafhopper (*Empoasca fabae*). Potato leafhopper has historically been the most damaging leafhopper to attack snap beans in Florida, but presently it is rarely a problem. As a result of feeding on the plant's sap with their piercing-sucking mouthparts, leafhoppers can cause bean leaves to wrinkle and turn yellow. Under severe infestations, plants may be dwarfed and produce no pods. This leafhopper has several generations a year in Florida. Adults lay their eggs in small slits in the leaves, and both adults and nymphs feed on the plant (26,36).

Garden Fleahopper (*Halticus bractatus*). This plant bug is a major pest in home gardens, but not generally in commercial fields, because it is controlled by insecticides used against other snap bean pests. Garden fleahopper has a wide host range that includes many vegetable and field crops, as well as weedy species, but it generally prefers legumes. Both nymphs and adults feed on the plant, removing sap with their piercing-sucking mouthparts. Fleahoppers resemble flea beetles in appearance and behavior, but flea beetles have chewing mouthparts. Under high feeding pressure from fleahoppers,

seedlings may die and older plants may be stunted. When fecal material is deposited on pods, black spots may reduce marketability. Although the fleahopper is known to overwinter in the egg stage in other states, adult fleahoppers have been observed in Florida during all months except December. The life cycle may be completed in about one month. Eggs are laid in feeding punctures in plant stems, with each female producing 80 to 100 eggs over her 30 to 50 day lifespan. The egg stage lasts about 14 days. Nymphs pass through five instars in an average of 39 days (37).

Chemical Control

Ninety-seven percent of Florida's snap bean acreage received insecticide applications in 2000, totaling 47,900 pounds of active ingredient (38). The most frequently used insecticides include methomyl (Lannate®), *Bacillus thuringiensis*, acephate (Orthene®), endosulfan (Thiodan®/Phaser®), and imidacloprid (Admire®/Provado®). Other insecticides labeled for use on snap bean include esfenvalerate (Asana®), dimethoate (Cygon®), carbaryl (Sevin®), diazinon, azinphos-methyl, disulfoton (Di-Syston®), malathion, naled (Dibrom®), phorate (Thimet®), pyrethrins plus rotenone (Pyrellin®), pyrethrins plus piperonyl butoxide (Pyrenone®), oxydemeton-methyl (Metasystox-R®), azadirachtin, dicofol (Kelthane®), soap, and oil. Newly registered materials include bifenthrin (Capture®), zeta-cypermethrin (Fury®), and spinosad (Spintor®). A section 18 exemption is currently active for the use of pyriproxyfen (Knack®) on snap bean in Florida and this use is expected to continue until a full registration is obtained.

Methomyl (Lannate®). Methomyl is a broad-spectrum carbamate insecticide used in the management of aphids, armyworms, corn earworms, cucumber beetles, cutworms, leafhoppers, loopers, lygus bugs, Mexican bean beetles, saltmarsh caterpillars, and thrips. The median price of methomyl is \$25.12 per pound of active ingredient, and the cost per maximum labeled application (0.9 lb ai/A) in 2001 was \$22.61 per acre (39,40). Methomyl may be applied up to 1 day before harvest (PHI=1 day) when 0.75 to 1.5 pints per acre are used, or up to 3 days before harvest (PHI=3 days) when over 1.5 pints per acre are used. The restricted entry interval (REI) under the Worker Protection Standard is 48

hours. No more than 10 applications may be made to the crop and the material limit is 4.5 lb ai/acre/crop (40).

In 2000, Florida growers applied an average of 0.35 pounds of active ingredient of methomyl per acre at each application to 30 percent of their snap bean acreage, an average of 1.8 times. Total usage was 6,900 pounds of active ingredient. During the years in which usage data have been collected, Florida snap bean growers have applied methomyl to a range of 30 to 62 percent of their snap bean acreage, an average of 1.6 to 6.7 times per year. Growers have applied methomyl at rates ranging from 0.34 to 0.48 pounds of active ingredient at each application and a total ranging from 6,500 to 72,500 pounds of active ingredient annually (11-14,38).

***Bacillus thuringiensis* (B.t.).** B.t. is a microbial insecticide that acts as a stomach poison and must therefore be eaten by the insect to be effective. It is used in the management of the larval stage of several lepidopteran pests, including armyworms, cutworms, green cloverworms, loopers, saltmarsh caterpillars and velvetbean caterpillars. The price of B.t. is \$10.25 per pound (41). 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.

In 2000, Florida growers applied B.t. to 44 percent of their snap bean acreage, an average of 3.1 times. During the years in which usage data have been collected, snap bean growers in Florida have applied B.t. to between 21 and 49 percent of their snap bean acreage, each making an average of 2.2 to 4.0 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 (11-14,38).

Acephate (Orthene®). The organophosphate insecticide acephate is used as a foliar spray in the management of aphids, armyworms, bean leaf beetles, bean leafrollers, corn earworms, cutworms, fleahoppers, grasshoppers, green cloverworms, leafhoppers, loopers, lygus bugs, plant bugs, thrips, and whiteflies. The median price of acephate is \$16.47 per pound of active ingredient, and the cost per maximum labeled application (0.98 lb ai/A) in

2001 was \$16.14 per acre (39,42). The PHI and REI for acephate are 14 days and 24 hours, respectively. There is a material limit of 2.0 lb ai/acre/season (42).

In 2000, Florida growers applied an average of 0.54 pounds of active ingredient of

acephate per acre at each application to 30 percent of their snap bean acreage, an average of 1.8 times. Total usage was 10,300 pounds of active ingredient. During the years in which usage data have been collected, snap bean growers in Florida have applied acephate at a rate ranging from 0.50 to 0.62 pounds of active ingredient per acre at each application, to between 13 and 39 percent of their snap bean acreage. Growers have made an average number of applications ranging from 1.8 to 3.5 each year, totaling between 6,800 and 25,200 pounds of active ingredient annually (11-14,38).

Endosulfan (Thiodan®/Phaser®). Endosulfan is a cyclodiene chlorinated hydrocarbon insecticide that acts as a contact poison. It is used in the management of whiteflies, aphids, armyworms, bean leaf skeletonizers, cowpea curculios, cucumber beetles, cutworms, flea beetles, leafhoppers, Mexican bean beetles, and stinkbugs. The median price of endosulfan is \$15.02 per pound of active ingredient, and the cost per maximum labeled application (1.0 lb ai/A) in 2001 was \$15.02 per acre (39,43). The PHI and REI for endosulfan are 3 days and 24 hours, respectively. No more than 3 applications may be made per year and the material limit is 3.0 lb ai/acre/year (43).

In 2000, Florida growers applied an average of 0.59 pounds of active ingredient of endosulfan per acre at each application to 54 percent of their snap bean acreage, an average of 2.1 times. Total usage was 24,700 pounds of active ingredient. During the years in which usage data have been collected, snap bean growers in Florida have applied endosulfan at an average rate ranging from 0.53 to 0.74 pounds of active ingredient per acre at each application, to between 5 and 54 percent of their snap bean acreage. Growers have made an average number of applications ranging from 1.7 to 4.3 each year, totaling between 1,700 and 32,000 pounds of active ingredient annually (11-14,38).

Imidacloprid (Admire®/Provado®).

Imidacloprid is a neonicotinoid insecticide used in the management of aphids, leafhoppers, whiteflies, and thrips. The median price of imidacloprid is \$281.25 per pound of active ingredient, and the cost per maximum labeled application (0.38 lb ai/A) in 2001 was \$106.88 per acre (39,43). The PHI and REI for imidacloprid are 21 days and 12 hours, respectively. There is a material limit of 0.5 lb ai/acre/year and the material should not be used more than twice during a season (43).

In 2000, Florida growers applied an average of 0.18 pounds of active ingredient of imidacloprid per acre at each application to 20 percent of their snap bean acreage, an average of 1 time. Total usage was 1,300 pounds of active ingredient.

Carbaryl (Sevin®). Carbaryl is a broad-spectrum carbamate insecticide used in the management of armyworms, bean leaf beetles, blister beetles, corn earworms, cowpea curculios, crickets, cutworms, flea beetles, grasshoppers, green cloverworms, leafhoppers, Mexican bean beetles, tarnished plant bugs, sowbugs, stinkbugs, thrips, velvetbean caterpillars, and webworms. The median price of carbaryl is \$7.17 per pound of active ingredient, and the cost per maximum labeled application (1.5 lb ai/A) in 2001 was \$10.76 per acre (39,43). The PHI and REI for carbaryl are 3 days and 12 hours, respectively.

In 2000, Florida growers applied an average of 0.88 pounds of active ingredient of carbaryl per acre at each application to less than one percent of their snap bean acreage, an average of 1.8 times. Total usage was 300 pounds of active ingredient. During the years in which usage data have been collected, snap bean growers in Florida have applied carbaryl at an average rate ranging from 0.54 to 1.60 pounds of active ingredient per acre at each application, to between <1 and 11 percent of their snap bean acreage. Growers have made an average number of applications ranging from 1.8 to 2.7 each year, totaling between 300 and 3,300 pounds of active ingredient annually (11-14,38).

Chemical Alternatives

Due to the pending loss of endosulfan on snap bean, various replacements are required to ensure that enough chemistries are available to combat resistance. Due to efforts of USDA, through IR-4, a number of potential and pending insecticides are in the regulatory pipeline.

Cultural Control

Several cultural controls are recommended for the prevention of silverleaf whitefly infestations, but not all are practical for the snap bean crop. The most important cultural control tactics in snap bean production are early planting of spring crops, rapid destruction of crop residues, and establishment of a host-free period. Weed hosts should also be controlled, particularly phasey bean (*Macroptilium lathyroides*), which is very prevalent in south Florida. However, southeast Florida never experiences a host-free period, since vegetable production takes place in close proximity to nurseries of ornamental plants, some of which are whitefly hosts, including some asymptomatic geminivirus hosts. Heaviest infestations of silverleaf whitefly are observed in fields encountered near crops with recent or current infestations, and planting of susceptible crops should therefore be avoided until whitefly migration has ended (10,21,44).

Destroying vegetation along fence rows and ditch banks surrounding bean fields helps to reduce influx of bean leafhoppers. Also, snap beans should not be planted near cowpeas, from which leafhoppers will migrate, although this is not always possible to achieve (26).

Biological Control

Silverleaf whitefly. Several predators and parasites naturally attack the silverleaf whitefly, including ladybird beetle larvae, green lacewing larvae, and the parasitic wasps *Encarsia* species and *Eretmocerus* species. Many growers in southwest Florida rely on the naturally occurring biological control of the whitefly that occurs in weeds during the summer fallow period. Natural control of whitefly populations can be encouraged by avoiding the use of broad-spectrum insecticides (21,44). Research on the

release of parasitic wasps as biological control agents has been continuing for several years. U.S. Department of Agriculture scientists from ARS and APHIS have reared 46 species or populations of parasites and predators of whiteflies that have been imported from Africa, Asia, Europe and South America. The most promising are introduced species of *Eretmocerus* and *Encarsia*. Work is focusing on field trials and mass rearing (23). Researchers have also been studying the use of entomopathogenic fungi to manage whitefly populations. Such fungi can be applied to the crop in a spray, but adequate coverage under appropriate environmental conditions is necessary for maximum efficacy. Testing of these products in commercial fields is already under way, but they are not yet commercially available (21). However, in a state such as Florida, with heavy pressure from fungal pathogens and the resulting high use of fungicides, these may not be a practical alternative in field production (10).

Mexican bean beetle. A biological control program for Mexican bean beetle was initiated in Florida in 1975, with the introduction of the larval parasitoid *Pediobius foveolatus*. This eulophid wasp is unable to overwinter in Florida, probably because Mexican bean beetles are not present as larvae in the winter months. However, it has an outstanding ability to find its host, which has contributed to the success of the inoculative release programs in Florida. Annual releases of *P. foveolatus* were first made in Alachua and surrounding counties in the spring of 1975. By the fall, no unparasitized 4th-instar larvae were found in Alachua County, and no beetles were present the following spring. The parasitoid was also recovered up to 400 miles from the release site. The most important factors in the success of the parasitoid were the widespread presence of beggarweed, which supports populations of Mexican bean beetle until it enters diapause in the winter, and the long season of warm temperatures that permitted development of up to ten generations of the parasitoid (34).

Releases made the following year in north Florida yielded similar results. The impact on the beetle population lasted for two additional years with no new releases. In 1979, patchy populations of the beetle returned in the most northern counties of the state, but in Alachua County, the original release site,

only moderate infestations of Mexican bean beetle occurred. The last minimal releases were made in 1986. It has been determined that populations of Mexican bean beetle can be kept below economically damaging levels with annual releases of *P. foveolatus* when necessary. Economic analysis also revealed that annual releases could be made at a very low cost (34).

Bean leafroller. Predators and parasites observed to naturally attack the bean leafroller in Florida include the tachinid fly *Chrysotachina alcedo*, a *Polistes* species wasp, and the stink bug *Euthyrhynchus floridanus*. A nuclear polyhedrosis virus has also been found to kill 40 to 50 percent of larvae under conditions of high larval density late in the season (28).

Melon thrips. Preliminary research on the biological control of melon thrips by entomopathogenic fungi has been carried out in greenhouse tests in Florida. Thrips infested bean plants were treated with strains of *Beauveria bassiana* and *Paecilomyces fumosoroseus*. While the latter was found to be inadequate as a biological control agent, *B. bassiana* provided some degree of control. The soil-inhabiting pupal stage is believed to be the most susceptible to that fungus, but more research is needed (45). Again, the high fungal disease pressure in Florida may limit the use of these fungal pathogens as biological control agents (10).

Disease Management

Disease Pathogens

The most important diseases (and their causal pathogens) of snap beans in Florida are bean golden mosaic virus (BGMV), white mold (*Sclerotinia sclerotiorum*), rust (*Uromyces appendiculatus*), common bacterial blight (*Xanthomonas campestris* pv. *phaseoli*), Rhizoctonia root and stem rot (*Rhizoctonia solani*), and Pythium root/stem rot and damping-off (*Pythium* spp.). Additional diseases that may affect snap beans in the state include halo blight (*Pseudomonas syringae* pv. *phaseolicola*), brown spot (*Pseudomonas syringae* pv. *syringae*), anthracnose (*Colletotrichum lindemuthianum*), Alternaria leaf spot (*Alternaria alternata*), Fusarium disease (*Fusarium solani* f.sp. *phaseoli* and *Fusarium oxysporum* f. sp. *vasinfectum*), gray mold (*Botrytis*

cinerea), powdery mildew (*Erysiphe polygoni*), southern blight (*Sclerotium rolfsii*), wet rot (*Choanephora cucurbitarum*), Cercospora leaf blight (*Cercospora canescens* and *C. cruenta*), ashy stem blight (*Macrophomina phaseolina*), common bean mosaic virus, and bean yellow mosaic virus (9,10,18,46).

Bean Golden Mosaic (caused by bean golden mosaic virus, BGMV). Bean golden mosaic, the most economically important viral disease of snap beans in Florida, is relatively new to the state, having first been reported in 1993, when it affected approximately one-third of the snap bean acreage in south Florida (47). From the first year of its appearance, the disease began to cause severe damage to snap bean fields, particularly in Miami-Dade County. Field surveys in 1993 and 1994 in south Florida documented field bean golden mosaic incidence of up to 100 percent. Fields in the Delray Beach area had an average incidence of 38 and 40 percent over the two years, and incidence within fields in the Homestead area averaged 79 and 86 percent, respectively, during the two years. In Miami-Dade County, bean golden mosaic rapidly spread to all snap bean growing areas. Significant reductions in production of snap beans in south Florida in 1993 and 1994 were attributed to the virus (9,48). Since its appearance in 1993, the disease has caused millions of dollars in losses to commercial snap bean growers in south Florida (49).

Bean golden mosaic virus is a geminivirus that produces a leaf mottle of light and dark green areas, with puckering in the darker areas. Leaf margins may curl downward and leaves may be completely malformed in susceptible varieties. The virus may also cause stunting of the bean plant and shedding of flowers, which can result in irregular pod set. Yield reductions are usually greatest when plants are infected early in the season (50). Pre-bloom infection can lead to losses of up to 90 percent, since flowers abscise (10). In addition, the disease causes pods to be deformed, reducing quality of the product. Losses therefore occur from both direct yield reduction and reduction in marketability quality (47).

Whitefly transmitted viruses like bean golden mosaic are difficult to manage. The most important

factor in preventing its spread is adequate management of silverleaf whitefly (*B. argentifolii*), which transmits the virus. The adult silverleaf whitefly can acquire the virus from an infected plant by feeding on it for as little as six minutes, although longer feeding is necessary for transmission to be most efficient. The whitefly is then able to infect healthy plants for a period of several days to several weeks. The disease is most severe when bean plants are at the seedling stage during times when virus-carrying whiteflies are abundant. High temperatures contribute to higher whitefly populations, as well as more rapid disease development (9,51). Despite this, highest disease incidence in Miami-Dade County (south Florida) is in the spring, during the third crop. If summer rains are timely and adequate, whitefly populations are reduced for the fall crop (10).

White Mold (caused by *Sclerotinia sclerotiorum*). White mold, also called sclerotinose, watery soft rot, and sclerotinia rot of beans, is one of the key diseases of snap beans during the cool season in Florida. The heaviest disease period is between late December and January, and it is a problem every winter, particularly in the Homestead area. The disease occurs on a number of commercial vegetable crops, including potato, tomato, cabbage, celery, and lettuce, as well as wild hosts, particularly ragweed. Approximately 15 percent of snap bean acreage is affected with white mold throughout the state (18,46).

The presence of small, black resting structures (*sclerotia*) and a cottony, white mass (*mycelium*) are characteristic of the pathogen. Sclerotia, which are able to survive between crop cycles, are the source of inoculum infesting individual fields from year to year. Usually, white mold in snap beans appears after the start of blossoming. The fungus enters senescent petals and from there moves into the plant, killing the stem above the infection point. The pathogen can also enter the plant through leaves or pods on the soil surface (46,52).

This fungus prefers cool, moist weather. The resulting disease is most severe at temperatures in the range of 60 to 70°F (15 to 21°C). The disease is spread most readily under conditions of high humidity with dew formation. Reduced air

circulation due to close plant spacing or weed growth increases severity of the disease. Under sufficiently moist conditions, sclerotia in the soil produce infectious spores, which are carried in the air and splashing rain to host plants, initiating disease development upon germination. Sprinkler irrigation may favor disease development, and poor drainage can also increase white mold problems. Timing of fungicidal applications is critical. Essential time for treatment is during the blooming period, when the fungus attacks senescing flower petals (18,46,50,52,53).

Rust (caused by *Uromyces appendiculatus*).

Bean rust occurs every year on Florida snap beans but is generally well controlled with the use of resistant varieties and chemical sprays. Fungicide timing is essential in achieving adequate control, with preventative sprays necessary due to the short length of the disease cycle. If fungicide sprays are delayed until rust symptoms appear, economic loss may be severe. Approximately 15 to 20 percent of snap bean acreage in Florida is affected by rust each year. Rust is a common disease on most types of snap beans in Florida, but is especially severe on pole beans. Although it is easily managed on bush beans, virtually all pole beans are infected, since it is more difficult to achieve thorough coverage of the foliage (9,18).

The disease is more common during the cooler months and is generally not seen in south Florida between May and November. In Miami-Dade County, the disease usually appears first in January and continues to increase in severity until final harvest in April. Heavy dews during cool months provide sufficient moisture for spores to germinate and penetrate host plants. Spore germination can occur between 10 and 25°C (50 to 77°F), but the optimal temperature range is 17.5 to 22.5°C (63.5 to 72.5°F). Symptoms appear within five days of infection, and spore production begins after another five to ten days. The bean rust fungus differs from other rust fungi in not requiring an alternate host to complete its life cycle (46,54).

The first symptom of bean rust is the appearance of pale yellow spots on lower leaf surfaces. One or two days later, the round spots become raised and the

leaf surface breaks, exposing pustules of red spores. These characteristic, spore-producing pustules are primarily found on the lower leaf surface and occasionally on pods. If the disease is severe and pustules cover much of the leaf surface, premature leaf drop may occur. When leaves are severely affected before blossoming, yield losses may be much greater than when the disease occurs after the formation of blossoms. On susceptible bean varieties, pustules may be surrounded by yellow halos, while on resistant varieties only very small spots may appear. Although use of resistant varieties is an important management tool for bean rust, 57 races of the rust fungus have been identified, leaving most bean varieties susceptible to at least one race of the fungus. Growers rely on planting varieties of bean resistant to the races of the fungus found in their area. However, new races commonly appear, complicating the use of resistant varieties (46,50,54).

Common Bacterial Blight (caused by *Xanthomonas campestris* pv. *phaseoli*). Although up to three bacterial diseases regularly affect snap beans in the U.S., common bacterial blight is the only bacterial disease of importance in Florida. It is an occasional disease that becomes more severe in years of higher rainfall during the winter months. Due to its sporadic nature, it generally affects five percent or less of snap bean acreage in the state, but in some fields and in some years close to 100 percent of plants may be infected (18,53).

The bacteria is known to be seedborne. When seeds are infected with bacterial blight, seedlings may die before or soon after emergence. Those that survive, as well as the dead seedlings, are the source of inoculum for healthy plants. Under wet conditions, the bacteria can be spread by windblown rain, overhead irrigation, or mechanical means. When infected, older plants develop water-soaked spots that are more evident on the lower leaf surface. The spots later turn brown with a yellow halo, and large areas of dead tissue can result. Spots also develop on pods, starting out as water-soaked areas that later develop brick-colored borders. In some fields, pod infection is prevalent, while leaves are only slightly affected. Common blight bacteria can survive in the soil between growing seasons (50,53).

Rhizoctonia Root and Stem Rot (caused by *Rhizoctonia solani*). Rhizoctonia rot is widespread on snap beans in Florida and occurs annually, since the pathogen is found in all soils. The disease causes an annual yield loss of approximately ten percent throughout the state, although individual fields may experience up to 100 percent infection rates. Stand losses of up to 75 percent have been reported. Snap bean growers generally use in-furrow treatments with chloroneb at planting to manage Rhizoctonia diseases (18,50).

Rhizoctonia rot can cause stem lesions on seedlings before or after emergence. Infections of seedling stems are most common near the soil surface. Older lesions can rot the outer part of the stem and cause the seedling to fall over (46,55). *R. solani* can also cause a soil rot on pods where they touch the ground (16). Disease development can occur over a wide range of soil types, pH, temperature, moisture and fertility. Optimum soil temperatures for development of the disease range from 75 to 85°F (23 to 29°C). Control of Rhizoctonia rot is difficult. Efforts are usually concentrated on tactics that contribute to rapid seedling growth, to minimize the period during which the plant is susceptible (46,55).

Pythium Root/Stem Rot and Damping-off (caused by *Pythium* spp.). Pythium is a soilborne fungus that causes damping-off, which can rot bean seeds and seedlings anytime until plant emergence. The disease is more severe under conditions of excess moisture, deep planting, and recent incorporation of plant material such as weeds or cover crops into the soil. In older plants, Pythium produces a root rot (50).

Pythium diseases are most common early in the fall crop when the weather is still hot and rainy. Growers usually apply seed treatments like thiram or mefenoxam or use in-furrow treatments to control Pythium (18). However, high rates of Pythium rots can be seen any time that there is wet weather and unprotected seed. Up to 15 percent of snap bean acreage may be affected every year in south Florida (10).

Chemical Control

Fungicides totaling 290,300 pounds of active ingredient were applied to 99 percent of the state's snap bean acreage in 2000 (38). The most commonly used fungicides in Florida snap bean production are chlorothalonil, sulfur, mefenoxam (Ridomil Gold®), copper (as hydroxide, sulfate, oxychloride), and pentachloronitrobenzene (PCNB).

Other foliar fungicides registered for snap bean in Florida include iprodione, dicloran, and harpin protein (Messenger®). There are a number of seed treatment fungicides labeled for snap bean as well. These include chloroneb, PCNB, *Trichoderma harzianum*, thiram, captan, *Bacillus subtilis*, and fludioxonil (Maxim®). Fungicides registered in 2002 for snap bean include myclobutanil and *Pseudomonas fluorescens* (seed treatment), but products with these active ingredients were not available in Florida.

Chlorothalonil. Chlorothalonil, a broad-spectrum nitrile fungicide, is one of the most important chemicals used in snap bean disease management in Florida, particularly for the control of rust, but also for anthracnose, *Cercospora* leaf blights, and the pod-blight damage phase of *Alternaria* leaf spot (9). The median price of chlorothalonil is \$10.32 per pound of active ingredient, and the cost per maximum labeled application (2.22 lb ai/A) in 2001 was \$22.99 per acre (39,56). The PHI and REI for chlorothalonil are 7 days and 12 hours, respectively. There is a material limit of 9.0 lb ai/acre/season. The minimum re-treatment interval is seven days (56).

In 2000, Florida growers applied an average of 1.29 pounds of active ingredient of chlorothalonil per acre at each application to 75 percent of their snap bean acreage, an average of 4.0 times. Total usage was 138,000 pounds of active ingredient. During the years in which usage data have been collected, snap bean growers in Florida have applied chlorothalonil at an average rate ranging from 0.95 to 1.46 pounds of active ingredient per acre at each application, to between 41 and 82 percent of their snap bean acreage. Growers have made an average number of applications ranging from 2.6 to 5.9 each year, totaling between 36,800 and 258,700 pounds of active ingredient annually (11-14,38).

Sulfur. Sulfur is a contact and protectant fungicide used in Florida snap bean production to control rust and powdery mildew. The median price of sulfur is \$0.88 per pound of active ingredient, and the cost per maximum labeled application (8.0 lb ai/A) in 2001 was \$7.04 per acre (39,57). The PHI and REI for sulfur are 0 days and 24 hours, respectively (57).

In 2000, Florida growers applied an average of 1.52 pounds of active ingredient of sulfur per acre at each application to 60 percent of their snap bean acreage, an average of 3.6 times. Total usage was 116,300 pounds of active ingredient. During the years in which usage data have been collected, snap bean growers in Florida have applied sulfur at an average rate ranging from 1.52 to 3.59 pounds of active ingredient per acre at each application, to between 33 and 81 percent of their snap bean acreage. Growers have made an average number of applications ranging from 3.6 to 6.5 each year, totaling between 104,800 and 307,600 pounds of active ingredient annually (11-14,38).

Mefenoxam (Ridomil Gold®). Mefenoxam is a systemic acylalanine fungicide used in Florida snap bean production to manage *Pythium* diseases. Although it is very effective in controlling *Pythium* soil-borne diseases, it is not effective against other soil fungi such as *Rhizoctonia* or *Fusarium* and does not control *Pythium*-induced aerial blight on mature plants. Mefenoxam can be used as a seed protectant and as a soil treatment. The median price of mefenoxam is \$157.00 per pound of active ingredient, and the cost per maximum labeled application (0.5 lb ai/A) in 2001 was \$78.50 per acre (39,56). The REI for mefenoxam is 48 hours (56).

In 2000, Florida growers applied an average of 0.17 pounds of active ingredient of mefenoxam per acre at each application to 16 percent of their snap bean acreage, an average of 1.0 time. Total usage was 1,000 pounds of active ingredient. During the years in which usage data have been collected, snap bean growers in Florida have applied mefenoxam at an average rate ranging from 0.09 to 0.25 pounds of active ingredient per acre at each application, to between 16 and 81 percent of their snap bean acreage. Growers have made an average number of

applications ranging from 1.0 to 2.3 each year, totaling between 200 and 5,100 pounds of active ingredient annually (11-14,38).

Copper Hydroxide. Florida snap bean growers use copper hydroxide primarily in the management of bacterial blight. The median price of copper hydroxide is \$2.11 per pound of active ingredient, and the cost per maximum labeled application (1.13 lb ai/A) in 2001 was \$2.37 per acre (39,58). The REI for copper hydroxide is 24 hours and there is no PHI (58).

In 2000, Florida growers applied an average of 0.74 pounds of active ingredient of copper hydroxide per acre at each application to 18 percent of their snap bean acreage, an average of 1.5 times. Total usage was 7,100 pounds of active ingredient. During the years in which usage data have been collected, growers applied copper hydroxide to between 2 and 43 percent of their snap bean acreage, an average of 1.5 to 7.7 times per year. The average rate per application has ranged from 0.29 to 0.81 pounds of active ingredient per acre. Total annual usage in Florida has ranged from 500 to 59,900 pounds of active ingredient (11-14,38).

PCNB. PCNB is a protective, organochlorine fungicide that snap bean growers in Florida apply at planting for the management of *Rhizoctonia* rot and damping-off. The median price of PCNB is \$7.00 per pound of active ingredient, and the cost per maximum labeled application (1.5 lb ai/A) in 2001 was \$10.50 per acre (39,59). The REI for PCNB is 24 hours (59).

In 2000, Florida growers applied an average of 1.0 pound of active ingredient of PCNB per acre at each application to 15 percent of their snap bean acreage, an average of 1.2 times. Total usage was 6,900 pounds of active ingredient. During the years in which usage data have been collected, growers applied PCNB to between 15 and 23 percent of their snap bean acreage, an average of 1.0 to 1.2 times per year. The average rate per application has ranged from 0.75 to 1.0 pounds of active ingredient per acre. Total annual usage in Florida has ranged from 3,800 to 6,900 pounds of active ingredient (11-14,38).

Cultural Control

Plant spacing is the most important component of cultural disease management for snap bean production in Florida. Wider spacing results in greater air circulation and consequent reduction in trapped moisture on the plants, which reduces disease severity. Researchers in Homestead have found that while decreasing between-row spacing can increase yields of some cultivars without increasing disease problems, reduced in-row spacing (between plants) can result in higher levels of disease, especially white mold. The most appropriate spacing of snap bean plants for both yield and disease management has been determined to be between-row spacing of 24 inches (61 cm) and in-row spacing of 3.5 to 4.5 inches (8.9 to 11.4 cm). These recommendations are most appropriate for snap beans grown in Miami-Dade County from December to March (9). Despite these findings, the most commonly used spacings are 36 inches (91 cm) between rows and 2 to 2.5 inches (5 to 6 cm) between plants (10). Many snap bean growers presently utilize the wider between-row spacing as a management strategy for white mold (18). Additional cultural controls recommended for white mold management include turning the soil at least six inches (15 cm) deep and flooding fields for five to six weeks during the summer, where possible (50). The use of crop rotation is not an effective management strategy for white mold, because the fungus has a wide host range and its spores are airborne (53).

The use of disease-free seed is generally the most effective control of common bacterial blight. Additionally, since the bacteria is able to survive in soil, disease severity can be reduced by avoiding planting in infested fields for at least three years. The bacteria is easily spread throughout the field under wet conditions, so staying out of the field when plants are wet can also aid in management of the disease (50).

Although growers rely primarily on the application of protectant fungicides for rust control, one of the most essential management tactics for the disease is the prompt destruction of crop residues. Continuing rust development in fields after harvest is a key source of inoculum for newly planted snap bean fields (54).

Since snap beans are susceptible to several soilborne diseases, choice of land is important. Planting in well-drained fields free of low spots that can accumulate water can aid in management of these diseases, as can rotation with crops that are less susceptible or that must be grown in fumigated, mulched beds (9). Snap bean growers throughout the state frequently rotate away from old land with *Rhizoctonia* build-up to less-farmed land and rotate with less susceptible crops like sweet corn. Many growers (covering approximately 60 percent of snap bean acreage in Florida) also apply foliar fertilizers to encourage general crop growth and reduce the period during which plants are susceptible (18).

Management of *Rhizoctonia* rot can be further aided by additional cultural control tactics, including using disease-free, quality seed that will germinate quickly, avoiding deep seeding, planting when soil temperature is optimal for rapid germination, minimizing old plant debris on the soil surface, controlling soil insects and nematodes, and avoiding overseeding. A major source of disease inoculum on snap beans in Florida has been undecomposed green matter in the soil. Therefore, waiting 30 days after bottom-plowing the old crop in a double-cropping system is recommended to allow green matter to decompose (55).

Post-Harvest Diseases and Their Management

White mold is primarily a field disease, but it can severely affect snap beans after harvest. The fungus causing the disease can infest pods just before harvest without showing symptoms. If diseased pods are present in shipping containers, the fungus can spread to adjacent pods, creating a mass of cottony-white fungal growth referred to as nesting. One infected pod can mean the loss of an entire shipment by the time the beans reach terminal markets (46,52,53).

Post-harvest losses are greatest when beans are transported at temperatures between 66 and 75°F (18.9 to 23.9°C). Although some post-harvest losses from *Sclerotinia* usually occur in Florida, the problem is minimal when the disease has been well managed in the field. Additionally, most snap bean packers in Florida now hydrocool beans in chlorine water after sorting, and then maintain the beans in the

shipping container at 38 to 40°F (3.3 to 4.4°C), which greatly reduces incidence of post-harvest diseases (16,46,60).

Nematode Management

Nematode Pests

Nematodes that attack plants are microscopic roundworms found in the soil, which feed on or in plant roots. As a result of damage to the plant's root system, most symptoms of nematode attack are related to an insufficient supply of water and nutrients to above-ground plant parts. Plants can experience yellowing, stunted growth, wilting and failure to respond adequately to irrigation and fertilization. Nematode damage may also render the plant more vulnerable to attack by soilborne fungal and bacterial pathogens. Plants with symptoms of nematode damage are not distributed uniformly throughout the field, but rather affected plants occur in patchy areas (61).

Single species of nematodes do not usually attack a host plant alone, occurring instead in mixed communities. Plant-parasitic nematodes most damaging to snap beans include root-knot, sting, awl, stubby-root, and reniform nematodes. Root-knot and reniform are the key nematodes in muck soils and the calcareous "Rockdale" soils of Miami-Dade County. Although some nematode problems can be greater during the fall cropping season, due to high soil temperatures, nematode populations may also build during the spring season if double-cropped beans follow beans or squash (20,61).

Root-knot Nematodes (*Meloidogyne* spp.). Although three species of root-knot nematode can attack snap beans, *Meloidogyne incognita* is the species occurring most frequently. Root-knot attack can cause severe stunting, yellowing, early defoliation, widespread development of root galls, and reductions in yield. Decreased root branching and root growth often produce wilting. In addition, root rots can occur as a result of secondary fungal infections. When soil populations of root-knot nematodes are high at planting, seedlings may be stunted or killed, resulting in patchy stand establishment. Under lighter infestations, symptoms may not be obvious until later in the season. The

clearest sign used in diagnosis of root-knot presence is the appearance of galls (swollen areas) on the roots of infected snap bean plants. Galls may be present as a few spherical swellings or they may cover large areas as extended swellings. They are easily distinguished from the nitrogen fixing *Rhizobium* spp. nodules normally associated with bean and other legume plants (61).

Snap beans are highly susceptible to root-knot nematodes. Populations can build quickly on the crop, which can potentially cause great losses to any susceptible crops that follow. The damage threshold for root-knot nematodes on snap beans is very low. Consequently, pre-plant treatment of the field with nematicides is recommended for any detection of the nematode in soil samples or in the previous crop. However, the cost of treatment prohibits most snap bean growers in Florida from treating with nematicides (10,61).

Yield losses of 50 to 90 percent are often reported on snap beans. Factors such as the species involved, the initial nematode population in the soil, the snap bean cultivar, and environmental conditions determine how much damage the crop experiences. Damage from root-knot is usually greater during the fall cropping season, when higher soil temperatures permit faster buildup of the population. However, if fields have experienced summer flooding, nematode populations are low at the start of the season (10,61).

Sting Nematodes (*Belonolaimus longicaudatus*). Sting nematodes remain in the soil throughout their lives, feeding on the outside of plant roots, at or near the root tip or on root hairs. They damage snap beans by producing a tight swelling of short roots on infested plants. Under heavy infestations, new roots can be killed in a way that appears like fertilizer salt burn. Sting nematodes are especially damaging to seedlings, and they may prevent seedling emergence by attacking the shoot tip of a germinating seed. Sting nematodes prefer light, sandy soils and are not found in Florida's muck soils (61-63).

Awl Nematodes (*Dolichodorus* spp.). Awl nematodes also feed externally on plant roots, most often at root tips but also along the sides. They damage the plant by inhibiting root elongation. As a result, the plant's ability to take in sufficient water

and nutrients is diminished, leading to the foliar symptoms described above. Awl nematodes have been found feeding on bean seed embryos, preventing germination, and on bean seedlings, discoloring and destroying roots (61,62).

Stubby-root Nematodes (*Trichodorus* spp.).

Another external feeder, stubby-root nematodes stop growth at the root tip, resulting in a generally smaller root system or "stubby root" symptoms, in which the root system develops as clusters of short, stubby branches. These nematodes have been found in both sandy and muck soil, but are damaging only to snap beans in sandy soils. Populations of stubby-root nematodes can build up quickly in the presence of a suitable host, but may also diminish rapidly in the absence of host plants (61,62).

Reniform Nematodes (*Rotylenchulus* spp.).

Reniform nematodes feed within the plant root, entering as second-stage juveniles and settling at a feeding site. By releasing growth regulators into the surrounding tissue, the nematodes cause the plant to redirect nutrients to the cells around the feeding site, using up energy and disrupting the vascular system. Yields of snap beans have been found to be more closely related to the population density of reniform nematodes at the end of the crop season than the initial population density. Reniform nematodes, which are common in south Florida, are potentially damaging on the Rockdale soils of Miami-Dade County, where action thresholds have been estimated at counts of 200 or more reniform nematodes per 100 cc of soil (51,61,63,64).

Chemical Control

Metam-sodium (Vapam®) and dichloropropene (Telone®) are the fumigant nematicides available in Florida. The only non-fumigant nematicide registered for snap beans is ethoprop (Mocap®), which is less effective against root-knot nematodes. Very low doses of these nematicides are usually adequate, because nematode populations are able to increase only minimally during the very short growing season of snap beans (61).

Minimal use of nematicides has been reported on Florida snap beans, in part because the management of soil-borne diseases is crucial, so growers choose

soil treatments based on pathogen control. In addition, non-fumigant nematicides leach rapidly in the high pH soils of south Florida, and soil fumigation is considered uneconomical. The use of dichloropropene was last reported in 1990, when it was applied to approximately one percent of the Florida snap bean acreage (14).

Cultural Control

Although *Meloidogyne incognita* is the only nematode for which resistance has been incorporated into commercial snap beans, many resistant cultivars have been developed. The nature of the resistance is a delay in nematode development rather than reduced ability of the nematode to penetrate the plant root. For many resistant cultivars (including Nemasnap, Kabanima, P.I. 313709, Alabama no. 1, Carioc, Manoa Wonder, BAT 1297, A55, A56, A322, A439 and AB 136), resistance is lost when soil temperatures exceed 27 to 29°C (80 to 85°F). Use of these resistant varieties may therefore be limited to the spring crop, when soil temperatures are lower. Resistant cultivars for which heat instability is unknown include Tendergreen, Tenderpod, Saginaw, Wingard Wonder, Rico 23, P.I. 165435, and Alabama 2, 8 and 19, many of which are old varieties, or breeding lines that may be low yielding, horticulturally unacceptable (i.e., developed for home garden), and/or commercially unavailable (61,65).

Crop rotations are practiced when possible, but since the nematodes that affect snap beans also attack most vegetable crops, growers are not always able to incorporate into a rotation sequence crops on which nematodes are unable to reproduce. Crop rotation becomes especially difficult when populations of root-knot and sting nematodes occur together. Research has shown that snap bean yields can increase following a summer cover crop of hairy indigo or *Crotalaria spectabilis*, as long as weeds are controlled. Furthermore, rotation with corn or southern peas resistant to root-knot can reduce the need for nematicide treatments in snap beans. However, neither winter rye nor fallow within corn and snap bean multiple-cropping systems have been shown to provide adequate reduction of root-knot populations alone. A combination of management

methods has proven necessary to reduce nematode populations below economically damaging levels (61).

Populations of *M. incognita* can also be suppressed by summer fallow, which is generally the most important cultural control for nematodes. For fallow to be effective in reducing nematode populations, however, weeds must be controlled. Mechanical weed control further aids by bringing up nematodes from deeper soil layers, exposing them to drying by the sun and wind. Other cultural controls include rapid destruction of crop root systems after harvest, disking of fields soon after harvest, and alternate flooding and drying cycles in the summer. Flooding can be practiced only in some areas of the state. Use of resistant cultivars, crop rotations, fallow, and other cultural controls when used singly are not enough to substantially reduce damage to snap beans from nematodes, but each can be an important component of a multiple-tactic nematode management strategy (61).

Weed Management

Weed Pests

Weeds are a significant problem in snap bean production in Florida. Competition from weeds for nutrients, moisture, and light is especially crucial during crop establishment. Therefore, weed management should be emphasized during the early part of the season. Throughout the season, weeds can harbor insect and disease pests. When present at harvest, weeds can contribute to mechanical pod damage, as well as reduce efficiency of harvest operations. The diversity of weed species present in any field depends on a number of factors, including the season, soil type, and geographic region within the state (66). The weeds that have been reported as most problematic to snap bean growers are, in decreasing order of importance, pigweed, ragweed, poundcake weed (*Parthenium* weed), purslane, mustard, nutsedge, grasses and nightshade (20).

Pigweed (*Amaranthus* spp.). Pigweeds (*amaranths*) are summer annual herbs with erect stems that can grow to two meters (6.5 feet) tall. The species present in Florida include smooth pigweed (*Amaranthus hybridus*), spiny amaranth (*Amaranthus*

spinus), and livid amaranth (*Amaranthus lividus*). Smooth and spiny amaranths are the principal amaranth weeds in Florida. Pigweeds reproduce solely by seed, producing very small, dark seeds. Smooth pigweed flowers from July to November, and spiny amaranth flowers from June to October (67-69).

Ragweed (*Ambrosia* spp.). Common ragweed (*A. artemisiifolia*) and giant ragweed (*A. trifida*) are common weeds in cultivated fields in Florida. Also summer annuals, ragweeds have erect, branching stems and can reach six to 12 feet (1.8 to 3.6 meters) in height. They reproduce by seeds and flower from July to October (67,68).

Poundcake Weed (*Parthenium hysterophorus*). Poundcake weed, also called parthenium weed, is an annual with a deep tap root that can grow to two meters (6.5 feet) in height. It has an erect stem that becomes woody as the plant ages. *Parthenium* reproduces by seeds, which germinate after rains. The plant flowers within 6 to 8 weeks and senesces under drought conditions. Seeds can remain dormant in the soil for many years. On the soil surface they can remain viable for two years (70). *Parthenium* weed is only found in the southern part of the state (69). It is resistant to most herbicides (10).

Purslane (*Portulaca oleracea*). Another summer annual, purslane has branched stems and clustered leaves. It reproduces by seed, flowering from late spring to October. Purslane is drought resistant and does not die easily (10,67,68).

Chemical Control

A total of 10,600 pounds of herbicide active ingredient was applied to snap beans grown in Florida in 2000 (38). The only herbicide reportedly used in Florida snap bean production was metolachlor (Dual®). Other preemergence herbicides labeled for use in snap bean include trifluralin, EPTC, pendimethalin (Prowl®), lactofen (Cobra®), imazethapyr (Pursuit®), and clomazone (Command®), while postemergent herbicides include paraquat, glyphosate, quizalofop (Assure®), bentazon (Basagran®), pelargonic acid (Scythe®), and sethoxydim (Poast®). Imazamox was registered in 2002 for snap bean, but product with this active ingredient was not available in Florida.

Metolachlor (Dual®). Metolachlor is a selective, preemergence acetanilide herbicide used to control certain broadleaf and many annual grass weeds. Snap bean growers apply it either pre-plant incorporated or pre-emergence (8). The median price of metolachlor is \$13.76 per pound of active ingredient, and the cost per maximum labeled application (1.9 lb ai/A) in 2001 was \$26.28 per acre (39,56). The REI for metolachlor is 24 hours (56).

In 2000, Florida growers applied an average of 1.19 pounds of active ingredient of metolachlor per treated acre at each application to 23 percent of their snap bean acreage, an average of 1 time. Total usage was 10,600 pounds of active ingredient. During the years in which usage data have been collected, snap bean growers have applied metolachlor an average of 1.0 to 1.1 times yearly to between 5 and 31 percent of the crop's acreage. An average of 0.57 to 1.39 pounds of active ingredient per treated acre have been used per application. Total annual usage has ranged from 1,400 to 13,900 pounds of active ingredient (11-14,38).

Cultural Control

Snap bean growers in Florida commonly practice mechanical cultivation between rows for weed control, as well as to mix in dry sidedress fertilizer. In addition to cultivation, use of weed-free seed and clean equipment can help prevent weed problems. Many weeds can be reduced by such cultural tactics as the use of cover crops during the non-crop period, or rotation schemes involving smother crops that compete well with weeds (68).

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