Pepper Diseases: A Field Guide

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Asian Vegetable Research and Development Center
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Pepper Diseases
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PREFACE

AVRDC adopted pepper (*Capsicum* spp.) as a new crop in 1986 on the basis of its high consumption, and its nutritional and cash value to farmers and consumers in developing countries. The goals of the pepper program are to improve the genetic and management components of pepper production in the hot-humid tropics, enhance yield and crop quality in existing areas of production, and adapt peppers to new regions.

On a global scale, diseases and pests are the primary constraints to pepper production. Research at AVRDC focuses on pepper disease control through an integrated program of host resistance and management practices. A global collection of almost 6000 pepper accessions is being systematically screened for resistance to a number of pests and diseases in an effort to characterize *Capsicum* germplasm.

This field guide is envisaged as a quick reference for horticultural extension workers and for teachers of agriculture, and researchers, particularly in developing countries. The publication contains a vivid presentation of pepper diseases and it is our hope that it becomes a useful guide for those involved in pepper production throughout the world.

AVRDC acknowledges the generous support of the Japan Shipbuilding Industry Foundation in the production of this field guide.

Emil Q. Javier
Director General, AVRDC
INTRODUCTION

This field guide contains illustrations and descriptions of many of the diseases and disease-like disorders that affect pepper throughout the world. The guide is not all-inclusive, but an attempt has been made to include as many of the economically important diseases as possible. The guide is designed to serve as an aid in the identification of pepper diseases and should be useful to extension agents, agricultural advisors, plant disease diagnosticians, commercial pepper growers, home gardeners, and others interested in pepper production. The guide is not intended to be a diagnostic manual, because final disease diagnosis should not be made solely on the basis of symptoms. Users of the guide should, in most cases, have their field identifications confirmed by a specialist in a diagnostic laboratory.

No attempt has been made to include specific disease control recommendations, because they vary so much from one region to another and because they are constantly changing. Host plant resistance generally is considered to be the most desirable means of disease control and should be utilized whenever resistant cultivars adapted to local needs are available. Some comments concerning management practices that may be used to minimize disease losses are included with the descriptions of bacterial, fungal, and nematode diseases but not for viral diseases. Management practices frequently employed to reduce virus disease incidence include: selection of planting dates to avoid high populations of vectors, close plant spacing to compensate for diseased plants, use of barrier crops to minimize virus spread, use of oil sprays to reduce virus transmission by aphids, use of reflective mulches to repel aphids and thrips, and seed treatment to eliminate tobamoviruses from the seed coat.

References have been included with most of the disease descriptions to provide the reader with
additional sources of information about each disease. Below are some useful references for those who are interested in more detailed information about pepper diseases in general.


The authors welcome comments and corrections concerning the guide, and solicit additional information including photographs of disease symptoms that could be used to enhance future editions.
Bacterial Soft Rot

Erwinia carotovora pv. carotovora

Symptoms: Soft rot frequently begins in the peduncle and calyx tissues of harvested fruit (Fig. 1), but infection can occur through wounds anywhere on the pod (Fig. 2). Internal tissue near the site of infection softens and the lesion rapidly expands reducing the interior of the pod to a watery mass in a few days. Fruit infected on the plant often collapse and hang on the plant like a water-filled bag. When the contents leak out, a dry shell of the pod remains (Fig. 3).

Additional Information: Soft rot is primarily a postharvest disease although it does occur in the field. The disease is worse during rainy periods because the bacteria are splashed from the soil onto the fruit which are more susceptible because of their high moisture content. Postharvest decay can be reduced by harvesting fruit when they are dry, minimizing injury during handling, and storage at a cool temperature. Washing may increase the incidence of infected fruit, but these losses can be reduced by chlorination of the wash water and drying the fruit rapidly after washing. Soft rot in the field can be reduced by controlling insects that cause injury to pepper pods. (See: Coplin, D. L. 1980. Erwinia carotovora var. carotovora on bell peppers in Ohio. Plant Dis. 64:191-194; Mazzucchi, U., and Dalli, A. 1973. Epidemics of fruit soft rot on green peppers (Capsicum annuum L.) caused by Erwinia carotovora var. carotovora. Inf. Fitopatol. 23:17-20 [In Italian].)
Bacterial Spot

*Xanthomonas campestris* pv. *vesicatoria*

**Symptoms:** Leaves, fruit, and stems are affected. Leaf lesions begin as circular, watersoaked spots that become necrotic with brown centers and thin chlorotic borders (Fig. 4). Enlarged spots may develop straw colored centers (Fig. 5). Generally, the lesions are slightly sunken on the upper leaf surface and slightly raised on the lower surface (Fig. 4). Severely spotted leaves turn yellow and drop; defoliation is common (Fig. 6). Fruit symptoms generally occur as raised, brown lesions that are wart-like in appearance (Fig. 7). Narrow, elongated lesions or streaks may develop on stems.

**Additional Information:** The disease has a wide geographic distribution occurring wherever pepper is grown under overhead irrigation or rainfed conditions. It spreads rapidly during warm, rainy weather. The bacterium can be seed-borne and persists in crop debris. Clean seed and crop rotation are important in disease management. Copper sprays reduce the rate of disease development. (See: HIGGINS, B.B. 1922. The bacterial spot of pepper. Phytopathology 12:501-516; TEGEGN, T. 1985. A review of bacterial leaf spot of peppers (*Capsicum annuum* L.) caused by *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye and some methods of its control. Acta Horticulturae 158:369-376.)
Bacterial Wilt

*Pseudomonas solanacearum*

**Symptoms:** The disease occurs in scattered plants or groups of plants in certain areas of the field. The initial symptom in older plants is a slight wilting of lower leaves, but in young seedlings the upper leaves wilt first. After a few days, the initial wilting is followed by a sudden, permanent wilt of the entire plant with only slight or no leaf yellowing (Fig. 8). The vascular tissues of the lower stem and roots are discolored (Fig. 9; diseased plant on the right). Cross sections cut from roots and lower stems of infected plants exude milky streams of bacteria from the vascular system when suspended in water.

**Additional Information:** Bacterial wilt of pepper is mainly a problem in tropical or subtropical climates with relatively high rainfall. The disease can cause substantial losses in pepper, although it is not as susceptible as tomato, tobacco, potato, or eggplant. The pathogen has a wide host range and can survive in the soil for long periods. Although it may be of limited value, rotation with non-solanaceous crops is recommended. (See: **DAVIDSON, H. F. 1935. Bacterial wilt of solanaceous crops. Trop. Agr. 85:257-259; KELMAN, A. 1953. The bacterial wilt caused by *Pseudomonas solanacearum*. N. Carolina Agr. Expt. Sta. Tech. Bull. No. 99. 194 pp.**
Anthracnose (Ripe Rot)

_Colletotrichum gloeosporioides, C. capsici, C. acutatum, and C. coccodes_

**Symptoms:** Anthracnose may occur in the field or develop as a postharvest decay of pepper pods. Typically, symptoms first appear on mature pods as small, water-soaked, sunken lesions that rapidly expand. The lesions may increase to 3-4 cm in diameter on large-podded fruit (Fig. 10, 11). Fully expanded lesions are sunken and range from dark red to light tan with varying amounts of visible dark stromatic fungal tissue. Pale buff to salmon spore masses occur scattered or in concentric rings on the lesions (Fig. 12). Occasionally, lesions develop on immature pods. Pre- and postemergence damping-off, shoot necrosis, and leaf spots are also symptoms expressed in some geographic areas.

**Additional Information:** The disease has a wide geographic distribution occurring wherever pepper is grown under overhead irrigation or rainfed conditions. Immature pods are infected, but generally symptoms are not expressed until the pod becomes fully mature and undergoes the final color change. The pathogens can be seed-borne in pepper, persist in crop debris, and have a wide host range. Clean seed and crop rotation are important elements in disease management. Application of fungicides can reduce disease losses. (See: Higgins, B. B. 1926. Anthracnose of pepper (Capsicum annuum L.). Phytopathology 16:333-345; Hadden, J. F., and Black, L. L. 1989. Anthracnose of pepper caused by _Colletotrichum_ spp. Pages 189-199. In: S. K. Green (ed.) Tomato and Pepper Production in the Tropics. AVRDC. Tainan, Taiwan, ROC. 619 pp.)
Cercospora Leaf Spot (Frogeye)

Cercospora capsici

**Symptoms:** Leaf lesions typically are brown and circular with small (Fig. 13) to large (Fig. 14) light gray centers and dark brown margins. These lesions may enlarge to 1 cm or more in diameter and sometimes coalesce. Stem, petiole, and peduncle lesions also have light gray centers with dark borders, but they are typically elliptical. Abscission of infected leaves occurs commonly with or without associated yellowing (Fig. 15). Under severe disease pressure extensive defoliation occurs. The fruit is not attacked.

**Additional Information:** The fungus can survive on seed and in association with crop residues. The disease is very common and can cause defoliation under prolonged periods of wetness. Extensive defoliation may result in sunscalding of fruit and reduced vigor of plants. Fungicides may be needed to manage the disease during periods favoring disease development. (See: Heald, F. D., and Wolf, F. A. 1911. New species of Texas fungi. Mycologia 3: 5-22; Chupp, C. 1953. A Monograph of the Fungus Genus Cercospora. Ithaca, New York. 667 pp.)
Choanephora Blight

Choanephora cucurbitarum

Symptoms: Initial symptoms are often associated with flowers, flower buds, or apical growing points of the plant. Infected tissue turns brown to black, and the fungus grows rapidly downward, killing off portions of the upper plant (Fig. 16, 17). A wet rot is associated with infected tissue which often appears somewhat silvery to gray because of the spore-producing stalks which are visible to the naked eye (Fig. 18).

Damping-Off and Root Rot

*Rhizoctonia solani, Pythium spp., and Fusarium spp.*
(See also Gray Mold, Phytophthora Blight, and Anthracnose)

**Symptoms:** Seedlings fail to emerge (preemergence damping-off); small seedlings suddenly collapse (postemergence damping-off) [Fig. 19, 20]; or seedlings are stunted (root rot and collar rot) [Fig. 21] in irregular patches of nursery beds (Fig. 20) or scattered areas of the field with direct-seeded crops.

**Additional Information:** Preemergence damping-off is a result of the death of young seedlings after germination but prior to emergence above the soil. Postemergence damping-off results from decay of the hypocotyl near the soil line causing young seedlings to topple over. Root rot and collar rot results from infections that occur after the seedling stems have hardened. The fungi that cause these seedling diseases are soil inhabitants whose activities are enhanced by undecomposed organic matter in soil and high soil moisture. Generally, *Pythium* spp. are more active at lower temperatures and *R. solani* at higher temperatures. To minimize plant losses, seed should be treated with a fungicide, nursery beds should be located on well-drained sites and treated prior to seeding, and covered beds should be well ventilated to prevent high humidity.
Fusarium Wilt

Fusarium oxysporum f.sp. capsici

Symptoms: Disease symptoms are characterized by an initial slight yellowing of the foliage and wilting of the upper leaves that progresses in a period of a few days into a permanent wilt with the leaves still attached (Fig. 22, 23). By the time aboveground symptoms are evident, the vascular system of the plant is discolored, particularly in the lower stem and roots (Fig. 24). Prior to death of the plants, there is no external discoloration of the stem or major roots and the cortical tissue remains intact. Generally, the disease appears in localized areas of the field where a high percentage of the plants wilt and die (Fig. 22) although scattered wilted plants may also occur.

Additional Information: High temperatures and wet soil conditions favor disease development. The disease is most likely to occur in poorly drained areas of the field. Fusarium wilt was characterized only recently, so its geographic distribution is unknown. There are numerous reports of Fusarium diseases, but there is not sufficient information provided to distinguish the host-specific Fusarium wilt from other Fusarium-caused diseases. (See: Black, L. L., and Rivelli, V. 1991. Fusarium oxysporum f. sp. capsici forma specialis nov. identified as the causal agent of a wilt in pepper. Plant Dis. 75: [in press].)
Gray Leaf Spot

Stemphylium solani

**Symptoms:** Leaf lesions are small circular spots, usually less than 3 mm in diameter, with a white center and a narrow dark border (Fig. 25, 26). Multiple lesions on leaves cause them to turn yellow and drop. Lesions on stems and petioles tend to be elliptical and are more irregular in shape (Fig. 27). The fruit pods are not affected.

**Additional Information:** Gray leaf spot is most damaging in nursery beds where it can cause significant defoliation and extensive stem lesions. Stem lesions cause the plants to be brittle and subject to breaking over after being transplanted into the field. Although the leaf spots can be seen at all stages of plant growth, they seldom are numerous enough to cause a problem in the field. (See: BLAZQUEZ, C. H. 1969. Occurrence of gray leafspot of peppers in Florida. Plant Dis. Rep. 53: 756; SINCLAIR, J. B., HORN, N. L., and TIMS, E. C. 1958. Unusual occurrence of certain diseases in Louisiana. Plant Dis. Rep. 42:984-985.)
Gray Mold

*Botrytis cinerea*

**Symptoms:** The most common symptom is a sudden collapse of succulent tissues such as young leaves, stems, and flowers. The lesions rapidly expand forming irregularly shaped watersoaked areas that result in death of seedlings (Fig. 30) and branches of older plants (Fig. 28). Gray powdery spore masses of the fungus frequently occur on the surfaces of dead plant tissues. Fruit may be attacked particularly when infected foliage or floral parts come in contact with the pod (Fig. 29). Fruit lesions begin as soft olive-green spots that may expand to encompass the entire fruit.

Phytophthora Blight

*Phytophthora capsici*

**Symptoms:** The disease can occur on pepper at any stage of growth and all plant parts may be affected. The collar rot and wilt phase is most common and is characterized by a dark brown stem discoloration extending upward from the soil line (Fig. 32) accompanied by a sudden wilt of the entire plant (Fig. 31) without foliar yellowing. Splashing water carries inoculum into the canopy that causes stem, leaf, and fruit infections. Upper stem lesions are dark brown and occur primarily at branch points (Fig. 34) causing death of branches above the lesion. Leaf lesions rapidly expand to form round or irregularly shaped, dark green, water-soaked areas that later dry and become a light tan (Fig. 33). Fruit infections begin as water-soaked, dull green spots that expand rapidly to encompass the entire pod. Later the pods become flaccid and wrinkled (Fig. 33, 36). Damping-off and tip blight may occur on seedlings (Fig. 35).

**Additional Information:** The disease has a wide geographic distribution. The causal fungus can survive in host debris, in the soil, and in association with other crops such as cucurbits, eggplant, and tomato. The collar rot and wilt phase of the disease is most severe in over-irrigated or poorly drained wet areas of the field. Aboveground infections are associated with extended periods of rainfall or overhead irrigation. Planting on elevated beds, good water management, and the use of fungicides are cultural practices that can minimize disease losses. (See: Leónian, L. H. 1922. Stem and fruit blight of peppers caused by *Phytophthora capsici* sp. nov. Phytopathology 12:401-408; Weber, G. F. 1932. Blight of peppers in Florida caused by *Phytophthora capsici*. Phytopathology 22:775-780.)
Powdery Mildew

**Leveillula taurica** (asexual stage: *Oidiopsis sicula*)

**Symptoms:** Chlorotic blotches or spots that may become necrotic with time appear on the upper leaf surface (Fig. 37, 38). When lesions are numerous they may coalesce resulting in a general chlorosis of the leaves. On the lower leaf surface, the lesions develop a necrotic flecking and generally, but not always, are covered with a white to gray powdery growth (Fig. 39). The disease progresses from the older to younger leaves and shedding of the foliage is a prominent symptom.

Stem Rot (Southern Blight, Collar Rot)

*Sclerotium rolfsii* (sexual stage: *Pellicularia rolfsii*)

**Symptoms:** The disease generally occurs as a sudden wilt of individual plants (Fig. 40) scattered about the field. Initially there is no foliar discoloration, but later the leaves may turn yellow. The cortical tissue at the base of the stem is brown and decayed above and below the soil line. White mycelial growth usually is visible on the base of the stem and on the soil around the base of the plant (Fig. 41). Sclerotia about the size of mustard seed that are tan to brown when mature are produced in the mycelial mat (Fig. 42). Fruit or branches may become infected at the point of soil contact.

**Additional Information:** The disease has a wide geographic distribution in warm climates. High soil moisture and temperature favor disease development, although symptom expression may be more severe during dry conditions following a wet period. The fungus has an extremely broad host range and is a good saprophyte. Sclerotia are its principal means of long-term survival in the absence of a host or suitable substrate. Deep plowing to bury sclerotia and plant debris and allowing time for plant debris to decompose before planting reduce disease incidence. Soil fungicides or fumigants provide some benefit in areas where the disease is severe. (See: AYCOCK, R. 1966. Stem rot and other diseases caused by *Sclerotium rolfsii*. North Carolina Agr. Expt. Sta. Tech. Bull. 174. 202 pp.)
Verticillium Wilt

Verticillium albo-astrum and V. dahliae

Symptoms: Initial symptoms are wilting and upward curling of the lower leaves (Fig. 44). The tips and margins of those leaves first turn yellow and then brown. Subsequently, the plant may be stunted or the entire plant may permanently wilt in which case the leaves turn yellow and begin to shed (Fig. 43). The woody vascular tissue of the stem develops a brown discoloration (Fig. 45) near the soil line that often extends up the stem and into lower branches.

Additional Information: Verticillium wilt occurs in Europe, Canada, and in the northern and western parts of the United States. Included among other important susceptible crops are tomato, eggplant, potato, and cotton. The pathogen can survive in the soil for several years, but a 3-4-year crop rotation with nonsusceptible crops has been helpful in disease management. (See: Kendrick, J. B., Jr., and Middleton, J. T. 1959. Influence of soil temperature and of strains of the pathogen on severity of Verticillium wilt of pepper. Phytopathology 49:23-28; Evans, G., and McKee, C. D. 1975. A strain of Verticillium dahliae pathogenic to sweet pepper in Southwestern Ontario. Can. J. Plant Sci. 55:857-859.)
Root-Knot

Meloidogyne incognita; occasionally M. arenaria or M. hapla

Symptoms: Aboveground symptoms may include stunting, yellowing, wilting, and general lack of vigor (Fig. 46). Root systems of affected plants are diminished in size and develop small knots or galls (Fig. 47). The galls on pepper are much smaller than those on crops such as tomato or cucurbits and are easily overlooked. The disease generally is more severe in localized areas of the field.

Additional Information: M. incognita races 1, 2, 3, and 4 attack pepper. This species of root-knot nematode has a wide host range and is widespread throughout areas with warm climates. Root-knot is most damaging in sandy soils. Resistant cultivars (Fig. 48, resistant on left) and long rotations with cereals, grasses, and other nonsusceptible crops are the most practical means of root-knot control. Soil fumigants and nematicides also are effective disease management practices. (See: SASSER, J.N., and CARTER, C.C. (ed.) 1985. An Advanced Treatise on Meloidogyne. Volume I. Biology and Control. N. Carolina State Univ. Graphics, Raleigh. 422 pp.)
Viral Diseases

Plant viruses constitute a large and important group of pathogens that affect pepper. Most plant virus movement among plants is by insect vectors. Important vectors of pepper viruses include many species of aphids (Fig. 49, *Myzus persicae*), two species of leafhoppers (Fig. 50, *Circulifer tenellus*), several species of thrips (Fig. 51, *Frankliniella occidentalis* [top] and *F. fusca* [bottom]), and a single species of whitefly (Fig. 52, *Bemisia tabaci*). A few of the viruses are carried on the seed and a few are transmitted in nature only by mechanical means.

Information in this guide should be useful in diagnosing virus disease problems of pepper, but the user is cautioned against making firm diagnoses based on symptoms alone. Virus diseases are particularly difficult to diagnose by symptoms because there is so much overlap in symptomatology. Furthermore, symptom expression can be altered by many factors among which are cultivar, age of host plant, environmental conditions, host plant nutrition, and viral strain differences, not to mention the occurrence of virus mixtures.

For additional information see:


Alfalfa Mosaic

Aphid-Transmitted Bacilliform Virus

**Symptoms:** The foliage exhibits a distinct bright yellow to white mosaic that sometimes causes large areas of interveinal leaf tissue to be bleached in appearance (Fig. 53-56). The symptoms are frequently referred to as a calico mosaic. Chlorotic line patterns and veinal necrosis also may occur. Generally, the leaves are not distorted. Infected plants may be slightly stunted and at times the fruit are distorted.

**Additional Information:** Alfalfa mosaic virus is found worldwide and has an extensive natural host range. The virus frequently occurs in alfalfa and other members of the Fabaceae. It is found most commonly in pepper that has been planted near alfalfa, clover, or other legume fields. It is not generally considered to be a major threat to pepper production. (See: FLETCHER, J.D. 1983. New plant disease records in New Zealand: additional hosts of alfalfa mosaic virus. N.Z. J. Agr. Res. 26:403-404; SHANNON, E. 1989. Chile disease control. N. Mexico State Univ., Coop. Ext. Ser. Guide H-219. Las Cruces, N.M. 7 pp.)
Chilli Veinal Mottle

Aphid-Transmitted Potyvirus

**Symptoms:** Leaf mottle and dark green vein-banding are the most characteristic symptoms (Fig. 59). Leaves of some cultivars are reduced in size and distorted (Fig. 57). Necrotic ringspots have been observed on a few cultivars. Early infection usually results in stunted plants. Pods on infected plants are smaller and occasionally show mottling and slight distortion (Fig. 58).

**Additional Information:** This is the most common virus infecting pepper in Malaysia, and it is known to occur in Taiwan, Thailand, Korea, Indonesia and the Philippines. It is frequently found occurring in mixtures with other viruses in pepper. Available information on host range indicates that the virus is restricted to solanaceous crops. (See: ONG, C.A., VARGHESE, G., and TING, W.P. 1979. Aetiological investigations on a veinal mottle virus of chilli (*Capsicum annuum* L.) newly recorded from Peninsular Malaysia. MARDI Res. Bull. 7:78-88; FUJISAWA, I., HANADA, T., and SAHARAN, A. 1986. Virus diseases occurring on some vegetable crops in West Malaysia. Jap. Agr. Res. Quart. 20:78-84.)
Cucumber Mosaic

Aphid-Transmitted Cucumovirus

**Symptoms:** Symptomatology is extremely variable. One of the most common expressions is a severely stunted, nonproductive plant that has dull light green foliage with a leathery appearance but no distinctive foliar markings (Fig. 60). At times leaf symptoms are striking and may include narrowing (Fig. 61), mosaic, yellowing, chlorotic or necrotic ringspots (Fig. 62 & 64), and oakleaf patterns (Fig. 63 & 65). Necrosis of the terminal shoots occurs in some instances (Fig. 62). Fruit may develop chlorotic or necrotic rings (Fig. 63). Other fruit symptoms include a rough surface, dull color, and distortion.

**Additional Information:** This virus is worldwide in distribution and has an extremely wide host range among both crop plants and weed species. Severe disease outbreaks frequently occur in pepper planted near other susceptible crops such as cucurbits. Although seedborne in some plant species, there is no evidence the virus is transmitted through pepper seed (See: Simons, J.N. 1957. Three strains of cucumber mosaic virus affecting bell peppers in the Everglades area of south Florida. Phytopathology 47:145-150; Lockhart, B.E.L., and Fischer, H.U. 1976. Cucumber mosaic virus infections of pepper in Morocco. Plant Dis. Rep. 60:262-264.)
Pepper Mottle

Aphid-Transmitted Potyvirus

**Symptoms:** Susceptible cultivars develop a severe leaf mottle which generally is accompanied by green vein-banding and leaf distortion (Fig. 66, 67 & 69). Severe fruit distortion occurs with many isolates (Fig. 69). ‘Tabasco’ seedlings develop a systemic necrosis and are killed by the virus. Older ‘Tabasco’ plants develop necrotic rings on the stems and pods, shed their leaves (Fig. 68), and then produce distorted new growth with a mosaic.

**Additional Information:** This virus was first identified in 1972 from pepper in Florida and Arizona. It is now known to be widely distributed in the southern U.S.A., Mexico, and Central America, and is one of the most damaging viruses affecting pepper in that region. There are also reports of its occurrence in India and Thailand. The virus apparently is restricted to plants of the Solanaceae family. It frequently occurs in mixed infections with other viruses in pepper. (See: Nelson, M.R., and Wheeler, R.E. 1978. Biological and serological characterization and separation of potyviruses that infect peppers. Phytopathology 68:979-984; Purcifull, D.E., Zitter, T.A., and Hiebert, E. 1975. Morphology, host range, and serological relationships of pepper mottle virus. Phytopathology 65:559-562.)
Pepper Severe Mosaic

Aphid-Transmitted Potyvirus

Symptoms: Necrotic streaks and spots develop on stems, leaves, and fruit (Fig. 70-72) followed by shedding of the leaves. New growth after leaf drop shows a severe mosaic. Yield is greatly reduced.

Additional Information: The virus was first identified in 1977 from pepper in Argentina. It has not been reported to occur elsewhere. The only plant species known to be systemically infected by the virus are members of the Solanaceae. (See: Feldman, J.M., and Gracia, O. 1977. Pepper severe mosaic virus: a new potyvirus from pepper in Argentina. Phytopath. Z. 89:146-160.)
Pepper Veinal Mottle

Aphid-Transmitted Potyvirus

**Symptoms:** Leaves develop chlorosis along the main veins (Fig. 73, 74) followed by interveinal chlorosis, and are often small and severely distorted. Such leaves frequently abscise prematurely leaving the plants partially defoliated. Infected plants produce fewer and smaller fruits.

Potato Y

Aphid-Transmitted Potyvirus

Symptoms: Mosaic and dark green vein-banding are the most typical symptoms (Fig. 75, 77 & 78). Leaf crinkle, leaf distortion, and plant stunting are also commonly observed. 'Tabasco' plants develop yellow blotches on the leaves (Fig. 76). Some strains cause necrosis of the veinal tissues and the apical branches. Fruit set and size are reduced on infected plants. At times fruit may exhibit mosaic patterns and/or may be deformed.

Additional Information: Potato virus Y occurs worldwide, but it is more prevalent in warmer climates. It is perhaps the most common virus infecting pepper worldwide. Several strains of this virus are known to occur in pepper. The virus also commonly causes disease in potato, tobacco, and tomato. (See: Gebre Selassie, K., Marchoux, G., Delecuelle, B., and Pochard, E. 1985. Variability of natural strains of potato virus Y infecting peppers in South-Eastern France. Characterization and classification into pathotypes. Agronomie 5: 621-630 [in French]; Nagai, H. 1983. Breeding sweet pepper (Capsicum annuum L.) for resistance to potato virus Y. Hort. Bras. 1(2): 3-9 [in Portuguese].)
Tobacco Etch

Aphid-Transmitted Potyvirus

**Symptoms:** Leaves generally express mosaic and broad dark green vein-banding (Fig. 79 & 81). Leaf distortion (Fig. 79, 81 & 82), fruit distortion (Fig. 82), and plant stunting are also symptoms frequently associated with infections by this virus. Yield and fruit quality are greatly reduced in most cultivars. 'Tabasco' pepper plants wilt and die 1-2 weeks after infection by the virus (Fig. 80). Total crop loss may occur with this cultivar in some seasons.

**Additional Information:** Tobacco etch virus is widespread in North and Central America and also has been reported to occur in Puerto Rico, Hawaii, Venezuela, Sudan, and Southeast Asia. This is the most common and damaging virus affecting pepper in the USA. Several strains are known to occur in pepper although they have not been well characterized. The virus commonly causes disease in tobacco and tomato. (See: ZITTER, T.A. 1972. Naturally occurring pepper virus strains in South Florida. Plant Dis. Rep. 56:586-590; BENNER, C.P., KUHN, C. W. DEMSKI, J. W., DOBSON, J. W., COLDITZ, P., and NUTTER, F. W. 1985. Identification and incidence of pepper viruses in Northeastern Georgia. Plant Dis. 69:999-1001.)
Beet Curly Top

Leafhopper-Transmitted Geminivirus

Symptoms: Typical symptoms include upward rolling of the margins of older leaves and pronounced curling of the younger leaves (Fig. 83). Petioles curve sharply downward. Plants infected in early developmental stages are distinctly yellowed and dwarfed (Fig. 84). Very few pods are produced after infection has occurred, and those produced are small, misshapen, and usually ripen prematurely (Fig. 85). Plants infected early in the season generally do not survive.

Bell Pepper Mottle

Mechanically-Transmitted Tobamovirus

Symptoms: Foliar symptoms include vein-clearing, mosaic, mottle and chlorosis (Fig. 86). Plants infected during early stages of growth may be stunted. It is difficult to distinguish symptoms caused by this virus in pepper from other tobamoviruses.

Additional Information: Bell pepper mottle virus was first identified in 1972 from pepper in Argentina. It is not known to occur elsewhere. This virus does not cause disease in tobacco or tomato. (See: Feldman, J.M., and Oremianer, S. 1972. An unusual strain of tobacco mosaic virus from pepper. Phytopath. Z. 75:250-267; Wetter, C., Dore, I., and Bernard, M. 1987. Bell pepper mottle virus, a distinct tobamovirus infecting pepper. J. Phytopath. 119:333-344.)
Pepper Mild Mottle
(Capsicum Mosaic or Samsun Latent Tobacco Mosaic)

Mechanically-Transmitted Tobamovirus

Symptoms: Leaves develop a mild systemic mosaic and at times show crinkling (Fig. 87, 88). Young 'Greenleaf Tabasco' plants develop systemic necrosis, but are not killed. Pods generally develop severe symptoms including rings, line patterns (Fig. 89), necrotic spots, and distortion (Fig. 90). Stunting occurs when plants are infected during early stages of growth.

Additional Information: The virus is known to occur in the Americas, Australia, Europe, Iceland, Japan and Taiwan. This virus does not cause disease in tomato or tobacco. Infested seed and crop debris often serve as primary sources of inoculum. The virus can be eliminated from seed coats by soaking seed in a 10% solution of trisodium phosphate for 2 hours. (See: PARES, R.D. 1988. Serological comparison of an Australian isolate of Capsicum mosaic virus with Capsicum tobamovirus isolates from Europe and America. Ann. Appl. Biol. 112:609-612; WETTER, C. 1984. Serological identification of four tobamoviruses infecting pepper. Plant Dis. 68: 597-599.)
Mechanically-Transmitted Tobamoviruses

Symptoms: Similar for both diseases. Symptoms vary with the cultivar but include mosaic, stunting, systemic chlorosis (Fig. 91, 92), and at times systemic necrosis with an associated leaf drop.

Additional Information: Both viruses occur worldwide and cause disease in tomato and tobacco. They are differentiated by serology and their reactions on certain tobacco cultivars. Infested seed and crop debris often serve as primary sources of inoculum. These viruses can be eliminated from seed coats by soaking seed in a 10% solution of trisodium phosphate for 2 hours. (See: Wetter, C. 1984. Serological identification of four tobamoviruses infecting pepper. Plant Dis. 68:597-599; Rast, A. Th. B., 1988. Pepper tobamoviruses and pathotypes used in resistance breeding. Capsicum Newsletter 7:20-23.)
Tomato Spotted Wilt

Thrips-Transmitted Tospovirus

Symptoms: Symptomatology is extremely variable. Leaves may develop mosaic, chlorotic flecking, chlorotic and necrotic ringspots, and deformation (Fig. 93-96). In some cultivars systemic necrosis of terminal shoots and leaf drop occur followed by new growth that has a systemic mosaic and is severely distorted. Fruit symptoms can include chlorotic and necrotic spotting, mosaic, ring patterns, and distortion (Fig. 96-98). Plants infected at an early stage are severely stunted and generally remain that way although plants of some cultivars have been observed to recover and produce near normal growth.

Chilli Leaf Curl

Whitefly-Transmitted Geminivirus

**Symptoms:** Curling and yellowing of the leaves and severe stunting of the plant are characteristic symptoms (Fig. 99-101). Infected plants have shortened internodes and leaves that are greatly reduced in size with their margins curled upward giving them a boat shape. Leaf margins develop a pale green to bright yellow color which extends into the interveinal areas.

Tigré Disease

Whitefly-Transmitted Geminivirus Complex

**Symptoms:** Tigré disease is characterized by leaf curling and a distinct marginal and interveinal chlorosis (Fig. 102, 103). Leaves of infected plants are reduced in size, puckered, and rolled upward at the margins. Plants infected during early stages of growth are severely stunted.

**Additional Information:** Tigré disease is a severe disorder of pepper in certain regions of Mexico where it is associated with whitefly infestations. Chino del tomate virus (CdTV) and pepper mild tigré virus (PMTV) have been identified as components of the complex that incites the disease. In pepper, CdTV alone causes a mild mosaic and slight leaf distortion (Fig. 104), but at times is symptomless. PMTV alone causes interveinal chlorosis and mild stunting (Fig. 105). These two geminiviruses have distinct but overlapping host ranges. Both are transmitted by *Bemisia tabaci*, but neither by mechanical means. (See: BROWN, J.K., CAMPODONICO, O.P., and NELSON, M.R. 1989. A whitefly-transmitted geminivirus from peppers with tigré disease. Plant Dis. 73:610; BROWN, J.K., and NELSON, M.R. 1989. Two whitefly-transmitted geminiviruses isolated from pepper affected with tigré disease. Phytopathology 79:908.)
Serrano Golden Mosaic

Whitefly-Transmitted Geminivirus

Symptoms: Viral infection causes a bright golden mosaic in the foliage of pepper (Fig. 106, 107).

Additional Information: This virus was identified as the cause of a golden mosaic disease of pepper and tomato observed in northwestern Mexico in the fall of 1989. More recently the virus has been identified from tomato in Arizona. It is transmitted from pepper or tomato to pepper and tomato by *Bemisia tabaci*, and from pepper to pepper mechanically. (See: BROWN, J.K., and POULOS, B.T. 1990. Serrano golden mosaic virus: a newly identified whitefly-transmitted geminivirus of pepper and tomato in the United States and Mexico. Plant Dis. 74:720.)
Texas Pepper Geminivirus

Whitefly-Transmitted Geminivirus

Symptoms: Affected plants display leaf curl and distortion. The leaves tend to curl upward at the margins, exhibit bright yellow spots, and at times yellow margins that extend into the interveinal tissues (Fig. 108-110).

Additional Information: This disease was first observed in pepper in south Texas during the fall of 1987 in association with high populations of *Bemisia tabaci*. The virus is transmitted by *B. tabaci* and also by mechanical means. Its host range is restricted to solanaceous species that include tomato and tobacco. The causal agent has been identified as a geminivirus distinct from previously described whitefly-transmitted geminiviruses. Until more information is available on its relationship to other geminiviruses, the pathogen has been given the provisional name Texas pepper geminivirus. (See: STENGER, D.C., DUFFUS, J.E., and VILLALON, B. 1990. Biological and genomic properties of a geminivirus isolated from pepper. Phytopathology 80:704-709.)
Aphid Feeding Injury

*Myzus persicae*, *Aphis gossypii*, and others

**Symptoms:** Distortion and mottling of young leaves which become cupped due to downward curling of the leaf margins are characteristic (Fig. 111). Chlorotic spots may occur on the leaves in association with feeding injury. High populations can cause a general chlorosis and leaf drop resulting in sunscald and/or reduced fruit size. Aphids (Fig. 113, 114) secrete honeydew which serves as a substrate for the growth of gray-black sooty mold on the surfaces of foliage and fruit (Fig. 112).

Mite Feeding Injury

Polyphagotarsonemus latus, Broad Mite

**Symptoms:** Leaves are generally curled downwards giving an 'inverted spoon' appearance (Fig. 115). Laminar development of young leaves is suppressed causing them to be narrow or filiform. Affected leaves develop a bronzed appearance particularly on the lower side (Fig. 116); they become thickened and brittle. With heavy mite infestations the apical meristem is killed. Pods develop a russeted, corky surface and may be distorted (Fig. 117).

**Additional Information:** The broad mite (Fig. 118) is a very destructive plant feeder with an extensive host range. It is known to occur in Australia, Asia, Africa, Europe, North America, South America, and the Pacific Islands. (See: **JEPPSON, L.R., KEIFER, H.H., and BAKER, E.W. 1975. Mites Injurious to Economic Plants. University of California Press, Berkeley, 614 pp.; PEIRIS, J.W.L. 1953. Chilli leaf curl complex. Trop. Agr. 109:201-204.**
Thrips Feeding Injury

Scirtothrips dorsalis, Thrips palmi

Symptoms: Leaves are distorted and generally curl upward developing a 'boat-shaped' appearance (Fig. 119, 120). The leaves become crinkled and the laminae may be greatly reduced by high thrips populations causing new leaves to be narrow or filiform. The lower surface of the leaves develops a silvery sheen that later turns bronze particularly near the veins (Fig. 121). Damaged pods are distorted and show a network of russeted streaks caused by the thrips feeding injury (Fig. 122).

Additional Information: Scirtothrips dorsalis has been known to cause leaf curl symptoms on chilli in India and Sri Lanka for many years. During the 1980s numerous reports were made of Thrips palmi (Fig. 123) infestations causing extensive damage to pepper throughout the Orient and Pacific Islands. In 1991 T. palmi was identified for the first time in the continental U.S.A. occurring on south Florida vegetable crops, including pepper. (See: LEWIS, T. 1973. Thrips: Their Biology, Ecology and Economic Importance. Academic Press, London. 349 pp; SAKIMURA, K., NAKAHARA, L.M., and DENMARK, H. A. 1986. A thrips, Thrips palmi Karny (Thysanoptera: Thripidae). Fla. Dept. Agr., Entom. Cir. No. 280.)
Mutations

Noninfectious condition caused by changes in chromosome number or structure

**Symptoms:** Various symptoms may include filiform, lanceolate, or willow leaf distortion; chlorophyll deficiency (Fig. 124); chimeric leaf variegation (Fig. 125, 126); or distorted buds.

Blossom-End Rot

Calcium deficiency and water imbalance

Symptoms: A water-soaked area develops on the pod wall near the blossom end, but rarely in the blossom scar. The affected tissue rapidly desiccates becoming light brown and leathery in appearance (Fig. 127-129). Affected pods ripen prematurely (Fig. 127). Saprophytic fungi generally colonize the dead tissue turning it dark. Soft rot bacteria may enter the pod through damaged tissue (Fig. 129).

Salt Injury

High salt concentration in soils

**Symptoms:** Young plants are stunted or killed (Fig. 130). Roots may be burned or the hypocotyl desiccated depending on the location of the high salt concentration. Salt accumulation in low areas of the field can result in stunting or death of plants (Fig. 131).

**Additional Information:** High salt concentrations naturally occur in some soils, but damaging levels often result from overfertilization, improper placement of fertilizer, or use of irrigation water that has a high salt content.
Sunscald

Fruit exposure to direct sunlight and excessive heat

**Symptoms:** A bleached sunken lesion develops on the exposed side of the fruit (Fig. 132). The affected wall tissues desiccate and become papery.

**Additional Information:** Mature green fruits tend to be most sensitive. Sunscalding often predisposes fruit to secondary pathogens, which may incite fruit rots. (See: RABINOWITCH, H.D., BEN-DAVID, B., and FRIEDMAN, M. 1986. Light is essential for sunscald induction in cucumber and pepper fruits, whereas heat conditioning provides protection. Scientia Hortic. 29:21-29.)
Gramoxone (Paraquat) Injury

**Symptoms:** Typical damage appears as circular white to tan lesions that are less than 3 mm in diameter (Fig. 136-138). Multiple lesions on the same leaf may coalesce causing large irregular necrotic areas (Fig. 137) and leaf drop.

**Additional Information:** Damage may be caused by spray drift from paraquat application to the furrows in the pepper field or from aerial or high-pressure application of paraquat to nearby fields.
Phenoxy Herbicide Injury (2,4-D, 2,4,5-T, MCPA, etc.)

**Symptoms:** Developing leaves of affected plants characteristically form narrowed laminae and prominent, raised veins (Fig. 139-141). At times the leaf margin becomes wavy. Plants receiving high dosages develop filiform leaves, i.e. leaves composed primarily of the midrib with little or no laminar development. Flower drop and development of adventitious roots on the lower stem may occur in affected plants.

**Additional Information:** Low levels of phenoxy herbicides can cause growth distortions in pepper and many other susceptible broadleaf plants. Crop plants may be exposed by spray drift, volatile drift, contaminated sprayers, or contaminated water. (See: Klingman, G.C., Ashton, F.M., and Noordhoff, L.J. 1975. Weed Science: Principles and Practices, John Wiley & Sons, New York, 431 pp.)
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