Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(1): 962-970

Received: 24-11-2019
Accepted: 27-12-2019

RP Singh
Senior Scientist and Head, Mahayogi Gorakhnath Krishi Vigyan Kendra, Gorakhpur, Uttar Pradesh, India

Smita Tiwari
Scientist-Plant Pathology, Regional Agricultural Research Station, Sagar, Madhya Pradesh, India

Mamta Singh
Scientist-Plant Breeding and Genetics, Krishi Vigyan Kendra, Sagar, Madhya Pradesh, India

Ashutosh Singh
Assistant Professor, Biotechnology and Crop Improvement, College of Horticulture and Forestry, RLBCAU, Jhansi, Uttar Pradesh, India

AK Singh
Subject Matter Specialist-Agronomy, Mahayogi Gorakhnath Krishi Vigyan Kendra, Gorakhpur, Uttar Pradesh, India

Corresponding Author:
RP Singh
Senior Scientist and Head, Mahayogi Gorakhnath Krishi Vigyan Kendra, Gorakhpur, Uttar Pradesh, India

Important diseases of greenhouse crops and their integrated management: A review

RP Singh, Smita Tiwari, Mamta Singh, Ashutosh Singh and AK Singh

Abstract
Greenhouse cultivation is a form of protected cultivation which has some level of control over plant microclimate to alleviate one or more of abiotic or biotic stress for optimum plant growth. Nowadays, it is an emerging technology for raising vegetables, flowers and others high valued as well as perishable crops. In modern agriculture, protected structures have an extreme potential for more production with higher productivity. Quantity and quality of produce is also much better than open field produces. Gross and net returns are higher in these structures as compared to open conditions. The initial cost of protected structures is higher but it is compensated in 3-5 years with the good production of crops. Farmers are facing problems of low yield and poor-quality marketable produce due to various constraints like diseases, insect-pests, lack of planting materials and management technology worldwide. Among these, the major diseases in greenhouse crops are caused by fungi, bacteria, viruses and nematodes. Some of the minor diseases occurring under field condition have become major under protected condition. Greenhouses are designed to protect crops from many adverse conditions, but most pathogens and several pests are impossible to exclude. Windblown spores and aerosols containing bacteria enter doorways and ventilators. Soilborne pathogens enter in windblown dust and adhere to footwear and machinery. Aquatic fungi can be present in irrigation water, insects that enter the greenhouse can transmit viruses and can carry bacteria and fungi as well. Once inside a greenhouse, pathogens and pests are difficult to eradicate. In this review article, the major diseases and their integrated management are described based on pathogen types: fungi, bacteria, and viruses that are common in protected cultivation.

Keywords: Diseases causative agent, protected horticultural crops, integrated management

Introduction
Horticultural crops cover large varieties of fruits, vegetables, flowers, plantation and spices crops. Area under horticultural crops in India is 25.43 million hectare and producing 311.72 million tons production with productivity of 122.5 tons/ha, Horticultural Statistics at a Glance (2018) [12]. Fruits and vegetables are highly nutrient dense. They contain vitamins, minerals, fiber, antioxidants and other micronutrients essential for human health and thus excellent food sources to combat malnutrition. Horticultural crops can also fight hunger malnutrition and environmental degradation indirectly. Their market value contributes to generation income through direct sales and added value, thus alleviating rural poverty and providing additional opportunities to purchase nutritious food. Vegetable cultivation is the major attraction to farmers as it is comparatively more remunerative than field crops. India is a leading vegetable producing country in the world and is grown in every part of our country under varied agro-climatic and soil conditions in plains as well as in hilly regions. Presently it is occupying 10.26 million hectares area and producing 184.39 million tons production with productivity of 179.7 tons/ha, Horticultural Statistics at a Glance, (2018) [12]. There is a need to achieve the target of 225 million tons by the end of 2020 and 350 million tons by 2030, IIVR Vision, (2030) [13].
Production of horticultural crops like vegetables, fruits and flowers under protected cultivation system results in effective use of land resources, besides being able to increase the production of quality fruits, vegetables and flowers both for the export and domestic markets by offsetting biotic and abiotic stresses to a great extent that otherwise prevalent in open cultivation. Protected cultivation of high value cash crops is gaining momentum in India and provides appropriate conditions for off-season cultivation of tomato, capsicum, cucurbitaceous crops, eggplant, flowers etc. have become the choice of farmers. Farmers are facing problems of low yield and poor-quality marketable produce under protected cultivation due to various constraints like changing cultural practices, diseases/pests, lack of quality planting material

and management technology. Among these diseases are posing great threat to protected cultivation reported by several scientist namely Simone and Momol, (2001) [33], Hochmuth, (2003) [11], Rowe *et al.,* (2010) [28], Gooding, (2010) [9] and Shishido, (2011) [31]. Under greenhouse cultivation, crop wise important diseases and their integrated management are discussed in details and which are earlier informed by Sasaki, *et al.,* (1985) [30], Reuveni and Raviv, (1997) [26], Ferguson, *et al.*, (2009) [6] and Pundit, (2010) [24].

Fungal diseases in protected horticultural crops:

Fungal diseases constitute one of the biggest groups of foliar pathogens causing immense damage under protected environment. It has found that the incidence and severity of diseases vary considerably under protected environment when compared to open field. Some soil borne pathogens significantly reduces yield and quality in horticultural crops under greenhouse conditions. The important fungal diseases namely late blight, powdery/downy mildew, leaf mold, anthracnose, wilt and stem rot causing severe losses have been described in details.

Late blight of tomato and bell pepper

Causative agent: Late blight of tomato and Phytophthora blight of bell pepper are caused by *Phytophthora infestans* and *P. capsici*, respectively (Kishi, 1998; Tsitsigiannis, *et al.*, 2008; Shishido, 2011) [17, 38, 31].

Symptoms

The blight disease appears on leaves of tomato or bell pepper as circular or irregular lesions, rather large, greenish-black and water-soaked. These lesions enlarge rapidly and turn dark brown to purplish-black. When the disease develops on green tomato fruit, it results in large, firm, brown, leathery-appearing lesions, often concentrated on the sides or upper fruit surfaces. In moist and cloudy weather, white cotton like fungal growth appears near the outer margin of lesion on underside of the leaves. Infected areas on stems appear brown to black; entire vines might be killed in a short period when moist conditions persist (Tsitsigiannis, *et al.*, 2008; Rowe, *et al.,* 2010; Shishido, 2011) [38, 28, 31].

Integrated Management

Green manuring followed by application of *Trichoderma* powder@ 5 kg/ha within a week of ploughing. Use certified and healthy seeds, which must be collected from diseased free area. Seeds should be treated with Thiram @ 2-3 g/kg of seed before transplanting. Mulching in greenhouses effectively reduces the disease severity because less moisture is supplied from the soil surface and warmer soil temperatures prevail (Shtienberg, *et al.,* 2010) [32]. In addition, all infected crop debris and fruits must be collected from the greenhouse and burnt. Spray Copper hydroxy chloride 50% WP @ 3g/liter or Metalaxyl MZ 72% WP @ 2g/liter or Mancozeb 75% WP @ 2g/liter of water. It is better to avoid capsicum cultivation in severely affected net-houses (Japan Green Horticulture Association, 2003; Shishido, 2011; Beniwal, 2015) [14, 31, 3].

Leaf mold of tomato

Causative agent: Leaf mold is caused by the fungus *Fulvia fulva*. It is also called 'brown leaf mold' or simply leaf mold.

Symptoms

In general, lower leaves are affected first, then younger leaves. Pale-green or yellowish areas appear on the upper leaf surface, often becoming distinctly yellow later. The edges are indefinite and spots might grow together. At the same time, the fungus begins to grow on the undersides of the leaves in areas corresponding to the pale upper surface areas. The grown fungal spots are olive-green to grayish purple and velvety. They are more deeply colored in the respective centers of the areas. As the disease progresses, the spots turn yellowish brown. Then the leaves curl, wither and drop prematurely (Tsitsigiannis, *et al.,* 2008; Mercure, 2010; Shishido, 2011) [38, 19, 31].

Integrated Management

For controlling the disease, protected horticulture facilities should be kept warmer than the outside at night. Ventilation is particularly important when the humidity is greater than 85%. Crop residue should be removed and destroyed once the tomato crop is harvested to reduce the pathogen inoculums. Provide adequate spacing of plants, support plants (e.g. stakes, trellis or cages) and prune suckers and branches to increase air circulation and reduce humidity in the canopy. Spray Chlorothalonil 75% WP or Mancozeb 75% WP or Copper hydroxide 77% WP @ 2g/liter water or apply preventive measures with registered fungicides such as Thiophanate-methyl70% WP @ 1g/liter, Triflumizole50%WS and Chlorothalonil 75% WP (TPN) in combination with cultural methods explained above (Japan Green House Association, 2003; Shishido, 2011) [14, 31].

Gray mold

Causative agent: Gray mold disease caused by *Botrytis cineria.* However, this disease is quite prevalentin horticultural crops (e.g. tomato, bell-pepper, strawberry, cucumber, eggplant etc.) under protected cultivation (Tsitsigiannis, *et al.,* 2008; Mercure, 2010; Shishido, 2011) [38, 19, 31].

Symptoms

Light tan or gray spots first appear on leaves or flower petals, which become covered with gray-brown fungal growth. The infected leaves and flowers collapse and wither later. Stem might also be infected, forming elliptical spots where an infected leaf meets the stem. Old flower petals are particularly susceptible, usually starting with light watery spots. The fruit skin usually breaks over the decayed area and a dark gray growth of fungus appears over the spot (Kishi, 1998; Tsitsigiannis, *et al.,* 2008; Shishido, 2011) [17, 38, 31].

Integrated Management

Adequate spacing between plants and proper weed management is recommended for good air circulation. Avoid excessive humidity and do not allow water to form on foliage. At night maintain the greenhouse temperature higher than out doors to prevent condensation of water on leaves (Shishido, 2011) [31]. Registered fungicides i.e. Chlorothalonil 75% WP or Mancozeb 75% WP @ 2g/liter or Difenoconazole 25% WP @ 0.5ml/liter or Iprodione 50% WP @ 2g/liter or Azoxystrobin 23% SC @ @ 0.5ml/liter or Diethofencarb-thiophanate-methyl 65% WP @ 0.5ml/liter (Japan Green House Association, 2003) [14] should be sprayed at 5-7 days intervals. The fungus is famous for producing mutant strains against chemicals. Therefore, alternating usage of these fungicides is recommended.

Downy mildew of cucurbits

Causative agent: Downy mildew is a polycyclic disease and caused by the fungus *Pseudoperonosporacubensis*, which attacks only cucurbit species, i.e. cucumber, melons, gourds, pumpkins and watermelons.

Symptoms

Initial symptoms of downy mildew typically include angular yellow spots on leaf surface, usually of the lower, older leaves. On the undersides of the spots, a dark-gray fungal growth might be visible when high humidity prevails. As the disease progresses, the yellow spots enlarge and become necrotic or brownish in the center with browning spreading to the margins of the spots. Such spots might merge to form large brown areas on the leaves (Ferguson, *et al.*, 2009; Shishido, 2011) [6, 31].

Integrated Management

All parts of infected plants should be removed and discarded. Weeds of the Cucurbitaceous family such as *Trichosanthescucumeroides* surrounding protected horticulture facilities should also be removed because these might serve as reservoirs of the fungus. Growing cucurbits in environments where humidity levels can be manipulated can help to manage downy mildew. For example, trellising cucurbits, increasing plant or row spacing or growing in passive or traditional greenhouses can help reduce relative humidity and leaf wetness. Dew formation should be avoided by providing adequate heating and ventilation in protected horticultural facilities (Ushio and Takeuchi, 2006) [38] and mulching in greenhousesreduces the disease severity, primarily because less moisture is supplied from the soil surface (Shtienberg, *et al.*, 2010) [32]. Bioagent *Bacillus subtilis* @ 10 g/liter of water is effective for management of downy mildew in vegetables and ornamental plants reported by Beniwal, (2015) [3]. For chemical control, it is important to implement appropriate control procedures in the early stages of disease development, usually when only a few spots are evident on a few leaves of one plant. Under favorable conditions, the spores are readily dispersed by air currents; further disease development might occur very rapidly within in a few days. Registered fungicides i.e. Chlorothalonil 75% WP or Cymoxanil 8% + Mancozeb 64% WP @ 2g/liter water or Fosetylaluminium80% WP @ 3g/liter or Azoxystrobin 23% SC @ 0.5ml/liter or Dimethomorph 50% WP @ 1g/liter water should be spray for the management of diseases.

Powdery mildew of ornamentals and vegetables

Causative agent: Powdery mildew is a very common disease of many ornamental and vegetable crops. It is attributable to several fungi including *Oidiumviolae*, *Oidiopsissicula*, *Sphaerothecafuliginea* and *S. humuli*. Among these, *Oidiopsishaplophylli* (*syn. Oidiopsissicula*) species is more common in ornamental and vegetable crops, which are grown under greenhouse condition (Reis *et al.*, 2007; Tsitsigiannis, *et al.*, 2008; Mercures, 2010) [25, 38, 19].

Symptoms

All powdery mildew fungi cause similar symptoms; old leaves at lower portions are usually affected first. Then a fine white powdery fungal growth appears on the surface of the leaves. Bright white spots, yellowish white incase of *Oidiopsissicula*, approximately 5-10mm in diameter, develop and might grow together. Whole leaf blades might turn brown and dry up with a severe infection. However, infected leaves seldom drop off from the plant, fruits are unaffected (Tsitsigiannis, *et al.*, 2008; Mercures, 2010) [38, 19].

Integrated Management

Although the disease prefers dry conditions for developing mycelia and forming conidia on the surface of plants, germination of conidia requires moisture. Therefore, the disease development in consistent with the humidity condition (Jarivs, 1989; Ushio and Takeuch, 2006) [15, 39], but good air circulation is generally effective to prevent infection of the pathogen. Avoid excessive use of nitrogen in the crops. A variety of resistant ranges exist among commercial cultivars in different crops. Beniwal (2015) [3] reported *Bacillus subtilis* @ 10 g/liter of water is effective for management of powdery mildew in vegetables and ornamental plants. Therefore, integration of cultural and chemical methods is practically important if susceptible cultivars are grown. Some registered fungicides i.e. Wettable sulfur 80% WP @ 2-3g/liter (Japan Green House Association, 2003) [14] or Chlorothalonil 75% WP @ 2g/liter or Azoxystrobin 23% SC @ 0.5ml/liter or Myclobutanil 10% WP or Pyraclostrobin 20% WG @ 1g/liter or Tebuconazole 25.9% EC @ 1ml/liter water include for disease management. Beniwal (2015) [3] also reported powdery mildew management with use of Hexaconazole @ 0.5 ml/liter of water.

Sclerotinia stem rot of ornamentals and vegetables

Causative agent: Sclerotinia stem rot, also designated as white mold, results from infection by a fungus, *Sclerotinia sclerotiorum*, it is a destructive disease of numerous succulent plants, particularly vegetables and herbaceous ornamentals. The disease is particularly common in solanaceous and cucurbit crops in protected horticulture (Giesler, 2010) [7].

Symptoms

Leaves of infected plants start wilting and become gray–green before turning brown and eventually curling and dying. It is important to observe stems for white mycelia and sclerotia to differentiate this disease from other stem and root rot diseases. In a few days diseased stem areas are killed, and become tan and eventually bleached. This bleached stem has a pithy texture and shreds easily. Infected plant parts generally have signs of the fungal pathogen as white, fluffy mycelia, and sclerotia on the surface of or embedded in the stem tissue (Kishi, 1998) [17].

Integrated Management

Collect and destroy all infected plant material when noticed, to prevent sclerotia from contaminating the soil. Soil at the base of severely affected plants should also be removed and discarded in the garbage (not composted) to eliminate any sclerotia, which may have fallen to the ground. Several weeds can also be a host for this fungus. Therefore, it is important to maintain good weed control. If possible, avoid wetting the foliage. Susceptible plants should be planted only in well-drained soils. The results of foliar fungicide applications vary significantly for this disease. Therefore, chemical treatments are only recommended where severe disease incidences have occurred. Currently, registered chemicals i.e.Thiophanate-methyl 70% WP, Iprodione 50% WP, and Captan 75% WP (Japan Green House Association, 2003) [14] are used to management of the disease.

Anthracnose of strawberry

Causative agent: Anthracnose is a destructive disease of strawberry in warm and continental climate (optimal development temperature is approximately 30 ^{0}C), and are caused by three fungal pathogens i.e. *Colletotrichum acutatum,C.fragariae* and *C. gloeosporioides.* These pathogens can infect fruits, buds, blossoms, petioles, runners, crowns, and foliage. Anthracnose fruit rot, most often associated with *C. acutatum*, is a destructive menace worldwide (Treuchek and Heidenreich, 2010) [37].

Symptoms

Lesions first appear as small, dark spots on stolons and petioles. They enlarge to become dark, elongated, dry, sunken lesions which often girdle the stem. When petioles or runners become girdled, individual leaves or entire daughter plants might wilt and die. Petiole infections occur at the base of the petiole, causing the leaf to bend sharply at the point of attachment and hang down. Black leaf spots are caused by *Colletotrichumfragariae*or, *C. gloeosporioides*, whereas irregular leaf spots are the result of infection by *Colletotrichumacutatum*. The black leaf spots are about 1-2 mm in diameter and are usually black, but may remain light grey. Leaves can become heavily spotted without dying. This symptom usually appears after stolons (runners) and petioles are affected. Symptoms in fruits appear as whitish, water-soaked lesions up to 3 mm in diameter. As lesions develop, they turn a light tan to dark brown and eventually become sunken and black within a few days. After several days, lesions might be covered with spore masses that are pink to orange. Infected fruits eventually dry down to form hard, black and shriveled mummies(Kishi, 1998) [17].

Integrated Management

Plants and soil from infested nurseries are the most common primary source of inoculums, especially in annual in annual production system. In perennial systems, the fungi might survive in infected plants and debris, providing inoculums for the subsequent fruiting season. Crown infections often occur in the nursery but do not appear until after planting. Management is extremely difficult when environmental conditions are favorable for the pathogens. Management practices including usage of anthracnose-free plants should therefore start at planting to reduce inoculums levels. Infected fruits during an early season should be culled and removed from the plants. Anthracnose fruit rot might be controlled partly with protective fungicide applications from flower bud emergence to harvest. Currently registered fungicides i.e. Propineb 70% WP, Bitertanol 25% WPand Mancozeb 75% WP @ 2g/liter should be used (Japan Green House Association, 2003) [14].

Fusarium wilt

Causative agent: Fusarium wilt affects and cause severe losses on many ornamental and vegetable crops like cucumber, melon, strawberry, tomato etc. especially under the warm soil conditions which commonly occur in protected horticulture. Most of the wilt-causing *Fusarium* fungi belong to the species *Fusarium oxysporum*. Different host plants are attacked by special forms or races of the fungus: *F. oxysporum* sp. *lycopersici*attacks only on tomato, *F. oxysporum* sp. *cucumerinum*on cucumber, *F. oxysporum* sp. *melonis*on melon and *F. oxysporum* sp. *Fragariae*on strawberry (Tsitsigiannis, *et al.*, 2008) [38].

Symptoms

Most Fusarium wilts have disease cycles and develop similarly to those of Fusarium wilt of tomato, which begins as a slight vein clearing on outer leaflets and drooping of leaf petioles. Subsequently, the older leaves wilt, turn yellow and necrotic, and the entire plant might be killed, often before the plant reaches maturity. These symptoms in many cases appear on one side of the stem at first and progress upward until all foliage wilts and the stem dies. In a cross section of the stem near the base of the infected plant, a brown ring is evident in the area of the vascular bundles. The upward extent of the discoloration depends on the disease severity. Fruits, which might occasionally become infected, rot and drop off (Kishi, 1998; Agrios, 2005; Tsitsigiannis, *et al.*, 2008) [17, 1, 38].

Integrated Management

Fusarium wilt is soil-borne. Therefore, the use of resistant cultivars is the most reliable and practical measure for controlling the disease. Several such cultivars, including rootstocks for grafting, are available at present. Use of healthy seeds and transplants ismandatory. If they are suspected of being infected, hot-water treatment of seeds should precede planting. The fungus is so widespread and so persistent in soils that seedbed sterilization and crop rotation are expected to be of limited effect. However, soil fumigation with chloropicrin, dazomet, or methyl-isothiocyanate is currently practiced in some protected horticulture facilities where severe incidences of this disease have occurred. The biological control is the best alternative especially against soil borne pathogens. Biological control of pathogens, i.e. the total or partial destruction of pathogen populations by other organisms, occurs routinely in nature. Sundaramoorthy and Balabaskar (2013) [35] reported use of Trichoderma spp. For Fusarium wilt management in tomato. Akrami and Yousefi (2015) [2] reported that effective management of wilt management in tomato through application of *Trichoderma harzianum, T. asperellum* and *T. viride*. Beniwal (2015) [3] reported wilt management through soil application of *Trichoderma spp.* (10g/m^2), *Pseudomonas fluorescens* (10ml/m^2). Soil drenching with copper oxychloride 50% WP @ 3g/liter or Carbendazim 50% WP @ 1g/liter water is effective for control the disease.

Verticillium wilt

Causative agent: Verticillium wilts also occur worldwide but are most important for their effects in temperate regions. The pathogen attacks more than 200species of plants including ornamentals and vegetables in protected horticulture. There are two species i.e. *Verticilliumalbo-atrum* and *V. dahliae*, causes Verticillium wilts in most of the plants under protected cultivation (Roustaee and Baghdadi, 2007; Sanei *et al.*, 2008; Tsitsigiannis, *et al.*, 2008; Shishido, 2011) [27, 29, 38, 31].

Symptoms

The symptoms develop slowly and often appear only on the lower or outer part of the plant or on only a few of its branches. Older plants infected with the fungus are usually stunted and their vascular tissues show characteristic discoloration. Aboveground vascular tissue is also discolored and can be seen by cutting through a node near the base of the plant. In many hosts and most areas, however, Verticillium induces wilt at lower temperatures than Fusarium does. Tolerant or resistant varieties may show symptoms but seldom die (Agrios, 2005; Tsitsigiannis, *et al.*, 2008) [1, 38].

Integrated Management

Planting of susceptible crops should be avoided, especially where solanaceous crops have been grown repeatedly. Crop rotation with broccoli and corn for a period of at least 2 years (the longer the rotation, the better) can reduce the inoculums and subsequent plant infection. Thermal inactivation via soil solarization is useful for controlling this disease in regions with high summer temperatures. In addition, soil fumigation with dazomet and/or methyl-isothiocyanate can be practical in protected horticulture facilities where severe disease has occurred (Shishido, 2011) [31]. Naraghi *et al.* (2010) [20] reported control of Verticillium wilt in tomato through *Talaromycesfalvus* in greenhouse experiment. Soil drenching with Carbendazim 50% WP @ 2g/liter water or Copper hydroxide 77% WP @ 3g/liter water is effective for management of the disease.

Bacterial diseases in protected horticultural crops

Bacterial diseases can be extremely serious and destructive, affecting crops in protected horticulture. Plant pathogenic bacteria develop mostly in the host plant as parasites, on plant surfaces, especially buds, as epiphytes and partly in plant debris or in the soil as saprophytes. Some air-borne bacterial pathogens such as *Clavibactermichiganensis* sub sp. *michiganensis*, which causes bacterial canker of tomato and *Pseudomonas syringae*pvpv. *lachrymans*, which causes bacterial spot or angular leaf spot of cucurbits, produce their populations in the plant host. Other bacterial plant pathogens are soil-borne such as *Ralstonia solanacearum* which causes bacterial wilt of solanaceous crops. Soil-borne bacteria build up their populations within the host plants, but these populations decline only gradually when released into the soil (Tsitsigiannis, *et al.*, 2008; Shishido, 2011) [38, 31].

Bacterial wilt of solanaceous crops

Causative agent: Bacterial wilt of solanaceous plants, which is caused by the bacterium known as *Ralstonia solanacearum* (formerly *Pseudomonas solanacearum*), and continues to be a devastating disease in many countries (Tsitsigiannis, *et al.*, 2008; Shishido, 2011; Meng, 2013) [38, 31, 18].

Symptoms

The first symptom is appeared as chlorosis, stunting and the entire plant suddenly wilts and dies. Such dramatic symptoms occur when the soil temperature is high (>30 ^{0}C), and soil moisture is abundant. Under less conducive conditions, wilt and decline are slower, and numerous adventitious roots often form on the lower stems. In both cases, however, a brownish discoloration is present, first in the vascular system, and in advanced cases, spreading into the pith and cortex, Plant Problem Clinic (2010) [22].

Integrated Management

Soil fumigation, using chloropicrin is an effective measure to control bacterial wilt in protected horticulture, although it is difficult to eliminate the bacteria thoroughly from the soil. The bacterial cells are released into the soil from decaying roots and stems after plants die. For that reason, infected roots should be removed immediately. To prevent secondary infection, sanitation is important for keeping tools and facilities clean and disinfested. Kasugamycin 3% SL @ 1.25ml/liter and copper oxychloride 50% WP @ 3 g/liter sprays are effective for control of the disease. Crop rotation excluding solanaceous crops usually must be done for 3 years, because the bacterium can survive for long periods in the soil, even in the absence of host plants. Soil drainage also influences the degrees of the disease. Various resistant cultivars are available for tomatoes and eggplants including rootstocks for grafting (Shishido, 2011) [31]. Application of bleaching powder @ 15kg/ha has also been found effective against this disease. Seedling dip with streptocycline (@ 40-100ppm solution) avoids early invasion and infection by the pathogen through wounds formed during transplanting. Streptomycin sulphate 9% SP or oxytetracycline when sprayed @ 200ppm at 7 days interval provides good control. Several biological control agents such as *Pseudomonas fluorescens, Bacillus licheniformis, B. cereus, B. subtilis* and mycorrihiza are very effective in delaying and reducing the wilt development, The Hindu, (2008) [36]. Beniwal (2015) [3] reported effective management of bacterial wilt through application of *Pseudomonas fluorescens*(10g/m^2)/bleaching powder (300g/200m^2)/Streptocycline (0.1 g/liter of water) + Copper oxychloride (3 g/liter of water).

Bacterial canker of tomato

Causative agent: The disease bacterial canker is caused by the bacteria, *Clavibactermichiganensis* pv. *Michiganensis* (Cmm). This organism is seed-borne (on the surface and within the seed coat) and might survive for short periods in soil, weeds outside the green house, facility structures and equipment and for longer periods in plant debris (Warner *et al.*, 2002; Tsitsigiannis, *et al.*, 2008; Zitter, 2010) [40, 38, 41].

Symptoms

Early symptoms of the disease are wilting, curling of leaflets, and browning of leaves, often only on one side of the plant. Because the leaves die, the petioles remain green and firmly attached to the stem. Symptoms are classifiable into two types: external symptoms resulting from bacterial colonization of the surface tissues and internal symptoms resulting from bacterial invasion of the vascular tissue. External symptoms on fruit might be observed at any age, but are usually seen first on green fruit. White spots of 2-3mm diameter develop on the most-exposed parts of the fruit, and the spots have a dark brown center, which becomes raised, surrounded by a distinct white halo. Therefore, they are often called "bird's-eye spots".

Integrated Management

Bacterial canker is very difficult to eradicate once established in a greenhouse. Therefore, preventing the introduction and spread of the disease in a greenhouse is very important. Practice strict overall greenhouse sanitation and biosecurity procedures. Buy disease-free seed/transplants from a reputable source. Treated seed and seed derived from an "acid extraction" procedure is highly recommended. Use tomato cultivars, if any, that are resistant to bacterial canker. Diseased plants should be removed with surrounding healthy plants by cutting the plants off at the ground line immediately after they are detected. Sanitation is important by disinfecting hands, shoes, tools, and crop-supporting wires. Soils and seedbeds must be sterilized to destroy the bacteria with steam or chloropicrin fumigation. Infested facilities should be rotated out of tomatoes for at least 3 years. Weeds belonging to the Solanaceae family should also be destroyed. Registered chemicals such as Kasugamycin 3% SL @ 1.25ml/liter and Copper oxychloride 50% WP @ 3g/liter sprays might help in protecting healthy plants, particularly if only external

symptoms are present (Shishido, 2011) [31].

Bacterial spot/Angular leaf spot

Causative agent: Angular leaf spot (bacterial spot) of cucurbits is caused by the bacterium *Pseudomonas syringae*pv*lachrymans*. The bacterial pathogen is surviving in seed and diseased plant debris over winter in protected horticulture facilities for up to 2 years.

Symptoms

On leaves, the bacterium causes small, angular, water-soaked areas (lesions) which later turn brown or straw-colored. Leaf lesions are delimited by the veins, causing the angular appearance of the lesions. Under humid conditions, white, milky exudates, consisting of bacteria, form on the lesion, which becomes a thin, white crust when dried. Affected leaf tissue often dries and drops out, leaving irregularly shaped holes in the leaves. Lesions might also occur on petioles and stems. Infections on fruits are first small, circular, water-soaked and soft but older lesions are chalky and cracked. Fruit spots usually occur when fruits are about half grown. Below the lesions, flesh may be brown down to the seed layer. If attacked when very young, the fruit may fall off the plant (Kishi, 1998) [17].

Integrated Management

Resistant cultivars and preventive chemicals, cultural practices are strongly recommended including the use of pathogen-free seeds, crop-rotation out of cucurbits for at least 2 years, and restriction of overhead watering. Regarding chemical sprays, Copper oxychloride 50% WP @ 3g/liter (Hansen, 2009) [10] or Streptomycin sulphate 9% SP + Tetracycline hydrochloride 1% SP (Agrimycin) @ 6g/liter at younger stage of the crop growth (do not use during fruiting stage) or Copper hydroxide 77% WP @ 2g/liter or Cuprous oxide 4% DP @ 2g/liter can be applied at the first sign of disease.

Viral diseases in protected horticultural crops

Viral diseases cause severe damage and large economic loss in protected horticulture worldwide. The amount of such losses can vary depending on the virus strain, the host species, the age of the plant at infection time. Tomato, cucumber and capsicum are very sensitive to virus diseases under protected cultivation (Tsitsigiannis, *et al.*, 2008) [38]. Viruses usually begin infection through a wound, very often from insect feeding. Once a plant is infected, the virus spreads systemically within the plant. More than 80% of plant viruses can be transmitted by insects, primarily aphids, leafhoppers, thrips, and whiteflies, and secondarily by mites, fungi, and nematodes. In addition, viruses are often spread by propagation of infected plant parts (cuttings, bulbs, and sometimes seeds), some can also be spread by mechanical means including contact (rubbing, abrasion, or by handling). Some important diseases namely tomato mosaic virus, tomato leaf curl virus, tomato spotted wilt virus and cucumber mosaic virus are causing severe disease in protected environment have been described in details.

Tomato mosaic virus (ToMV)

Causative agent: It is positive sense single stranded RNA virus (+ssRNA) from the genus *Tobamovirus* and the family *Virgaviridae* that infects a wide range of plants, especially tobacco and other members of the family Solanaceae (in tomato, chilli, eggplant). TMV is distributed worldwide and may cause significant losses in the field and protected horticulture (Cerkauskas, 2004; Tsitsigiannis, *et al.*, 2008; Gooding, 2010) [5, 38, 9].

Symptoms

Symptoms appear as light and dark green mottled (mosaic) areas on leaves. Leaves on infected plants are often small, curled and puckered. Plants infected early in their development are stunted and have a yellowish cast. TMV can reduce size and number of fruits produced. The earlier a plant becomes infected, the greater the loss. Fruit usually do not show any malformation. Occasionally, mottling, bronzing, and internal browning of fruit occur. Environmental conditions influence the symptoms. These include temperature, day length and light intensity as well as the variety, the age of the plant at infection and the virulence of the strain of ToMV (Cerkauskas, 2004; Tsitsigiannis, *et al.*, 2008) [5, 38].

Integrated Management

Eradicate perennial and biennial weeds from the garden, field, greenhouse, and surrounding areas. Dry heating seed at 70 °C for 4 days or at 82-85 °C for 24 hr will help to eliminate surface-borne virus. ToMV on the seed coat can be eliminated by soaking seed for 15 min in 100 g/l of tri-sodium phosphate solution (TSP), rinsing thoroughly and spreading seeds out to dry. Use TMV-resistant tomato varieties when feasible. Avoid following tomato crops with susceptible crops such as tobacco, pepper, eggplant, or cucurbits. Make sure transplants are healthy and certified as disease free. If growing transplants in a greenhouse, then use steam-pasteurized soil. Avoid touching or handling plants prior to setting them in the field. Remove diseased seedlings that show leaf twisting, mosaic or unusual growth. Do not touch other seedlings while discarding them. Remove diseased plants from the field as soon as virus symptoms are noticed. Disinfect tools, stakes, and equipment before moving from diseased areas to healthy areas. This can be done by: (1) heating or steaming at 150 °C for 30 minutes; (2) soaking 10 minutes in 1% formaldehyde or a 1:10 dilution of a 5.25% sodium hypochlorite, do not rinse; or (3) by washing in detergent at the concentrations recommended for washing clothes or dishes. Discourage use of tobacco by workers, and encourage the practice of washing hands with soap and water before and after handling plants. Keep all solutions fresh. Alternatively, tools should be washed thoroughly, dipped for 30 minutes in 3% (w/v) TSP, and not rinsed before use. Hands should be washed and scrubbed well with 3% TSP, then rinsed thoroughly with water (Cerkauskas, 2004; Tsitsigiannis, *et al.*, 2008) [5, 38].

Tomato yellow leaf curl virus (TYLCV)

Causative agent: TYLCV is positive sense single stranded DNA virus (+ssDNA) from the genus *Begomovirus* and the family *Geminiviridae*. It is the most destructive disease of tomato in protected environment and causes severe economic losses. TYLCV is transmitted in a circulative-persistent non-propagative manner by the whitefly (Glick *et al.*, 2009; Brown, 2010) [8, 4].

Symptoms

Reduced internodes and stunted growth are appeared more severe in new growth of plants and vary somewhat among the different cultivars. The new leaves are also greatly reduced in

size and wrinkled, are yellowed (chlorotic) leaf edges between the veins, and have margins that curl upward, giving them a cup-like appearance. Flowers may appear but usually will drop before fruit is set.

Integrated Management

The most effective treatments used to control the spread of TYLCV are insecticides and resistant crop varieties. Imidacloprid 17.8% SL @ 250ml/ha or Thiamethoxam 25% WG @ 200g/ha should be used for control of the disease (Poston and Anderson, 1997) [23]. Other methods to control the spread of TYLCV include planting resistant/tolerant lines (Globe, Roma, Cherry, Tygress (Seminis), HA-3068, HA-3073, HA-3074, HA-3371, TY02-1155, TY02-1184, TY02-1276, TY02-1298, TY02-1314 (Hazera) etc), crop rotation, and breeding for resistance of TYLCV. As with many other plant viruses, one of the most promising methods to control TYLCV is the production of transgenic tomato plants resistant to TYLCV (Glick *et al.,* 2009) [8]. Clean up old field as soon as possible after harvest. Establish and maintain a tomato-free period in tomato production region.

Tomato spotted wilt virus (TSWV)

Causative agent: TSWV is negative sense single stranded RNA virus (-ssRNA) from the genus Tospovirus and the family *Bunyaviridae*. They are the sole group of plant infecting viruses in this family, as all other described members of the *Bunyaviridae* infect animals. It is one of the most economically devastating diseases of tomato around the world (Jones, 2005; Tsitsigiannis, *et al.,* 2008) [16, 38].

Symptoms

Tomato plants infected causes a wide variety of symptoms including wilting, stem death, stunting, yellowing, poor flowering; and sunken spots, etches, or ring spots on leaves. Initially, leaves in the terminal portion of the plant stop growing, become distorted and turn pale green. In young leaves, veins thicken and turn purple, causing the leaves to appear bronze. Necrotic spots or ring spots frequently occur on infected leaves. Stems of infected plants often have purplish-brown streaks. Infected fruit may exhibit numerous rings pots and blotches and may become distorted if infected when immature. On ripe fruit, yellow spots with concentric rings or necrotic streaks may be present (Tsitsigiannis, *et al.,* 2008) [38].

Integrated Management

Remove and destroy infected plants as soon as symptoms appear, to further reduce virus spread. Blue or yellow sticky cards are attractive to thrips, and are useful for monitoring populations. Avoid sequential planting because thrips can continue to emerge from the soil for 2–3 weeks after crop residues are plowed and roto-tilled. If economical, soil can be fumigated with metham sodium (Vapam) or 1, 3-dichloropropene (Telone) to eliminate thrips associated with crop debris. Control of insects, especially thrips, is important to reduce spread of the virus by vectors. Apply systemic insecticides Imidacloprid 17.8% SL @ 250ml/ha or Thiamethoxam 25% WG @ 200g/ha for control of the disease. Spray bordering weeds and the tomato crop with insecticides to suppress thrips populations and spread of TSWV (Singh, 2015) [34].

Cucumber mosaic virus (CMV)

Causative agent: CMV is a plant pathogenic positive sense single stranded RNA virus (+ssRNA) in the family *Bromoviridae*. It is the type member of the plant virus genus, *Cucumovirus*. This virus has a worldwide distribution and having the widest host range (tomato, pepper, cucurbits, carrots, celery, lettuce, spinach, beets, pokeweed, motherwort, milkweed, wild cucumber plants and many ornamentals etc.) of any known plant virus(Tsitsigiannis, *et al.,* 2008; Zitter and Murphy, 2009) [38, 41].

Symptoms

Symptoms of cucumber mosaic can vary greatly depending on the crop infected and the age of the plant when infection occurs. Almost all cucurbits are susceptible to CMV, with symptoms varying in severity. When vigorous vine crops become infected in the 6- to 8-leaf stage, the symptoms first appear on the youngest, still expanding leaves which develop a greenish yellow to dark green mottling of the leaves. One of the most common expressions is a severely stunted, nonproductive plant that has dull light green foliage with a leathery appearance but not distinctive foliar markings. Vines are sometimes dwarfed and may be yellowish near the center of the hill and “bunchy" because of shortening of the stem between the leaves. In severe cases all except the youngest leaves at the runner tips (rosettes) may rapidly turn brown and die. Cucumber fruit may show yellow and green mottling or have dark green "warts" on pale green fruit. Cucumber fruit produced in the later stages of the disease is sometimes smooth and pale whitish green (called "white pickle") and more blunted at the ends than fruit produced on healthy vines (Tsitsigiannis, *et al.,* 2008; Zitter and Murphy, 2009) [38, 41].

Integrated Management

Since CMV can overwinter in perennial plants and weeds the virus can enter the roots and present itself at the top of the plant in the springtime where it can be retransmitted by aphids. Eradicate all biennial and perennial weeds and wild reservoir hosts in and around fields. Maintain a distance of at least 10 yards between susceptible crops and weeds or other susceptible plants, including those in ditch banks, hedge or fence rows, and other locations. Grow seedlings in a structure or seedbed protected with netting of mesh size of 32 or greater to prevent aphids from entering. Discard any seedlings or young plants that show virus symptoms. Do not touch other seedlings while discarding them. Avoid touching or handling plants prior to setting them in the field. Diphands in milk while handling plants. Do not clip or damage young seedlings since this increases the possibility of mechanical transmission of the virus from contaminated tools or hands. Remove diseased plants from the field as soon as virus symptoms are noticed. This will reduce the spread of the virus by aphid vectors. Resistant plants are the best management practice, because they require fewer inputs, are easy to use, and don’t have adverse effects on the environment. Both transgenic plants (Ntui *et al.,* 2013) [21] and selective breeding (Zitter and Murphy, 2009) [41] have been used to manage CMV. Chemical spray followed by neem seed kernel extract (2%) is also effective in rotation with insecticides. Spray of imidacloprid 17.8 SL @ 1ml/liter of water to control of sucking insects.

Conclusion

Greenhouse cultivation is the most intensive form of crop production. Investment and labour costs are greater in this sector than in any other, however, yield and quality of produce are correspondingly high. The seasonal as well as off seasonal vegetable crops can be produced in greenhouse cultivation and maximizing crop productivity per unit area and increasing the quality of produce year around. Use of protected vegetable cultivation can increase production by more than five folds and increase productivity per unit of land, water, energy and labour. Horticultural crops are adversely affected by several diseases caused by fungi, bacteria, viruses etc. under protected environment and it is a major challenge to greenhouse production. The warm and humid climatic condition of greenhouse provide an ideal environment for the development of several foliar and soil borne plant diseases and are difficult to eradicate. Integration of cultural, physical, biological and chemical control options is needed to prevent widespread outbreak of the diseases in greenhouse within the soil and aerial environment.Disease-free seed/planting materials production of costly vegetables/flowers and genetically superior transplants can be produced under protected structures continuously.

References

1. Agrios GN. Plant pathology, fifth edition, Academic Press, New York, USA, 2005, 523-526.
2. Akrami M, Yousefi Z. Biological Control of Fusarium wilt of Tomato (*Solanum lycopersicum*) by *Trichoderma* spp. as Antagonist Fungi. Biological Forum-An International Journal.2015; 7(1):887-892.
3. Beniwal RS. Disease management of crops in protected cultivations/greenhouses. Singh, A, Dhankhar, SS, Dahiya, KK. (eds.) Training manual on protected cultivation of horticultural crops, 2015, 1-84.
4. Brown JK. Bemisia: Bionomics and management of a global pest. Eds. Stansly, PA and Naranjo, SE. Springer, Dordrecht, the Netherlands, 2010, 528.
5. Cerkauskas R. Tobacco mosaic virus, Tomato mosaic virus. In: Kalb T, (Ed.) Tomato Diseases, AVRDC-The world vegetable center, Tiwan, ROC Fact Sheet, 2004, 04-608.
6. Ferguson G, Cerkauskas R, Celett M. Downy mildew of greenhouse cucumber, Fact sheet, 2009, 1-9. ISSN 1198-712X. http://www.omafra.gov.on.ca/english/crops/facts/09-013w.pdf.
7. Giesler LJ. Sclerotinia stem rot, soybean disease, University of Nebraska-Lincoln, 2010. http//www. pdc.unl.edu/agriculturecrops/soybean/scleortiniastemrot.
8. Glick M, Levy Y, Gafni Y. "The Viral Etiology of Tomato Yellow Leaf Curl Disease - A Review". Plant Protection Sciences, 2009; 3:81-97.
9. Gooding GV. Virus diseases of greenhouse tomato and their management. Vegetable disease information note, 15 (VDIN-0015), North Carolina State University, 2010, 15. http://www.ces.ncsu.edu/depts/pp/notes/oldnotes/vg15.htm.
10. Hansen MA. Angular leaf spot of cucumber, Virginia Cooperative Extension, Publication, Virginia Technology, Virginia State University, 2009, 450-700. http//pubs.ext.vt.edu/450/450-700/450-700.html.
11. Hochmuth G. Vegetable Crops. Vegetable crops service programs, Institute of Food and Agricultural Sciences, University of Florida, 2003. http://edis.ifas.ufl.edu.
12. Horticultural Statistics at a Glance. Government of India, Ministry of Agriculture and Farmers' Welfare, Department of Agriculture Cooperation and Farmers' Welfare, Horticulture Statistics Division, 2018.
13. IIVR Vision. Compilation by B. Singh, Major Singh and A.B. Rai, Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, 2030.
14. Japan Green House Association. Handbook of protected horticulture (in Japanese), Engei Joho Center, Tokyo, Japan, 2003.
15. Jarivs WR. Managing diseases in greenhouse crops. Plant Disease. 1989; 73:190-194.
16. Jones DR. Plant viruses transmitted by thrips. European Journal of Plant Pathology. 2005; 113:119-157.
17. Kishi K. Encyclopedia of plant disease in Japan, Zennokyo, Tokyo (in Japanese), 1998.
18. Meng F. *Ralstonia solanacearum* Species Complex and Bacterial Wilt Disease. Journal of Bacteriology and Parasitology. 2013; 4(2):1-4.
19. Mercure PS. University of Connecticut Integrated Pest Management Program, University of Connecticut. 2010; http://www.hort.uconn.edu/imp/styles/menu.htm.
20. Naraghi L, Heydari A, Rezaeel S, Razavi M, JahanifarH,Khaledi EM. Biological control of tomato Verticillium wilt disease by *Talaromyces flavus*. Journal of Plant Protection Research. 2010; 50(3):360-65.
21. Ntui VO, Kynet K, Azadi P, Khan RS, Dong Poh C, Nakamura I. Transgenic accumulation of a defective *Cucumber mosaic virus* (CMV) replicase derived double stranded RNA modulates plant defense against CMV strains O and Y in potato. Transgenic Research. 2013; 22:1191-1205.
22. Plant Problem Clinic. Bacterial wilt of tomato, Fact sheet, Public Service, Clemson University, 2010. http://www.clemson.edu/public/regulatory/plantindustry/plantproblemclinic.
23. Poston JE, Anderson PK. The Emergency of Whitefly-Transmitted Gemini viruses in Tomato in the Western Hemisphere. Plant Disease. 1997; 81:1358-1369.
24. Pundit L. Some virus diseases of greenhouse crops. Integrated Pest Management, University of Connecticut.http://www.hort.uconn.edu/ipm/greenhs/htms/gcrpvirus.htm, 2010.
25. Reis A, Bioteux LS, Paz-Lima ML. Powdery mildew of ornamental species caused by *Oidiopsishaplophylli* in Brazil. Summa Phytopathologic.2007; 33(4):405-408.
26. Reuveni R, Raviv M. Control of downy mildew in greenhouse-grown cucumbers using blue photo selective polyethylene sheets. Plant Disease. 1997; 81:999-1004.
27. Roustaee A, Baghdadi A. Study of interaction between plant nutrition (N, P, K and Ca) and verticilliose wilt disease (*Verticillium dahliae*) in cucumber. Communications in Agricultural and Applied Biological Sciences. 2007; 72(4):1017-1022.
28. Rowe RC, Miller SA, Riedel RM. Late blight of potato and tomato, HYG-3102-95, Ohio State University Extension Fact Sheet.http://ohioline.osu.edu/hyg-fact/3000/3102.html.2010
29. Sanei SJ, Waliyar F, Razavi SI, Okhovat M. Vegetative compatibility, host range and pathogenicity of *Verticillium dahlia* isolates in Iran. International Journal of Plant Production. 2008; 2:37-46.

30. Sasaki T, Honda Y, Umerkawa M, Nemoto M. Control of certain diseases of greenhouse vegetables with ultraviolet-absorbing vinyl film. Plant Disease. 1985; 69:530-533.
31. Shishido M. Plant disease management in protected horticulture. Horticulture Research. 2011; 65:7-18.
32. Shtienberg D, Elad Y, Bornstein M, Ziy G, Graya A, Cohen S. Polyethylene mulch modifies greenhouse microclimate and reduces infection of *Phytophthora infestans* in tomato and *Pseudopernospora* in cucumber. Phytopathology. 2010; 100:97-104.
33. Simone GW, Momol MT. Vegetable Disease Recognition and Management. Florida Greenhouse Vegetable Production Handbook. http://edis.ifas.ufl.edu. 2001.
34. Singh B. Integrated pest management in greenhouse, Singh A, Dhankhar, SS, Dahiya, KK. (eds.) Training manual on protected cultivation of horticultural crops.2015; 55-60:1-84.
35. Sundaramoorthy S, Balabaskar P. Biocontrol efficacy of Trichoderma spp. against wilt of tomato caused by *Fusarium oxysporum* f. sp. *lycopersici*. Journal of Applied Biology & Biotechnology. 2013; 1(3):36-40.
36. The Hindu. Management of bacterial wilt in tomato. Today's Paper, Science Technology and Agriculture. http://www.thehindu.com/todays-paper/tp-features/tp-sci-tech-and-agri/management-of-bacterial-wilt-in-tomato/article1447116.ece.2008.
37. Treuchek B, Heidenreich C. Strawberry anthracnose, Tree fruit and berry pathology, New York State Agricultural Experiment Station, Cornell University. http://www.nysaes.cornell.edu/pp/extension/tfabp/santsmf.shtml, 2010.
38. Tsitsigiannis DI, Antoniou PP, Tjamos SE, Paplomatas EJ. Major diseases of tomato, pepper and eggplant in greenhouses. The European Journal of Plant Science and Biotechnology. 2008; 2(1):106-124.
39. Ushio S, Takeuchi T. Decrease in downy mildew occurrence on cucumber of forcing culture using a heating control unit with a dew condensation sensor. Annual Report of Kanto-Tosan Plant Protection Society. 2006; 53:51-54.
40. Werner NA, Fulbright DW, Podolsky R, Bell J, Hausbeck MK. Limiting Populations and Spread of *Clavibactermichiganensis* subsp. *michiganensis* on Seedling Tomatoes in the Greenhouse. Plant Disease. 2002; 86(5):535-542.
41. Zetter TA. Bacterial diseases of tomato, Fact Sheet Page: New York State Agricultural Experiment Station, Cornell University, 2010,735-750 http//vegetablemdonline.ppath.cornell.edu/factsheets/TomatoBacterial.htm.
42. Zitter TA, Murphy JF. The plant health instructor: *Cucumber mosaic virus*. American Phyto-pathological Society. http://www.apsnet.org/edcenter/intropp/lessons/viruses/Pages/ Cucumbermosaic.aspx. 2009.