Florida Crop/Pest Management Profiles: Snap Beans[1]

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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 44% of the US total in terms of production and 27.4% in terms of cash receipts.[1] During the winter months (January, February, and March), Florida produces 100% of the fresh market snap beans grown in the United States.[1, 2]

In 2009–2010, Florida growers produced 193.2 million pounds of snap beans, with a value of $0.69 per pound and a total value of $135 million. Snap beans were planted on 36,400 acres, and 32,200 acres were harvested, yielding an average of 6,000 pounds per acre.[1, 2]

In 2007, there were 373 snap bean producing farms in Florida. Of those farms, 68.6% produced snap beans on less than 5 acres, and as a group, these farms represent 0.4% of the state's total snap bean acreage. An additional 11.5% maintained 5–49 acres of snap beans (representing 1.85% of the state's snap bean acreage); 8.6% planted 50–249 acres (10.7% of acreage); 4.8% planted 250–499 acres (13.8% of acreage); and 6.4% planted more than 500 acres (73.2% of acreage).[3]

During the 2009–2010 season, snap beans ranked third for harvested acreage and first for production value among Florida's diverse vegetable commodities. Harvested acreage for snap beans represented 14.4% of the state's total vegetable acreage, while production value represented 22% of total production value for Florida vegetables.[1]

Total production costs in 1999–2000 for bush-type snap beans in the Dade County area were estimated at $3,329 per acre. Of that total, $1,128 represents harvest and marketing costs, and $2,200 represents preharvest operating costs. Costs for fungicides totaled $177.63 per acre; costs for herbicides totaled $3.39 per acre; and costs for insecticides totaled $131.32 per acre. Therefore, direct costs for pesticides accounted for 14.2% of preharvest operating costs and 9.4% of total production costs.[4]

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 2007, 96% of snap bean production in the state was for the fresh market.[3]

Production Regions

The principal production region for snap beans in Florida is the southeastern region (mainly Miami-Dade and Palm Beach Counties). Miami-Dade County is both a state and national leader in the production of fresh market snap

1. This document is CIR1231, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date October 1999. Revised August 2000, April 2003, and October 2012. Reviewed December 2015. Visit the EDIS website at http://edis.ifas.ufl.edu.

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beans. Approximately half of the state's production occurs in Miami-Dade County, and it is home to 63% percent of the state's snap bean harvested acreage and 27% percent of its farms. Palm Beach County is second in harvested area, accounting for 17.8% of harvested acres and 8.8% of snap bean farms in Florida.[1, 3]

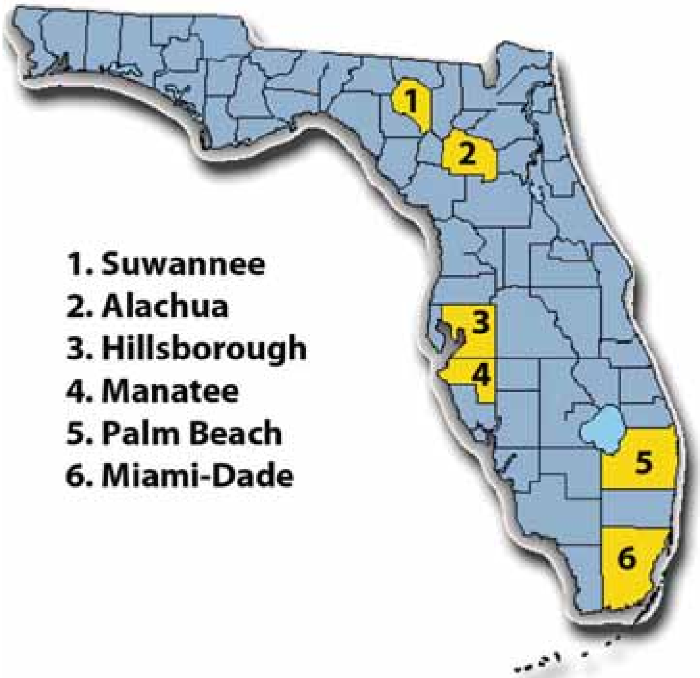

Figure 1. Production regions for snap beans in Florida.

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.[1, 5, 6]

Both bush-type and pole-type snap beans are grown in Florida, but the majority grown are 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 1–1.5 inches (2.5 –3.8 cm), with a distance of 18–36 inches (46–91 cm) between rows and 2–4 inches (5–10 cm) between plants, generating a population of 172,240 plants per acre. Pole-type snap beans are usually planted 1–1.5 inches (2.5–3.8 cm) deep, with 36–48 inches (91–122 cm) between rows and 3–5 inches (8–13 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.[6, 7]

One-half of the nitrogen and potassium fertilizer is applied at planting, with the rest added later in one or two additional applications.[8] In 2006 when usage data was collected, 87% of snap bean acreage in Florida received an average of 3.0 applications of nitrogen annually. Approximately 29 pounds of nitrogen per acre were used at each application, with a statewide total of 2.5 million pounds. Approximately 60 pounds per acre of phosphate have been applied to an average of 1.3 times annually to 65% of snap bean acreage, with total usage of 1.7 million pounds. Potash has also been applied an average of 2.6 times per year to 81% of the acreage. About 45 pounds of potash per acre are used at each application, and a total of 3.2 million pounds have been used annually.[7]

There are not many worker activities required for snap beans. Since the seeds are mechanically seeded, hand labor is only required for rogue double plants or reseeding holes. For machine-harvested beans in Florida (>95% 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 packinghouse. 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 38–40°F (3.3–4.4°C). Many 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.[5, 9-11]

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 stink bug, 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, leaffooted 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.[12-15]

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 was 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. This pest's host range is much broader than that of sweet potato whitefly. Silverleaf whitefly attacks more than 500 plant species.[16, 17]

The whitefly damages the bean plant directly by removing plant sap with its piercing-sucking mouthparts. Both adults and immature nymphs produce feeding damage. Feeding can result in stunting and defoliation, as well as the production of honeydew, where sooty mold can grow. The adults feed and mate primarily on the underside of leaves, and they are most active from mid-morning to mid-afternoon. The adults fly within the crop canopy, complete migratory flights, and prefer yellow and green objects when settling. Each adult female deposits 50–400 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, when it will have two red eyes. Usually, all stages of the life cycle can be seen together on the plant.[16, 17]

In addition to directly damaging the bean plant, silverleaf whitefly is a vector of bean golden mosaic virus in Florida and possibly tomato yellow leaf curl virus (TYLCV).[8, 9] Small numbers of whiteflies are sufficient to spread the virus, so diligent management is essential in areas where geminiviruses such as BGMV are present. Silverleaf whitefly sampling plans have been developed for cotton, but they are not completely developed for vegetable crops. Not enough data is available to establish action thresholds for most crops. Also, the silverleaf whitefly rapidly developed a resistance to insecticides and became difficult to control with conventional chemical tactics. This is 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.[16, 18]

MELON THRIPS (*THRIPS PALMI*)

First reported in Miami-Dade County in 1990, melon thrips is a major pest of snap beans in South Florida. This 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 severely defoliated 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 68–77°F (20–25°C) and longer at higher or lower temperatures.[9, 19, 20]

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.[9, 13, 21, 22]

BEAN LEAFROLLER (URBANUS PROTEUS)

Bean leafroller is found throughout the state but used to be a prevalent problem in Miami-Dade County. It 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*). Bean leafroller is unable to withstand extended freezing temperatures, so it breeds throughout the year only in the southern part of the state. It often migrates 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.[3, 23]

The bean leafroller's life cycle may be completed in as little as 30 days. Eggs hatch in three to four days, after they are deposited on the lower leaf surface individually or in clusters of two to six. The larvae, which pass through five instars in 15–20 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 7–20 days, after which the adult emerges.[23]

Bean plants can tolerate defoliation of up to about 30% 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.[24, 25]

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 they have resistance to many insecticides and have a 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.[23, 24]

SOUTHERN GREEN STINK BUG (*NEZARA VIRIDULA*)

Southern green stink bug 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. The insect damages the plant with its piercing-sucking mouthparts, removing plant sap and puncturing 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.[26]

As an adult, the insect overwinters during the coldest months, and is most prevalent from October to December and from March to April. Up to four generations per year occur in warmer climates. The southern green stink bug completes its life cycle in 65–70 days. Three to four weeks after reaching the adult stage, females deposit one to two masses of 30–130 eggs 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.[26]

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).[26] Even a small number of stink bugs on snap beans can affect the grade standard because damage to the pods lowers the quality of product harvested.[9]

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 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.[13, 21, 27]

SOUTHERN ARMYWORM (*SPODOPTERA ERIDANIA*)

Southern armyworm is a minor pest of Florida snap beans. It has a wide host range, including vegetables such 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, and 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.[13, 21]

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 5–20 days to mature into adults, depending on temperature. Many generations occur each year. Development is faster under hot, dry conditions.[27]

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 (also the family of the beneficial ladybird beetles). Commonly found throughout the eastern United States, 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.[27-29]

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 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 40–75) 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 find moist, sheltered places to overwinter, and are able to fly long distances to find new bean fields.[28, 29]

Although Mexican bean beetles can feed on leaves, flowers, and pods, they most commonly attack leaves. The most important stage of the insect in terms of damage to the plant is the larval stage. Economic thresholds on bean plants vary depending on variety and conditions, but have been estimated at 1–1.5 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.[28, 29]

BANDED CUCUMBER BEETLE (*DIABROTICA BALTEATA*)

The banded cucumber beetle, another occasional minor pest, is found throughout Florida, but it is more common in the southern part of the state. Cucumber beetle adults prefer to feed on leaves of bean and soybean, but they can damage many plants, including vegetables such as cucumber, squash, beet, pea, sweet potato, okra, corn, lettuce, onion, and cabbage. Adult cucumber beetles chew holes in 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 11–17 days in the larval stage, cucumber beetles pupate in the soil, and four to six days later, the adult emerges.[30]

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, shepherdspurse, 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 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.[22, 27]

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. Using piercing-sucking mouthparts, these leafhoppers feed on the plant sap, causing 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.[24, 31]

GARDEN FLEAHOPPER (*HALTICUS BRACTATUS*)

This plant bug is a major pest in home gardens, but not 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 80–100 eggs over her 30–50 day lifespan. The egg stage lasts about 14 days. Nymphs pass through five instars in an average of 39 days.[32]

Chemical Control

Eighty percent of Florida's snap bean acreage received insecticide applications in 2010, totaling 32,300 pounds of active ingredient.[33] The most frequently used insecticides include acephate, dimethoate, and *Bacillus thuringiensis*. Older insecticides labeled for use on snap bean include methomyl (Lannate®), imidacloprid (Admire®/Provado®), esfenvalerate (Asana®), carbaryl (Sevin®), chlorpyrifos, diazinon, disulfoton (Di-Syston®), malathion, naled (Dibrom®), phorate (Thimet®), pyrethrins plus piperonyl butoxide, azadirachtin, dicofol, soap, oil, bifenthrin, zeta-cypermethrin, spinosad (Spintor®), and pyriproxyfen (Esteem®).[34] Other active ingredients recently registered for insect and mite management include acequinocyl (Kanemite®), acetamiprid (Assail®), bifenazate (Acramite®), buprofezin (Courier®), chlorantraniliprole (Coragen®), flubendiamide (Belt®), lambda and gamma cyhalothrin, methoxyfenozide (Intrepid®), novaluron (Rimon®), spinetoram (Radiant®), spirotetramat (Movento®), and thiamethoxam (Cruiser®). Some of these may be seed treatment as well as foliar.

METHOMYL (LANNATE®)

Methomyl is a broad-spectrum carbamate insecticide used to manage aphids, armyworms, corn earworms, cucumber beetles, cutworms, leafhoppers, loopers, lygus bugs, Mexican bean beetles, saltmarsh caterpillars, and thrips. Methomyl may be applied up to one day before harvest (PHI=1 day) when 0.75–1.5 pints per acre are used, or up to three 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.[34, 35]

In 2000, Florida growers applied an average of 0.35 pounds of active ingredient of methomyl per acre at each application to 30% of their snap bean acreage, an average of 1.8 times. Total usage was 6,900 pounds of active ingredient. During the years usage data was collected, Florida snap bean growers have applied methomyl to a range of 30%–62% of their snap bean acreage, an average of 1.6–6.7 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.[36]

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.[34, 37] *B.t.* may be applied up to the day of harvest (PHI=0), and the restricted entry interval (REI) under the Worker Protection Standard is four hours.[34]

In 2010, Florida growers applied *B.t.* to 7% of their snap bean acreage with an average of 3.9 applications.[33] In 2000, Florida growers applied *B.t.* to 44% of their snap bean acreage, an average of 3.1 times. During the years usage data was collected, snap bean growers in Florida applied *B.t.* to 21%–49% of their snap bean acreage, each making an average of 2.2–4.0 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.[36]

ACEPHATE (ORTHENE®)

The organophosphate insecticide acephate is used as a foliar spray to manage aphids, armyworms, bean leaf beetles, bean leafrollers, corn earworms, cutworms, fleahoppers, grasshoppers, green cloverworms, leafhoppers, loopers, lygus bugs, plant bugs, thrips, and whiteflies. The PHI for acephate is 14 days, while the REI for acephate is 24 hours. There is a material limit of 2.0 lb ai/acre/season.[34, 38]

In 2010, Florida growers applied an average of 0.71 pounds of active ingredient of acephate per acre at each application to 49% of their snap bean acreage, an average of 1.3 times. Total usage was 23,600 pounds of active ingredient.[33] In 2000, Florida growers applied an average of 0.54 pounds of active ingredient of acephate per acre at each application to 30% of their snap bean acreage, an average of 1.8 times. Total usage was 10,300 pounds of active ingredient. During the years usage data was collected, Florida snap bean growers applied acephate at a rate ranging from 0.50 to 0.62 pounds of active ingredient per acre at each application, to 13%–39% of their snap bean acreage. Growers made an average of 1.8–3.5 applications each year, totaling between 6,800–25,200 pounds of active ingredient annually.[36]

IMIDACLOPRID (ADMIRE®/PROVADO®)

Imidacloprid is a neonicotinoid insecticide used to manage aphids, leafhoppers, whiteflies, and thrips.[34, 39] The PHI for imidacloprid is 21 days, and the REI is 12 hours. 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.[34, 39]

In 2000, Florida growers applied an average of 0.18 pounds of active ingredient of imidacloprid per acre at each application to 20% of their snap bean acreage, an average of one time. Total usage was 1,300 pounds of active ingredient.[36]

CARBARYL (SEVIN®)

Carbaryl is a broad-spectrum carbamate insecticide used to manage 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 PHI for carbaryl is 3 days, while the REI is 12 hours.[34, 39]

In 2000, Florida growers applied an average of 0.88 pounds of active ingredient of carbaryl per acre at each application to less than 1% of their snap bean acreage, an average of 1.8 times. Total usage was 300 pounds of active ingredient. During the years usage data was collected, Florida snap bean growers applied carbaryl at an average rate ranging from 0.54 to 1.60 pounds of active ingredient per acre at each application to <1%–11% of their snap bean acreage. Growers have made an average of 1.8–2.7 applications each year, totaling between 300 and 3,300 pounds of active ingredient annually.[36]

Cultural Control

Several cultural controls are recommended to prevent 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 (*Macroptylium 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 be avoided until whitefly migration has ended.[9, 16, 40]

Destroying vegetation along fence rows and ditch banks surrounding bean fields helps to reduce influx of bean leafhoppers. Although it is not always possible, snap beans should not be planted near cowpeas, because leafhoppers will migrate from cowpeas to other plants.[21]

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.[16, 40] Research on the release of parasitic wasps as biological control agents has been continuing for several years. USDA 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.[18] 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. These products are being tested in commercial fields, but they are not yet commercially available.[16] However, these may not be a practical alternative in field production in states like Florida where the heavy pressure from fungal pathogens results in the high use of fungicides.[9]

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.[29]

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. 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.[29]

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%–50% of larvae under conditions of high larval density late in the season.[23]

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 *Paecilomyces fumosoroseus* 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.[41] Again, the high fungal disease pressure in Florida may limit the use of these fungal pathogens as biological control agents.[9]

Disease Management

Disease Pests

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.[8, 9, 13, 42]

BEAN GOLDEN MOSAIC (CAUSED BY BEAN GOLDEN MOSAIC VIRUS, BGMV)

Bean golden mosaic is the most economically important viral disease of snap beans in Florida. It is relatively new to the state, having been first reported in 1993, when it affected approximately one-third of the snap bean acreage in South Florida.[42] 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%. Fields in the Delray Beach area had an average incidence of 38% and 40% 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.[8, 43] Since its appearance in 1993, the disease has caused millions of dollars in losses for commercial snap bean growers in South Florida.[44]

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.[45] Pre-bloom infection can lead to losses of up to 90%, since flowers abscise.[9] In addition, the disease causes pods to be deformed, reducing quality of the product. Losses occur from both direct yield reduction and reduction in marketability quality.[42]

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.[8, 45] 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.[9]

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% 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 can survive between crop cycles, and they 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, 47]

This fungus prefers cool, moist weather. The resulting disease is most severe at temperatures in the range of 60–70°F (15–21°C). The disease is spread most readily under conditions of high humidity with dew formation. Reduced air circulation caused by 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. These spores initiate disease development on 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.[13, 46-49]

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 because of the short length of the disease cycle. If fungicide sprays are delayed until rust symptoms appear, economic loss may be severe. Approximately 15%–20% 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 because it is more difficult to achieve thorough coverage of the foliage.[8, 13]

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 at 50–77°F (10–25°C), but the optimal temperature range is 63.5–72.5°F (17.5–22.5°C). 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 because it does not require an alternate host to complete its life cycle.[50]

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 using 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.[50]

COMMON BACTERIAL BLIGHT (CAUSED BY *XANTHOMONAS CAMPESTRIS* PV. *PHASEOLI*)

Although up to three bacterial diseases regularly affect snap beans in the United States, 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. Because of its sporadic nature, it generally affects 5% or less of snap bean acreage in the state, but in some fields and in some years, close to 100% of plants may be infected.[13, 49]

The bacteria are 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. 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.[49]

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 10% throughout the state, although individual fields may experience up to 100% infection rates. Stand losses of up to 75% have been reported. Snap bean growers generally use in-furrow treatments with chloroneb at planting to manage Rhizoctonia diseases.[13, 51]

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.[47, 52] *R. solani* can also cause a soil rot on pods where they touch the ground.[11] The disease can develop 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 when the plant is susceptible.[47, 51]

PYTHIUM ROOT/STEM ROOT AND DAMPING-OFF (CAUSED BY *PYTHIUM* SPP.)

Pythium is a soilborne fungus that causes damping-off, which can rot bean seeds and seedlings any time 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.[48]

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*.[13] However, high rates of Pythium rots can be seen any time that there is wet weather and unprotected seed. Up to 15% of snap bean acreage may be affected every year in South Florida.[9]

Chemical Control

Fungicides totaling 195,600 pounds of active ingredient were applied to 94% of the state's snap bean acreage in 2010.[33] The most commonly used fungicides in Florida snap bean production are sulfur, chlorothalonil, thiophanate methyl, copper hydroxide, and azoxystrobin. Older foliar fungicides registered for snap bean in Florida include iprodione and dicloran. There is a number of seed treatment fungicides labeled for snap bean as well. These include PCNB, *T. gamsii*, *Bacillus subtilis*, *B. pumilus*, fludioxonil (Maxim®), mefenoxam (Ridomil®), and myclobutanil.[34] Other active ingredients recently registered for fungal management include boscalid (Endura®), fluazinam (Omega®), fluxapyroxad (Priaxor®), penthiopyrad (Fontelis®), pyraclostrobin (Headline®), and tebuconazole (Folicur®).

SULFUR

Sulfur is a contact and protectant fungicide used in Florida snap bean production to control rust and powdery mildew.[34, 52] The PHI for sulfur is 0 days, and the REI is 24 hours.[52]

In 2010, Florida growers applied an average of 1.97 pounds of active ingredient of sulfur per acre at each application to 51% of their snap bean acreage, an average of 2.3 times. Total usage was 85,300 pounds of active ingredient.[33] During the years (1990-2000) usage data was collected, Florida snap bean growers applied sulfur at an average rate ranging from 1.52 to 3.59 pounds of active ingredient per acre at each application to 33%–81% of their snap bean acreage. Growers made an average of 3.6–6.5 applications each year, totaling between 104,800–307,600 pounds of active ingredient annually.[36]

CHLOROTHALONIL

Chlorothalonil, a broad-spectrum nitrile fungicide, is one of the most important chemicals used in snap bean disease management in Florida. It is particularly important for the control of rust but is also used for anthracnose, Cercospora leaf blights, and the pod-blight damage phase of Alternaria leaf spot.[8] The PHI for chlorothalonil is 7 days, and the REI is 12 hours. There is a material limit of 9.0 lb ai/acre/season. The minimum re-treatment interval is seven days.[34, 53]

In 2010, Florida growers applied an average of 1 pound of active ingredient of chlorothalonil per acre at each application to 50% of their snap bean acreage, an average of 3.0 times. Total usage was 55,800 pounds of active ingredient.[33] During the years (1990-2000) usage data was collected, Florida snap bean growers applied chlorothalonil at an average rate ranging from 0.95 to 1.46 pounds of active ingredient per acre at each application to 41%–82% of their snap bean acreage. Growers made an average of 2.6–5.9 applications each year, totaling between 36,800–258,700 pounds of active ingredient annually.[36]

COPPER HYDROXIDE

Florida snap bean growers use copper hydroxide primarily to manage bacterial blight.[34, 54] The REI for copper hydroxide is 24 hours, and there is no PHI.[34, 54]

In 2010, Florida growers applied an average of 0.46 pounds of active ingredient of copper hydroxide per acre at each application to 44% of their snap bean acreage, an average of 1.5 times. Total usage was 11,000 pounds of active ingredient.[33] During the years (1990-2000) usage data was collected, growers applied copper hydroxide to 2%–43% percent of their snap bean acreage, an average of 1.5–7.7 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.[36]

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 3.5–4.5 inches (8.9–11.4 cm). These recommendations are most appropriate for snap beans grown in Miami-Dade County from December to March.[8] Despite these findings, the most commonly used spacings are 36 inches (91 cm) between rows and 2–2.5 inches (5–6 cm) between plants.[9] Many snap bean growers use the wider between-row spacing as a management strategy for white mold.[13] Additional cultural controls recommended for white mold management include turning the soil at least 6 inches (15 cm) deep and flooding fields for five to six weeks during the summer, if possible. Crop rotation is not an effective management strategy for white mold, because the fungus has a wide host range and its spores are airborne.[48, 49]

Using disease-free seed is generally the most effective control of common bacterial blight. Additionally, since the bacteria are 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 managing the disease.[49]

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.[50]

Choice of land is important because snap beans are susceptible to several soilborne diseases. Planting in well-drained fields free of low spots that accumulate water helps to manage these diseases, along with crop rotation using crops that are less susceptible or that must be grown in fumigated, mulched beds.[8] Snap bean growers throughout the state frequently rotate away from old land with *Rhizoctonia* buildup to less-farmed land and rotate with less susceptible crops like sweet corn. Many growers (covering approximately 60% of snap bean acreage in Florida) also apply foliar fertilizers to encourage general crop growth and reduce the time plants are susceptible.[13]

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.[51]

Post-Harvest Diseases and 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, 47, 49]

Post-harvest losses are greatest when beans are transported at temperatures of 66–75°F (18.9–23.9°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 38–40°F (3.3–4.4°C), which greatly reduces incidence of post-harvest diseases.[11, 46, 55]

Nematode Management

Nematode Pests

Nematodes are microscopic roundworms found in the soil that attack plants by feeding on or in plant roots. Nematodes damage the plant's root system, so 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.[56]

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. Some nematode problems can be greater during the fall cropping season because of the high soil temperatures, but nematode populations may also build during the spring season if double-cropped beans follow beans or squash.[15, 56]

ROOT-KNOT NEMATODES (*MELOIDOGYNE* SPP.)

Although three species of root-knot nematode can attack snap beans, *Meloidogyne incognita* is the species that occurs 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.[56]

Snap beans are highly susceptible to root-knot nematodes. Populations can build quickly on the crop, and they 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 Florida snap bean growers from using nematicides.[9, 56]

Yield losses of 50%–90% 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. Root-knot damage 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.[9, 56]

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.[56-58]

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.[56, 58]

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.[56, 57]

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. Snap bean yields 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. Common in South Florida, reniform nematodes 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.[45, 56, 58, 59]

Chemical Control

Metam-sodium (Vapam®) and dichloropropene (Telone®) are the fumigant nematicides available in Florida. The non-fumigant nematicide ethoprop (Mocap®) is also registered for snap beans, but it is less effective against root-knot nematodes. Very low doses of these nematicides are usually adequate because nematode populations only increase minimally during the very short growing season of snap beans.[34, 56]

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.

Cultural Control

Many nematode-resistant snap bean cultivars have been developed, but the only resistance incorporated into these beans is for the nematode *Meloidogyne incognita*. 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 80–85°F (27–29°C). Use of these resistant varieties may 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.[56, 60]

Crop rotations are practiced when possible, but the nematodes that affect snap beans also attack most vegetable crops. Growers are not always able to incorporate crops that nematodes cannot reproduce on into the rotation sequence. 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 has 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.[56]

M. incognita populations 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 also helps with nematode control by bringing nematodes up from deeper soil layers and 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. Using resistant cultivars, crop rotations, fallow, and other cultural controls by themselves 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.[56]

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. If weeds are present at harvest, they 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.[61] 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.[62]

PIGWEED (*AMARANTHUS* SPP.)

Pigweeds (amaranths) are summer annual herbs with erect stems that can grow to 6.5 feet tall (2 meters). The species present in Florida include smooth pigweed (*Amaranthus hybridus*), spiny amaranth (*Amaranthus spinosus*), 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.[62-64]

RAGWEED (*AMBROSIA* SPP.)

Common ragweed (*A. artemisiifolia*) and giant ragweed (*A. trifida*) are common weeds in cultivated fields in Florida. Ragweeds are summer annuals that have erect, branching stems and can reach 6–12 feet (1.8–3.6 meters) in height. They reproduce by seeds and flower from July to October.[63,64]

POUNDCAKE WEED (*PARTHENIUM HYSTEROPHORUS*)

Poundcake weed, also called parthenium weed, is an annual with a deep tap root that can grow to 6.5 feet (2 meters) in height. It has an erect stem that becomes woody as the plant ages. Parthenium reproduces by seeds, which germinate after rain. The plant flowers within 6–8 weeks and senesces under drought conditions. Seeds can remain dormant in the soil for many years. Parthenium weed is only found in the southern part of the state.[62] It is resistant to most herbicides.[9]

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.[9, 63, 64]

Chemical Control

A total of 20,800 pounds of herbicide active ingredient was applied to snap beans grown in Florida in 2010.[33] The only herbicide reportedly used in Florida snap bean production was s-metolachlor (Dual Magnum®). Older 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, bentazon (Basagran®), pelargonic acid (Scythe®), sethoxydim (Poast®), and imazamox (Raptor®).[34] Other active ingredients recently registered for weed management include carfentrazone (Aim®), clethodim (Select®), fomesafen (Reflex®), halosulfuron (Sandea®), and pyraflufen (ET®).

S-METOLACHLOR (DUAL MAGNUM®)

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.[5, 34] The REI for metolachlor is 24 hours.[34, 53]

In 2010, Florida growers applied an average of 1.37 pounds of active ingredient of metolachlor per treated acre at each application to 14% of their snap bean acreage, an average of one time. Total usage was 7,100 pounds of active ingredient.[33] During the years (1990-2000) usage data was collected, snap bean growers applied metolachlor an average of 1.0–1.1 times yearly to 5%–31% of the crop's acreage. An average of 0.57–1.39 pounds of active ingredient per treated acre was used per application. Total annual usage has ranged from 1,400 to 13,900 pounds of active ingredient.[36]

Cultural Control

Snap bean growers in Florida commonly practice mechanical cultivation between rows for weed control and to mix in dry sidedress fertilizer. In addition to cultivation, using weed-free seed and clean equipment can help prevent weed problems. Many weeds can be reduced by other cultural tactics such as the use of cover crops during the non-crop period or rotation schemes involving smother crops that compete well with weeds.[64]

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