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CARNATION DISEASES AND THEIR MANAGEMENT- A REVIEW

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ABSTRACT

Carnation is valued for its cut flowers but its cultivation is under continuous threat due to diseases caused by fungi, bacteria, nematodes and viruses. In the present communication these diseases have been described under the heads of vascular pathogens, stem and root rots and foliar diseases alongwith their integrated disease management.

Carnation (*Dianthus caryophyllus* L.) is one of the most important commercial flowers of the world and is valued for its cut flowers. It is preferred to roses and chrysanthemum in several exporting countries due to its excellent keeping quality, wide range of forms, ability to withstand long distance transportation and remarkable ability to rehydrate after continuous shipping. Diseases are one of the most limiting problems that affect production of cut flowers. The number of diseases has increased due to increase in acreage and also as a result of continuous importation of propagative material often infected from different parts of the world. At the same time, some changes in the relative importance of some diseases have been observed, which is probably due to the management given to these diseases and the introduction of susceptible varieties. In the present communication attempt has been made to cover the various diseases that affect carnation world over and for convenience these diseases have been described under three heads viz., vascular pathogens, stem and root rots, and foliar diseases.

A. Vascular Pathogens

1 Fusarium wilt (*Fusarium oxysporum* (Schlechtrnd ex Fr.) f.sp. *dianthi* (Pril. & Del.) Snyd. & Hans.)

The pathogen infects the vascular system of plants affecting the absorption of water and nutrients (Pizano, 1997), which leads to chlorosis and wilting of lower leaves and shoots with typical expression on one side of the plant. At the affected side, the stem is often shrivelled and turns greyish. The leaves attached to the shrivelled stem usually withers completely while the remaining leaves are green and turgescent for a while. Eventually, wilt also spreads to other sides quickly, followed by death of the plant. The wilted plants become stunted, yellow and dry often with hollow stem (Hood and Stewart, 1957; Baayen and Maat, 1987). Vascular browning of stem is also associated with the disease.

Growth of the pathogen in culture media is favoured by nitrates and inhibited by ammonium, particularly ammonium nitrate, as acid conditions favour the development of pathogen (Orozco-de-Amezquita *et al*., 1993). Highest wilt incidence was recorded at 30^{0}C, soil pH 6.0 and 60 per cent soil moisture, while 15°C temperature, 4.0 pH and 10 per cent soil moisture did not favour disease development (Chandel, 2000). The most severe wilt epidemics developed at low radiation intensities (200-300μE/m^2/s) and at temperature close to 25-26°C while plants remained symptomless at higher solar radiation intensities (>1000μE/m^2/s) and temperature <18°C (Ben-Yephet and Shtienberg, 1994; Baayen and Schoffelmeer, 1997). The possibility of spreading wilt pathogen by water cannot be ruled out as spores of fungus remain viable in water at a wide range of temperature (Rattink, 1976; Mirkova, 1998) and spores could easily be washed out of infected soil into the drainage water from where it could spread the disease. However, infected cuttings are not an important source of wilt disease but the use of water in which cut carnations infected with wilt

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have stood, is particularly dangerous (Rattink, 1974). The disease has a very slow dissemination rate at the beginning, but once the soil has been colonized, the dissemination rate is very high (Arbelaez, 1987).

2 Verticillium wilt (*Verticillium cinerescens* Syn.: *Phialophora cinerescens* (Wollenweb.) Van Beyma)

The spores of *V. cinerescens* enter the xylem vessels directly through the wounds and because of short length of the vessels, the spores are carried over short distances only, which explains why conidia are found only in the lower part of the stem and foliar symptoms are delayed (Peresse, 1971). As the pathogen invades the vessels, ultrastructural changes takes place in the associated living cells, which results in the formation of thick, heterogenous, extracellular wall and obstructs the diseased vessels by compounds such as polysaccharides and phenolics which impart resistance to the plants (Moreau *et al*., 1973).

The role of pectolytic and cellulolytic enzymes produced by the fungus in the disease development process is not clear (Catesson *et al*., 1972). Microscopic examination revealed that xylem is invaded vertically by mycelium and conidia, and laterally by hyphae passing through the pits between adjascent vessels (Peresse, 1974).

3 Bacterial wilt (*Burkholderia caryophylli* (Burkholder) Yabuuchi = *Pseudomonas caryophylli* (Burkholder) Starr & Burkholder and *Erwinia chrysanthemi* pv. *dianthicola* Burkholder *et al.*)

B. caryophylli produces grayish-green foliage and sudden wilting of plants. Roots may rot and the vascular discolouration in stem appears yellowish to brown. Stem base shows cracking symptoms. *E. chrysanthemi* pv. *dianthicola* causes slow wilting and shows symptoms of stunting, reduction of root system, brown discolouration of vascular bundles and necrosis at the stem base (Almeida and Malavolta Junior, 1995). High temperature favours disease development.

B. Stem and Root Rots

1 Basal rot/Root rot/Root and crown rot (*Phytophthora nicotianae* Breda de Haan var. *parasitica* (Dastur) Waterhouse)

Infected plants show symptoms of wilting, a brown discolouration on the collar and consequently dieing. The fungus is able to grow over the range of 10-35°C but the optimum temperature is 27°C (Ryu *et al*., 1998). Disease development is more rapid at 5-35°C than at 15-20°C (Ann *et al*., 1990). Though, *P. nicotianae* var. *parasitica* is the predominating, other species namely *P. capsici* and *P. cryptogea* were also isolated from carnations. *P. nicotianae* var. *parasitica* from other hosts and *P. capsici* from capsicum have been reported pathogenic to carnation (Ann *et al*., 1990).

2 Collar rot/Stem rot/Root rot (*Rhizoctonia solani* Kuhn Tel.: *Thanatephorus cucumeris* (Frank) Donk

Lesions develop at or just below soil level on the stem but roots are not often affected. The rots at the ground level causes the stems to break. The entire plant wilts and dies. In a dry and humid weather the disease spreads faster (Sharma, 1994). Susceptibility decreases with plant age. All plants developed severe stunting and wilt 30 days after inoculation at 5-30°C but only after 3-4 months at 20-25°C, while no symptoms were expressed at <20°C.

3 Fusarium stub dieback/Fusarium basal rot (*Fusarium roseum* Link Tel.: *Gibberella zeae* (Schwein.) Petch

The pathogen attacks and kills the stubs of mature plants when flowers are cut or plants are pinched and subsequently girdle the main branches. It grows down roots, the sidebreak of main stem, causing wilting and death of branches without discolouration of inner vascular tissues. Most infection occurs on the upper part of second year plants indicating that the fungus is air-borne

(Nelson *et al*., 1974, 1975; Han *et al*., 2001). The pathogen is found in the mother blocks rotting some carnation stems as a consequence of the injuries caused by the continuous harvesting of the cuttings. Severe losses have been found only on those crops whose management has been deficient, specially after very high flower yields (Arbelaez, 1987). It has shown that perithecia are produced and release ascospore under light and temperature conditions generally suitable for carnation growth. Raising the air temperature to 30-32°C at peak disease severity may reduce the amount of available inoculum, but this has not been shown to control the disease effectively and does not favour crop growth (Horst *et al*., 1975).

4. Sclerotium root rot/basal rot (*Sclerotium rolfsii* Sacc. Tel.: *Athelia rolfsii* (Curzi) Tu & Kimbrough)

Rotting of stem starts at the soil level extending to leaves. Cottony growth of the fungus mycelium is commonly seen on the infected portions. White to dark brown spherical sclerotial bodies are clearly visible at advanced stages of infection.

5. Pythium root rot/foot rot (*Pythium vexans* de Bary, *P. irregulare, P. aphanidermatum* (Edson) Fitzp.)

The infection results in rotting of stem at soil level resulting in wilt. The leaves gradually get discoloured and start drying from bottom upwards.

6. Nematode (*Meloidogyne incognita* (Kofoid & White) Chitwood & *Heterodera trifolii* Goffart)

One of the nematode most frequently found in some standard and miniature carnation varieties is the cyst nematode, *Heterodera trifolii*. The rate of development of this nematode is favoured by a temperature over 24°C (Anbrogioni and D'Errico, 1994). This nematode, in addition to its effect on the general development of the plant, increases severily the incidence of the vascular wilt caused by *F. oxysporum* f.sp. *dianthi*, since it causes the loss of resistance of some varieties possibly due to the fact that the injuries caused by the larvae favour the entrance of the fungus to the plant (Rebellon *et al*., 1989). Beside this nematode, root galls caused by *M. incognita* have also been reported in carnation.

C. Foliar Diseases

1. Alternaria leaf spot/blight (*Alternaria dianthi* Stevens & Hall and *A. dianthicola* Neergaard)

It is a major disease affecting carnations. The initial symptoms are small purple lesions produced on leaves which later turn to grayish-brown. On expansion the lesions merge and result in blighting of leaves. The infections are generally noticed on lower leaves just above the ground level and gradually progress upwards. Grayish-brown lesions are also seen on stems. The disease appears mainly during rooting time. On plants grown for flower production, the symptoms appear in the first few months after transplanting (Arbelaez, 1987). The optimum temperature and pH for *A. dianthi* are 25-30°C and pH 6 for vegetative growth while for spore germination it ranged from 20-25°C (Gu *et al*., 1996). Under natural conditions symptoms appear in December-January and are most severe during July-October. Disease severity is significantly correlated with the minimum temperature (Meeta *et al*., 1998). The level of disease decreases as planting date is delayed (Dhiman *et al*., 1991).

2. Fairy ring spot (*Cladosporium echinulatum* (Berk.) De Vries Tel.: *Mycospharella dianthi* (Burt) Jorst.)

The disease initiates as small pinhead necrotic lesions on the leaves and leaf sheaths which later enlarge to circular-oval spots and shows tan to grey center where large number of conidiophores and conidia develop. This brownish growth can be seen in the form of dull and dark bands, giving the name 'fairy ring' spot to the disease. The margins of the spots are distinct and purple to dark purplish in colour (Dhancholia and Paul, 2001). In severe cases

the lesions may coalesce and give the leaf a blighted appearance. Under these conditions, the leaves dry up and may defoliate. On petals, the pathogen produces light brown lesions (Cedeno and Carrero, 1997). The pathogen also affects severely the calyx, petals and the stems of susceptible varieties causing severe losses, since the affected flowers can not be exported (Arbelaez, 1999). The symptoms shows up during rooting and flower production specially on plants of 3 to 6 months old. Sporulation is very abundant on the underside of the leaf during rainy season (Arbelaez, 1987).

3. Rust (*Uromyces dianthi* (Pers.) Niessl)

Small pustules of powdery brown spores develop on the leaves and stems. Due to high disease intensity, plants withter off thereby affecting growth and flower quality. The pathogen is air borne in nature and urediniospores remain viable for upto 6 months depending on the storage conditions. The pathogen is more often found in areas of high precipitation during the rainy season and on plants of any age, with more incidence on 2 to 4 months old plants (Arbelaez, 1987). Carnation plants become infected when urediniospores were kept in free water on the leaf for 24h and uredinia appeared in 2 weeks after inoculation (Spencer, 1979). Lorenzini *et al*. (1999) have suggested that infection frequency and stomatal density could be considered valuable indices of partial resistance in an initial selection for resistant cultivars. Rust is always associated with water drip, low temperature with high humidity (Gjaerum and Langnes, 1984). Rust development is negatively correlated with maximum temperature while positively correlated with minimum temperature (Sharma and Verma, 2003).

4. Bacterial leaf spot/blight (*Burkholderia* andropogonis (Smith) Gillis Syn.: *Pseudomonas andropogonis* (Smith) Stapp & *P. woodsii* (Smith) Stevens)

Disease appears as small, water soaked, yellow specks which upon coalesce cause extensive blight. Disease development takes place in three distinct phases as slow peripheral spread, rapid extensive spread and declining vertical spread which is related to temperature and rainfall (Diatloff and Rochecouste, 1991).

5. Viruses

Carnations are affected by several viruses and among them *Carnation mottle virus* (genus *Carmovirus,* CarMV), *Carnation vein mottle virus* (genus Potyvirus, CaVMV), *Carnation ring spot virus* (genus *Dianthovirus,*CaRSV), *Carnation etched ring virus* (genus *Cauliovirus,* CaERV), *Carnation latent virus* (genus *Carlavirus,* CaLV) and *Carnation necrotic fleck virus* (genus *Closterovirus,* CaNFV) are most serious. Plants show wide variety of mosaic symptoms due to these viruses like mottling, chlorotic mottle or green vein mottle, necrotic flecks, rings, line patterens 'etched', whitish or necrotic streaks etc. Most of the viruses are transmitted either by sap (mechanically) or by the aphid (*Myzus persicae*).

The other pathogens which have also been reported on carnation are *Fusarium avenaceum, F. culmorum, F. graminearum* (basal rot), *Sclerotinia sclerotiorum* (Stem & root rot), *Peronospora dianthicola* (downy mildew) and *Botrytis cinerea* (grey mold), *Stemphylium botryosum* (Calyx rot), *Ustilago violacea* (anther smut), *Septoria dianthi* (leaf spot) etc.

Disease Management

To achieve a meaningful management of the pathogen and a substantial degree of disease control, all the four components of disease pyramid are to be managed. This goal can be achieved by the integration of methods directed against the causal agent, in favour of the host and for modification of the environment. The package of practices consisting of a combination of cultural, biological, chemical methods and host resistance help in reducing the diseases.

Cultural practices

Crop and field sanitation: Several diseases can be reduced by adopting good field sanitation.

Removal of infected plants and their debris helps in keeping the primary inoculum load at minimum level. Deep summer ploughing and exposing the soil to high prevailing temperature is effective in reducing soil-borne inoculum. To achieve the control of leaf spots and rust pathogens in carnations, manual removal of leaves and infected plant parts has advocated (Arbelaez, 1987; Meeta *et al*., 1998). Removal of weeds from fields is also essential as this practice modifies the microclimate by lowering the moisture/humidity. Prevention of moisture accumulation and ground irrigation are recommended as cheaper alternatives for the management of rust disease (Rumine and Bonifacio, 1983). Hand weeding alongwith removal of diseased leaves was found effective for the management of Alternaria leaf spot (Meeta *et al*., 1998).

Physical methods/Soil solarization: Soil solarization for nearly seven weeks during summer months significantly reduced or eliminated inocula of *F. oxysporum* f.sp. *dianthi* (Elena and Tjamos, 1997) and *P. nicotianae* var. *parasitica* (Garibaldi and Tamietti, 1989). Steaming before planting was found an effective approach for the management of vascular pathogens (Rattink, 1976; Arbelaez, 1988).

Crop rotation: Significant reduction in soil-borne pathogens can be obtained through crop rotation. As most of these pathogens have wide host range, care should be taken while selecting crops for rotation. For example, *P. nicotianae* var. *parasitica* from other hosts and *P. capsici* from capsicum have been reported pathogenic to carnation (Ann *et al*., 1990). Similarly, *P. cryptogea* has also been isolated from carnations.

Adjustment of date of planting: The choice of planting in relation to crop disease has one principal aim to reduce to a minimum the period over which pathogen meets the susceptible stage of the host. This can be exploited for disease management by altering the date of planting. Dhiman *et al*. (1991) reported that the level of Alternaria leaf spot disease decreased as planting date was delayed.

Nutrient management: Maintenance of optimum plant health with sufficient, but not excessive, levels of fertility can be beneficial in crop resistance to infection. Higher doses of nitrogen in carnation results in lush growth and high relative humidity which predisposes the crop for the attack of Fusarium stub dieback (Nelson *et al*., 1974, 1975). Amendment of compost to the soil (inducing N deficiency) resulted in a reduced incidence of carnation wilt. Subsequent application of N fertilizer increased disease levels again, thereby indicating that N deficiency does not provide a lasting protection against wilt pathogen but delays disease development (Filippi and Bagnoli, 1992). Addition of Ca, K and N to substrate inoculated with *F. oxysporum* before planting did not reduce the number of spores of the fungus but considerably reduced wilting and discolouration of conducting tissues (Kovacikova and Altmanova, 1989). The number of *F. oxysporum* f.sp. *dianthi* colonies in the soil decreased following treatments with potassium nitrate and potassium sulfate as they increased soil pH (Burbano *et al*., 1990).

The use of composted olive pumice or a commercial composted pine bark instead of a sphagnum peat in a container media delayed the appearance of wilt (Pera and Calvet, 1989). Fusarium wilt was promoted by fresh, non-decomposed organic matter in the substrate and an acid pH while the best control was obtained when cuttings were grown on topsoil plus decomposed dung substrate at pH 7.0 (Duskova and Kovacikova, 1989). Peat drenches with vermicompost (@ 25%) immediately after planting of carnation significantly suppressed the spread of wilt and reduced pathogen propagules by 50 per cent (Orlikowski, 1999).

Regulatory methods: Some pathogens are introduced through infected planting material from one country to another or from one region to another. The incorporation of infected cuttings

from different countries has been highlighted as major cause of *F. oxysporum* f.sp. *dianthi* and *Phialophora cinerescens* in Colombia, which have caused big losses in production of carnation flowers (Arbelaez, 1987, 1999). The risk of introduction of the pathogens (especially *S. rolfsii*) with plant material avoiding proper quarantine has been suspected (Sepulveda Chavera, 1993). The cyst nematode (*Heterodera trifolii)* entered in Colombia through infected cuttings imported from Israel (Arbelaez *et al*., 1985).

Meristem culture: Meristem culture of carnation infected with carnation mottle virus resulted in 28 per cent of the plants being freed of the virus. However, two months heat treatment of the infected mother plants at around 38°C before taking the meristem, raised the level of healthy plants to 100 per cent (Goethals and Hoof, 1971). A successful protocol for meristem tip culture to eliminate carnation latent virus was developed (Mangal *et al*., 2002).

Chemical Control

A greater reduction in vascular wilt incidence was observed when soil fumigants (methyl bromide, chloropicrin, metham-sodium, dazomet, formaldehyde, etc.) having broad spectrum activity were combined with steaming (Arbelaez, 1988; Orozco-de-Amezquita *et al*., 1993; Navas-Becerra *et al*., 2000). Satisfactory control of vascular wilts and Rhizoctonia root rot was obtained by drenching/soil mixing of benomyl, carbendazim, thiophanate methyl and thiophanate (Pergola and Garibaldi, 1972, 1973, 1974, 1975; Evans, 1976; Fletcher and Martin, 1972; Etebarian, 1998). Application of strobilurins (azoxystrobin, Kresoxim-methyl and trifloxystrobin) showed high efficacy against *F. oxysporum* f.sp. *dianthi*, *R. solani* and *P. nicotianae* var. *parasitica* when applied as soil drenching or mixing at transplanting (Gullino, 2000; Gullino *et al*., 2000, 2002; Gilardi *et al*., 2000). Rhizoctonia root rot can also be controlled by dipping the cuttings in captaf (0.3%) or carbendazim (0.1%) for 30 minutes before planting (Meeta and Mathur, 1991). Treatment with propiconazole (Tilt) provided moderate control of Fusarium wilt (Varchenko *et al*., 1989) while 100 per cent survival of sclerotium root rot infected plants was obtained with tebuconazole (0.1%) drench (Meeta and Gupta, 1995). Application of ethazol (50 or 100 ppm), diazoben (25 ppm) and propylene oxide as pre planting or soil drenching at weekly/fortnightly interval gave good control of Pythium root rot (Raabe and Hurlimann, 1972; Raabe *et al*., 1973), while application of ethazol and prothiocarb at various rates did not give satisfactory control of Phytophthora root rot. However, mancozeb and captafol slowed down the spread of pathogen considerably (Tramier and Antonini, 1975).

Use of broad spectrum protectant fungicides (captafol, mancozeb, zineb, chlorothanil) gave good control of Alternaria leaf blight (Bhandari *et al*., 1987) and cladosporium leaf spot (Braithwaite *et al*., 1989; Lo and Huang, 1997). Sprays of systemic fungicides (difenoconazole, hexaconazole, bitertanol, oxycarboxin, myclobutanil) were quite effective against most of the foliar pathogens (Ferrin and Rohde, 1991; Lozoya and Cruz, 1993; Wang *et al*., 1994; Lo and Huang, 1997). The combination or alternate use of both protective and systemic fungicides could be the best strategy for the control of these diseases. The applications of streptomycin sulfate, oxytetracycline and fosetyl-Al have been advocated for the control of bacterial leaf spot (Trujillo and Nagata, 1994). To manage viral disease, spraying with a combination of skimmed milk, oil and insecticide one day before each cultural operation or at intervals of 21 days have been found effective (Hein, 1975).

Biological Control

Trichoderma aureoviride proved most effective against *F. oxysporum* f.sp. *dianthi* and maximum antagonist occurred at 28°C, which

was near to optimum for wilt disease. The antagonist also showed tolerance to a wide range of pesticides (Carver *et al*., 1996). *T. viride* 85/1 and *T. harzianum* 658 applied during rooting of carnation cuttings strongly promoted growth of plants and gave good control of *F. oxysporum* f.sp. *dianthi* (Manka *et al*., 1997; Weber *et al*., 1998). Mixing of oospores of *Pythium oligandrum* with peat (100 oospores/gram of peat) 10 days before carnation planting resulted in strong inhibition of wilt pathogen (Orlikowski *et al*., 2002). Saprophytic *Fusarium* isolates from the rhizosphere of carnation controlled wilt very effectively when rooted cuttings were dipped before transplanting in spore suspension of the antagonist while soil application of chlamydospores diluted in talc or as infested wheat grains were less effective (Garibaldi *et al*., 1990). Similarly, saprophytic fungi especially *Penicillium* and *Fusarium* strongly inhibited the *F. roseum* pathogen (Migheli and Garibaldi, 1987). In another study, Migheli *et al*. (1993) reported that the use of *T. harzianum, Penicillium canescens, P. puberulum, Aspergillus fimigatus* and Mycelia sterilia effectively reduced the incidence of Phytophthora root rot.

Use of *Pseudomonas putida* str. WCS 358, *Pseudomonas* spp. Str. WCS 417 and X 13 have shown potential against *F. oxysporum* f.sp. *dianthi* (Xu *et al*., 1988). Addition of *Pseudomonas* sp. str. WCS 417r and Fe-EDDHA instead of Fe-DTPA as iron source in nutrient solution further intensified this reduction (Van Peer *et al*., 1990). Infecting carnation with *P. fluorescens* WCS 417r before *F. oxysporum* f.sp. *dianthi* inoculation led to reduced cell wall degradation (Steijl *et al*., 1999). Use of *P. aureofaciens* and *P. chlororaphes* in the hydroponic solution significantly reduced wilt incidence and bacteria were sufficiently viable in the rhizosphere to protect against the pathogen (Sorokina *et al*., 1999). A detail account on biological control of wilt pathogen by the use of antagonists in isolation or in combination with other antagonist/pesticide has given elsewhere (Sharma *et al*., 2006).

Verticillium lecanii was found infesting uredinia of carnation rust. Rust infection was prevented or the formation of urediniospores was arrested in the presence of *V. lecanii* depending on the time of application of *V. lecanii* conidia (Spencer, 1980, 1981).

Host Resistance

Host resistance is considered as the best approach to manage the diseases and list of germplasm showing different disease reaction to various diseases, except Fusarium wilt, the detailed account of which has given elsewhere (Sharma *et al*., 2006), is as below:

Rhizoctonia rot

Resistant: William Sim, Dusty Pink, White Lilia (Gupta *et al*., 1995).

Highly susceptible: Scania, Sam's Pride (Gupta *et al*., 1995).

Bacterial wilt

Highly resistant/Resistant: *Dianthus capitatus* ssp. *andrzejowskianus, D. henteri,* F1 of *D. caryophyllus* x *D. capitatus* (Onozaki *et al*., 1998).

Nematode (M. incognita)

Highly resistant: Desio, Catelaro, Kappa, Rara, Izu Pink, Target, Antalia (Cho *et al*., 1996).

Alternaria blight

Resistant: Leza, Amber Rose, Lena, Yellow Sim (Hilal and Kamel, 1990), Exquisite (Dhiman *et al*., 1991), Scania (Meeta *et al*., 1996).

Highly susceptible: New Arthur (Hilal and Kamel, 1990), Yellow Dusty, Harvest Moon, Leena, Shocking Pink (Meeta *et al.,* 1996).

Rust

Resistant: Nibbio, Desio, Gallimuraylia, Kortina, Isac, Leza (Aydin and Katircioglu, 1995), Mai Britt, Red Baron (Spencer, 1981), Rosa, Arthur Sim (Semina and Shestachenko, 1981).

Moderately resistant: Indios, Calypso, Astor, Gastellero Nobbi, Fanbio, Kontinent (Aydin and

Katircioglu, 1995), Tempo (Sharma and Verma, 2003), Lena, Yellow Sim (Hilal and Kamel, 1990).

Susceptible: White Sim, white Calypso, Raggio di Sole, Bianco New Nobbi, Irene, Aurigo (Aydin and Katircioglu, 1995), New Arthur (Hilal and Kamel, 1990), Crowly Sim, White Sim, Alice (Spencer, 1981), Impala (Sharma and Verma, 2003).

Bacterial blight

Resistant: Cal Red, Cal Improved White (Trujillo and Nagata, 1994).

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