

Florida Crop/Pest Management Profiles: Strawberry¹

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Production Facts

* Florida consistently ranks second in the U.S. in the production of strawberry (1,2).

* Florida produces between 10 and 15 percent of the total U.S. crop, and 100 percent of the domestically produced winter crop (1,2).

* 238,000,000 pounds of fresh berries valued in excess of \$313 million were produced during the 2009 crop year on 8,800 acres (2).

* Production costs average over \$27,000 per acre (3), which makes strawberry one of the most expensive crops to produce.

Production Regions

Approximately 95 percent of Florida's commercial strawberry production acreage is located in the east central counties of Hillsborough and Manatee with the remainder in several southwestern counties (1).

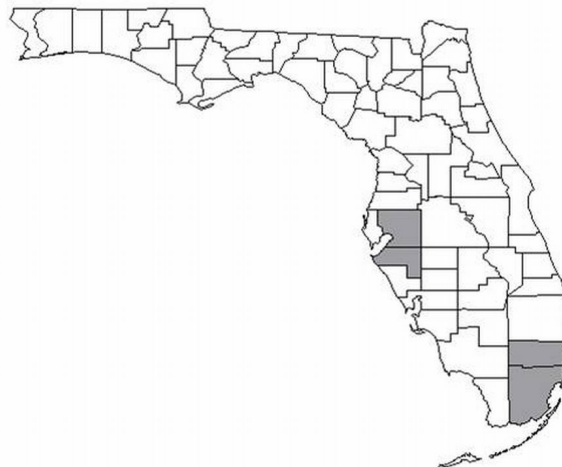


Figure 1.

Production Practices

Because of the great value of the crop, as well as the initial investment, strawberries are exclusively grown on plastic mulch that has had the soil sterilized in some manner. Strawberries are grown as an annual crop in Florida on the raised bed system, with generally two rows of plants per bed (3,4). Methyl

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bromide is still registered and used in production, and growers are adopting replacement fumigants (metam, methyl iodide, dimethyl disulfide, and dichloropropene) to a greater extent each season. Chloropicrin is almost always applied in combination with these other fumigants to serve as a disease-specific treatment. These fumigants are ideally applied approximately two weeks prior to planting transplants, but newer fumigant labels may increase this period to nearly a month. Fumigants are generally applied during the bedding process, and row middles are not treated. The bed is then immediately covered with plastic virtually impermeable film (VIF) mulch.

Several principal varieties are cultivated in Florida, and these varieties can change year-to-year. Current cultivars include Camarosa, Carmine, Camino Real, Gaviota, Strawberry Festival, Sweet Charlie, Treasure, Ventana, and Winter Dawn. To avoid the reintroduction of mites, nematodes, and other pathogens to the treated beds, growers are encouraged to use only the best quality transplants available, many of which come from Canada. Transplants are set in late September through early November. Drip and overhead irrigation is used to help establish plants, irrigate plants, and protect the plants from frost (3). Following early vegetative growth, the cool nights and short days of winter stimulate the plant to produce flowers, which—after pollination—develop into fruits ready for harvest in four to six weeks. This results in three or four crops of fruit from each plant (based on a 30-day cycle). Flowers are continuously present on plants in production areas from shortly after planting until the end of harvest, but there are typically two peak flowering periods each season, one in November or December and the other in mid- to late January. The average harvest period runs from late November through early April. Due to the frequency of harvest, preharvest intervals (PHIs) and restricted entry intervals (REIs) are important factors when growers select pesticides for use on strawberries (5). Pesticides are applied exclusively by ground application equipment.

Worker Activities

Worker activities include hand and tractor-driven related operations, such as cultivation, fertilization, operating the fumigation rig, and laying drip tape. For fumigation, the only field task is shoveling dirt on the mulch to bury it, which generally requires three people per end. The two-row fumigation rig will cover about eight acres a day. With an average size farm of 40 acres, shovel crews would be needed about 40 hours (five days) a year. Workers set transplants and cut runners in early and midseason and generally wear gloves for these tasks. Fruit are harvested by hand every three days throughout the harvest season, usually without gloves. As a general rule, there is one picker for every acre during nonpeak parts of the production season and one-and-a-half workers per acre during the peak parts of the season. Picking is finished in four hours each day during the nonpeak parts of the season, while picking takes place eight hours a day during the peak. The shipping container is often what is filled in the field, so very little rehandling occurs (6).

Insect/Mites

Insect/Mite Pests

The principal pests on strawberry in Florida are the twospotted spider mite, thrips, and lepidopterous larvae (fall and southern armyworms). Minor and occasional pests include corn earworm and sap beetles. Insects that may occasionally be seen on strawberry, but are generally managed incidentally, include fruit flies, whiteflies, lygus bugs, saltmarsh caterpillars, aphids, leafrollers, tobacco budworms, mole crickets, and ants (5,6).

SPIDER MITES (*Tetranychus urticae*, *T. turkestanii*, *T. tumidus*)

The twospotted spider mite (*T. urticae*) is oval, about 0.5 mm long, and may be brown or orange-red, but a green, greenish-yellow or an almost translucent color is most common. All mites have needle-like, piercing-sucking mouthparts. Spider mites feed by penetrating the plant tissue with their mouthparts and are typically found on the underside of the leaf. Spider mites spin fine strands of webbing on the host plant—hence their name. When twospotted spider

mites remove the sap, the mesophyll tissue collapses, and a small chlorotic spot forms at each feeding site. Continued feeding causes a stippled-bleached effect on the upper surfaces of leaves, and later the leaves turn yellow, gray, or bronze. Complete defoliation may occur if the mites are not controlled (7).

THRIPS (*Frankliniella occidentalis/Scirtothrips dorsalis*)

The western flower thrips and the newly emergent chili thrips have become an increasingly larger concern for strawberry growers in Florida. These insects feed in the flowers and lead to poor fruit set and berry malformation. They can be easily confused with non-harmful thrips species, so precise scouting is required to determine which species are present and whether they are at a density requiring treatment (6).

FALL ARMYWORM (*Spodoptera frugiperda*)

Adults can be seen along the Florida coast during all months but are most abundant from planting to December. The fall armyworm does not enter diapause and cannot survive extended periods of low temperatures, instead maintaining populations in warmer areas from which adults move northward in the spring. The forewings are a mottled gray/brown with a variable pattern, while hindwings are a opalescent white. The female moth is highly mobile, migrating each spring from frost-free areas in the southern part of the state and spreading throughout the southeast region of the country. Eggs are laid in masses of 100 to 150, and each moth may lay over two thousand eggs in total. Control at the egg stage is extremely difficult due to the protective covering over the mass and its typical position on the underside of leaves. After approximately two to three weeks of feeding, larvae drop to the ground and form pupae in the soil at a depth of about 1 to 3 inches (2 to 8 cm). In Florida, the pupal stage lasts about eight to nine days during the summer and about 20 to 30 days during the winter. Although the life cycle of the fall armyworm can be completed in about 30 days during the summer, it can take 60 days in the spring and fall and up to 90 days during the winter (7).

SOUTHERN ARMYWORM (*Spodoptera eridania*)

The forewings of the mature armyworm moth are gray and brown with irregular dark brown and black markings. Up to four generations per year occur in Florida. Larvae are defoliators and feed gregariously while young, often skeletonizing leaves. As they mature, they become solitary and may feed on the surface of fruit (7).

CORN EARWORM (*Helicoverpa zea*)

This caterpillar, also called tomato fruitworm and cotton bollworm, attacks a wide variety of vegetable and field crops. It is capable of overwintering throughout the state. There are up to seven generations per year in Florida, but like fall armyworms, the aggressive and cannibalistic nature of the larvae limit the number of mature larvae present at any one time. Both larva and adult corn earworm are variable in color and pattern (7).

SAP BEETLES (Family Nitidulidae)

These beetles overwinter in pupal or adult stages and become active early in spring with subsequent egg deposition at that time. Eggs may be laid as deep as 15 cm in the soil or in fruit that drops to the ground. The larvae bear a fleshy protuberance ventrally and go through three or four instar stages. The adult beetle's wings do not cover the entire insect, thus exposing the terminal abdominal segments, and the antennae are club-shaped. Both larval and adult sap beetles feed on strawberry, although many other vegetable crops are preferred hosts. In Florida, conditions can support two generations of sap beetles per year (7).

Controls

Nonchemical

The principal nonchemical control measure is the purchase and release of beneficial predatory mites to manage spider mites (5). Approximately fifteen percent of Florida strawberry production is under this practice, which saves about four miticide applications per season. Other nonchemical measures include using resistant varieties, purchasing or planting certified pest-free plants, and sanitation. The use of

certified plants (for mites) is used but is frequently not reliable. While there are a number of nonchemical control measures, usage is limited due to their limited effectiveness. All Florida growers scout for insect/mite pests, and the majority apply a control measure when they believe a pest/damage threshold has been reached (6).

Biochemical & Chemical

The predominant miticides used on Florida strawberry are hexythiazox, bifenthrin, abamectin, and bifenthrin (8). Insecticides commonly used for worm management include spinosad, naled, and malathion. Other foliar insecticides/miticides labeled for use in strawberry as of 2010 include acequinocyl, azadirachtin, *Bacillus thuringiensis* (Bt), *Beauveria bassiana*, borate, buprofezin, carbaryl, chlorantraniliprole, chlorpyrifos, diazinon, dicofol, endosulfan, etoxazole, fenbutatin-oxide, fenpropathrin, fenpyroximate, *Helicoverpa zea* nuclear polyhedrosis virus, *Heterorhabditis indica*, imidacloprid, methoxyfenozide, naled, oils, propargite (nonbearing/transplant), pyrethrins, pyriproxyfen, soaps, spinetoram, spiromesifen, sulfur, and thiamethoxam. Methoprene, pyriproxyfen, and spinosad are formulated for fire ant control in strawberry (5). Most Florida growers alternate pesticides to reduce pest resistance (6).

Nematodes

Nematodes are a serious problem affecting Florida strawberry production areas as well as the primary driving pest. No nematode-resistant strawberry varieties exist, and there are no postplant remediation strategies available. Strawberries are susceptible to multiple nematode species. Sting nematodes, root-knot nematodes, and foliar nematodes are the main problems, with sting nematode being by far the most severe (9).

Strawberry production problems caused by sting nematodes tend to occur in more or less definite areas where transplants fail to grow-off normally. Infested areas consist of spots that vary in size and shape, but the boundary between diseased and healthy plants usually is fairly well defined. Initially a field may have only a few such areas, which may then increase in size and number until the entire field becomes

infested. The effect on strawberries is both stunting and decline, the intensity of which is related to initial population level and the rates at which populations increase during the course of strawberry crop growth. Affected plants become semidormant, with little or no new growth. Leaf edges turn brown, progressing or expanding from the edges to midrib to include the entire leaf. Leaves seldom become chlorotic, although cases have been reported in which leaf yellowing occurs when essential nutrients are present in limited supply. Since the outer older leaves die first, the plant gradually decreases in size and eventually may be killed. Nematode infested plants are much more susceptible to drought conditions and injury from fertilizer salt accumulation (9).

Controls

Nematode management is viewed first and foremost as a year-round, programmatic activity requiring consideration of all cultural, chemical, and agronomic practices within the areas where strawberry plants are grown. Because strawberries must be vegetatively propagated and transplanted into the field, growers must first pay special attention to the source of strawberry transplants to ensure that they are not infested with nematodes (as well as mites, diseases, etc.). After final harvest, the crop is destroyed as quickly as possible to remove nematode food sources. In most cases, delays in crop destruction contribute to greater nematode population increases and greater difficulty in achieving nematode management (9).

Nonchemical

The fact that all populations of sting nematode have such a wide host range, including numerous weeds and grasses, must be considered in developing programs such as crop rotation systems for nematode management. Cover crop rotations with American jointvetch, hairy indigo, or sunn hemp have been shown to reduce sting nematode populations. In addition to sting nematode suppression, hairy indigo has also been reported to be resistant to several root-knot nematode species. Field fallowing, particularly when coupled with early crop destruction, generally provides a reduction in total nematode densities in soil (9).

Chemical

Over the decade of the 1990s, methyl bromide use remained fairly constant. The material was used by over ninety-eight percent of Florida growers, and approximately 200 pounds of the material was used per field acre. Total state usage of methyl bromide for strawberry production ranged from 845,000 to 1,230,000 pounds between 1992 and 2002. However, the United States' participation in the Montreal Protocol requires a gradual phase-out of methyl bromide. Methyl bromide manufacturers have begun this phase-out by adding higher percentages of chloropicrin into the methyl bromide formulations. Evidence of this transition is apparent in the 2002 chemical use values, which report a state use of 918,000 pounds of methyl bromide and 449,000 pounds of chloropicrin, which is roughly equivalent to one-third of the total fumigant use (10). Between thirty and forty percent of growers still used methyl bromide:chloropicrin (50:50) in 2009.

Methyl iodide has been registered for use in Florida for several years, although adoption is small due to label constraints. Other registration efforts have been ongoing to find suitable replacements for methyl bromide in strawberry production. Florida and the Environmental Protection Agency (EPA) have registered two formulations of 1,3-dichloropropene (Telone[®] EC and InLine[®]) under Special Local Needs [24(c)] registrations, and nearly half of growers are using dichloropropene/chloropicrin products. Telone[®] consists of 91.7 percent 1,3-dichloropropene, while InLine[®] contains 60.8 percent 1,3-dichloropropene and 33.3 percent chloropicrin. Metam is used by nearly a quarter of growers. Dimethyl disulfide is also registered for strawberry nematode control.

Diseases

Plant pathogens attack virtually all strawberry plant parts resulting in direct yield loss as well as loss due to quality factors. Infection of fruit by one pathogen may lead to infection or colonization by other pathogens, confounding the situation. Major disease problems on Florida strawberry fruit are botrytis (gray mold) and colletotrichum diseases, while powdery mildew, angular leaf spot, common

leaf spot, leaf blight, and leaf scorch are primarily strawberry leaf diseases (11). Although viruses are generally not an issue in Florida strawberry production, much of one cultivar was infected with strawberry necrotic shock disease during the 2009–2010 season (12).

BOTRYTIS FRUIT ROT (GRAY MOLD) **(*Botrytis cinerea*)**

Gray mold is the most important strawberry disease in Florida and nationally. It attacks fruit in all stages of development in the field and in transportation. The disease flourishes under cool, wet weather conditions, at which time the fuzzy gray mold appears. Under less severe conditions, light brown spots, which later turn dark brown, develop on the fruit. The fruit becomes soft at first, then hard and dry, with no clear line of demarcation between infected and healthy fruit tissue. The disease is often more severe in the late part of production (11).

In severe epidemics, the fungus can also cause blight of flower buds and stalks, foliage buds, and unexpanded young leaves. Attacks on these parts of the plant usually occur during prolonged periods of cool, damp weather. These structures turn dark in color and die (11).

COLLETOTRICHUM DISEASES (*C. acutatum*, *C. fragariae*, *C. gloeosporioides*)

Colletotrichum can cause a range of different diseases on strawberry in Florida. Currently, the most important diseases are anthracnose fruit rot and root rot caused by *C. acutatum*. Anthracnose root rot causes problems during the plant establishment period in October and causes a blackening of the roots that can reduce the vigor of plants and, when severe, causes the plant to wilt and die. Anthracnose fruit rot epidemics can force growers to abandon production fields. The disease develops on young fruit and produces sunken, dark lesions on the fruit making them unmarketable. In severe epidemics, the pathogen also causes a flower blight and can produce sunken lesions on leaf petioles.

Colletotrichum crown rot can also be an important disease and is primarily caused by *C. gloeosporioides* but also *C. fragariae*. The crowns of

infected plants become necrotic and cause the sudden wilt and death of apparently healthy plants when temperatures are warm in the fall or spring. Treasure cultivar is considered highly resistant to crown rot. Sweet Charlie, Carmine, and Camino Real have moderate levels of resistance, and Festival and Camarosa are highly susceptible (11).

POWDERY MILDEW (*Sphaerotheca macularis*)

Once infected with powdery mildew, strawberry leaf edges begin to roll upward, and a sparse white growth of conidia and conidiophores may be seen on the under surface of the leaves. If infection is severe, leaves may show purple blotches or they may be killed. In Central Florida, the disease is typically most severe in November and December, and it may reappear in late February and March. Cultivars differ widely in their resistance to powdery mildew. Unfortunately, some of the most popular cultivars in Florida (Strawberry Festival, Camarosa, and Winter Dawn) are quite susceptible to the disease (11).

ANGULAR LEAF SPOT (*Xanthomonas fragariae*)

This disease favors cool, wet weather and can become severe when overhead irrigation is used for freeze protection. The first signs of angular leaf spot are dark green water lesions on the under surfaces of the leaves. These later become visible on the upper surfaces as reddish or brownish angular spots of variable size. The most notable sign is the occurrence of whitish, slimy droplets of bacterial exudate on the under surface of the leaflets during cool weather. When the droplets dry, a thin, clear scaly film or clear raised bumps appear. The leaf under surfaces may also appear as if coated with clear lacquer at this point. The disease diminishes upon the onset of warmer weather (11).

LEAF SPOT (*Mycosphaerella fragariae*)

Spots are small, purplish-red lesions less than 3 mm in diameter. The final lesion size depends on the variety. On certain varieties, the lesions remain very small and numerous, and leaflets appear "rusty." On others, the lesions increase in size to 6 mm or larger and develop white or gray centers with

reddish-purple to dark purple borders. Severe infection can result in death of leaflets and defoliation of plants (11).

LEAF BLIGHT/FRUIT ROT (*Phomopsis obscurans*)

Phomopsis leaf blight and fruit rot can be a serious problem on plants produced in the Southeastern U.S. The initial infection spots of this fungus are larger than leaf spot. From one to five lesions may occur on a leaf. The lesions are circular and reddish-purple at first. Mature lesions are zonate and dark brown in color, with a light brown to tan periphery ringed by a purple zone. The spots are frequently V-shaped with the widest part of the lesions at the leaf margin and the narrow base centered on a vein. Black specks (pycnidia) dot the central area of the older lesions.

This fungus also affects fruit. Initial lesions appear as round, light pink, water-soaked areas on the surface. Lesions may coalesce. Infected areas turn brown, and the entire fruit ultimately becomes infected (11).

LEAF SCORCH (*Marssonina fragariae/Diplocarpon earliana*)

This fungus produces numerous purplish blotches of irregular shape and small size. Clusters of the blotches turn brown but never white or gray as in the case of leaf spot. Dark glistening acervuli appear in the lesions on the upper surfaces of the leaves. In severe cases, the leaf margins curl upward, and the leaves progressively dry to a tan color from the margins to the midrib (11).

CHARCOAL ROT (*Macrophomina phaseolina*)

Charcoal rot was first reported in Florida in 2005. Infected plants wilt, are stunted, and eventually die. The disease affects the plant roots and crown, and it can be difficult to distinguish from other crown diseases (11).

PHYTOPHTHORA CROWN ROT (*Phytophthora cactorum* and *P. citricola*)

Phytophthora crown rot can be a serious disease of annual production strawberry in Central Florida. The disease is characterized by a sudden decline and wilt of plants. Reddish-brown coloration on the internal crown makes symptoms difficult to distinguish from those produced by *Colletotrichum gloeosporioides* or *C. fragariae*. Infected transplants are the primary source of inoculum for epidemics in Florida. The pathogen produces zoospores that infect strawberry plants under wet conditions. Phytophthora species produce oospores that may persist in infested soil and plant debris; however, oospores have not been observed in Florida. The disease favors warm temperatures and prolonged periods of wetness, conditions that are common during the plant establishment period (October) in Florida (11).

Controls

Nonchemical

Nonchemical control strategies include planting certified plants, using resistant varieties, crop rotation, irrigation management, sanitation/destruction, and the use of plastic mulch. However, their use alone or in the absence of fungicides would result in severe losses. Nonchemical methods must be considered as tools that, in the presence of all other factors at a given time, add effectiveness to the overall disease management program. Growers may plant multiple varieties of strawberries to reduce the risks posed by various diseases and pests and also take advantage of market conditions. There is effort placed in producing disease resistant varieties; however, there are currently no major marketable varieties available with high levels of resistance to multiple pathogens. Certain varieties show select disease resistance, but no single variety has all the necessary characteristics for season-long productivity.

Chemical

Although chloropicrin is used as a fungicidal fumigation treatment, in-season fungal control is still required. Fungicides historically used for strawberry disease control in Florida include azoxystrobin,

boscalid, captan, fenhexamid, myclobutanil, potassium bicarbonate, pyraclostrobin, thiophanate, and thiram (10). Other fungicides actively registered in Florida in 2010 include *Bacillus pumilus*, *Bacillus subtilis*, carbonic acid, copper (in hydroxide, sulfate, oxychloride, and octanoate forms), cyprodinil, dodine, fludioxonil, fosetyl-Al, *Gliocladium virens*, hydrogen dioxide, iprodione, mefenoxam, phosphoric acid, polyoxin D, propiconazole, *Pseudomonas fluorescens*, pyrimethanil, quinoxifen, *Reynoutria sachalinensis* extract, *Streptomyces lydicus*, sulfur, *Trichoderma harzianum*, trifloxystrobin, and triflumizole (11). Many more biological-based fungicides have become available in the past several years.

Weeds

Weed pressure has historically been one of the more difficult management aspects for Florida strawberry growers for several reasons. First, when methyl bromide is employed as the sterilant, the dormant weed seeds—such as Carolina geranium and cut-leaf evening primrose—remain viable. Since no treatment is capable of controlling weed emergence the entire strawberry season (six to seven months), these weeds become mid- to late-season problems that impact quality and harvest efficiency. The desired effect of methyl bromide is that it does control the majority of yellow and purple nutsedge, which are considered the worst weeds in this crop. Since the methyl bromide alternatives (except for methyl iodide) don't control nutsedge, these species—as well as the aforementioned late season weeds—will be a problem in rows during some or most of the season (13).

Another consideration, with respect to weeds, is their ability to harbor spider mites. Soon after transplants are set, Carolina geranium seedlings appear. The potential for mite reinfestation is not great when the weed grows from transplant holes in the plastic mulch, because in that position miticide applications will kill resident mites on both the weeds and strawberry plants. However, this plant also grows in the row ends and field perimeter, and these areas are not treated. Consequently, spider mites can reinfest fields from these plants after miticide residues have decreased (13).

Herbicide resistance has also been observed in Florida strawberry production. Goosegrass in the row middles has become resistant to paraquat, due to heavy reliance on this single herbicide. Growers also reported potential glyphosate damage to strawberry plants due to transmission from shallow roots present in treated row middles. In addition to nutsedge and resistant weeds, other problematic weeds include purslane, pusley, Carolina geranium, cut-leaf evening primrose, and eclipta. Dayflower is an emerging weed problem (13).

Controls

Nonchemical

Florida strawberries are grown in fumigated, raised beds covered with plastic mulch. The plastic generally suppresses certain annual weed populations; however, external borders of the mulch and transplant holes allow weeds to germinate. Hand weeding may be used for these areas, but it is time consuming and costly.

Chemical

Commonly used herbicides for row-middle weed management include paraquat and glyphosate. Care is taken to prevent herbicide drift from contacting any portion of the strawberry plant or its fruit. Other herbicides actively registered in Florida in 2010 for use in Florida-grown strawberry include acifluofen, carfentrazone, clethodim, dacthal, flumioxazin, napropamide, oxyfluorfen, pelargonic acid, pendimethalin, sethoxydim, and terbacil (14).

Other Pests

Other pests in Florida strawberry include sporadic pests such as birds and slugs/snails. Bird predation of strawberries used to be viewed as a sporadic event, but in three of the last four years, bird predation losses have been substantial. The species primarily associated with this phenomenon are American robin, cedar waxwing, and crows. It is estimated that these birds consume approximately 400,000 flats of strawberries (over \$2 million in losses). An Extension specialist who works with vertebrate pests stated that the current technologies (propane cannon at a rate of one per ten acres or robin

distress calls) have minimal effect, while twisted reflective ribbon (silver on one side/red on the other) may be slightly more effective. Additionally, audio devices are generally not acceptable since much of the growing area is now bordered by residential developments. Since the strawberry is a "naked" fruit, taste repellents such as methyl anthranilate (grape flavoring) and capsaicin (pepper) cannot be used. The specialist stressed that the most important aspect in trying to rid the field of birds is to try and scare them as soon as they start inhabiting the field. Flock presence draws in more birds.

The only two active ingredients registered in Florida that claim repellency and that can be used on strawberry are azadirachtin and thiram. For slugs/snails, there is metaldehyde +/- carbaryl or a phosphoric acid/iron bait.

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