

MANAGEMENT OF POST-HARVEST DISEASES OF FRUITS, VEGETABLES AND TUBER CROPS

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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
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Management of Post-harvest Diseases of Fruits, Vegetables and Tuber Crops

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Foreword

Quality preservation of fruits and vegetables after harvest, transportation and in storage is of equal important as the cultural and the management aspects of their production. Deterioration in quality of produce after harvest is a serious problem, and results due to physical injuries and biochemical changes consequent to infection by microorganisms.

The publication entitled *Management of Post-harvest Diseases of Fruits, Vegetables and Tuber Crops* describes in details various aspects of post-harvest care of almost all fruits, vegetables and tuber crops, and this has basically been written to be used as a textbook as per the recommendations of the University-level Textbook Writing Scheme of the Education Division of the Indian Council of Agricultural Research.

The publication has description of symptoms and causal organisms of each and every known fungal, bacterial and viral diseases of fruits, vegetables and tuber crops during post-harvest stage. In addition, control measures, physical, chemical and biological methods including use of eco-friendly bio-pesticides, myco-parasites, etc to be adopted in each case are exhaustively given. Further, appropriate practices to minimize losses on post-harvest storage are also highlighted; and the references cited cover available literature in India and abroad up to the year 2010.

It is hoped that the book will serve as a valuable source of information for students at the graduate/post-graduate level in Plant Pathology and as a reference book for research workers, progressive farmers and business officials associated with import of fruits, vegetables and tuber crops.

Dr Susamma Philip, former Professor and Head, Department of Plant Pathology, Kerala Agricultural University, deserves special appreciations for her earnestness and commitment in bringing out such a valuable publication.

Dr Alice Abraham
Former Professor
Kerala Agricultural University

Contents

| | |
|-----------------|------------------------|
| <i>Foreword</i> | Page No. <i>iii</i> |
|-----------------|------------------------|

PART-A MANAGEMENT OF POST-HARVEST DISEASES OF FRUIT CROPS

| | | |
|-------------|--|-----|
| Chapter 1. | APPLE (<i>Malus domestica</i>) | 3 |
| Chapter 2. | APRICOT (<i>Prunus armeniaca</i>) | 17 |
| Chapter 3. | BANANA (<i>Musa</i> spp.) | 18 |
| Chapter 4. | CITRUS (<i>Citrus</i> spp.) | 32 |
| Chapter 5. | EMBLICA/GOOSEBERRY/AONLA (<i>Phyllanthus emblica</i>) | 45 |
| Chapter 6. | GRAPE (<i>Vitis vinifera</i>) | 48 |
| Chapter 7. | GUAVA (<i>Psidium guajava</i>) | 59 |
| Chapter 8. | JACKFRUIT (<i>Artocarpus heterophyllus</i>) | 67 |
| Chapter 9. | LITCHI (<i>Litchi chinensis</i>) | 69 |
| Chapter 10. | MANGO (<i>Mangifera indica</i>) | 71 |
| Chapter 11. | PAPAYA (<i>Carica papaya</i>) | 83 |
| Chapter 12. | PEACH (<i>Prunus persica</i>) | 92 |
| Chapter 13. | PEAR (<i>Pyrus communis</i>) | 95 |
| Chapter 14. | PINEAPPLE (<i>Ananas comosus</i>) | 98 |
| Chapter 15. | PLUM (<i>Prunus domestica</i>) | 105 |
| Chapter 16. | POMEGRANTE (<i>Punica granatum</i>) | 106 |
| Chapter 17. | SAPOTA (<i>Manilkara zapota</i>) | 109 |
| Chapter 18. | STRAWBERRY (<i>Fragaria chilensis</i>) | 111 |

PART-B MANAGEMENT OF POST-HARVEST DISEASES OF VEGETABLE CROPS

| | | |
|-------------|--|-----|
| Chapter 19. | CUCURBITS | 117 |
| | [Cucumber (<i>Cucumis sativus</i>); Pumpkin (<i>Cucurbita pepo</i>); Watermelon (<i>Citrullus lanatus</i>); Muskmelon (<i>Cucumis melo</i>); Chayote/chow-chow(<i>Sechium edule</i>); Bittergourd (<i>Momordica charantia</i> var. <i>charantia</i>); Snakegourd (<i>Trichosanthes anguina</i>); Bottlegourd (<i>Lagenaria siceraria</i>); Ridge-gourd (<i>Luffa acutangula</i>); Sponge-gourd (<i>Luffa aegyptiaca</i>); Round-gourd (<i>Citrullus vulgaris</i>); Koval (<i>Coccinia cordifolia</i>)] | |

| | |
|---|-----|
| Chapter 20. SOLANACEOUS CROPS | 143 |
| [Brinjal (<i>Solanum melongena</i>); Chilli (<i>Capsicum annuum</i>); Potato (<i>Solanum tuberosum</i>); Tomato (<i>Lycopersicon esculentum</i>)] | |
| Chapter 21. LEGUME CROPS | 192 |
| [Garden-pea (<i>Pisum sativum</i>); Cowpea (<i>Vigna unguiculata</i>); Common-bean (<i>Phaseolus vulgaris</i>); Clusterbean (<i>Cyamopsis tetragonoloba</i>); Winged-bean (<i>Psophocarpus tetragonolobus</i>); Dolichos-bean (<i>Dolichos lablab</i>); Sword-bean (<i>Canavalia gladiata</i>)] | |
| Chapter 22. COLE CROPS | 217 |
| [Cabbage (<i>Brassica oleracea</i> con var. <i>capitata</i> Alef. var. <i>capitata</i>); Cauliflower (<i>Brassica oleracea</i> con var. <i>botrytis</i> Alef. var. <i>botrytis</i>); Knol-khol (<i>Brassica oleracea</i> con var. <i>acephala</i> Alef. var. <i>gongylodes</i>)] | |
| Chapter 23. ROOT CROPS | 232 |
| [Beet root (<i>Beta vulgaris</i>); Carrot (<i>Daucus carota</i> var. <i>sativus</i>); Radish (<i>Raphanus sativus</i>)] | |
| Chapter 24. BULB CROPS | 242 |
| [Onion (<i>Allium cepa</i>); Garlic (<i>Allium sativum</i>)] | |
| Chapter 25. MISCELLANEOUS VEGETABLES | 257 |
| [Amarathus (<i>Amarathus</i> sp.); Drumstick (<i>Moringa oleifera</i>); Lady's finger (<i>Abelmoschus esculentus</i>)] | |
| Chapter 26. SPICES AND CONDIMENTS | 264 |
| [Ginger (<i>Zingiber officinale</i>); Turmeric (<i>Curcuma longa</i>)] | |

PART-C

MANAGEMENT OF POST-HARVEST DISEASES OF TOPICAL ROOT/ TUBER CROPS

| | |
|---|-----|
| Chapter 27. TROPICAL ROOT/TUBER CROPS | 277 |
| [Tapioca/Cassava (<i>Manihot esculenta</i>); Sweet-potato (<i>Ipomoea batatas</i>); Colocasia (<i>Colocasia esculenta</i>); Elephant-foot yam (<i>Amorphophallus campanulatus</i>); Dioscorea (<i>Dioscorea alata</i>)] | |
| <i>Appendix 1</i> | 300 |
| <i>References</i> | 303 |
| <i>Subject Index</i> | 355 |

Part – A
MANAGEMENT OF POST-HARVEST
DISEASES OF FRUIT CROPS



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CHAPTER I

Apple (*Malus domestica* Borkh.)

Apple is rich in soluble fibre pectin that helps reduce blood cholesterol levels. Quercetin, a flavonoid, present in apple, fights against cancer.

FUNGAL DISEASES

Apple-scab, c.o. *Venturia inaequalis* (Cke.) Wint.

Anamorph : *Spilocaea pomi* Fr.

Apple-scab is one of the most destructive diseases of apple. It occurs in all apple-growing areas of the world, and causes heavy losses to apple-growers. In India, the disease had first appeared in 1955 in Jammu and Kashmir, and it had caused epidemic during 1983 (Gupta 1990).

Symptoms : Apple-scab's occurrence on fruits in storage was well documented by Sugiki *et al.* (1984). Storage scab appears after 45 days in Golden Delicious cultivar in storage (Fig. 1.1).

Dark, almost black, small velvety spots appear on fruits. Later, these spots enlarge and the centre loses its velvety appearance and becomes brown and corky. The loosened cuticle of the fruit appears as whitish band around the dark spot. Scab-infected fruits are also unfit for storage due to pronounced shrinkage and rotting caused by other fungi. Varietal resistance for the disease has been reported; Golden Mira is accepted as a variety resistant to apple-scab and powdery mildew (Bergamini and Giongo 2002).

Control measures : Post-harvest dip treatment of apple-fruits in Bitertanol (0.075%) gave maximum control. Carbendazim (0.05%) and Captan (0.2%) also protected the crop (Sharma and Kaul 1997). Storage after dipping fruits in a mixture of lime sulphur and copper hydroxide was also reported (Palm *et al.* 2002).

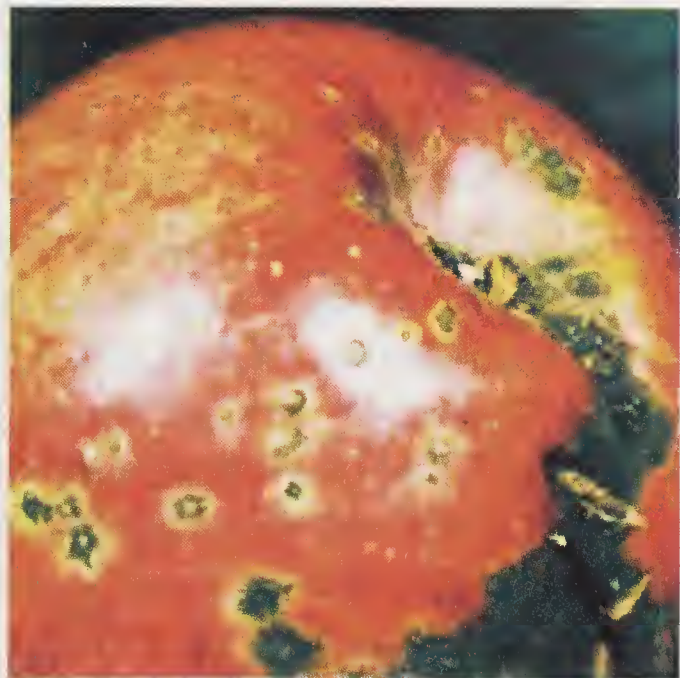


Fig. 1.1. Apple-scab

Soft-rot/blue-mould, c.o. *Penicillium expansum* Thom.

P. solitum Westling *et al.* 1911

P. crustosum Thom. 1930

Blue-mould is considered as one of the major post-harvest diseases. This disease occurs wherever apples are grown or are shipped. It has been estimated that blue-mould causes 80-90% of storage decay. The rot is responsible for major damages in storehouses (Agarwala and Sharma 1968; Mandal and Dasgupta 1982). The losses are especially high since they are incurred after harvesting, plucking and storage. In addition to losses, mycotoxins, Patulin and Citrinin, are reported in the infected apple-fruits. High Performance Liquid Chromatography (HPLC) analysis of Patulin also showed its presence in the nearby non-rotted areas (Singh and Sumbali 2008).

Symptoms : Soft-rot can usually be identified in the early stages by light colour and soft watery texture of the rotted area. A characteristic strong mouldy odour is often emitted. Rot advances rapidly. Rotten areas become blue or green in colour but do not wrinkle. When stored under high humidity, surface becomes studded with characteristic grey-blue cushions of fruiting-bodies.

Red Delicious cultivar is reported as highly susceptible (Singh and Sumbali 2004).

Control measures : Due to the serious nature of the disease, control measures of the disease with a combination of natural compounds, chemicals and antagonists have been attempted.

Pre-harvest spray with Benlate (500ppm) and Topsin M (0.1%) is effective (Borecka 1977). The disease can be avoided by observing stringent precautions during picking, grading and packing. Diseased and injured fruits are to be culled.

Fruits are to be placed in the cold storage immediately after picking. Jahangir *et al.*(1993) observed protection of Red Delicious apples from rots (*P.expansum*) by storing at 0°C.

Several workers have suggested use of wrappers treated with double boiled linseed oil. Use of skin coatings and wrappers provides protection (Kaul and Munjal 1983). Naik and Joshi (1973) controlled the disease by dipping fruits in Diphenyl amine (1,000 ppm) for five minutes or in Aureofungin (500 ppm) for 20 minutes.

Bavistin (Carbendazim) and Tecto-60 (Thiabendazole) at 250-750 mg/ml was effective in containing blue-mould infection in harvested fruits under ambient temperature (15-25°C) and at air-cooled (6-8°C) conditions. Post-harvest dipping of fruits in Benomyl and TBZ (Roy 1975; Northover 1975) as well as in Tecto-60 (Thiabendazole), Rovral (Iprodione) and Bavistin (Chib *et al.* 1985) was also found effective. Conway (1982) observed treating fruits in 8% calcium chloride (pressure infiltration), followed by storage, to be effective for three months.

Pre- and post-harvest application of ammonium molybdate controlled

post-harvest decay due to blue-mould and grey-mould. A significant reduction in severity and incidence of disease was noticed on storage at 1°C for three months (Nunes *et al.* 2001). Spraying of Harpin in the orchard, a few days before harvest was also promising by eliciting hypersensitive response in plants (Guyde *et al.* 2003).

Biological control is recorded as an effective mean for controlling disease. Certain bacteria and yeasts isolated from phylloplane of leaves and fruits serve as potential antagonists. Control of blue-mould is achieved with antagonistic bacteria (L-22-64), *Pseudomonas cepacia*; and yeasts, *Pichia anomola*, *Candida sake*, *C.olephila* and *Sporobolomyces roseum* (Janisiewicz 1987; Janisiewicz *et al.* 1994; Jijakli *et al.* 1993; Bagwan and Meshram 2001). Control of fungal-rot in diphenyl amine treated apple-fruit by means of a natural antagonist *Candida sake* (CPA-1) was also reported (Zanella *et al.*, 2002). Vero *et al.* (2002) utilized successfully two yeast antagonists, *Cryptococcus laurentii* (Strain 317) and *Candida ciferii* (Strain 283), isolated from the fruit surface of apples, in controlling blue-mould infection. Sanhueza and Cattanio (2003) from Brazil also reported effectiveness of antagonistic yeast, *C. laurentii*. Efficacy of yeasts like *Saccaromyces* sp., *Candida* sp., *Cryptococcus* sp. and *Rhodotorula* sp. was reported from China (He Dan *et al.* 2003). Selected isolates of *Aureobasidium pullulans*, *Rhodotorula glutinis* and *Bacillus subtilis* were also biocontrol agents in reducing post-harvest pathogens like *P. expansum*, *Botrytis cinerea* and *Pezizula malicortis* (Leibinger *et al.* 1997).

The yeast *Debaromyces hansenii* (10^9 cfu/ml) in combination with sodium bi-carbonate (1.0% w/v) showed minimum spoilage after 42 days of storage under ambient conditions (Singh *et al.* 2009).

Combination of biocontrol agent (*Pseudomonas syringae*) and pressure infiltration of fruits with calcium chloride reduced severity of infection by blue-mould (Janisiewicz *et al.* 1997). Ting *et al.* (2001) successfully controlled blue-mould (*P. expansum*) and grey-mould (*Botrytis cinera*) in storage by dip treatment with four isolates of *P. syringae*.

Brown-rot, c.o. *Monilinia fructigena* (Aderh. & Ruhl.) Honey *M. laxa* (Aderh. & Ruhl.) Honey

The fungus is worldwide in distribution (Byrde and Willetts 1977) and causes serious losses on apple. The disease is reported from India also (Bose 1969; Sharma *et al.* 2001). Four isolates of *Monilinia* have been recorded from Uttar Pradesh. Maximum decay is caused by *M.laxa* (Kaul and Munjal 1980; Sharma and Kaul 1987), when the fruits are stored between 20 and 27°C, and complete suppression of growth is at 0°C (Sharma and Kaul 1988). The pathogen over-winters in rotted infected fruits and in twig cankers.

Symptoms : Small brown spots appear on the maturing fruits. Under storage, first indication of the disease on the fruit is the development of small, circular

brown spots. In humid conditions, tufts of white growth can be noticed in concentric circles around the point of infection (Snowdon 1990). Even if slightly infected fruit is stored, the disease can spread also to adjacent healthy fruits.

Control measures : The efficacy of hot-water and Carbendazim treatment is reported in controlling brown-rot (Sharma and Kaul 1990). Fruit wrappers impregnated with DCNA (Dichloran) and sodium orthophenyl phenate(SOPP) as well as coating peel with mustard oil protect the crop in storage (Kaul and Munjal 1983).

Phytophthora fruit-rot, c.o. *Phytophthora* spp.

P. cactorum (Lebert. & Cohm.) Schroet.

P. syringae, *P. cryptogea* (Behr and Urban 1986)

In India, *P. cactorum* was found to be associated with fruit-rot as early as 1875, and has been recorded since 1951 (Bose and Mehata 1951; Gupta 1999).

The fungus is soil-borne and becomes active during rainy season. It was reported from Kumaon (Bose 1969). It also causes collar-rot on apple-trees. The fruits hanging low on the branches are likely to be affected severely. Once fruits are infected, they serve as the source of inoculum and can infect other apples during storage.

Symptoms : Infection usually occurs on fruits that fall on the ground or on which water is splashed. Externally, the rot is irregularly outlined. The diseased flesh turns pale to light brown. Vascular bundles and strands becomes dark brown. In the advanced stage, affected portion may become spongy, intensely discoloured and water-soaked. Contamination with infected soil leads to major wastage of apples in storehouses due to rotting by *P. syringae* (Edney 1978).

Control measures : Spraying trees with Dithane M-45 (0.2%) in early July, followed by another spray two weeks later is effective in controlling post-harvest diseases (Kanwar 1988). But Bharat and Sharma (1994) reported residues of Mancozeb on the stored fruits up to 35 days. Similar observations on residues were available from Pakistan also (Zahida and Masud 2002).

Treating fruits with Captan (0.2%) protects them against rotting caused by zoospores or from infected soil (Edney 1978). Infected fruits should not be stored with healthy fruits.

Bitter-rot, c.o. *Glomerella cingulata* (Ston.) Spauld. & Schrenk.

Colletotrichum fructigenum (Berk.) & Schrenk.

C. gloeosporioides Penz.

The disease is of worldwide occurrence, and has been reported from several countries including New Zealand (Brook 1977), Israel (Patil and Shohan 1983) and India (Chand *et al.* 1968).

Symptoms : Faint light-brown discolouration appears beneath the peel. The discolouration increases and extends in a cone-shaped manner. Lesions soon

become depressed and tiny with raised black dots beneath the cuticle. With increase of lesions, entire fruit becomes rotten. Most of the rotten fruits drop, while some cling as mummies. Epidemiology of the disease has shown that temperature at 25°C and relative humidity of 80% are ideal factors for maximum disease development on fruits. Removal of deadwood and mummies is important.

Disease resistance studies have shown that peel of the resistant varieties (Richard Red) contains higher quantities of total phenols as well as varied fractions of phenolic compounds in comparison to susceptible varieties.

Control measures : Copper fungicides are effective in checking the disease. Trisodium phosphate (2%) checks the disease in storage. Suppression of conidial germination and germ-tube elongation by three calcium salts, calcium chloride (CC), calcium propionate (CP) and calcium silicate (CS), has also been observed. Wrappers impregnated with DCNA (Dichloran) and sodium ortho-phenyl phenate (SOPP) as well as coated with mustard oil provide protection (Kaul and Munjal 1983).

Core-rot, c.o. *Alternaria* spp.

This disease is reported from all apple-growing areas of the world, including India and South Africa, where it is considered as a serious post-harvest disease (Agarwala and Sharma 1968; Dharam vir and Gaur 1971; Pierson *et al.* 1971; Prusky and Ben-Aire 1981; Tak *et al.* 1985; Jahangir *et al.* 1993).

A. alternata is a ubiquitous mould causing pre- and post-harvest damages to fruits (Torres *et al.* 1993). The disease is prevalent in refrigerated and stored fruits also.

Symptoms : Infection starts at the injured or other physiologically weakened tissues as brown to black, slightly sunken with clear-cut circular brown lesions on the fruit surface. Tissues beneath the lesions become soft and brown, while skin remains firm and tough. Longitudinal section of the fruit reveals discolouration around the central core (Fig.1.2). Profuse fungal growth is visible when the fruit is cut open and exposed (Philip 2002).

Serdan *et al.* (2002) in their studies on the core-rot of apples in South Africa observed association of 30 isolates of *Alternaria* spp., including *A. arborescens*, *A. infectoria* and *A. tenuissima*. The fungus produces an array of toxic secondary metabolites like



Fig. 1.2. Core-rot in apple

alternariol (AOH), alternariol monomethyl ether (AME), tenuazonic acid (TeA), altertoxin(ATX-1) etc. Singh and Sumbali (2004 a) in their studies on the post-harvest damage caused by *A. alternata* observed tenuazonic acid (TeA)-producing strains of *A. alternata* on the commercially important apple cv Red Delicious.

Control measures : Core-rot of apple is controlled by fungicides (Rovral, 500 ppm), growth regulators (Maleic hydrazide, 100 ppm) and hydrogenated groundnut oil (Tak *et al.* 1985). The disease was successfully managed in Israel by three foliar applications of beta aminobutyric acid (BABA) and potassium phosphite from beginning of the bloom until petal fall (Reuveni *et al.* 2003).

Whiskers-rot/soft-rot, c.o. *Rhizopus arrhizus* Fischer

R. oryzae Went & Prinsen Geerligs

R. stolonifer (Ehrenb.) Vuill.

This disease occurs in all apple-growing countries. The pathogens incite a soft-rot (Thakur and Chenulu 1970, 1970 a).

Symptoms : Affected fruits show a russet to verona brown discolouration on the peel that easily peels away from the underlying tissues. Tissues become soft and watery, and fruits are covered with white fungal mycelia and black fruiting bodies. The fungus is visible in seed cavities also. Soft-rot caused by *R. stolonifer* was recorded in cold storage fruits also (Mandal and Dasgupta 1982). Soft-rot development was observed in a wide temperature range from 7 to 40°C.

Control measures : The fruits are required to be stored below 10°C; over-ripe fruits should not be stored. The disease development was found to be slow at 7-8°C, and was of low intensity, and at temperature between 20 and 40°C, intensity of infection increased and disease development was fast (Thakur 1972). Thakur and Chenulu (1970) reported protection of fruits by dipping them in 2 aminothiazole plus thiourea (5%). Thakur *et al.* (1974) recorded growth regulators like 2, 4-D (100 ppm) and 2, 4, 5-T (100 ppm) to be effective as protectants.

Pink mouldy-rot, c.o. *Trichothecium roseum* Link. ex Fr.

This disease has been reported from India (Raina *et al.* 1971; Sreekantiah *et al.* 1974; Gracha and Singh 1980; Kaul and Munjal 1981 and Dasgupta and Mandal 1989), and is found associated with scab. The pathogen is usually carried from orchards and gains entry through wounds and bruises that occur during picking and handling of fruits. Fruit decays during transit and storage (Sharma *et al.* 2001).

Symptoms : Two types of symptoms are observed. In the first type, light-brown spots of about 4-mm diameter are seen on the surface. Later these spots enlarge and produce characteristic light centre with a brown advancing margin. In the advanced stage of infection, white to pink fungal growth develops on the infected surface. But the fruits remains firm. In the second type of infection,

chocolate- brown sunken irregular patches develop on the fruit surface. The pulp of the infected fruit may be seen radiating unevenly towards the core and the seed cavities are seen fully covered with pink spore mass. In both, affected fruits become bitter in taste. In China, Chen *et al.* (2002) reported small black to brown spots on the bagged fruits. They appeared due to poor ventilation in bags.

Control measures : Gupta and Sharma (1978, 1981) reported Bavistin (0.05%) and Difolatan (0.15%) as pre-harvest spray; both were equally effective against the disease. Similar results were also observed with Thiabendazole (0.1%) (Blanpied and Purnasiri 1968), Delan (1,000 ppm) and Saprol (1,250 ppm) (Pandey *et al.* 1980, 1980 a).

Fly- speck and sooty-blotch

Fly-speck, c.o. *Microthyriella rubi* Petr.

Zygophiala jamaicensis E.W. Mason

Sooty-blotch, c.o. *Gloeodes pomigena* (Schw.) Colby

Phyllachora pomigena Sacc.

Although fly-speck and sooty-blotch are caused by different fungi, they often appear together, and are difficult to be distinguished separately. Sooty-blotch, previously attributed to fungus *G. pomigena*, is now considered as a disease complex with different mycelial types (Sutton and Sutton 1994; Johnson *et al.* 1997).

Symptoms : Fly-speck produces characteristic small, round, black spots on the peel of the fruit. The spots have a shining appearance and are of a pinhead size or smaller and usually are numerous in comparison to the sooty-blotch fungus, which produces irregular, dull-black to grey spots. Both fly-speck and sooty -blotch spots are superficial, and do not penetrate deep into the fruit. But they damage fruit appearance. Golden Delicious is more susceptible to infection than Red Delicious group. The spots are prominent on the fruits borne on the inner part of the tree, as they are exposed to contaminated water dripping from upper branches. Philip (2002) observed severe infections in consignments received at Thiruvananthapuram from Bengaluru.

Control measures : The disease can be controlled by spraying Captan (0.2%), followed by Benlate(0.05%)(Gupta and Dutt 1974) in the field. The spray schedule recommended for scab (*V. inaequalis*) was helpful in controlling sooty- blotch and fly-speck also (Sharma and Sharma 1990). As the disease is superficial,it can be controlled by dipping fruits in chlorine water (500 ppm) for 5 minutes, followed by brushing and rinsing them with fresh water. This will help in removal of black spots from peel (Hendix 1991). This can be followed by wax-coating.

Influence of application of coconut soap (Biofa cocana RF) applied just before harvest against the sooty-blotch on apple fruits cv. Pinova was evaluated in Switzerland. Coconut soap and 1% lime sulphur reduced disease development significantly (Fuchs *et al.* 2002). Post-harvest brushing, rinsing

or dipping of apples with commercial disinfectants like sodium hypochlorite, hydrogen peroxide, peroxy acetic acid and soap were also practised (Batzer *et al.* 2002).

Biological control of fly-speck, as effectively as by fungicide, is achieved with *Chaetomium globosum* formulation containing a carbon source (cellulose suspension) (Davis *et al.* 1991).

Black mould-rot, c.o. *Aspergillus niger* Van Tiegh.

A. versicolor (Vuill.) Tiraboschi

Black rot is one of the most important post-harvest diseases of apples in India.

Symptoms : The rot appears mostly on injured fruits, and is characterized by small water-soaked circular lesions. As the disease advances, rotting continues, and pulp becomes soft and brown. Black masses of conidia and conidiphores at the point of infection become visible.

Control measures : Wrappers impregnated with chemicals and sodium bicarbonate dip treatments are used for controlling storage rots caused by *A.niger*, *Gliocladium roseum* and *Sclerotium rolfsii*. Potassium iodide wraps and sodium bicarbonate dip treatments (Sumbali and Mehrotra 1983) also provided effective control. Use of fixed oils, coconut oil, groundnut oil, mustard oil, castor and cotton-seed oil, protects the crop against post-harvest decay as they are water repellent and stable. Besides, all of them possess antifungal efficacy and act as therapeutants in preventing decay (Sumbali and Mehrotra 1980, 1983). Sulphurdioxide fumigation by using sodium metabisulphate also was effective protectant against storage rots (Kaul and Munjal 1983).

Marssonina-blotch, c.o. *Marssonina coronariae* (Ell. & J.J. Davis) Davis
syn: *M. mali* (P. Henn.) S. Ito

This disease is responsible for widespread defoliation in apple in Himachal Pradesh. It was first recorded in 1992, and assumed epiphytotic proportion in 1995. The disease is favoured by a moderate temperature of 20-22°C and high relative humidity, following rains in summers (Sharma 2004).

Symptoms : It appears initially as circular spots of 4-5 mm on the fruit surface that later become oval, depressed and dark brown with age and black at harvest (Bala *et al.* 2001; Sharma and Sharma 2006).

Fruit-rot, c.o. *Sphaeropsis pyriputrescens* Xiao & J.D. Rogers

The disease is reported from the USA on Granny Smith and Golden Delicious.

Symptoms : The disease starts at the calyx- end of the fruits. Decayed fruits show no symptoms of wounding but appear brown. Internal decay occurs and decayed pulp appears yellowish brown. Pycnidia of the fungus appear on the surface of the decayed fruits (Xiao *et al.* 2004).

Control measures : Combination spray of any Dithiocarbamate(0.2%) and Carbendazim (0.1%) during summer at 20-25 days interval is reported to be effective in managing the disease (Sonali *et al.* 2004).

Grey mould-rot/dry-eye rot/Botrytis- rot,
c.o. *Botryotinia fukeliana* (de Bary)
Botrytis cinerea Pers.

Grey mould or dry-eye rot of apple is an important disease, caused by *B. cinerea*; 12% incidence of this disease was reported from Shimla markets (Agarwala and Sharma 1968).

Symptoms : The disease is characterized by translucent, watery, light- brown to dark-brown spots. It spreads by contact.

Control measures : Fungicides available are not effective in controlling the disease. However, pre-harvest application of Cyprodinil has been recorded as effective in reducing grey-mould incidence and in reducing lesion diameter in stored apples (Sholberg *et al.* 2003). Biologically disease can be controlled by spraying conidia of *Trichoderma harzianum* on the trees during bloom. The spores were shaken in water, filtered and diluted to a concentration of 10^7 spores/ml. This suspension was added to 0.1% malt extract with 0.01% Tween - 80 and was used for spraying on the flowers (Tronsomo and Ystaas 1980).

Sclerotinia fruit-rot, c.o. *Sclerotinia sclerotiorum* (Lib.) de Bary

Fungus attacks in the field and causes rot in fruits at the calyx-end. Rot in storage due to *S. fructigena* has also been reported. Infection may take place through wounds or eyes on the fruits. The pulp is rendered soft and brown until fruit is mummified.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|---|---|-----------------------------------|
| Eye-rot | <i>Nectria galligena</i> Bres | |
| <i>Pestalotia</i> -rot | <i>Pestalotia hartigi</i> Tub | |
| <i>Stemphylium</i>- rot | <i>Stemphylium</i> sp. | |
| Fruit- spot | <i>Phoma mali</i> Schultz & Sacc. | |
| Brooks fruit- spot | <i>Mycosphaerella pomi</i> (Pass.) Lindau | |
| Soft- rot | <i>Khuskia oryzae</i> | Khanna and Chandra 1975 |
| | <i>Clathridium corticola</i> | Thind <i>et al.</i> 1977 |
| <i>Septonema</i> -rot | <i>Septonema</i> sp. | |
| Stalk-end rot/ Bull's eye rot/ | <i>Pezicula malicortis</i> (Jackson) Nannf. | |
| <i>Gloeosporium</i>- rot/ | <i>Gloeosporium malicortis</i> | Wilkinson, 1954; Snowdon, 1990 |
| Bitter- rot | <i>G. album</i> | Jamaluddin <i>et al.</i> , 1972 |

| Disease | Causal organism | Authority |
|------------------------------------|--|---|
| | <i>G. fructigenum</i> | Chand <i>et al.</i> , 1968 |
| Phyllosticta- rot | <i>Phyllosticta mali</i> | |
| Botryodiplodia-rot | <i>Botryodiplodia theobromae</i> Pat. | Usha and Saksena, 1979 |
| Cladosporium-rot | <i>Cladosporium herbarum</i> (Pers) Link. ex Gray | |
| Fruit-rot | <i>Gleocladium roseum</i> (Link). Bainier | Sumbali and Mehrotra, 1980 |
| Sour-rot | <i>Geotrichum candidum</i> Link. | Jamlauddin <i>et al.</i> , 1975 |
| Black-rot | <i>Botryosphaeria obtusa</i> (<i>Physalospora obtusa</i>) | |
| Conidial state: | <i>Sphaeropsis malorum</i> Peck. | Holmes and Rich, 1970; Venkatasubbaiah <i>et al.</i> , 1991 |
| Mucor core-rot | <i>Mucor piriformis</i> Roberts | Sharples and Hims, 1986 |
| Phomopsis-rot | <i>Phomopsis mali</i> (<i>Diaporthi citri</i>) | |
| Ring-rot | <i>Botryosphaeria beringeriana</i> | Xu <i>et al.</i> , 1992 |
| Irregular brown-rot | <i>Curvularia lunata</i> (Wakker) Boedjin | |
| Fusarium-rot | <i>F.avenaceum</i> , <i>F. culmorum</i> , <i>F. lateritium</i> and <i>F.solani</i> | |
| Storage-rot | <i>Gliocephalotrichum bulbilium</i> J.J. Ellis & Hesselt | Jamaluddin <i>et al.</i> , 1975a |
| Bacterial blister-spot | <i>Pseudomonas syringae</i> pv. <i>papulans</i> (Rose) Dhanvantri | |
| Russetting due to yeast | <i>Aureobasidium pullulans</i> (de Bary) Arnaud <i>Rhodotorula glutinis</i> Amr Abd | |

NON-PARASITIC STORAGE DISORDERS

Apples undergo serious physiological disorders when stored for a longer time. Some of these can be prevented if corrective measures are taken before picking or packing of fruits. Common disorders noticed in storage are as follows.

Apple-scald

Symptoms : This disorder is characterized by turning of fruit-peel into faint-brown or brown colour (Fig. 1.3); and internal breakdown occurs rapidly; thus skin dies and



Fig. 1.3. Apple-scald

readily peels-off from the fruit with a slight pressure. Fruit pulp turns brown and also breaks down.

Control measures : It can be contained by dipping fruits in 2,000 ppm diphenyl amine (DPA) or 2,700 ppm ethoxyquin. Wrapping fruits in paper oiled with 1.5 mg DPA before packing is also effective (Kanwar 1988). It can be controlled by using ultra-low oxygen atmosphere of 1.2% O₂ + 1% CO₂ with no ethylene removal (Coquinot and Richard 1992).

Soft-scald

It is different from the scald.

Symptoms : This is characterized by discrete brown lesions, which are smooth, slightly sunken, and generally confined to equatorial parts of the apple-fruits. Pulp beneath is also affected; tissues are initially pale-brown, soft, spongy and moist. In advanced stages, lesions may show dark spots (Brooks and Harley 1934). There is sharp demarcation between the healthy and the affected tissues. Pulp of the affected area becomes soft and discoloured.

Control measures: Harvesting crop at optimum maturity is very important. Wax application immediately after harvest proved beneficial in reducing incidence. Calcium chloride treatment has been found beneficial. Application of antioxidants combined with oils is also effective (Wills and Scott 1982). Storing fruits at 2°C (36 °F) proved advantageous.

Bitter-pit

This is one of the most critical disorders of apples, and most of the apple cultivars are susceptible to it. Sometimes, it is discernible in fruits while they are still on the orchards, but usually this develops only after harvest (Perring 1986). Affected fruits show small, deep-coloured spots (Fig. 1.4).

Symptoms : Fruits calyx-end tends to be affected first. Spots colour is green on yellow varieties and deep-red on red varieties. They become sunken and brown and underlying cells also turn brown and dry. In severely affected fruits, spots may appear scattered in the pulp. Sunken pits and coloured tissues taste bitter. The fruits may become mis-shaped due to severe pitting.

Control measures : Bitter-pit is caused by imbalanced water uptake by plants and is induced due to deficiency of calcium in fruits. The incidence of disorder can be reduced through proper cultural practices, regular irrigations and application of balanced



Fig.1.4. Bitter-pit on apple

fertilizers. Three or four calcium sprays at one or two week intervals before harvest can reduce bitter-pit incidence. Summer pruning and delayed harvesting are also reported effective in reducing disease incidence (Bonn 1980). Bonn (1981) observed reduction in interval of disease development and extended interval of bitter-pit and pulp breakdown by spraying with 0.9% calcium nitrate and by winter application of gypsum at 4 tonnes/ha in the first year and 2 tonnes/ha in the subsequent year, followed by 10-12 sprayings of calcium nitrate (0.9%) during the season in orchards. Dipping fruits in calcium chloride solution immediately after harvest was also effective (Scott *et al.* 1985). Bitter-pit prediction in harvested fruits can be done by dipping fruits in ethephon (2,000 ppm), followed by storage at 20°C for 5 days. This will give indication whether the disease would develop in storage on fruits (Ginsburg *et al.* 1976).

Post-harvest treatment to cv. Golden Delicious dipped in 2% flaked or anhydrous calcium chloride with or without 1% lecithin or 0.2% zinc chloride preceded by 3-4 orchard sprays of calcium nitrate was reported to reduce bitter-pit incidence under cold storage in boxes for five months (Fochessati 1981).

The incidence and severity of calcium-related bitter-pit was significantly reduced by gypsum use. Coarse gypsum (2-4 tonnes/ha) sprinkled on the surface of the soil and covered with a mulch (black polyethylene sheet), topped with saw dust, to protect mechanically was reported (Lang *et al.* 2001). Bitter-pit development and its relation with mineral nutrients and cultivars was also well understood (Kim and Ko 2004)

Water-core

Symptoms : Water-core symptoms develop before harvest, and can be observed when affected fruits are cut. Any external symptoms are hardly observed but when fruit is cut open, affected one shows watery or glassy appearance of the pulp. Affected fruits have poor keeping-quality. They emit a fermented sweetish odour. Severely affected fruits are heavier than normal ones and hence healthy fruits can be segregated by floating them in a mixture of water and alcohol. The affected fruits can also be detected and segregated by measuring transmittance of light through fruits (Bramlage and Shipway 1967). High temperature at the time of maturity favours development of water-core. The intensity of the disorder increases as fruits overmature.

In Himachal Pradesh, core-rot caused by *Alternaria alternata* was also found associated with water-core (Gupta and Sharma 2008).

Control measures : This disorder increases as apples overmature. Picking of the fruits at the proper time reduces water-core. Heavy irrigation and manuring with nitrates and potash fertilizers in the orchards are beneficial (Walker 1975). Ensuring proper drainage in the orchard reduces disorder. The fruits should be stored in the ventilated environment at the right maturity.

Jonathan-spot

This is common on Jonathan apple. On other varieties, this is known as spys-pot, physiological-spot and senescent-spot.

Symptoms : The disease originates at lenticels. The spots may be dark brown, black or moderately light brown. They appear only after harvest and are likely to be on overmature fruits (Richmond and Dewey 1969).

Control measures : The disorder can be reduced by harvesting apples at the optimum maturity, followed by prompt cooling. Fruits storage in an atmosphere of 2.5-5% CO₂ and 3% O₂ controls the disease (Pathak 1980). The discolouration can be removed by peeling of the skin.

Lenticel spots

Lenticel spots are centred on the natural openings called lenticels (Richmond and Dewey 1969).

Symptoms : Lenticel spots are slightly depressed, are up to 5 mm in diameter, and remain fairly superficial, unless invaded by fungi like *Alternaria* (Brooks and Cooley 1917).

Other disorders include brown heart that is due to excessive concentration of carbon dioxide in the tissues, bruising and other injuries like hail damage, chilling injury, core flesh, senescent breakdown, alcohol formation, black-end etc (Snowdon 1990).

POST-HARVEST DISEASES MANAGEMENT

Several investigators have reported better control with integrated strategies. Control of apple diseases with a combination of natural compounds, plant resistance and by the use of antagonists is commonly practised (Bosshard *et al.* 1987; Pathak 1997). The common methods include the following.

Cold storage

Cold storage of apples is the general practice followed by cultivators and consumers. Keeping fruits in cold storage at 0 °C immediately after harvesting is recorded as an effective measure (Jahangir *et al.* 1993).

Use of wrappers, wax-coating and chemicals application


Dipping of fruits in the fungicide solution before storage is very common. Wax-coating is effective in enhancing shelf-life. Bee wax and cantaleen wax are used for this. Mahajan and Chopra (1992) studied effect of post-harvest application of fungicides and wax-coating on the quality and storage of apples in Punjab; these applications slowed down metabolic rate in apple-fruits. And shelf-life was also prolonged by 30 days or more over control. Fruits treated with calcium chloride (8%) at pressure infiltration (10³ KPa) showed least decay on storage at 0°C for three months (Conway 1982; Sams and Conway 1985; Husein *et al.* 2001). The treatment significantly reduced TSS/acid ratio in apples stored at 0-1°C.

Two formulations of phenolic compound, Echinolan, developed in Russia, gave promising results. Both formulations prolonged keeping quality of apples by controlling fungal diseases and other functional disorders during storage. Echinolan B₄ at 0.01% was most effective (Vorob'eva and Vorob'eva 2000).

Controlled atmosphere storage

Controlled atmosphere is commonly practised for long-duration storage. Carbon dioxide 3% and oxygen 2% is the ideal combination. Apple-fruits (cv. Gala) preserved in controlled atmosphere with removal of ethylene remained intact up to eight months; rotting and senescence were also not observed. (Brackmann *et al.* 2003). Scald incidence was observed to be significantly lower in the CA storage (Erkan *et al.* 2004).

Alternate control measures include use of UV type C (254 nm) irradiation, yeasts, chitosan and harpin. Capdeville *et al.* (2002) evaluated all these factors for their ability to induce resistance and calculated area under disease progressive curve(AUDPC). UVC proved most effective, followed by harpin, chitosan and yeasts. Fresh fruits were more responsive than controlled atmosphere (CA) stored fruits. Harpin is a bacterial product that induces resistance in plants by eliciting hypersensitive response in them. The use of this may minimize cost of control strategies and reduce risks associated with excessive fungicides use.



CHAPTER 2

Apricot (*Prunus armeniaca* L.)

It is an important fruit-crop of the cold arid regions of India, and is one of the most delicious temperate fruits with a pleasant flavour. Ripe apricot is an excellent dessert and is used for the table purpose. Orange-coloured fruits are full of beta carotene and vit. C.

FUNGAL DISEASES

Brown- rot, c.o. *Monilinia laxa* (Aderh & Ruhl.) Honey
M. fructigena (Aderh & Ruhl.) Honey

Symptoms and control measures for this are detailed under brown-rot of peaches.

Rhizopus- rot, c.o. *Rhizopus* spp.

Symptoms and control measures are detailed under *Rhizopus*-rot of peaches.

Sclerotinia disease caused by *Sclerotinia sclerotiorum* (Lib.) de Bary has also been reported on apricots (Walker 1975).

BACTERIAL DISEASES

A bacterial disease caused by *Pseudomonas syringae* Van Hall was reported by Durgapal (1971). It appeared on the fruits as reddish-purple to dark-brown lesions.

POST-HARVEST MANAGEMENT

Apricots are soft and delicate and need to be consumed/processed within three days after harvest. They can be stored for 72-80 hr at room temperature. Storage life can be extended by storing at 5°C and at 85% relative humidity. Under controlled atmospheric conditions, fruits can be stored for 10 days at 3°C.



CHAPTER 3

Banana (*Musa* spp.)

Banana and plantain is a dessert fruit or a starch staple to a large population of the world. The fruit is rich in vitamins A, B,C, minerals and energy. Several fungi are reported to cause post-harvest losses in banana.

Cheriyān (1987) recorded maximum reduction in total sugars, total soluble solids and vitamin C in fruits infected with *Colletotrichum gloeosporoides*. Under pathogenesis, changes in protein and phenol contents in banana-fruits were also recorded. Protein concentration exhibited gradual fall under pathogenesis by prominent fungi, *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Helminthosporium speciferum*, *Curvularia lunata*, *Aspergillus flavus* and *Trichothecium roseum*. The maximum reduction was observed due to *B.theobromae*.

Fungal association and changes in carbohydrate and protein contents of fruits have been well understood. Fungal population associated with fruits increases as ripening proceeds. Carbohydrates and proteins increase at the initial stages of ripening but decline after 12 days. Calcium carbide application hastened ripening process in cv. Nendran as carbohydrate and protein contents decreased by eighth or ninth day after treatment. Ripening is correlated with fungal association and reduction in shelf-life of fruits (Bandyopadhyay and Chaudhuri 2007).

Gradual decline in total phenols was reported by Singh *et al.* (1994). Total phenols, orthodihydric phenol and anthocyanin contents of banana-peels also reduce during rotting, and thus pre-dispose fruits to fungal infection (Khan *et al.* 2001).

FUNGAL DISEASES

Anthracnose, c.o. *Colletotrichum musae* (Berk. & Curt.) Arx.

Anthracnose and crown-rot are considered as the major post-harvest diseases of banana (Stover 1972; Waredlaw 1972; Stover and Simmonds 1987). Anthracnose is also known as black-rot, crown-rot or ripe-rot, depending on the symptoms.

It is one of the most important and widely distributed diseases of ripening

bananas (Meredith 1961; Bilgrami *et al.* 1979, 1981). Dastur (1916) first reported its occurrence in India. Lim *et al.* (2002) reported *C. muscae* from bananas in Korea. This fungus is also associated with crown-rot.

There are two types of anthracnose infections— latent infection and non-latent infection. Latent infection occurs in fields on uninjured green fruits. The fungus penetrates into cuticle, and is latent up to five months as subcuticular hyphae. When the fruit approaches maturity, fungus resumes activity and produces typical lesions on the fruit surface, while non-latent infections begin during or after the harvest on the bruised fruit surface and continue to develop without dormant period.

Symptoms : Young latent infections appear as small black-and-circular specks on the flowers, fruit-peels and distal-ends of banana-hands (Fig. 3.1). Soon the lesions increase in size, become sunken and coalesce to form larger spots on the surface of the fruits on which characteristic bright moist salmon-coloured spore masses appear when latency is broken. Severely infected fruits become dark due to blemishes. Infected fruits prematurely ripen and turn black and rotten. Most Cavendish varieties are susceptible to bruising and fruit-rot compared to Gros Michel varieties.



Fig. 3.1. Anthracnose on banana

Control measures: Pre-harvest protection. Protection from latent infection can be achieved through fungicidal spraying. Spraying bunches once a month with copper fungicides until fruit is ready for cutting has been found effective. Dithiocarbamates are also found useful in controlling diseases (Chin 1967).

Hot-water treatment. Burden (1968) observed effective control with a slight delay in ripening by dipping banana in water at 55°C for two minutes for *Colletotrichum musae*. But Tandon *et al.* (1976) observed this to be non-effective.

Use of fungicides and chemicals. The effect of systemic fungicide Benomyl in controlling established latent infection by *C. musae* is well documented. Burden (1968) observed dipping of fruits in Benomyl (100-400 ppm) as the most effective treatment. Concentration of 0.1% offers protection in commercial shipments also. Sridhar and Sohi (1974), Khanna and Chandra (1974), Quimio (1976) and Bolkan *et al.* (1976) also confirmed the above

results. The shelf-life of banana cv Robusta enhanced up to 21 days by treatment with Benlate (500 ppm), followed by storage in polyethylene cover of 200 micron thickness (Suharban 1977).

Thiabendazole (TBZ) was also reported to be effective. At 200- 400 ppm, almost complete control was obtained (Philips 1970). Rippon *et al.* (1973) found it effective for commercial shipments. Together with Benomyl, it was effective against non-latent infections also. TBZ is approved in the United States (the permitted residues being 3 ppm in the peel and 0.4 ppm in the pulp). This is being used in Australia, Camaroon, Jamaica, Carribean, Central America and the Windwards Islands where bananas are boxed for shipment. Ram and Vir (1983) tried Bavistin, Benlate, Thiabendazole (2,000 ppm concentration), and observed all of them effective against latent infection by *C. musae*. Propionic acid and Salicylic acid at (5,000 ppm) were effective, but the latter caused skin discolouration.

Zhu *et al.* (2004) recorded direct application of crude extract from peels of unheated green banana (UHGB) effective against *C. musae* and also in inducing tolerance before storage.

Cutting off hands from bunches and packing them in cardboard boxes have minimized incidence of anthracnose in bananas to a great extent. Jeger *et al.* (1995) stated that anthracnose importance as a disease in the international trade is reduced, as fruits are now transported in cartons rather than as whole bunches.

Crown-rot

Crown-rot is a disease complex; caused by several fungi, sometimes in association with bacteria (Lukezic *et al.* 1967). Microorganisms predominate differently depending upon the locality and other factors (Meredith 1971). Crown-rot organisms enter after the bunch has been harvested, and usually manifest due to mechanical injuries while harvesting and handling (Fig. 3.2).

Causal organisms include *Botryodiplodia theobromae* Pat, *Cephalosporium* sp., *Ceratocystis paradoxa* (Dade) Moreau, *Colletotrichum musae* (Burk and Curt.) Arx, *Fusarium pallidoroseum* (Cooke) Sacc., *Acremonium* spp. and *Verticillium thebromae* (Turc.) Mason and Huges.



Fig. 3.2. Crown-rot on banana-fruits

Symptoms: Typical symptoms of major fungi associated with this disease are as follows.

***Botryodiplodia theobromae* Pat.** Being a wound parasite, it readily attacks cushions after they have been deheaded. Infection extends from cushion region to finger-stalks, and from there to fingers, resulting in rotting and dropping of individual fingers. Along with this, a brownish black discolouration is also noticed on the surface of the fruit, and the fruit becomes soft and wrinkled. Light-grey cottony mycelium covers the whole fruit. Later peel gets shriveled and encrusted with pycnidial mass. Maximum damage to fruits occurs at 23-30°C and minimum at 7°C (Williamson and Tandon 1966; Philip and Nair 1999).

***Ceratocystis paradoxa* (Dade) Moreau.** Infection occurs when main stalk is cut or bananas are deheaded. Infected main stalks decay rapidly; tissues become blackened and soft and give a characteristic sweetish odour. Under humid conditions, fungus forms a cobweb-like mass of dark-coloured mycelia that invade cushion, finger-stalks and fingers. Infected fruits show uneven black discolouration of peel, and pulp is reduced to soft-and-wet consistency of dark-brown colour (Anon. 1971).

***Colletotrichum musae* (Berk and Curt.) Arx.** Infection occurs through small peel injuries on immature banana-fruits and results in the development of lesions; as *detailed under anthracnose*. In the ripening room, *Colletotrichum* infection also produces tip-rot when fruits are turning yellow (Anon. 1971).

Control measures : Crown-rot incidence can be reduced with pre-harvest fungicidal applications. In areas where fruit diseases cause serious losses, direct spraying of individual bunches (after 10-20 days of emergence) with fungicides is required. Three to four sprayings with any of the following chemicals can be given: Zineb (0.2%) or Maneb (0.2%) or CUO (0.5%).

In Central America, crown-rot is controlled by dipping (spraying) hands in Maneb (0.3%) or Zineb (0.1%). Addition of triton as a wetter improved fruit coverage by fungicides. Chlorine presence in the washing tanks supplemented effects of subsequent fungicidal treatments. Application of a paste containing lead arsenate or polyethylene polysulphide (PEPS) to freshly exposed crown tissues prior to placing of fruits in boxes was also effective (Anon. 1971).

Systemic fungicides also offer protection. Bavistin (500 ppm), Benomyl (500 ppm) and Thiabendazole (200-400 ppm) are all equally effective (Griffe and Burden 1974). Cheriyan (1987) could not get any positive results with Bavistin at 300 ppm or 500 ppm; with 1,000 ppm, shelf-life increased by 14 days, but its residue level on the fruits was above the permissible limit.

Storage at 7°C increases shelf-life of bananas up to 10 days without much changes in fruit quality.

Biological control. Yeast *Candida oleophila* suspension applied @ 10^7 cfu/ml with 2% CaCl_2 , followed by storage under modified atmospheric packaging (MAP) in the non-perforated polyethylene bags reduced crown-rot significantly as compared to untreated control (Bastiaanse *et al.* 2010).

Speckle/ black- spot/ black-tip, c.o. *Deightoniella torulosa* (Syd.)Ell.

The fungus causes symptoms on banana leaves and fruits. The disease is characterized by black discolouration just below the flower that progresses along the fruit. The diseased area is bordered by an irregular narrow grey or pale yellow margin. One side of the fruit is affected more than the other. Larger spots may measure up to 4 mm in diameter with a sunken centre, which may crack as fruit matures (Anon. 1971).

Pitting disease/Johnston-spot, c.o. *Magnaporthe grisea* (Hebert) Barr
Conidial stage : *Pyricularia grisea* Sacc.

The disease is prevalent in South America, Central America, Caribbean, the Canary Islands, Australia etc. (Snowdon 1990).

Symptoms : They appear as small reddish spots on the green-fruit peel, which is approaching maturity. Later, these spots develop into typical small, shallow black pits, which may sometimes be so many that bunch appearance is spoiled for marketing. Sometimes no apparent symptoms are noticed on the harvested bunch, but pits may develop during transport and storage. In the ripening room, fungal mycelia develop on the surface of these spots, and as the ripening proceeds, original pits get overgrown by secondary saprophytes (Anon. 1971).

Control measures : Pre-harvest spraying with any of dithio-carbamates at 0.2% concentration when bunch begins to develop gives protection (Anon. 1971).

Cigar-end rot/banana fruit-rot

The disease is considered a complex one, caused by several fungi, and is associated with *Trachysphaera fructigena* Tabor & Bunting in West Africa and with *Deightoniella* sp. in Jamaica (Meredith 1961a). In Egypt, it was recorded with increased temperature and humidity. Old and badly neglected plantations suffer sometimes to the extent of 100% (Anon. 1971). Ershad (1972) reported it from Iran. The disease is transmitted by air-borne spores, carried from the debris of banana-plants.

Verticillium theobromae was also reported from most banana- growing areas, including West Indies. In India, the disease was reported to be incited by *B. theobromae* from Madhya Pradesh (Dhingra *et al.* 1970), Hyderabad (Srivastava and Tandon 1971) and Kerala (Philip *et al.* 1980). In Kerala conditions, *B. theobromae* was also found to be associated with *V. theobromae* and *Trichothecium roseum*.

Symptoms : These appear from the tip of the immature fruits at the pistillate-end and spread upwards. The peel becomes folded and shrunken as infection

spreads slowly along the finger. Ashy conidia and conidiophores cover rotten portions, which become corrugated and impart a burnt ashy cigar appearance with a dark border (Fig. 3.3). Decay may extend up to one-third of the fruit, and the fruit develops a typical dry-rot.



Fig. 3.3. Cigar-end rot on banana

Control measures: Spraying of bunches at the time of flowering (after all hands open completely) with methyl- 2-benzimidazole carbamate (MBC) (0.1%), Benomyl (500 ppm) and Mancozeb (0.2%) is effective in reducing cigar- end rot (Dukade 1985).

Squirter disease, c.o. *Nigrospora sphaerica* (Sacc.) Mason

This disease caused serious losses to bananas in eastern Australia (Simmonds 1947).

The fungus penetrates through broken stem-ends resulting from mechanical injury, and converts pulp into a dark watery fluid without any symptoms on the peel. The disease is a common cause of wastage when fruits are packed as singles.

Dipping the hands in Thiabendazole solution of 0.04-0.01% was promising (Anon. 1971).

Freckle/black-spot disease, c.o. *Macrophoma musae* (Cooke) Berl. & Vogl.

The disease was reported from Central America (Wardlaw 1972) and from Kerala (Philip and Nair 1999).

Symptoms : The disease is characterized by spotting on the leaves and fruits. The fungus develops numerous minute, greyish brown or dark brown, raised, more or less rounded spots, 1 mm in size with black dots in the centre. Lesions are present in abundance on the upper surface of the fruits with a narrow water-soaked margin. Minute projecting pycnidia render roughness to fruits. In case of severe infection, affected fruits appear blackish (Wardlaw 1972).

Control measures are not necessary as the symptoms are superficial; on the peel only.

***Fusarium* tip-rot, c.o. *Fusarium* spp.**

Different *Fusarium* species are found associated with the disease, and it was reported from Fiji, Brazil, Trinidad, Uganda and Central America (Anon. 1971).

F. moniliforme and *F. roseum* were reported from Uttar Pradesh and Delhi (Khanna and Chandra 1974; Dharam Vir 1977); *F. solani* and *F. oxysporum* from West Bengal (Chakraborty *et al.* 1977; Mandal 1981; Das Gupta and Mandal 1989); *F. graminearum* and *F. semitectum* from Kalyan and Kerala (Bandopadhyay and Chauduri 2004; Cheriyan and Varghese 2007). And *F. dimereum* was also reported.

The causal fungus was also identified as *Gibberella fujikuroi*; the perfect stage of *Fusarium* sp.

Symptoms : The disease is characterized by tip rotting of the young immature fruits (Fig. 3.4). The infection originates from the base of the decaying perianth and causes blackening and wrinkling of peel, and premature yellowing of fruits. In advanced stage, brown-peel gets covered with rosy powdery fungus growth and inner pulp becomes soft and rotten (Fig. 3.5).



Fig. 3.4. *Fusarium*-rot on banana-fruits Fig. 3.5. *Fusarium*-rot at advanced stage

Symptoms due to *F. moniliforme* are evident on cutting fruits longitudinally. Deep-brown discolouration extending from tip to bottom is noticed; tissues become soft and pulpy (Dharm Vir 1977).

Control measures : Careful handling is essential to avoid wounds and bruises during transport and storage.

Storage of fruits at or below 10°C and relative humidity at 25 % is ideal for preventing storage-rots (Cheriyan and Varghese 2007).

Aureofungin has been reported to be effective. Sridhar and Sohi (1974) controlled post-harvest rotting by prophylactic treatment with Aureofungin at 100 ppm. Banana-rot caused by *Fusarium moniliforme* and *F. roseum* could be controlled with Aureofungin at 200 ppm; Cheriyan (1987) could not get any positive results with Aureofungin (50-200 ppm). And the fruits started showing rotting after seven days' storage.

Brown-rot/ *Botryodiplodia*-rot, c.o. *Botryodiplodia theobromae* Pat.

It is one of the most important diseases of ripe-bananas, causing extensive damage under stored conditions throughout the year. In Central America, it was reported to cause finger-rot (Goos *et al.* 1961). In India, the disease was

recorded from Uttar Pradesh, Delhi, Maharashtra, Andhra Pradesh and West Bengal (Srivastava *et al.* 1964; Chakraborty and Nandi 1976), and was found associated with crown-rot, tip-rot and finger-rot (Philip and Nair 1999) under Kerala conditions (Fig. 3.6).



Fig 3.6. *Botryodiplodia*-rot on the fruit

Symptoms and control measures detailed under crown-rot are recommended for this also.

Rhizopus-rot/soft-rot, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.

R. oryzae Went & Prinsen Geerligs

R. arrhizus Fischer

Symptoms : They appear as brown irregular lesions, which gradually increase in size, and within a short span, entire fruit surface gets covered with fungal growth. This results in softening of fruits, and decaying fruits emit a fermented odour (Cheriyān 1987; Philip and Nair 1999).

Mandal and Das Gupta (1983) observed black soft-rot caused by *Mucor heimallis*, where fruit-surface was covered by fluffy yellowish mycelial growth.

Control measures : Post-harvest management measures as detailed under *Fusarium*-rot are relevant for this also.

Green mould-rot, c.o. *Aspergillus flavus* Link. ex Fries

Symptoms : This rot develops as water-soaked lesions on fruits, which later become soft and juicy. In advanced stages, fruit-surface gets covered with olive-green dot-like mycelia with abundant sporulation (Cheriyān 1987).

Control measures : Avoid injuries and bruises on fruits during handling and storage. Fruits decay can be controlled by dipping them in any of the following fungicides/chemicals—Thiophenate methyl, Benlate, Thiabendazole, Bavistin, Propionic acid, sodium metabisulphite (all at 2,000 ppm). The shelf-life could also be extended by 8 days (Ram and Vir 1984).

Black mould-rot, c.o. *Aspergillus niger* Van Tiegh.

The disease is worldwide in occurrence. Wardlaw (1972) considered it as a secondary pathogen associated with rots. Thakur and Chenulu (1970) and Mandal and Das Gupta (1983) reported the disease from West Bengal.

The disease manifests itself as water-soaked circular lesions around the injured tissues. Rotting is gradual and whole surface gets covered with black fungal growth, and ultimately dry-rot symptoms appear. *Aspergillus oryzae* also caused similar symptoms. In advanced stages, affected fruits become black and shrivelled (Fig. 3.7) (Cheriyān 1987).



Fig. 3.7. Mixed infection by *Botryodiplodia theobromae*, *Fusarium* sp. and *Aspergillus niger* on banana

Control measures for Green mould -rot(*A.flavus*) are applicable for this also.

Watery soft-rot / *Sclerotinia* fruit-rot,

c.o. *Sclerotinia sclerotiorum* (Lib) de Bary

In 1930, this disease was reported from Palestine, and was considered as one of the most severe fruit-rots. The same was also observed in Bermuda and Costa Rica (Laguna and Salazar 1984).

Infection starts from the perianth region and progresses along the fingers with a brownish water-soaked appearance, which later turns dark-brown. Internal rotting is also noticed. The white inner tissue becomes reddish-black, and finally gets broken down and hollowed out. Black seed-like bodies representing fungal sclerotia are produced in abundance.

***Botrytis* end-rot, c.o. *Botrytis cinerea* Pers.**

The disease was reported by Singh and Khare (1977) from Uttar Pradesh.

The fungus produces a wet-rot. Infection begins at the fruit-tip or perianth, and spreads causing dark-brown discolouration on the peel, followed by rotting of the pulp. The surface of the decayed fruit is covered by dense, brown mycelia, characterized by sticky, wet, dark-brown epicarp and a reddish-green endocarp due to mycelial growth and fruiting bodies.

Pink mould-rot, c.o. *Trichothecium roseum* Link. ex Fr.

The disease was prevalent in Uttar Pradesh, Delhi, Andhra Pradesh, Bihar and Maharashtra (Srivastava and Tandon 1971). It originates mostly from stigma-end, and appears as pale-brown water-soaked lesions that enlarge to form large patches with a pink mouldy overgrowth.

Helminthosporium fruit-rot,c.o. *Helminthosporium spiciferum* (Bain.) Nicot

The disease was reported from Bhagalpur and caused considerable rotting to banana-fruits (Prasad 1977a). In fruits, gradual loss of ascorbic acid (vit. C) content was also noticed; due to production of ascorbic-acid degenerating enzymes, either by fungus or due to host-pathogen interaction.

Dothiorella-rot, c.o. Botryosphaeria ribis Grossenbe & Duggar

Kachawaha *et al.* (1992) observed 25-30% loss due to this disease from Sagar (Madhya Pradesh).

Decay begins characteristically from the tip-end of the infected flower part and develops as in the finger-rot. Minute black bodies (pycnidia) are formed on the peel. And a white-to-grey mould growth may also develop (Snowdon 1990).

Phytophthora finger-rot, c.o. Phytophthora nicotianae var. parasitica

The disease was reported from South Africa.

The rot is firm and black; advancing rapidly from stalk-end or tip-end of fingers. In advanced stage, white- spore growth may be noticed on the lesion surface (Snowdon 1990). The disease is of not much importance.

Banana black-rot, c.o. Thielaviopsis paradoxa Van. Honn

The disease was reported from Kerala (Cheriyann and Varghese 2007) on Nendran, which is the most important and widely used variety. Black-rot incited by *T. paradoxa* and soft-rot by *F. semitectum* were found very common in several districts of Kerala. Temperature, relative humidity and injuries lead to development and spread of the disease.

Fruits become soft and black. Under *in-vitro* conditions, intensity of the rotting was found maximum at 35°C and at 100% relative humidity.

Storage of banana-fruits at 10°C and below 25% RH is effective in reducing spoilage by *T. paradoxa* and *F. semitectum* without affecting fruit quality (Cheriyann and Varghese 2007).

Sooty mould, c.o. Capnodium sp.

The disease was recorded from the Philippines, South America and Central America (Stover 1975). The mould is associated with the honey-dew secreted by banana-aphid. Occasionally fungus *Cladosporium* sp. was also found associated with it.

Small, dark-brown flecks appear on the crown, pedicels and fingers of the fruits. These flecks increase in size and merge into blackish brown blotches that may extend up to 1/3rd of the fruit (Stover 1975).

The disease can be controlled by dipping in bleaching solution (0.05-0.1%).

Fruit-rot, c.o. *Penicillium citrinum* Thom.

The disease was reported from West Bengal and Kalyan (Sadhu *et al.* 1992; Bandyopadhyay and Chauduri 2004).

Diseased fruit's skin becomes soft and shows numerous green pinhead-like structures. On the removal of peel, pulp appears soft, yellow and shrivelled with water-soaked appearance. Fungi population increases with ripening; is significantly higher in fruits where ripening is hastened with calcium carbide.

***Curvularia* fruit-rot, c.o. *Curvularia lunata* (Wakker) Boed**

In Delhi, the disease was reported to cause 10% loss (Ram and Vir 1986). The symptoms appear as water-soaked sunken lesions with irregular margins. In the beginning infection is limited to peel. But in advanced cases, infection occurs in the pulp also. Dipping fruits in propionic acid or salicylic acid or sodium metabisulphite (all at 2,000 ppm) saved banana-fruits from infection.

Fruit-rot, c.o. *Chaetosphaeropsis truncata* Curzi & Barbiri

The disease was reported from Allahabad(Uttar Pradesh). Infection occurs at the stylar-end of the fruits as brownish and water-soaked skin discolourations; spreading around the point of incidence with rotting spreading upwards and covering fruit within 8-10 days. Skin colour turns black. In severe cases, skin shrivels and numerous dark-coloured pycnidia of pathogen appear all-over the fruit surface. Pulp rotting is faster than that of skin (Rai and Bihari Lal 1984).

BACTERIAL DISEASES

Bacterial disease, c.o. *Burkholderia cepacia*, was reported from Taiwan. Diseased fingers were recognized by their distorted shape; often narrow at the tip. Pulp appeared gelatinous and yellow.

POST-HARVEST DISEASES MANAGEMENT

Cultural practices

Field hygiene is very important. Male bud of the bunch should be removed when all hands open. Leaves which carry diseases like sigatoka should be collected and burnt. They should not be used for packing bunches. Bunches collected during the dry period from January to April (Kerala conditions) could be stored for longer period without fear of microbial spoilage as compared to bunches collected during other periods of the year (Suharban 1977). Bunches should be healthy while they are stored and ripened. Care should be taken as follows.

- Harvesting of the bunches should be at the correct stage of maturity (over-ripening should be avoided).
- Handle the bunches with care to minimize bruising.

- Storage needs to be carefully done, and rapid cooling is required in the holds.
- In the collecting stations, holds and storage rooms, cleanliness is a must to minimize contamination.

Stover and Simmonds (1987) emphasized need for good hygiene in the plantation and in the packing houses to manage diseases. They also pointed out the importance of transit time in development of a disease. Slow transport at warm temperature leads to pathogens becoming a problem. Introduction of rapid transport to distant markets with adequate facilities for controlling temperature helps reducing incidence of many diseases.

Cool chambers

A brick-wall evaporative chamber designed for maintaining freshness and for extending shelf-life of plantains was reported from Nigeria (Babarinsa *et al.* 2001).

Chamber enclosed by the cavity wall of the burnt-clay bricks is cool. The inside of the cavity is filled with sand, and is kept saturated with water. Water evaporates and cools chamber at 10°C. This condition delays ripening of banana, maintains freshness and extends shelf-life of plantain-fruits by 9 days and reduces weight loss by 80%. Packaging of these fruits in polyethylene bags (0.04 mm thickness) further extends shelf-life by another four days.

Low-temperature storage

Temperature plays an important role along with humidity in the growth of pathogens and in subsequent spoilage process. Refrigeration system prevents post-harvest spoilage of fruits, and microbial attack to fruits becomes slower below 5°C. But exposure to higher temperature immediately after storage favours microbial invasion and thus rapid spoilage. Refrigeration enhanced storage life of banana-fruits (Bhargava *et al.* 1965). Tandon (1967) studied effect of low-temperature storage at 10°C. The fruits remained healthy up to eight days. *B.theobromae* damaged maximum when fruits were stored at 25-30°C and minimum at 7°C and below (Williamson and Tandon 1966). Storage at 14.5°C with 12% wax-coating was effective in enhancing storage life for 25 days (Sadasivam *et al.* 1971). But Patil and Magar (1975) recorded 13°C as the optimum favourable temperature for ripening and storage of banana.

Wax-coating

It enhances storage of banana in refrigerated conditions, and offers protection against microbial infection. Dwarf Cavendish banana could be stored by coating with 12% wax-emulsion. Wax application at the cut ends reduced weight loss during refrigeration (Muthuswami *et al.* 1971; Sadasivam *et al.* 1971). But at the ordinary conditions (temperature 28° ± 2°C), wax did not enhance storage life (Anón. 1971; Cheriyan 1987).

Handling and packing

Proper packing and handling reduces injuries, moisture loss and recontamination, and maintains desirable storage atmosphere and extends storage life (Scott and Roberts 1967; Pantastico 1975). Storage of banana hands in boxes, cartons with packing materials like paper and hay-cuttings was found effective only up to seven days (Cheriyann 1987).

Packaging has an impact on fruit losses and on the marketing system. Scott *et al.* (1970), Silvis *et al.* (1976) and Suharban (1977) reported efficiency of different thickness polythene covers in delaying ripening. They also recommended dehanding of bunches, followed by fungicidal treatment (dipping in Benlate 500 ppm) and packing in polyethylene bags (200 microns) as the best method for transporting bananas from one place to other.

Vacuum packing

This is effective for small-scale packing. Vacuum is created in a polythene cover by removing air from inside (Fig. 3.8). Accessory attached to common vacuum cleaner can also be utilized. Vacuum gives oxygen-free atmosphere, and thus eliminates aerobic bacteria and retards oxidation. With the addition of ethylene absorbent (aluminium silicate and potassium permanganate, mixed in equal proportion, wrapped in a muslin cloth and kept inside the polythene packet), shelf-life of the fruits increased up to 40 days (Sreenarayanan and Rajeev 1996). But vacuum packing without ethylene absorbents is also effective for maintaining keeping-quality up to 20 days with retention of original fruit colour and taste (Philip and Nair 1999).



Fig. 3.8. Vacuum packed banana

Modified and controlled atmosphere (CA storage)

Modified atmosphere storage is becoming increasingly popular in extending shelf-life of fruits and vegetables. Modified atmosphere with 2-5% oxygen and 3-8% carbon dioxide has been shown to extend shelf-life of fruits. Quazi and Freebairn (1970) observed that oxygen negated effects of ethylene and high carbon dioxide concentration delayed climacteric, and low oxygen and high carbon dioxide inhibited ethylene synthesis and thus prolonged storage life. Use of protective coating in addition to modified atmosphere increased shelf-life further (Habibunnisa 1995).

Use of antibiotics and systemic fungicides

Meredith (1960) reported effectiveness of sodium salicylanilide and Nystatin (Mycostatin) against common diseases of banana. A post inoculation

dip with Mycostatin at 200-400 ppm controlled wound infection. Anathanarayanan and Seshadri (1965) also recorded effectiveness of Mycostatin as a protectant fungicide, while Tandon *et al.* (1976) could not get any positive results with Mycostatin (100-400 ppm). Aureofungin is also reported to be effective. Sridhar and Sohi (1974) observed complete control of post-harvest rotting with prophylactic treatment of Aureofungin at 100 ppm.

■

CHAPTER 4

Citrus (*Citrus* spp.)

Citrus-fruits are popular and are extensively grown in tropical and subtropical regions. In India, common citrus fruits are Nagpur mandarin, Kinnow mandarin (*Citrus reticulata* Blanco), Khasi mandarin, lemon, sweet orange (*C. sinensis*) and acid lime (*C. aurantifolia*). India ranks sixth among the citrus-producing countries of the world, and citrus-based fruit industry in India is the third largest after mango and banana. Citrus was grown in 0.45 million ha, and its production was approximately 3.8 million tonnes per annum; with an annual loss of 18-23% due to post-harvest diseases alone (Naqvi 2001).

Kinnow (*Citrus reticulata* Blanco) marketing has expanded throughout India and abroad because of its high juice content and attractive fruit colour. Kinnow-fruits contain high levels of vit. C, vit. A, beta carotene (precursor of vit. A), xanthophyll, cryptoxanthin and violaxanthin, which are responsible for orange colour of the rind and juice (Murrata 1997). In general, fruits are stored at a low temperature in January and February to avoid glut in the market. Physiological changes occurring during storage period makes fruits susceptible to fungal infection (Eckert and Ratnayake 1983).

FUNGAL DISEASES

***Penicillium*-rots, c.o. *Penicillium* spp.**

Blue mould-rot, *P. italicum* Wehmer

Green mould-rot, *P. digitatum* Sacc.

These are considered as the most important storage rots of citrus, causing considerable damage during transit and storage. In Andhra Pradesh, losses as high as 50% were reported by *Penicillium*-rots (Sathyanarayanawamy and Sreeramulu 1962).

Penicillium-rots are reported from several countries (Bai 1977; Adisa and Fajola 1982; Naqvi 2001; Singh and Thakur 2003). Spores of these fungi are in the atmosphere of the citrus-growing areas, and the initial infection occurs through wounds in the peel. Kaul and Lall (1975) observed entry through stem-end region. *P. digitatum* occurs commonly on sweet orange (*Citrus sinensis* Linn. cv. Sathgudi). *P. citrinum* (Sadhu *et al.* 1992) and *P. chrysogenum* (Verma

2008) are also reported on citrus-fruits. Fruit decay is determined chiefly by temperature. At 28-30°C, fruits rot completely within 5-7 days (Philip 2002).

Symptoms : They appear as water-soaked patches. Soon rot advances rapidly and whitish area becomes blue or green due to characteristic mouldy growth (Fig. 4.1). A broad band of white growth is visible on the margin of the lesions.

Watery spot size increases under favourable conditions completely covering fruits by fungal growth. On pressing, peel breaks off easily. Endopolygalacturonase, an enzyme, was isolated from grape-fruit (*C. paradisi*) infected with *P.citrinum*. This readily degrades pectin and sodium polypectate (NaPP) fractions of fruits (Barmore and Brown 1981). Cell-wall degradation as well as pectin dissolution in mandarin-fruits under pathogenesis by *P.digitatum* and *P. italicum* was reported from Korea also (Hwang *et al.* 2002).



Fig. 4.1. *Penicillium*-rot on citrus-fruit

Control measures: Use of hot-water. Post-harvest curing of sweet-lime by heat treatment using water at 45°C for 5 minutes significantly reduced decay by *P.italicum* (Mahmoodabadi *et al.* 2000). Dipping fruits in hot-water at 50°C for 2 min. or 60°C for 45 seconds was effective in getting acceptable quality of kinnow-fruits with extended storage life up to 90 days (Singh and Thakur 2002). The treatment significantly reduced decay and suppressed green mould-rot, caused by *P. digitatum*.

Use of biphenyl impregnated fruit-wrapper. Fruit wraps or paper sheets impregnated with a heated solution of biphenyl in a mixture of paraffin and mineral oil were placed at the bottom and at the top of the fibre-board cartons. This controlled *Penicillium*-rot during storage (Eckert 1967).

Use of radiations. *Penicillium*-rot was delayed up to 90 days of storage in fruits treated with 1.5 Krad gamma radiations. Irradiation benefits in delaying *Penicillium*-rots during short-term storage.

Use of chemicals. Prior to 1950, borax solution (6-8%) was used for controlling *Penicillium* and stem-end rots due to *Diplodia* and *Phomopsis citri*. The solution was heated to 43.5°C, and fruits were dipped for 5 min. In addition to borax, sodium carbonate solution (3-5% at 38-48°C) was also used to control *P.digitatum* in California. Fruit wraps or paper sheets impregnated with heated solution of biphenyl in a mixture of paraffin and mineral oil, placed at the bottom and top of the fibre board cartons (FBC) controlled

effectively *Penicillium*-rots (Eckert and Sommer 1967)). Dipping of the fruits in sodium ortho phenyl phenate (SOPP) 2% is also reported to be effective.

Use of systemic fungicides. Thiabendazole (TBZ) is noted for its effectiveness in controlling blue and green mould rots of citrus (Brown *et al.* 1967; Harding and Schade 1967; Subramanian *et al.* 1973,1973 a). TBZ at 0.2% in wax (Kokkalos 1973) or with flavour seal-wax (Latiff *et al.* 1975) or in combination with SOPP 1% (Hall *et al.* 1978) or dipping of fruits in it, followed by storage in cellophane-lined containers (Farooqui *et al.* 1978) is effective. Hot-water treatment with TBZ is effective up to 50 days of storage (Morales *et al.* 1981). Thiophenate methyl (0.25%) as a dip is recommended for preventing decay in citrus (Yamada *et al.* 1992). However, in *P. digitatum*, thiophenate methyl resistance was reported (Ushiyama 1979; Chander and Thind 1995). Activity of oxidative enzymes was found more in fruits infected by fungicidal resistant strains (Khilare and Gangwane 2002).

Pre-harvest spray of Bavistin (0.3%), 15 days prior to harvest reduces post-harvest rots due to *P. digitatum* and *P. italicum* in wax and unwaxed fruits in cold storage (Singh and Thakur 2003).

Pre-inoculation treatments under *in-vitro* conditions with Thiabendazole, Benomyl and Carbendazim (at 0.05%) were effective against green and blue mould-rots (Verma 2008).

Biological control. Use of bark extracts. The antifungal efficacy of the bark extract of *Acacia nilotica* (5 % aqueous extract) *in vivo* managed blue mould rot (*Penicillium italicum*) in mandarin oranges (Tripathy and Dubey 2003).

Use of essential oil. Oil from the epicarp of *Citrus sinensis* has been recorded as a potential source of natural pesticide, and it exhibited strong fungi toxicity at 0.5% concentration against *P.italicum*, *A. flavus* and *A. alternata* as a contact toxicant (Shukla *et al.* 2000). Essential oil of *Mentha piperita* exhibited maximum efficiency at 1,000mg/ml. Extracts of *Cymbopogon citratus* and *Cyperus scariosus* were also effective (Dhaliwal *et al.* 2004). Liquid formulations (emulsifiable concentrates) of essential oils of fennel, peppermint and caraway controlled *Pencillium*-rots as a protective or therapeutic agent (El Tobgy and Mahamoud 2010).

Lac-based formulations inhibited growth of *P.italicum* during storage. Fruits dipped in a lac-based formulation (stay fresh wax) for 30 seconds, packed in corrugated fibre boxes (CFB- 5 ply) and kept under cool chamber (temperature 5°C, relative humidity 90-95%) showed minimum spoilage and enhanced storage life up to 72 days; fruits showed no shrivelling also (Singh *et al.* 2008).

Alternaria-rot/core-rot/black-rot, c.o. *Alternaria citri* Ellis & N. Pierce

The fungus is widely distributed in all citrus-growing areas (Brown and Mc Cornack 1972; Whiteside 1979; Singh and Thakur 2003). Detection of

infected fruits is difficult owing to internal rotting that occurs before the appearance of external symptoms. In oranges, grape-fruits and mandarins, infected internal tissues become black due to rotting. Spores gain entry through wounds.

Symptoms : Externally fruits appear healthy and sound. Navel-end showing discolouration was also reported. Apparently sound fruits may show darkened colour. When they are cut open, such fruits may exhibit extensive rotting in the core area, which may be concentrated in the centre or spread length-wise. Presence of olive-brown to black growth is also visible in the hollow space. This type of damage is common in fruits arrived in Thiruvananthapuram markets from Bengaluru and Delhi (Philip 2002).

A. citri infection starts at the stem-end and causes internal black discolouration and maceration of the fruit-core during storage by producing endopolygalacturonase (endo PG). Isshiki *et al.* (2003) studied fungal colonization and endopolygalacturonase gene expression in interaction of *A. citri* with citrus-fruits.

The toxigenic behaviour of *A. alternata* isolates has also been reported. The isolates produce tenuazonic acid (TeA) as the major mycotoxin. Alternariol (AOH) and altertoxin (AT X-1) were also detected (Bamba and Sumbali 2006).

Control measures: Use of fungicides. Karathane (1%) and Kirti Copper (1%) as pre-inoculation sprays were effective in checking infection and disease development (Chand *et al.* 1967).

Biological control. *C. sinensis* epicarp is a potential source of natural pesticide. The oil contained in it has strong fungitoxicity against *A. alternata*, *Aspergillus flavus* and *P. italicum* (Shukla *et al.* 2000). *Acacia nilotica* bark (aqueous extract) possessed antifungal activity and inhibited core-rot (Tripathy and Dubey 2003).

Bioagents, *Bacillus subtilis*, *Pseudomonas fluorescens* (Pf-1) and yeasts, *Debaryomyces hansenii* and *Sporidiobolus pararoseus* all at 10^9 cfu/ml were reported to be effective (Sharma *et al.* 2008).

Anthraco-nose, c.o. *Glomerella cingulata* (Ston.) Spauld. & Schrenk.

Condial state: *Colletotrichum gloeosporioides* (Penz.) Sacc.

This disease has been recorded from all citrus-growing areas. Fruits may be disfigured by 'tearstain' patterns on the peel (Tanaka 1968) or they may show severe rotting with dark, sunken lesions.

Symptoms : They appear as small, brown spots on the rind, which gradually enlarge, depress and coalesce to form large spots, and in the advanced stage of infection, fruits are covered with dark blemishes (Cheriyann 1987).

Control measures : Pre-harvest spraying with Ethephon (250 ppm), 5-7 days before harvest, gives protection against *Colletotrichum*-rots (Barmore and Brown 1978).

Washing with water alone reduces anthracnose and stem-end-rot in oranges (Brown 1975). Brown and Barmore (1977) observed promising results against quiescent infections of *Colletotrichum* by dipping fruits in sodium hypochlorite solution (2%), followed by washing with running tap-water or fumigation with ethylene. Similar results could also be obtained by dipping in bleaching powder (2% solution), Flit 406 (0.2%) (Tandon 1961), borax (6-8%) or thio-urea (4%) (Srivastava 1968; Mishra and Naik 1984) and boric acid (4%) (Ram and Naidu 1976).

Stem-end-rots, c.o. *Botryosphaeria ribis* Grossenb. & Duggar

Conidial state : *Dothiorella gregaria* Sacc.

Diaporthe citri Wolf

Phomopsis citri Fawcett

Physalospora rhodina (Berk. & Curt.) Cooke

All the above fungi are widely distributed but their disease symptoms and causal organisms vary depending upon the climate (Brooks 1944). In Japan, Australia and United States, *Phomopsis*-rot appeared more important (Homma and Yamada 1969; Brown and Albrigo 1972; Singh *et al.* 1977).

Control measures : Benomyl (500 ppm) is reported to be effective against latent infections of *Diplodia* and *Phomopsis* spp. (Gutter and Yanco 1971). Dipping fruits in Benlate (0.05%) is effective up to 45 days (Dhuria *et al.* 1977).

Bark extract of *Acacia nilotica* was reported effective in inhibiting stem-end-rot (Tripathy and Dubey 2003).

***Botryodiplodia* fruit-rot,**

c.o. *Botryodiplodia theobromae* Pat./*Lasiodiplodia theobromae*

B. theobromae has been reported as the most important fruit-rot pathogen of *Citrus sinensis*. It was reported as the predominant disease from Israel and S.W. Nigeria (Zaubermann and Barkai Golan 1975; Adisa and Fajola 1982). And the disease has been reported from India also.

Maximum infection was observed at room temperature ($33 \pm 2^\circ\text{C}$) under Allahabad conditions (Srivastava and Tandon 1968).

Symptoms : The fungus produces brownish black discolouration on the stem-end of the fruit. The lesions later enlarge and cover major portion of the fruit-surface. In advanced stages, greyish mycelia with abundant pycnidial encrustations are noticed on the fruit-surface. The infection usually starts as a circular lesion, which at first is yellow but later turns brown and renders leatheriness to fruit with a strong decaying odour. The fruit rots within 4-6 days. A network of whitish mycelia that later turns dark is observed inside the fruit and also on the surface. Pycnidial encrustations are also noticed abundantly (Adisa and Fajola 1982).

Control measures : The disease could be checked before harvest in the field by the application of copper fungicide (0.3%). Benomyl (500 ppm) is effective against latent infections of *Diplodia* and *Phomopsis* spp. (Gutter and Yanco

1971). Dipping of fruits in antibiotics also offers protection. Cheema and Jeyarajan (1971) recorded effectiveness of Aureofungin at 50 ppm against stylar-end-rot of oranges caused by *B. theobromae*.

Low temperature storage at 15°C is effective for control of storage-rots (Srivastava and Tandon 1968).

Sour-rot, c.o. *Geotrichum candidum* Link.

The disease is especially prevalent after warm-wet seasons, and can cause serious losses.

Symptoms : Water-soaked spots appear on the fruits and the affected tissues become soft. Gradually spots increase in size and result in extensive cracking of the fruit. The lesion surface is covered with slimy off-white spores, and fruit-tissue beneath the surface breaks down into sour-smelling watery mass (Harding and Savage 1962; Butler *et al.* 1965; Shankhapal and Hatwalne 1974; Mor *et al.* 1984; Cheriyan 1987; Naqvi 2001). This fungus survives at 10-35°C temperature, and the maximum rotting is observed at 25°C.

Control measures : The disease is transmitted by fruit-fly *Drosophila melanogaster*. Fruit-rot of oranges caused by this fungus and others could be controlled successfully with Aureofungin 200 ppm (Shankhapal and Hatwalne 1975).

Latex of *Euphorbia hirta* (crude extract) is recorded as effective against this fruit-rot. It acts as a repellent (Purnima and Saxena 1990).

The antifungal activity of the bark extract of *Acacia nilotica* (50% aqueous extract) is also reported to be effective (Tripathy and Dubey 2003).

***Sporotrichum*-rot, c.o. *Sporotrichum aureum* Link.**

Fawcett (1936) reported occurrence of citrus scab due to *Sporotrichum citri* from Argentina.

Symptoms : Brown-coloured lesions are observed on the fruit surface that later cover fruits in a longitudinal pattern. The fruit becomes soft in advanced stages of infection (Cheriyan 1987).

Control measures : Dipping of fruits in Aureofungin 200 ppm controlled rot up to 49 days under cold storage (Cheriyan 1997).

***Aspergillus*/black mould-rot, c.o. *Aspergillus* spp.**

Aspergillus-rot has been reported from most of the citrus-producing areas of the world (Smoot *et al.* 1971). In India, it was recorded from Uttar Pradesh (Srivastava and Tandon 1969) and Punjab (Garcha and Singh 1980; Singh and Thakur 2003). *A. aculatus* and *A. meleus* were reported from Nigeria (Adisa and Fajola 1982).

Symptoms : *Aspergillus aculatus* *lizuka*. This fungus produces light-yellow discolouration on the fruit surface. And the rotted area is soft but oozes

out no watery fluid when pressed. Dark spore masses are noticed inside or on the fruit surface. Whole fruit rots within 8-9 days.

***Aspergillus meleus* Yukawa.** It produces dry-rot. Its infection starts slowly as circular lesions with brownish discolouration, gradually spreading on to the surface of the fruit.

***Aspergillus niger* Van Tieghm.** Water-soaked lesions appear on the fruit-surface. And lesions are soon covered by blackish fungal growth. Internal contents also soften and decay (Philip 2002).

Control measures : Pre-harvest spray of Bavistin (0.3%), 15 days prior to harvest reduces rot due to *A. niger* in waxed and unwaxed fruits in the cold storage (Singh and Thakur 2003). Systemic fungicides, Thiophenate methyl (0.25%) and Borax 6%, were effective against black mould-rot, caused by *A.niger* (Verma 2008).

Brown-rot/*Phytophthora*-rot

Several species of *Phytophthora*—*P. citricola*, *P. citriphthora*, *P. hibernalis*, *P. nicotianae* var. *parasitica* and *P.syringae*—are associated with brown-rot.

Symptoms : First, water-soaked spots appear on the peel. Infected fruits give characteristic pungent odour. Under humid conditions (at temperature around 25°C and relative humidity above 90%), cottony growth of fungus is visible on the peel. Fruits without any apparent symptoms may also produce rotting under storage.

Control measures : The orchards should be kept free of diseases with copper sprays (3: 4½ : 100 Bordeaux mixture). In orchards, where copper damage occurs, spraying with Captan (2g/litre) is recommended (Klotz *et al.* 1961).

The disease is noticed also on the fallen fruits, lying on the soil. Hence care should be taken to destroy infected fruits. Such fruits should not be used for storage or packing.

***Fusarium*-rot, c.o. *Fusarium* spp.**

Several species of *Fusarium*—*F.solani*, *F. moniliforme*, *F. oxysporum* and *F.compactum*—are associated with this disease (Cheriyian 1987; Shrivastava *et al.* 1993). *Fusarium*-rot is usually considered a minor disease in citrus-growing areas of South Africa, Israel, Australia (Jofee and Nadelm 1972; Gerlach 1977).

Symptoms : First circular water-soaked lesions appear that later turn light-brown with fluffy fungal growth over the decayed portions.

Control measures : Dipping fruits in a solution of sodium metabisulphite and salicylic acid (1,000 ppm each) gave complete control of decay (Gaur and Chenulu 1982), and also dipping in Aureofingon (200 ppm) gave good results (Cheriyian, 1987).

Antifungal activity of bark extract of *Acacia nilotica* is reported against soft-rots caused by *Fusarium moniliforme* and *Rhizopus stolonifer* (Tripathy and Dubey 2003).

Citrus greasy-spot, c.o. *Mycosphaerella citri* Tilak

Blemishes caused by the fungus on the rind of the fruit reduce external quality and marketability of the fruit.

One or two copper fungicide applications (0.2%-0.3%) before harvesting fruits provide effective control; two sprays gave excellent results (Timmer *et al.* 2000).

Antifungal activity of bark extract of *Acacia nilotica* is reported against soft-rots caused by *Fusarium moniliforme* and *Rhizopus stolonifer* (Tripathy and Dubey 2003).

Trichoderma-rot, c.o. *Trichoderma viride* Pers.ex Fr.

Trichoderma-rot is an important cause of losses in South Africa (Pienaar, 1969). It was also recorded from the USSR, USA, China, Israel, India. Snowdon (1990) observed rot on the mandarins and grapefruits in the UK.

Symptoms : Infected peels remain pliable, and become dark-brown eventually. Veins on the inner surface of the peel turn brown. But flesh beneath remains unchanged (Kanaujia 1979). Water-soaked lesions with greenish-white growth are also observed on the peel (Philip 2002).

Control measures : All measures detailed under the *Post-harvest management* are applicable to this disease.

Fruit-rot/soft-rot, c.o. *Aureobasidium pullulans* (de Bary) Arnaud

Panwar and Vyas (1973) reported the disease on *Citrus reticulata* Blanco. Babu *et al.* (1982) observed water-soaked areas on the fruit-surface, which increased centrifugally with age. Infected tissues turn soft with a pinkish tinge and spread to adjacent areas. Then infected tissues get separated from healthy tissues.

Post-harvest treatment with any common fungicide, followed by wax-coating is effective in controlling the disease (Naqvi 2001).

OTHER MINOR DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|------------------------|------------------------------------|---------------------------|
| Fruit-rots | <i>Hendersonula toruloides</i> | Khan, 1954 |
| | <i>Oospora citri auranti</i> | Moreau, 1954 |
| | <i>Rhizoctonia solani</i> | Parashar and Chohan, 1966 |
| | <i>Choanephora trispora</i> | Adisa and Fajola, 1982 |
| Soft-rot | <i>Ceratocystis fimbriata</i> | Singh and Chaudhari, 1974 |
| Soft-rot | <i>Cladosporium sphaerospermum</i> | Gaur and Chenulu, 1981 |
| Watery soft-rot | <i>Sclerotium rolfsii</i> | Malik and Bhargava, 1978 |

| Disease | Causal organism | Authority |
|------------------------------------|---|---|
| Core-rot | <i>Rhizopus stolonifer</i> | Garcha and Singh, 1980; Singh and Thakur, 2003 |
| Fluffy white-rot | <i>Acremonium cymosum</i> | Dhingra <i>et al.</i> , 1980 |
| Dirty core-rot | <i>Absidia corymbifera</i> | Mandal and Dasgupta, 1981 |
| Polar-rot | <i>Botryosphaeria ribis</i> | |
| Greasy-spot and Rind-blotch | <i>Mycosphaerella citri</i> | |
| Black-rot | <i>Pestalotiopsis versicolor</i> | Gaur and Chenulu, 1982 |
| Black encrustation | <i>Thielaviopsis state</i> of <i>Ceratocystis paradoxa</i> | |
| Grey mould-rot | <i>Botrytis cinerea</i> | |
| Septoria-rot | <i>Septoria</i> spp. | |
| Black-rot | <i>Guignardia citricarpa</i> | |
| Cottony-rot | <i>Sclerotinia minor</i> | |

BACTERIAL DISEASES

Citrus canker, c.o. *Xanthomonas campestris* pv. *citri*

It originated from Asia and was observed in Florida in 1912. In India, it is endemic and occurs in all citrus-growing areas. Acid lime canker is one of the major diseases in acid-lime cultivation in Vidarbha region of Maharashtra.

Symptoms : Lesions on the fruits are rough and corky. Sometimes several lesions may coalesce and form larger lesions. They appear as rough or corrugated pin-head like rusty spots on the peel. And sometimes, the spots may coalesce and form large irregular patches. Symptoms are noticed on leaves, twigs, petioles, branches, thorns, fruit-stalks and fruits.

Due to infection, reducing and non-reducing sugars and vit. C (ascorbic acid) get reduced, and citric-acid content increases in the juice (Vidhyasekaran and Durairaj 1971).

Control measures: *Pre-harvest treatments.* The canker is carried from the field and continues under storage. Hence, keeping plantation free of the disease is utmost importance. Spraying trees bearing fruits with streptomycin (500-1,000 ppm) at 15 days interval proved effective (Rangaswamy *et al.* 1959 a, b). The disease can also be controlled by spraying on trees streptocycline (100 ppm) + copper oxychloride (0.1%) at an interval of 7 or 15 days during winter, summer and monsoon flushes (Kale *et al.* 1994; Gaur and Sharma 2008).

Foliar spray of streptocycline (100 ppm) along with copper oxide 0.2% proved effective in controlling citrus canker. Streptocycline 100 ppm along with Carbendazim 0.1% also proved effective (Gaur and Sharma 2010).

Biological control. Neem-cake solution (neem-cake soaked in water for 7 days) sprayed without filtration is effective in reducing disease incidence and

increasing general plant vigour (Vaheeduddin *et al.* 1959). Foliar spray of garlic + green chilli extract also reduced disease incidence (Gaur and Sharma 2010).

Spraying of 0.2% talc-based *P. fluorescens* (1×10^9 cfu/g) was found highly effective (Gaur and Sharma 2010).

POST-HARVEST DISEASES MANAGEMENT

Pre-harvest treatments

Orchard sanitation and selection of healthy fruits for storage are utmost important. High inoculum of fungal pathogens and non-scientific methods of harvesting, packing, transporting and inadequate storage are main reasons for encountering losses that can be avoided by following practices.

Protective pre-harvest sprays prevent *Penicillium*-rot, stem-end-rot (*Lasiodiplodia theobromae*) and *Phomopsis*-rot in orange fruits (Brown and Albrigo 1970). Thiophenate methyl was effective when applied to grapefruits (*Citrus paradisi*), 47 days prior to harvest at 0.5 g/litre (Timmer 1973). Kuramoto and Yamada (1976) observed DF-125 effective against Benomyl and Thiophenate methyl resistant and susceptible strains, respectively. Pre-harvest spray with Bavistin (0.3%), 15 days before harvest reduced post-harvest rot in waxed as well as unwaxed fruits under cold storage (Singh and Thakur 2003). Three sprays of Carbendazim (0.1%) at 15 days interval prior to harvest reduced 70% decay and subsequent treatment on packing reduced decay up to 80% for three weeks under ambient conditions. And its residue level was below permissible levels (Naqvi 2004).

Pre-harvest spray with Prochloraz (45% EC 0.10%) at monthly intervals (4 times) after flowering, followed by Carbendazim (0.15%) was found effective in reducing post-harvest diseases during storage (Sharma *et al.* 2010).

Cleanliness in packing houses

Citrus-packing houses are usually fumigated daily by atomizing with a solution of 1-3% formaldehyde in the atmosphere. Fruit-conveying and treating equipments are also to be disinfected with quarternary ammonium compounds, hypochlorite, sodium o-phenyl phenate or formaldehyde. This helps in reducing post-harvest rots.

Use of hot-water

Thiabendazole (TBZ 0.1%) with hot-water is effective up to 50 days of storage against common storage rots (Morales *et al.* 1981).

Hot-water treatment, hot-water rinsing and hot-water brushing are generally practised for controlling fruit-rots (see hot-water treatment under *Penicillium*-rots).

Storage under refrigeration

Most of the citrus varieties are sensitive to chilling and hence cannot be stored at low temperature, as fruits are susceptible to physical stress. Under refrigeration (8-10°C), fruits retain their natural taste up to 30 days, and thereafter on continued storage show brittleness (Cheriyian 1987 ; Philip and Cheriyian 1995).

Wax-coating and polythene packing

Coating fruits with wax or fungicidal wax (6%) (Jawanda *et al.* 1977, 1978; Mann and Randhawa, 1978) or wax emulsions (6%) with 2,4-D or 2,4,5-T(100 ppm) offer protection (Sohi and Gupta, 1977). Polythene packing along with waxing (Mann and Sandhanwalia 1977) and storage in perforated polythene bags (200 microns) are also effective (Mohan and Sharma 1977; Jawanda *et al.* 1977, 1978). Wax-coating of fruits prior to harvest or after harvest with fungicides was also reported (Naqvi 2001; Singh and Thakur 2003).

Use of wrappers

Waxing, followed by storage in DPA wrappers and wrapping in newspapers (Jawanda *et al.* 1977, 1978) gave protection. Antifungal dips in along with lining materials like newspaper, tissue paper, wax paper, cellophane paper, polythene films (Farooqi *et al.* 1978) also proved effective. Effect of waxing and of wrapping in low-density polyethylene film (LDPE), followed by package in corrugated fibre boxes (CFB) exhibited low losses through decay for 30 days. Decay could also be minimized by storage at ambient conditions (Sharma *et al.* 2008).

Use of common chemicals

Eckert and Sommer (1967) reviewed methods of chemical control. Storage of fruits after cleaning and washing with sodium ortho-phenyl phenate (SOPP) 1 % or calcium or sodium hypochlorite 2% or fumigation with ammonia (100-150ppm) was found effective in reducing post-harvest losses (Mukherjee 1970; Mukherjee and Singh 1977). Fumigation impacted development of storage-rots. The packing houses are fumigated daily by atomizing with a solution of 1-3% formaldehyde into the atmosphere. Fruit conveying belts and treating equipment are also disinfected with quarternary ammonium compounds, hypochlorite sodium ortho-phenyl phenate (SOPP).

Dipping fully mature fruits in 2-4-D (100, 250, 500ppm) or gibberllic acid (50, 100, 200 ppm) solutions and ethrel (100, 500 ppm) also improved fruit appearance and shelf-life. Fruits could be marketed even after 47 days (Saraswathy and Azakiamanavalan 1997).

Non-systemic and systemic fungicides

Dipping in Dithane M-45 (0.2%) as well as in Captan or in Difolatan (500 ppm), followed by storage at low temperature (Adisa and Fajola 1982) protected fruits.

Systemic fungicides show improved distribution and penetration, and thus offer better protection over other groups of fungicides. They suffer less weathering, and consequently control disease better. Bavistin and Benomyl (1,000 ppm each) are also extensively utilized for post-harvest management (Ram and Naidu 1976; Kumbhare and Chaudhari, 1979; Gupta *et al.* 1980; Gaur and Chenulu 1982). Ethrel and Bavistin combined controlled storage degreening (Reddy and Shanker 1983). Jagannathan and Sampath (1995) observed superiority of Carbendazim (500 ppm) to Benomyl and TBZ. Philip and Cheriyan (1995) observed Aureofungin (200 ppm) to be effective against common fungal rots, and storage life was also enhanced by 49 days with it without any residual toxicity.

In general, TBZ and Benomyl protect fruits against post-harvest infections. But this is to be considered seriously as they pose health hazards to human-beings. Zahida and Masud (2002) monitored fungicides in samples collected from markets of Karachi, Pakistan, and observed residue levels above permissible levels in more than 50% of samples.

Biological control

Consumers demand for pesticide-free food and development of pathogenic strains resistant to currently used fungicides necessitate development of alternative technologies for controlling post-harvest damage to fruits and vegetables through bioagents. These include the following.

Use of homeopathic drugs. These drugs of plant origin when applied to harvested fruits of citrus, mango and guava are reported to prevent decay and enhance storage life (Khanna and Chandra 1976).

Use of plant extracts. Babu and Reddy (1986) showed effectiveness of leaf extracts of *Eucalyptus globulosa*, *Punicum granatum*, *Lawsonia inermis* and *Datura stramonium* in checking fruit-rot of lemons.

Biological control with yeasts. Yeast antagonist *Candida oleophila* was reported to reduce decay in oranges and grapes (Porat *et al.* 2002). This is included along with hot-water rinsing, hot-water brushing and sodium carbonate application.

Combination of *Pantoea agglomerans* (CPA-2) and sodium bicarbonate proved effective against common storage disease (Teixido *et al.* 2001).

Packing and storage

Harvested fruits are subjected to a variety of injuries that predispose them to various fungal rots till they reach consumers through a long marketing chain, and thus causes huge losses in value and volume. For reducing these losses, knowledge of packing systems and nature of physical damage caused during post-harvest journey from orchard to ultimate consumer are essential.

Packing systems and nature of physical damage to *Citrus reticulata* and *C. aurantifolia* were studied by Verma and Tikoo (2004). Damage usually occurs due to cuts on the fruit-surface, compression, overfilling and over-stacking of bags as well as due to vibration bruises that occur in transit and storage. Injuries predispose fruits to fungal infections, leading to fruit-rots. Infections and cullage losses are direct consequences of rough handling and unhygienic storage. The spectrum of post-harvest pathogens include blue-and-green mould-rot (*P.italicum*, *P. digitatum* *P. chrysogenum*), *Aspergillus*-rots (*Aspergillus flavus*, *A. fumigatus* and *A. niger*), core-rot (*Alternaria alternata*, *Absidia corymbifera*), soft-rot (*Fusarium moniliforme*, *Rhizoctonia stolonifer*), stem-end-rot (*B. theobromae*) and sour-rot (*G. candidum*). *Penicillium* spp. inflicted major fruit losses during winter and *Aspergillus* spp. were dominant during summer and monsoon months.

Packing materials. Packing of injured fruits without apparent symptoms (mechanical or frost) is bound to spread infection to healthy fruits. Singh and Jain (2004) assessed losses in long distance marketing from Punjab to Rajasthan of fruits packed in corrugated fibre boxes (CFB) and wooden boxes. Storage losses were lesser in wooden boxes (22.9%) compared to CFB packing (31%). *Alternaria alternata* caused maximum spoilage in CFB packing, followed by *P. digitatum* and *P.italicum*.

Evaporative cool chamber

Evaporative cool chamber 2.28m × 1.82 m × 2.133m (7.5 feet length × 6 feet width × 7 feet inside height with temperature at 13 to 14°C, relative humidity at 95-100% and with drip system for continuous watering and fan for air movement) can store fruits up to 25 days (Anon. 2005).

Vacuum packing

Vacuum packing has been reported as a feasible technique for storage of sweet oranges. Vacuum packed polyethylene bags in refrigeration retained quality of fruits to a great extent (Dawn *et al.* 2007).

Procedure for the storage of mandarin oranges has been standardized

This includes pre-harvest sprays, maturity standards, post-harvest treatments (application of Bavistin), degreening process with 5-10 ppm ethylene, followed by chlorine wash, post-harvest fungicidal wax coating (Sta-fresh 45% with 1,000 ppm TBZ), pre-cooling at 6-7°C with 90-95% RH and packing in vented polyethylene-lined CFB boxes, wrapping fruits in cryovac and polyethylene-heat shrinkable films, storage for long-term use and refrigerated storage at 6-7°C and 90-95% RH and use of cool chamber. An evaporative cool chamber for storing fruits (13-14°C, at 95-100% RH) up to 25 days is also included as an ideal step (Anon. 2005).



CHAPTER 5

Emblica/Gooseberry/Aonla (*Phyllanthus emblica* L.)

Its fruits contain proteins, fats, carbohydrates, fibres, tannins, and are rich source of iron, calcium, phosphorus and vitamins, especially vitamin C, vitamin B₁ and nicotinic acid (Singh *et al.* 1993). Medicinal properties of the fruits are also very well known.

FUNGAL DISEASES

Dry surface-rot, c.o. *Aspergillus niger* Van Tieghm., *A. aculeatus* Iizuka

The disease was reported from Uttar Pradesh (Srivastava *et al.* 1964), Maharashtra (Rao, 1966), Bihar (Jamaluddin and Tandon 1975), West Bengal (Dasgupta and Mandal, 1989), Sagar (Chopra *et al.* 1993) and Kerala (Philip 1998), and caused severe losses in fruit yield and quality.

Symptoms : The infection mostly initiates on the injured fruits as soft minute, water-soaked, light-brown spots that turn into an oblongly depressed area of about 1-2 cm in diameter. In advanced stages, mesocarp gets easily separated from the skin. Under moist conditions, fruit surface is covered with smooth, black or snuffy conidiophore heads, depending on the involved organisms. Rot due to *A. niger* is common and spreads quickly. Maximum diseases development occurs at $28 \pm 1^\circ\text{C}$. Aflatoxin production (B₂ and G₁) was also reported (Nallathambi *et al.* 2010).

Control measures : Fruit-rot causes severe losses in yield. Hot-water treatment for 10 min. ($50 \pm 1^\circ\text{C}$) for three days is effective. Dipping fruits in Carbendazim (0.1%) offers protection. Food preservatives like potassium metabisulphite and sodium benzoate are also reported to be effective in pre- and post-inoculation treatments. Carbendazim + Mancozeb (Sixer at 1,000 ppm) inhibited the rot (Patel *et al.* 2008).

The extract of *Azadirachta indica* was also found effective (Yadav *et al.* 2007).

Fruit-rot, c.o. *Colletotrichum gloeosporioides* Penz.

A severe pre- and post-harvest fruit-rot was recorded from Andhra Pradesh

(Wadia *et al.* 1984). Symptoms appear as isolated brown spots scattered over the fruit-surface, which coalesce to form lesions of 0.3-0.8 cm in diameter. A dark band demarcates infected region, and lesions turn hard. As the disease advances, pink spore masses appear over lesions. Common forest fruit- tree *Calophyllum inophyllum* is highly susceptible to this disease. Fruits of *C. inophyllum*, though economically unimportant, serve as a potential reservoir for fruit-rot organism.

Mouldy brown-rot, c.o. *Penicillium* spp.

Species of *Penicillium* — *P.islandicum*, *P. corymbiferum*, *P.funiculosum*, *P. oxalicum* have been reported from various states of India.

Symptoms appear on the intact fruits kept for 6-7 days under the ordinary storage. Colour turns orange, yellow, and finally fruit rots. Skin gets easily slipped off from the internal contents. By the time, scattered fungal growth in the form of pimple-like spots can be noticed all-over the fruit-surface (Fig. 5.1). This is followed by complete rotting.



Fig. 5.1. *Penicillium*-rot on aonla

Fruit-rot disease of *E. myriabolam* due to *P. funiculosum* was also reported from the markets of Tirupati (Andhra Pradesh). Symptoms appear as brown necrotic spots ranging in size up to one cm. Mature lesions are depressed, dark-brown and occasionally show concentric zones. In severe cases, lesions coalesce and give fruits a mummified appearance. This fungus also induces rotting in chilli, brinjal, clusterbean, carrot, beetroot, raddish and chayotes (Subrahmanyam and Sarma 1974).

Wrinkled-rot, c.o. *Phomopsis phyllanthii* Punith.

This disease was reported from Uttar Pradesh (Bihari Lal *et al.* 1982) and from West Bengal (Dasgupta and Mandal 1989). Rotting starts as discrete water-soaked small areas on any part of the fruit surface. Infected area gradually enlarges and turns depressed and yellowish brown with wrinkled skin. Under humid conditions, mycelial growth is noticed, and rotting becomes fast. Numerous pycnidia can be noticed on the rotten fruits.

Fruit-rot, c.o. *Phoma putaminum* Speg.

The disease was reported from several states of India (Jamaluddin, 1975; Pandey *et al.* 1980). The rot starts as a small pinkish-brown necrotic spot that extends towards both the ends and gives an eye-shaped appearance. In severe cases, lesions coalesce to bigger pustules. Mature lesions are dark brown in colour, and severely infected fruits show wrinkling. Soon underlying tissues get rotten and the fruit becomes soft.

Brown-rot, c.o. *Pestalotiopsis cruenta* (Syd.) Steyaert

The disease was reported from Uttar Pradesh (Tandon, and Srivasava 1964). Infection starts as brownish discolouration on the fruits that later develops into characteristic spots. Well-developed spots mummify with a deep-brown centre and an irregular light-brown outer rim. Fluffy fungal aerial growth can be noticed on the infected region with a dry dark-brown discolouration underneath.

Soft-rot, c.o. *Syncephalastrum racemosum* (Cohn) Yamamoto

The disease was reported from Lucknow. Numerous minute, brown necrotic lesions with white mycelial growth surrounded by water-soaked tissues are noticed on the fruit-surface. The fungus exhibits strong cellulolytic activity (Garg and Ompraksh 2004).



CHAPTER 6

Grape (*Vitis vinifera* L.)

It is one of the oldest cultivated plants. Its fruit is smooth skinned, juicy, greenish-white to deep-red or purple coloured. It is rich in minerals (potassium, sodium, phosphorus, calcium, magnesium, iron and zinc) and vitamins (vit. C, vit. B, vit. A, folic acid and niacin).

FUNGAL DISEASES

Grey mould-rot, c.o. *Botrytis cinerea* Pers.

Among the post-harvest diseases, this is considered to be the most important one. The disease occurs in the entire grape-growing areas of the world, and is considered as the principal cause of spoilage of grapes under storage. The fungus is a nuisance because of its rapid growth rate and ability to spread at cold temperature (0-5°C) (Harvey and Pentzer 1960).

Grey mould causes both pre-mature and post-harvest decay of table-grapes. Symptoms are prominent on the berries. The berries are resistant to infection when immature, but become susceptible on maturity. Conidia dispersed on the bunches reside superficially at the berry-pedicle attachment zone and cause bunch-rot during favourable climatic conditions. Nelson (1951) recorded effect of humidity on the infection of table-grapes.

Symptoms : In the early stages, tissues beneath the peel are affected and the pulp gets loosened from the peel. Later fungus advances into inner pulp and converts it into a soft watery mass of decayed tissues contained in a slightly intact brown peel. In the moist environment, pathogen sporulates on the peel and produces typical, powdery, greyish growth. Affected fruits shrivel and turn dark brown. The fungus invades stigma and style and become latent (Mc Cellan and Hewitt 1973; Nair 1985). In a compact bunch, inside fruits may split during growth. Infection of such fruits results in bunch-rot. Even a single infected berry may cause 'nest rot' in transit and storage. Uncontrolled infection from a single berry can spread to an entire packet of grape-berries. Mould incidence on grapes stored at 0°C is dependent on the harvest time, and is the highest when fruits are picked after rains.

Studies indicate that polysaccharide- and pectin-degrading enzymes are secreted by the pathogen during pathogenesis. Polysaccharides include high

molecular weight fractions composed of glucose units. *Botrytis*-rot also causes sharp reduction in the quantity of aromatic substances responsible for characteristic flavour of grapes. Grape cluster architecture determines susceptibility of berries to infection (Vail and Marois 1991). The cultivars with tight clusters are severely affected by bunch-rot in the field.

Control measures : Klerk (1990) outlined disease-management programme. This includes treatments to be carried out during winter/growing seasons, summer foliage management including fertilizer addition, irrigation and thinning of branches, harvesting procedures and techniques of storage and packing.

Pre-harvest treatments. Pre-harvest infection can be controlled by three applications of Captan (0.25%) at monthly intervals before the rainfall (Harvey 1959). Broome *et al.* (1995) developed a schedule for *Botrytis* bunch-rot. This includes spraying of Captan (3.2 kg/ ha ai) or Vinclozolin (1 kg/ ha ai) at late bloom, cluster thinning in addition to pre-harvest spray plus additional sprays after major rains. The spray schedule reduced post-harvest disease significantly.

The fact that *B. cinerea* spores can establish as latent infection in the flowers, a shift in the schedule of plant-protection operations was made and that led to inclusion of bloom sprays (Nair 1990). Latent infection by *B. cinerea* in grape pedicels and subsequent harvest decay was well established (Holz *et al.* 1997).

Allan *et al.* (1998) have recorded the effect of Fenhexamid marketed under the trade name 'Elevate' for application prior to disease establishment as a protectant fungicide with excellent plant compatibility. Elevate can be applied three times before harvest. This inhibits germ-tube formation and mycelial growth in susceptible varieties.

Post-harvest management. Sulphur dioxide fumigation. Generally *Botrytis*-rot is controlled in the storehouses with sulphur-dioxide fumigation. But control is reported with the reduced levels of SO₂; 200 ppm SO₂ controlled development and spread of disease when applied three times a week as compared to the standard practice of using 2,500 ppm applied every seven days (Marios *et al.* 1986). This treatment reduced bleaching of berries.

During initial stages of storage, forced air cooling, followed by 2-6 hours long weekly fumigation is usually practised during cold storage (Luvis *et al.* 1992). In export package, SO₂-generating sheets, which continuously emit gas within the package, are used (Adaskaveg *et al.* 2002; Palou *et al.* 2002). In Israel, use of sulphur pills in unventilated containers or introduction of gas through a tube into the containers was also practised as an alternative method (Crisosto and Smilanick 2002).

Effect of radiations. A dose of 200 Krad delays disease development of *Botrytis*-rot. But irradiated grapes developed severe off-flavours after a few weeks in cold storage (Eckert and Sommer 1967).

Biological control. *Botrytis*-rot is controlled with an antagonistic fungus *Trichoderma harzianum* and a bacteria (Ferreiera 1990). Kohl and Malhoek (2002) recorded *Ulocladium atrum* as a promising control agent for this disease in grape and strawberry. Yeast strain ID 244 of *Candida oleophila* has been recorded effective against *Botrytis*-rot of stored grapes cv. Ruby Seedless (El-Neshawy *et al.* 2003). Bio-fumigation with *Muscador albus*, a fungus isolated from the cinnamon-tree in Honduras, producing volatiles (a mixture of low molecular weight compounds) that are biocidal or biostatic to a broad variety of fungi *B. cinerea*, *Geotrichum* spp., *Monilinia fructicola*, *Penicillium digitatum* and *P. expansum*, has shown promise (Gabler *et al.* 2006).

Blue mould-rot, c.o. *Penicillium expansum* (Soto *et al.* 1973)

P. citrinum (Tandon *et al.* 1975)

P. frequentans (Mandal and Dasgupta 1981)

P. chrysogenum Thom (Singh and Kainsa 1983)

P. canescens (Sharma and Vir 1985 a)

P. aurantiogriseum (Shrivastava *et al.* 1993)

Symptoms : Infection originates from the weak pedicel-end or around any injury as a water-soaked area, which becomes brownish and get covered with a bluish-green growth with a characteristic smell. It progresses slowly during winter. Injuries predispose grape-berries to infection either before or after harvest. The mould spreads through contact and develops soft-rot slowly under refrigeration.

Control measures : Treatment with Difolatan (0.25%), Benomyl (500ppm) and Carbendazim (0.1%) as suspension drips for ½ to 1 min. are effective in enhancing shelf-life by checking storage-rot caused by *P. canescens* (Sharma and Vir 1984, 1985). Acetic acid fumigation is effective in controlling decay and berry shatter (Sholberg *et al.* 1996).

Studies from Italy have shown effects of spraying or immersion in yeast 5A (*Pichia guilliermondii*) in improving storage as compared to the treatment with yeast 'Aspire' (*Candida oleophila*). Thiabendazole at 0.1 –1.2 g/litre, followed by treatment with 'Aspire' was promising (Arras *et al.* 2001).

Black-mould (Snuffy mould), c.o. *Aspergillus* spp.

A. carbonarius

Gupta, 1956

A. tenuis

A. luchuensis

A. foetidus

Chahal and Malhi, 1969

A. niger Van Tieghem.

Bhargava *et al.*, 1976

A. rugulosus (Thom. & Raper)

A. terreus Thom.

Singh and Kainsa, 1983

A. aculeatus

Jarvis & Traquair, 1984

A. flavus, *A. quadrileneatus*,

A. nidulans and *A. varicolor*

It is considered as one of the worst types of rots on grapes. The disease occurs throughout the year but causes considerable damage only during summer months. The disease was reported from Uttar Pradesh, West Bengal and Meghalaya (Bhargava *et al.* 1976; Dasgupta and Mandal 1989).

Symptoms : They appear as brownish-rot at the stalk-end. Affected fruits fall off from the bunch. Water-soaked areas develop around the infected portion. White mycelial growth is visible at the centre. Later black conidial heads appear profusely on the lesions. The affected tissues become pulpy, shrunken and emit fermented odour. Spores are liberated easily when mature, resulting in soot-like deposits on the adjacent berries.

Control measures : Rotting due to *A.niger*, *A.flavus*, *A.quadrileneatus*, *A.nidulans* and *A.variecolor* can be controlled by pre-and and post-harvest dipping in antibiotic Aureofungin 0.05% (Prasad and Bilgrami, 1975) or by pre-harvest spraying with 2,6-dichloro-4-nitroaniline (DCNA) and Captan at 0.2 % concentration (Subramanian *et al.* 1973). Grape bunches dipped in Captan suspension (0.2%) for 10 minutes (Tandon *et al.* 1975) and packed with diphenyl (1-2g/3 kg packet) (Singh *et al.* 1985) were protected. Stable bleaching powder (6%) is also used as a protectant.

Application of growth retardant CC (Chlormequat) 2,000 ppm applied at the second rapid growth stage of berry development helps in controlling storage rots associated with *A.niger*, *A.flavus* and *Penicillium* sp. and due to *B.cinerea* (Ladiniya *et al.* 1990). Pre-harvest application of growth regulators, NAA(100 or 150 ppm), GA₃ (50 ppm) and CaNO₃ (0.75%), reduced spoilage during storage (Kumar and Gupta 1990).

Post-harvest treatment with Carbendazim (0.1%) or Thiabendazole (0.2%) checked infection by *A.niger* and enhanced shelf-life. Acetaldehyde vapours (0.5%) were effective in controlling rot caused by black mould, and in improving shelf-life of stored grapes (Avisar and Pesis 1991).

In mixed infections of *A.niger* and *B.theobromae*, Bavistin (0.1%) + potassium metabisulphite (5%) offered better control than either used alone (Mandal and Dasgupta 1983,1984).

Soft-rot, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.
R. oryzae Went & Prinsen Geerligs
Mucor circinelloides Van Tieghem
 (Shrivastava *et al.* 1993)

This is one of the most serious diseases of grapes, and was reported from Uttar Pradesh (Tandon 1968) and West Bengal (Mandal and Dasgupta 1981). Singh and Kainsa (1983) observed decay in packing due to *R.oryzae*. *Rhizopus* sp. has been recorded as a serious problem in storage at ambient temperatures (Sawant and Sawant 2001).

Symptoms : Infection appears as soft water-soaked areas, and coarse white mould-strands become visible to naked eye. Smooth, spherical spore-heads

(sporangia) are at first white and turn black later. Air currents spread spores. Infection occurs before, during and after the harvest. Primary infection usually occurs through injury (Barbetti 1980). In exuded juice, fungus enters through into the intact peel of mature berries. Once established, it spreads to adjacent healthy berries, and often forms 'nests' under warm humid conditions.

Optimum growth temperature lies between 30 and 35°C for *R.oryzae* and 20-25°C for *R.stolonifer* (Snowdon 1990).

Control measures : Avissar and Pesis (1991) reported effectiveness of acetaldehyde vapours (0.5%) in improving shelf-life of stored grapes.

Biological control. Detached grapes were immersed in aqueous suspension of yeast cells (*Kloeckera apiculata* and *Candida guilliermondii*) (5×10^8 cfu/ml), and were taken out and spray inoculated with 10^3 sporangiospores per millilitre of *R. stolonifer* and incubated. Both yeast strains were effective in reducing post-harvest decay of grapes caused by *R.stolonifer* (McLaughlin *et al.* 1992). The enhanced effect was noticed when yeast strain was applied with an aqueous suspension of calcium chloride (10^8 cfu/ml in 2% CaCl_2).

**Brown discolouration, c.o. *Alternaria alternata* (Fr.) Keissler
Stemphylium sp.**

The disease was reported from Andhra Pradesh (Ratnam and Nema 1967) and Maharashtra (Sawant and Sawant 2001). It is incited by other species of *Alternaria* also.

Symptoms : The disease is characterized by localized tan to dark-brown decayed areas on the stem-end or on any part of the berry. A dry brown-rot was described from Venezuela (Diaz Polanco and Bastida 1971). The fungus penetrates direct into sound grapes. Symptoms were found prominent on Anab-e-Shahi (Philip 2002). Circular brown lesions with dark margin are visible on the peel. In advanced stages, inside pulp becomes soft and decayed. Due to stem-end infection, fruits get easily separated from the cluster.

Control measures: *Pre-harvest application of fungicides.* Pre-harvest spray of Benomyl (500ppm) two weeks before harvest reduces post-harvest rot in storage.

Post-harvest treatments. Sulphur dioxide fumigation. The disease can be checked in by fumigation with sulphur dioxide (200 ppm) in a humid atmosphere (Couey 1965).

Granules of disodium sulphite are also used for fumigation. They (1g/kg of fruits) absorb moisture released by fruits and protect them from fungal-rot up to 50 days. But this causes bleaching or browning in fruits. Release of SO_2 causes browning of fruits due to SO_2 toxicity.

Use of antibiotics and weedicides. Dipping bunches in Aureofungin 500 ppm or Panactin 500 ppm or 2, 4-D 500 ppm was effective against

Alternaria-rot (Sharma and Vir 1985). Acetaldehyde vapours (0.5%) are also effective (Avisar and Pesis 1991; Swarta and Holz 1991).

Biological control. Dipping bunches in a spore suspension of *Trichoderma*, 20 days before the harvest reduced storage-rot and enhanced shelf-life under *in-vitro* studies (Sawant and Sawant 2001).

***Cladosporium*-rot (Green ball-rot), c.o. *Cladosporium* spp.**

Jamaluddin (1977) recorded *C.tenuissimum* Cooke in storage and transit from Allahabad. This is generally considered a minor disease. But *Alternaria* spp. and *Cladosporium* spp. are reported as major fungi associated with post-harvest rot of fruits in cold storage in Maharashtra (Sawant and Sawant 2001). *C. oxysporum* and *C. herbarum* were also reported.

Primary infection occurs before harvest. The disease appears on ripe berries as sharply delimited dark spots with a greenish growth of mycelia. The spore balls remain strongly attached to the fruit-surface. The lesions become black, firm, shallow and get localized to one side or at the blossom-end. The fruit becomes flat or wrinkled on the affected side. Affected tissues remain firmly attached to peel (Pathak 1980); the optimum temperature for infection ranges from 21 to 24°C. Wangikar *et al.* (1969) recorded shrivelling and browning of berries in the bunch, followed by rotting at the neck. The peel becomes thin, shrivelled and papery.

***Curvularia*-rot, c.o. *Curvularia pallescens* Boedijn**

The disease was reported by Jamaluddin and Tandon (1976) in their studies on market diseases of vegetables and fruits from Allahabad, and a loss of 5-7% was reported.

Symptoms appear as soft areas on the stalk-end or on any place of injury or on the cracked areas on the peel. Gradually lesions develop into distinct light-brown spots, which become finally dark citrine in colour.

Brown-rot (*Botryodiplodia*-rot), c.o. *Botryodiplodia theobromae* Pat.

The disease caused heavy losses in the USA; where it is known as summer bunch-rot (Hewitt 1974). The infection typically occurs at blossoming, and the fungus remains quiescent in the developing fruit and becomes active as berry matures. Sound mature grapes are also directly infected. In India, *B.plamarum* was reported by Patil and Moniz (1969). Mandal and DasGupta (1981) reported it from West Bengal and Meghalaya during March-April.

Symptoms : As rotting proceeds, pulp turns pinkish, peel cracks and juice leaks out, attracting fruit-flies and houseflies. In advanced stages, berry is covered by greyish black growth of the fungus (Philip 1998).

Control measures : Packing with potassium metabisulphite 5% as well as dipping in Bavistin (0.05%) are very effective. TBZ (0.25%) is also moderately effective in reducing infection. In mixed infections of *B.theobromae* and

A.niger, Bavistin (0.1%) + potassium metabisulphite (5%) proved better than either used alone (Mandal and Dasgupta 1983, 1984).

Bitter-rot, c.o. *Greenaria fuligena* Scribner and Viala

Luttrell (1946), Luttrell and Murphy (1953) and Critopoulos (1961) reported this disease. Om Prakash *et al.* (1974) reported it from Muzzaffarpur, Bihar on Anab-e-Shahi.

Symptoms : The fungus attacks ripe and unripe berries just near the peduncle, and the affected berries droop down. The affected berries become light brown to dark fuliginous, with full of dense acervuli, but do not shrivel. On young berries, superficial circular brown spots develop. In severe cases of infection, the lesions coalesce and spread rapidly over the fruit. Rotted fruits get soft and taste bitter. The skin of purple cultivars is bleached to a pink colour. The fungus causes girdling of the canes in the field.

Black-rot, c.o. *Guignardia bidwellii* (Ell.) Viala & Ravaz

Conidial state : *Phyllosticta ampellicida* (Engelm.) Aa

The disease is essentially a field disease, and is of greater significance in Europe and eastern USA (Luttrell 1946). A prolonged wet period causes severe infection. Fruit infection occurs after the fall of calyx, and when the fruit is half to nearly full in size.

Symptoms : The rot appears first on the fruit as light circular spots. Later entire berry becomes discoloured, and soon after, black specks (pycnidia) are formed. The affected berries turn into hard black mummies within a week or ten days and usually remain attached to the stem. Shattering of berries may occur depending upon the variety. The disease does not spread under storage.

Pimple-rot/*Phomopsis* fruit-rot, c.o. *Phomopsis viticola* Sacc.

The disease is responsible for 'dead arm' disease of grape vine. Pycnidia are formed on the infected branches, and during wet weather, spores get disseminated and cause direct infection on intact mature grapes (Hewitt 1974). In India, Gopakrishna *et al.* (1978) and Lal and Arya (1982) reported this disease.

Symptoms : Infected berries show small, brown spots, which soon get surrounded by distinct dark-brown margin. At the final stage of decay, white mycelial growth and black pinhead-like fruiting bodies develop over the entire surface. The tissues become pulpy and emit fermented odour.

Control measures : *Phomopsis* fruit-rot is controlled effectively by spraying before harvest with Bavistin, Difolatan, Calyxin (1,000 ppm each) and Dithane M-45 (0.25%) (Arya 1988).

Leaf extracts of *Eucalyptus* and *Aegle marmelos* (50% water extract), and mustard oil are effective against *Phomopsis* fruit-rot (Arya 1988).

Anthracnose (Bird's eye-rot), c.o. *Elsinoe ampelina* Shear

Conidial state: *Sphaceloma ampelinum*

Glomerella cingulata (*Colletotrichum loeosporioides* Penz.)

Gloeosporium ampelophagum (Pass.) Sacc.

Southworth reported the disease as early as 1891. Daykin and Milholland (1984) reported it as a major problem, caused by *C. gloeosporioides* on the muscadine grapes (*Vitis rotundifolia*) from North Carolina. Infection occurs at all stages of fruit development. The fungus remains latent; and the symptoms appear only at the time of ripening.

Symptoms : Immature berries are susceptible to infection. The disease appears first as dark-red spots on the berry (Fig. 6.1). Later these lesions become circular, sunken, ash-grey, and in the late stages spots are surrounded by a dark margin, which gives it the characteristic 'bird's eye-spot' appearance (Fig. 6.2).



Figs 6.1, 6.2. Anthracnose on grapes

Control measures : Fungicides like Captafol, Carbendazim, Mycobutanil and Ziram (all at 500 -1,500 ppm) are recorded as effective in controlling incidence and intensity of anthracnose (Datar 1994). But Carbendazim use may lead to development of resistance in the pathogen (Chander and Thind 1995). Hence, its use alternately or in a mixture with Thiophenate methyl (0.25%) or Benomyl (500 0ppm) is observed to be effective (Deokate *et al.* 2002).

An unusual bunch-rot of grapes caused by *Colletotrichum acutatum* was recorded from Australia (Melksham *et al.* 2002). Salmon-pink discharge of conidia from the infected fruit, and discolouration on grapes and vines were noticed.

Yeast-rotting, c.o. *Saccharomyces* sp.

Yeast-rotting is common and damages physically damaged fruits. Singh and Kainsa (1983) observed much decay in packed grapes due to fermentation by yeast *Saccharomyces* sp. The yeast group, *Candida* sp., *Endomycopsis* sp.,

Rhodotorula sp. and an actinomycete *Streptomyces* sp. were observed on decayed fruits from the baskets.

Sour-rot due to fermentation by acetic-acid bacteria and yeast was also recorded (Bisach *et al.* 1986). It was also recorded from West Bengal and Meghalaya (Dasgupta and Mandal 1989).

Symptoms : The most important feature of this disease is softening of tissues and fermentation of juice with a strong and sour alcoholic odour and conversion of fruits into a putrefied mass. Fruits become unsuitable for consumption; fruits tightly packed and/or in ill-ventilated containers suffer the most.

Control measures: Packing materials made of bamboo with paper-cuttings as cushioning material are found better in reducing spoilage than wooden boxes with paper-cuttings (Singh and Kainsa 1983).

Melting decay of grapes, c.o. Bacteria and yeasts

Bacillus subtilis (Ehrenberg)

Cryptococcus laurentii (Kuffedath)

Aureobasidium pullulans (de Bary) Arnaud.

The disease was recorded from California on fruits after two weeks of cold storage. Symptoms appear as cracking and as dissolution of epidermal cells, followed by development of sunken, decayed areas. In advanced stages, entire berry gets liquified. Affected berries were randomly distributed but sometimes berry-to-berry spread was also noticed (Morgan and Michailides 2004).

OTHER FUNGI ASSOCIATED WITH ROTTING

| Fungus | Authority |
|---|----------------------------------|
| <i>Cephalosporium rosegriseum</i> | |
| <i>Curvularia lunata</i> | Chahal and Malhi, 1969 |
| <i>Trichoderma lignorum</i> | |
| <i>Macrophomina phaseoli</i> (Syn: <i>Rhizoctonia bataticola</i>) | Ranganathan <i>et al.</i> , 1972 |
| <i>Monilinia fructicola</i> | Sholberg <i>et al.</i> , 2003 |
| <i>Pestalotia menezesiana</i> | Mishra <i>et al.</i> , 1974 |
| <i>Phoma glomerata</i> | Pandotra, 1976 |
| <i>P. macrostoma</i> | Jamaluddin, 1977 |

DISEASES MANAGEMENT

Pre-harvest fungicides application

Field application of fungicides (non-systemic as well as systemic) and certain chemicals is reported to be effective in reducing infection in the field as well as in storage. Thus Bavistin(0.1%), Blitox(0.5%), Dithane-M 45(0.2%) and potassium sulphate 2% (Pal *et al.* 1979), Benomyl(500 ppm), Thiophenate methyl (0.1%) and Carbendazim (01%)(Nicoli *et al.* 1979; Pearson *et al.*

1985), Captan 0.2% (Sall and Hirschfelt 1981), Benlate 500 ppm (Valdebenito, 1973; Kumar and Gupta, 1990) as well as Mycobutanil (Orpin 0.1%) showed good results. But Nicolli *et al.* (1979) observed undesirable residues in the fruit and in the vine. Scruno *et al.* (1991) observed suitability of dicarboximide fungicides for field application as well as for post-harvest fumigation during transport and storage.

Post-harvest management

Improvement in packing and use of quick-release grape guard

Paper sheets impregnated with NaHSO₃ (1.5g/kg of fruits) to release SO₂ in holdings are found effective in reducing stem drying, browning and berry-rot up to 12 weeks in cold storage (Mansour *et al.* 1984).

Application of vapours

Vapour phase H₂O₂ produced no changes in the colour of berries (Forney *et al.* 1991).

Fumigation

SO₂ fumigation (Eckert and Sommer 1967), followed by storage at 0°C controlled development and spread of disease for six weeks (Marois *et al.* 1986). Fumigants included use of sodium metabisulphite (1.5g/kg), which released SO₂ in contact with moisture in the packing materials (Kokkalos 1986), and sodium ortho-phenyl phenate (SOPP) 0.2% or 2-acetyl-3-hydroxy furan was commonly used.

In export package, SO₂ generator sheets are used, which continuously emit gas within the packages. But SO₂ is not acceptable for organic grapes, because of the issues associated with sulphite residues, SO₂ emission, and its negative impact on the grape quality. Hence alternative strategies to control grey mould are required.

Use of benzyl alcohol

This offered good results in packed grapes during storage in cartons for four weeks (Chambers 1990).

Alternate technologies

Addition of chlorine (200g) to ammonium bicarbonate and sodium bicarbonate is effective in controlling oxygen and carbon-dioxide levels. Immersing fruits in ethanol, exposure to UV light and ozone are also reported as new technologies in reducing damage in storage of table-grapes (Crisosto and Similanick 2002).

Modifying atmosphere (CA storage)

Controlled atmosphere (CA) storage as a possible alternative to SO₂ treatment for table-grapes has been reported. A concentration of 2% O₂ and

10% CO₂ helps prolonging storage life. Chapon (2002) reported high concentrations more effective than low oxygen concentrations. A threshold concentration of around 15% is optimum. Otherwise it may lead to phytotoxicity or flavour alteration. Crisosto *et al.* (2002) from Netherlands observed CO₂ enriched atmosphere during cold storage to limit losses from *Botrytis*-rot, but accelerated rachis browning of Red Globe table-grapes. A combination of 10 KPa CO₂ + 6 KPaO₂ up to 4 weeks is suggested for early harvested Red Globe grapes. Westerecamp and Blargues (2002) also observed use of modified atmosphere effective in controlling *B.cinerea* rot of grapes. CO₂- rich atmosphere is considered optimum for decay control of organically grown Thompson Seedless and Red Globe table-grapes during storage at 0°C with CO₂ at 15% or more in case of *Botrytis*-rot.

■

CHAPTER 7

Guava (*Psidium guajava* L.)

Guava-fruit is an excellent source of vitamin C. It contains niacin, pantothenic acid, thiamine, riboflavin, vitamin A, and is rich in minerals like phosphorus, calcium and iron. It is rich in pectin also, but is low in energy value. Fruits start showing a decline in vitamin content due to fungal infection.

FUNGAL DISEASES

Anthracnose, c.o. *Colletotrichum psidi* (*Gloeosporium psidi* Delacroix)
Glomerella cingulata (Stonem.) Spauld. & Schrenk.

Guava is attacked by a number of diseases during post-harvest stages, and anthracnose is the most destructive one (Srivastava and Tandon 1969; Liu 1972; Majumdar and Pathak 1997). Anthracnose causes heavy damage during rainy season; estimated losses may vary from 5 to 20%. Adisa (1985) reported this disease from Nigeria. The pathogen remains dormant in the young fruit for about 2-3 months. Studies on guava-fruits cv Allahabad Safeda at different stages of ripening indicated fruits to be the least susceptible at the green stage (Mishra and Kumar 1993). Rotting was observed only in ripe-fruits. In Punjab, anthracnose incidences ranged from traces to 68% (Singh *et al.* 2008).

Symptoms : The disease manifests in the form of pinhead-like lesions on the semi-ripe fruits. The lesions gradually become copper-brown, circular and sunken (Fig. 7.1). Acervuli appear in concentric circles, and lesions may coalesce and may cover 4-5 cm in diameter. Dried pink spore masses are visible within acervuli under moist atmospheric conditions. The pulp under the lesion becomes soft and brown without unpleasant odour. Production of pectinolytic enzymes by the pathogen has been recorded (Midha and Chohan 1967). Two vitamins — para amino benzoic acid (PABA) and choline—were found to inhibit fungus growth in *in-vitro*



Fig. 7.1. Anthracnose on guava

studies (Chatrath *et al.* 1968). Significant increase in fruit-rot was observed with increased spore load (Tandon and Singh 1969).

Control measures : The disease incidence can be reduced by spraying trees with Bordeaux mixture (3:3:50), Copper oxychloride(0.5%), Cuprous oxide [1.3-1.8 kg containing 50% copper in 54.6 litres water (3-4 lb containing 50% copper in 100 gal water)], Difolatan (0.2%) or Dithane-Z 78(0.2%) (Tandon and Singh 1969; Sohi and Sridhar 1969 Kaushik *et al.* 1972). Use of copper formulations was reported to cause russetting in Allahabad Safeda fruits. Six monthly spraying with Dithane Z-78 (0.2%) or Aureofungin (100 ppm) proved effective.

Several fungicides and chemicals are found to protect fruits against storage rots. Thiram, Kirti copper and Cuman are recorded as good protectants in pre-inoculation sprays against *Colletotrichum*-rot (Midha and Chohan 1971). Dipping fruits in Aretan (ethoxy-ethyl mercuric chloride 6% Hg) at 50 ppm is sufficient to check the growth of *P.psidii* and *C.gloeosporioides* (Khanna and Chandra 1976) with no symptoms of rotting in pre- and post- inoculation treatments.

Spraying trees before harvest as well as dipping fruits in Bavistin (0.1%) were promising (Singh *et al.* 2008).

In packed fruits, fumigation with sodium metabisulphite (2g/pack) and stable bleaching powder satisfactorily controlled anthracnose caused by *Glomerella cingulata* (Singh and Sharma 1982). Hot Benomyl at 48-50°C also proved effective (Wills *et al.* 1982; Majumdar and Pathak 1997) against anthracnose in pre- and post- inoculation and for post- inoculation treatment against *Pestalotia*-rots.

An actinomycete isolate (*Streptosporangium pseudovulgare* @ 6.2×10^7 cells/ml) of cowdung origin recorded destruction of pathogen in *in-vitro* conditions (Garg *et al.* 2004). This actinomycete showed great biocontrol potential against anthracnose. In 'Vrisksha Ayurveda' effects of cowdung paste for healing plant wounds are mentioned.

Fruits stored at 3-10°C in polyethylene plastic film bags with pores of 10- mm diameter retained physiological and biochemical characteristics and quality up to 18 days of storage (Gutierrez *et al.* 2002).

Stalk end-rot/Botryodiplodia-rot,

c.o. *Diplodia natalensis* Pole-Evans
Botryodiplodia theobromae Pat.
Lasiodiplodia theobromae

Symptoms : The pathogen also causes dry-rot in guava. Symptoms appear initially as light-brown spots, mostly at the stalk-end or at the calyx-end of the fruits. Infection may arise from other parts of the fruits also. Infection spreads quickly and within 3-4 days, entire fruit turns dark brown to black, and ultimately dries up (Fig. 7.2). A number of dried fruits can be seen on an infected tree. Twigs bearing infected fruits exhibit die-back symptoms. The

disease was recorded from Uttar Pradesh and Kerala (Edward *et al.* 1964, Srivastava *et al.* 1964; Srivastava and Tandon 1969 a; Rajagopalan 1971).

The pathogen produces symptoms on the ripe-fruits in storage. Considerable damage occurs during transit and storage. Affected fruits show brownish discolouration, mostly at the stem-end, which gradually proceeds downwards in an irregular wavy manner. In advanced stages, numerous



Fig. 7.2. *Botryodiplodia*-rot on guava

pycnidia are produced over the entire fruit-surface. As rotting advances, fruit becomes soft and watery, and its inner pulp becomes discoloured. Rotting spreads through contact. Warm humid weather favours disease. Patel and Pathak (1995) studied the influence of temperature and relative humidity on the disease severity in Rajasthan. Warm humid weather favours it, and low temperature retards its severity by adversely affecting pathogen physiology. The disease was found severe at 30°C and 100% RH. No symptoms occurred at 10°C and 30% RH. Activity of cell-wall degrading enzymes (CWDE) with rots was also studied. Pectic and cellulolytic enzymes (PG, PMG and Cx) were active at 30-35°C. Reduction in vitamin C (ascorbic acid) in ripe-fruits due to infection was also observed (Srivastava and Tandon 1966; Patel and Pathak 1995).

Control measures : Removal and destruction of infected unripe fruits along with infected stem showing die-back symptoms needs to be carried out. Wounds should be protected with Bordeaux paste. Application of Ziride 3,000 ppm as pre-harvest spray at 15 days interval is effective against dry-rot without any phytotoxicity to flowers and fruits (Rajagopalan 1971; Rajagopalan and Wilson 1972, 1972 a).

Careful handling, quick transport and storage of fruits at 10-15°C were promising. Imazalil (200 ppm) offered protection against rotting incited by *L.theobromae* (Majumdar and Pathak 1997). Dipping fruits in Tetracycline (500 ppm) controlled effectively the disease, and fruits remained healthy for ten days (Gupta *et al.* 1973).

Fruit canker/ *Pestalotia*-rot,

c.o. *Pestalotiopsis psidii* (Pat.) Mordue

P. versicolor (Speg.) Steyaert

The causal organism was first recorded as *Pestalotia psidii* from Maharashtra (Patel *et al.* 1950). Subsequently, it was known as *Pestalotiopsis psidii*, and has been recorded from all guava-growing tracts of India (Rangaswamy 1978; Mandal 1981; Madhukar and Reddy 1990; Majumdar and Pathak 1997). This fungus is responsible for canker and causes maximum damage to ripe-

fruits after harvest (Kaushik *et al.* 1969, 1972). It requires humid atmosphere (25-30°C and relative humidity 80-100%) for maximum development.

Symptoms : Water-soaked lesions of brown colour appear first. These later change into russet-coloured spots. And white fluffy growth along with black pinhead-like acervuli appear after a week (Dhingra and Mehrotra 1980).

Due to this infection, vitamin C content in fruits reduces considerably. Similar results were also reported with *A.niger* and *P.psidii*. This is due to increased respiration under pathogenesis (Srivastava and Tandon 1966; Singh and Tandon 1971).

Control measures: Pre-harvest treatments. Rawal and Saxena (1993) suggested sprays of Dithane Z-78(0.2%) and Thiophenate methyl (Topsin-M (0.1%) on the orchard against *Pestalotiopsis psidii* and *C.gloeosporioides* under storage.

Avoidance of injury protects fruits from several diseases.

Post-harvest treatments. Low temperature storage. Storage at low temperature and dry atmosphere prevents development of storage rots. Low temperature storage at 8-10°C is effective in enhancing storage life.

Use of hot-water. Dipping fruits in water at 50°C for 30 min. protected fruits from fungal attack by *P. versicolor* and *Rhizoctonia solani* (Madhukar and Reddy 1990).

Use of fungicides and antibiotics. Dipping fruits in Aretan (ethoxy-ethyl mercuric chloride 6% Hg) at 1 and 50 ppm is sufficient to check growth of *P.psidii* and *C.gloeosporioides*.

Post-harvest wash with Aureofungin (200 ppm) as well as Thiabendazole (2,000/2,500 ppm) keeps fruits free from infection of *P.psidii* and *Phoma psidii* (Kaushik *et al.* 1968, 1972; Bhargava and Singh 1974). Benlate 500 ppm was effective against fruit-rot (Singh and Bhargava 1977), and Benlate 200 ppm with 0.2% paraffin oil was also promising.

The efficacy of homeopathic drugs like potassium iodine and arsenic oxide against *Pestalotia*-rot in pre-inoculation trials was also demonstrated (Khanna and Chandra 1977).

Stylar-end rot, c.o. *Phomopsis psidii* de Camara

It is a disease of ripe-guavas and causes reduction in fruit yield (Rai 1956; Srivastava and Tandon 1969; Rao and Agarwal 1975). And also reduces nutritional value of fruits.

Symptoms : The disease starts as a circular water-soaked lesion at the stylar end. As the disease advances, small white or light brown pycnidia appear on the infected area, and they aggregate closely.

Control measures : Satisfactory control with Bavistin, Difolatan, Calyxin (1,000 ppm each) and Dithane M-45(1250 ppm) has been reported (Arya,

1988). Dipping fruits in Aretan (ethoxy-ethyl mercuric chloride 6% Hg) at 50 ppm is sufficient to check growth of *P. psidii* and *C. gloeosporioides*. Blitox (0.5%), Cuman L 0.1 % (Rao and Agarwal 1977) and Cuprasol 50 as well as Planofix (Majumdar and Pathak, 1997) are also effective against *Phomopsis*- and *Rhizopus*-rots.

Leaf extracts of *Eucalyptus* and *Aegle marmelos* (50% concentration), and mustard oil (1,500 ppm) were effective (Arya 1988).

Phytophthora fruit-rot, c.o. *Phytophthora nicotianae* (Breda de. Haan)
(*P. nicotianae* var. *parasitica* Breda de. Haan)

The disease was originally reported by Mitra in 1929. It causes extensive damage during rainy season, and is favoured by high humidity and moderate temperature.

Symptoms : They are of two types. First type is when fungus attacks unripe fruits at the blossom-end, and the infected fruits show small conspicuous, dark-brown circular spots; some of the fruits are shed prematurely. As the fruits ripen, spots extend and cover the fruit-surface. In the second type, infection is noticed on the fully ripened fruits as water-soaked brown patches, when fruit colour is changing from green to light yellow. Infected fruits become softer and emit undesirable odour. They show superficial mycelial growth during humid conditions. Rao (1966) reported occurrence of *P. nicotianae* along with several other fungi, and Singh *et al.* (1977) recorded it as a new disease problem from Punjab.

Control measures : For *Phytophthora* fruit-rot control, Kothari (1968) recommended weekly sprays on the orchard with Bordeaux mixture (2:2:50) and copper oxychloride (0.2%). Dipping fruits in Difolatan (500 ppm) can be safe for controlling *Phytophthora* fruit-rot. Post-harvest wash with Aureofungin (500 ppm) gave 100 % control for 5 days (Sharma *et al.* 1978) in non-inoculated treatments against *Phytophthora*-rots. Bio-assay studies with 12 different fungicides showed inhibition of the pathogen (Roy *et al.* 2004).

Essential oils (water extract) of *Nepeta hindostana* and *Ocimum canum* are reported to have inhibitory effects on *P. nicotianae* (Chauhan *et al.* 1994).

Fruit-rot, c.o. *Macrophoma allahabadensis* Kapoor & Tandon

The disease was reported from Allahabad (Kapoor and Tandon 1970). In the early stages, diseased fruits show a brownish water-soaked discolouration on the peel; spreading around the infection point. The mycelia colour on the fruit-surface turns from orange-cinnamon to dark-ivy green, and finally becomes black. Numerous dark-coloured pycnidia appear on the fruit-surface.

Fruit sucrose is hydrolyzed completely after infection, and D-glucose and D-fructose are either utilized or reduced in concentration. Considerable changes occur in amino acids, amides and organic acids (Kapoor and Tandon 1971), even changes in ascorbic acid content are noticed. The decline rate is

fast in the initial stages due to production of certain ascorbic acid-degenerating enzymes, produced by the pathogen or by the host-pathogen interaction (Kapoor 1982).

Cold storage (8-10°C) and avoidance of fruit injury are also effective measures.

***Aspergillus-rot*, c.o. *Aspergillus* spp.**

The following two diseases of this category are important.

***Black-rot*, c.o. *Aspergillus niger* Van Tiegh.**

***A. awamori* Nake Zawa**

The rot was reported by Gupta *et al.* (1979), Mandal (1981), Adisa (1985) and Madhukar and Reddy (1991).

The disease is characterized by brown spots of 0.1-0.3 cm diameter randomly distributed over the fruit-surface. Infected areas become water-soaked and the black concentric zones developed later around the point of infection consist of conidial heads. Underneath tissues become soft and decay.

Two-minute dip in Bavistin and Saprol (1,250 ppm each) was effective against *A. awamori* infection (Arya *et al.* 1981, 1988).

***Green mould-rot*, c.o. *Aspergillus nidulans* (Eidam) Wint.**

Mandal (1981) reported this disease from West Bengal. It was also reported from Punjab (Garcha and Singh 1980).

Infection is initiated with discolouration anywhere on the surface, but mostly at the injured site. Inner pulp becomes soft with characteristic green sporulating mass and liquid drops cover infected surface.

Gupta *et al.* (1979) recorded other species of *Aspergillus* also ; *A. wentii*, *A. clavatus* and *A. flavus*. A soft-rot due to *A. awamori* was also reported during monsoon from Allahabad (Bihari Lal *et al.* 1980).

Control measures under *A. awamori* are effective for this also.

***Soft-rot/ Rhizopus-rot*, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.**

***R. nigricans* Ehrenb.**

The disease was reported from India (Srivastava and Tandon (1969). Fruit-rot due to *R. oryzae* was reported from Nigeria also (Adisa, 1985).

Symptoms : The lesions on the affected fruits are water-soaked and circular. As the disease advances, affected area gets covered with strands of coarse mycelial growth.

Patel and Pathak (1966) studied relationship of temperature and relative humidity on the development of *Rhizopus-rot*. Growth retardation was noticed at low temperature.

Control measures : Injuries and bruises need to be avoided. Biocontrol of *Rhizopus-rot* with a yeast (*Saccharomyces cerevisiae*) at 250 ppm

concentration was reported from Allahabad (Dwivedi *et al.* 2001). No significant variation in nutritional value (vitamin C) and acidity and in other parameters, pH, shape and size of fruit was observed.

MINOR DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|--|--|---|
| Phoma-rot | <i>Phoma psidii</i> | Gosh <i>et al.</i> , 1965; Srivastava and Tandon, 1969; Singh and Bhargava, 1977 |
| Fruit-rot | <i>Cylindrocarpon tonkinense</i> | Jamaluddin, 1976 |
| Sour-rot | <i>Geotrichum candidum</i> | Shankhpal and Hatwalne, 1976 |
| Curvularia-rot | <i>Curvularia lunata</i> } | Gupta <i>et al.</i> , 1979 |
| Monilia-rot | <i>Monilia sitophila</i> } | |
| Black-rot | <i>Ceratocystis paradoxa</i> | Bihari Lal <i>et al.</i> , 1980 |
| Yellow mould-rot | <i>Mucor racemosus</i> | Mandal, 1981 |
| Sunken brown discolouration | <i>Myxosporium psidium guajavae</i> sp. nov | Mandal and DasGupta, 1984a |
| Soft-rots | <i>Rhizoctonia solani</i> <i>Choanephora cucurbitarum</i> } | Adisa, 1985 |
| Dry-rot | <i>Aspergillus fumigatus</i> <i>Penicillium</i> sp. <i>P. multicolor</i> <i>Cladosporium</i> sp. <i>Fusarium equiseti</i> <i>F. oxysporum</i> <i>F. solani</i> } | Adisa, 1985 Chakarabarti, 1983 |
| Cottony-rot | <i>Fusarium semitectum</i> } | Das Gupta and Mandal, 1989 |
| Blue-mould | <i>Penicillium expansum</i> } | |
| Watery soft-rot | <i>Gliocladium roseum</i> | Rao and Agarwal, 1977 |
| Fruit-rot | <i>Cylindrocarpon tonkinense</i> | Jamaluddin, 1976 |
| Fruits-rots | <i>Alternaria alternata</i> <i>Drechslera hawaiiensis</i> <i>Sclerotium rolfsii</i> <i>Cladosporium cladosporioides</i> <i>Paecilomyces variotii</i> <i>Chaetomium globosum</i> | Madhukar and Reddy, 1991 |
| Bacterial rot | <i>Erwinia</i> sp. | Adisa, 1985 |

Control measures: Pre-harvest application of fungicides. Spraying fungicides on the orchard often offers protection to harvested fruits against storage rot.

Post-harvest management. Guava-fruits suffer mainly due to diseases caused in the unripened stage. Pathogens like *C.gloeosporioides*, *L.theobromae* and *Pestalotipsis psidii* occur in fields as well as in transit and in storage.

Storage at low temperature. Storage of fruits at low temperature (15°C) with quick transportation helps in minimizing storage problems (Srivastava and Tandon 1969; Patel and Pathak1995).

Hot-water treatment. It protects against storage rots.

Use of fungicides. Several fungicides and chemicals are found to offer protection against storage rots.

Benomyl (0.3%) is recorded to be effective against common-rots. But Benomyl (0.2%) with paraffin (0.2%) is considered better in enhancing storage. Benomyl at 48-50°C also proved promising (Wills *et al.* 1982).

Use of chemicals. Dipping in chemicals other than fungicides also offers protection. Sodium carbonate (6%) has been found to be effective in checking rots with lesser intensity of infection. Singh and Chohan (1982) observed Alar 1,000 ppm and calcium nitrate 2% with promising results.

Use of leaf extracts. Crude leaf extracts of *Eucalyptus* and *Aegle marmelos* also protect against rots. Smearing fruits with 5% mustard oil and castor oil also offers protection (Arya 1988).

Biological control. Yeast (*Candida* sp.) is reported to have antagonistic activity. Fruits treated with suspension of *Candida* sp. (10^9 cfu/ml) for 5 min., followed by packing in high-density polyethylene covers (HDPE) showed no spoilage and offered minimal physiological losses in weight(PLW). This was due to reduced transpiration and respiration of fruits (Abhilasha *et al.* 2008; Lal *et al.* 2008).

Packing and storage: Use of wax and polyethylene packings. Fruits treated with 9% waxol showed increased shelf-life. Fruits chemical attributes were better under polyethylene packings, and organoleptic traits were better under carton packing (Jagadeesh *et al.* 2001). Similarly fruits kept in polyethylene plastic film bags with pores of 10-mm diameter and stored at 5-10°C showed good physiological and biochemical characteristic up to 18 days of storage (Gutierrez *et al.* 2002).

CHAPTER 8

Jackfruit (*Artocarpus heterophyllus* Lam.)

Jackfruit, known as a poor man's food, is native to Western Ghats. It is hardly recognized as a commercial fruit. Its semi-ripe fruits are used for making chips.

It is a good source of carbohydrates, total soluble solids, vitamins like carotene (Precursor of vit. A), thiamine, minerals like iron, phosphorus and calcium. It is a rich source of pectin also.

FUNGAL DISEASES

***Rhizopus-rot*, c.o. *Rhizopus artocarp* Racib.**

The disease was originally reported from Asom (Chowdhury 1945). Fruit-rot caused yield losses to the tune of 60-80% in Manipur (Pandey *et al.* 1979). The pathogen attacks male inflorescences and young fruits, and it lives saprophytically on plant debris, manure and compost pits.

Symptoms : They are noticed on the ripe-fruits that have sustained injury, and appear as water-soaked areas. Later the areas are covered with white mycelia and black pinhead-like sporangial heads. Inside tissues become rotten, and in the advanced stage, juice leakage with foul smell results in.

Control measures : Fruits should be taken care of so that they are not damaged at harvest. The disease incidence can be minimized by observing sanitation in orchards and by spraying tender/immature fruits with Bordeaux mixture (2:2:50). Spraying with Dithane M-45 or Iprodione (Rovaryl) at 0.2 was reported to be effective (Pandey *et al.* 1979; Singh and Bhowmik 1985; Ahamed 1985). Spraying with Benlate or Bavistin (500 ppm) was also effective.

***Phytophthora* fruit-rot, c.o. *Phytophthora* sp.**

The disease is observed during the south-west monsoon in Kerala.

Symptoms are noticed on fruits that are in close proximity to soil. Infection starts through a hole or a wounded area in the rind. Under artificial

conditions, water-soaked lesions occur within 48-78 hours after inoculation. Later they enlarge to form brown patches with sporulating hyphae near the edges.

Fruits touching ground should be kept on raised platforms. And soil around the fruits should be treated with copper-oxy-chloride (COC 0.3-0.5%).

***Botryodiplodia-rot*, c.o. *Botryodiplodia theobromae* Pat.**

This fungus is a wound-pathogen, and its infection symptoms originate at the wounded areas on mature fruits. And fruits rot within 3-4 days; profuse mycelial growth is visible on the fruit-surface. Pycnidial encrustations can be noticed in advanced stages of infection. The juice leaks out with a foul smell.

Proper care should be taken so that the fruits are not damaged at the time of harvest.

***Black-rot*, c.o. *Aspergillus niger* Van Tiegm.**

Symptoms of this fungus are noticed on the fully ripened fruits during rainy period of June and July. Infection can be noticed anywhere on the fruit surface, and within 3-4 days area becomes soft and black. Black fungal growth is visible on the fruit rind. Profuse leakage from the fruit with an offensive smell is also noticed.

***Brown-rot*, c.o. *Rhizoctonia solani* Kühn**

This disease was recorded during the south- west monsoon period from May to July on cv Mutton Varikka (Singapore Jack) from Vellayani, Thiruvananthapuram (Menon *et al.* 1979; Philip 2002). The disease is noticed only on jackfruits, which are in close proximity with the soil. The affected area turns slightly brownish and soft with mycelial mat spreading in all directions, particularly under high humidity. Mustard-like sclerotia are also observed in abundance on the surface and the inside area becomes soft and rotten.

Control measures : Fruits in close proximity to soil alone are affected. Hence fruits should not be allowed to touch the soil, instead they should be kept on the raised wooden platforms.



CHAPTER 9

Litchi (*Litchi chinensis* Sonn.)

Litchi is a non-climacteric fruit of South East Asian origin. India is the second largest producer of litchi, after China. It is well known for pleasant flavour and attractive colour, and also contains sugars, protein, fat, pectin, vit. C and organic acids like malic acid, citric acid, levulinic acid, phosphoric acid, glutaric acid, malonic acid, lactic acid, and minerals like calcium, phosphorus and iron (Pandey and Sharma 1998). The fruit is valued for its high antioxidant property.

Shelf-life of litchi at ambient temperature ($26 \pm 2^{\circ}\text{C}$) is less than 72 hours. Post-harvest losses of litchi are estimated to be 20-30%, and could reach as high as 50% (Jiang *et al.* 2001). Litchi-fruit contains a white translucent aril with a sweet citrus flavour, and is covered by a red leather-like pericarp, which contains anthocyanins. The fruit can be eaten fresh or processed as jelly or wine or used in ice-creams and sorbets (Rivera-Lopez *et al.* 1999; Hui 2008).

FUNGAL DISEASES

The fruit-rots are reported from India due to following fungi (Prasad and Bilgrami 1973).

- Aspergillus flavus* Link. ex Fries;
- A.nidulans* (Eidam) Wint;
- A.niger* Van Tieghem.;
- A.quadrilineatus* Thom. & Raper;
- A.varicolor* (Berk. & Bri.);
- Botryodiplodia theobromae* Pat.
- Colletotrichum gloeosporioides* Penz.
- Cylindrocarpon tonkinense* Bugn.
- Pestalotia* sp.

Studies on the effect of temperature and humidity on the decay of fruits of 'Shahi' variety showed no infection at 10°C and 30% relative humidity.

Slow pedicel end-rot, c.o. *Drechslera* sp. Chattopadhyay
(N.C. Mandal and M.K. Dasgupta sp nov)

Symptoms : Infection starts from the pedicel-end as a brown zone, turning to deep-black with sparse mycelial growth and later turning black in colour. The aril becomes soft, watery, and is covered with mycelial mat. Under high relative humidity, fungal nets are formed within fruits (Mandal and Dasgupta 1984a).

Fruit-rot, c.o. *Geotrichum candidum* Link. ex Pers.

This disease was recorded from Allahabad (Jamaluddin *et al.* 1975a).

Symptoms : Infection occurs through cracks or injuries on the fruit. In the early stages, infection starts as a small soft area on the fruit. Soon fruit turns soft and pulpy and nut-like covering becomes loose; and fluid with a disagreeable odour comes out and the brittle nut-like covering gets depressed. White waxy growth of the fungus is observed on the diseased surface.

Control measures are as detailed under tomato in the solanaceous crops.

Fruit-rots due to several fungi are reported from Australia (Scott *et al.* 1982). This includes *Aspergillus*-rots caused by *A. flavus* and *A. niger*.

Other fungi of minor importance are as follows.

Rhizopus oryzae;

Geotrichum candidum Link.; (Scott *et al.* 1982)

Botryodiplodia theobromae Pat;

Colletotrichum gloeosporioides Penz

Yeast-rots

POST-HARVEST DISEASES MANAGEMENT

Sulphur-dioxide fumigation is practised. But SO₂ fumigated fruits absorb 30-65% of the applied SO₂.

Dipping fruits in a solution of sodium ortho-phenyl phenate (SOPP, 0.25%) or in hot Benomyl (0.05% at 50°C for 2 min), followed by 6% wax emulsion increases storage life of fruits by four days (Prasad and Bilgrami 1973). Packing of fruits in polyethylene bags after the treatment was reported as effective.

Among the fungicides, Benomyl is known to have a strong-and-broad spectrum of activities, and is effective for controlling litchi fruit decay. But, it is not registered as a post-harvest chemical in many countries. As an alternative, gamma radiation has been reported as an effective treatment. Radiation at 0.5KGY in combination with low temperature storage (4°C) offered protection to litchi-fruits and increased shelf-life by 28 days (Hajare *et al.* 2010).



CHAPTER 10

Mango (*Mangifera indica* L.)

Mango is considered as one of the choicest fruits of the world because of its attractive colour, delicious taste and excellent nutritional properties. Mangoes, like many other fruits, are highly perishable. In general, fruit losses occur in the orchard as well as during the post-harvest operations of grading, packing, transportation, storage and marketing. Chenulu and Thakur (1968) reported an average loss of 17.7% due to fungal diseases. Weather conditions prevalent during the period (temperature of 25-30°C and relative humidity of 80-90%) favoured fungal infection. Infection generally originates at the stem-end region. In addition to this, the lenticels on the peel also serve as the site of infection (Sarkar, 1974).

The following diseases were reported from the survey of the fruit markets in different states of India (Raof and Omprakash 1983; Dasgupta and Mandal 1989; Sharma *et al.* 1994; Jadeja and Vaishnav 2000).

FUNGAL DISEASES

***Diplodia stem-end-rot*, c.o. *Diplodia natalensis* Pole-Evans**
(*Botryodiplodia theobromae* Pat. *Lasiodiplodia theobromae*) (Pat.) Griffon & Maubl.)

In addition to the above mentioned pathogens, *Dothiorella ribis* and *Phomopsis mangiferae* are also found responsible for causing stem-end-rot (Sohi *et al.* 1973).

Stem-end-rot is considered as the most important post-harvest disease of ripe mangoes. Pathak and Srivastava (1967) reported an annual loss of 4-6% in Indian markets due to this disease alone.

The disease is common in India. It was reported from north India (Chakravorty and Srivastava 1964), Kerala (Cheriyann 1987; Philip 2002) and from Gujarat (Jadeja and Vaishnav 2000). It was also reported from other countries, Sri Lanka (Fernando 1937), Philippines (Alicubuson and Schafer 1958) and Mauritius (Orian 1960). Wagan *et al.* (2001) also recorded *B. theobromae* as the predominant fungus from different markets in Pakistan, followed by *A.niger*, *Penicillium* spp. etc. Cultural and pathogenic variability has been reported in *L.theobromae* (Bhatt and Jadeja 2008).

Symptoms : They initiate as black irregular areas around the pedicel. Soon the affected areas enlarge to form circular black patches that gradually extend downwards (Fig. 10.1). Along with this, isolated circular or irregular patches are seen scattered over the fruit-surface. The whole fruit turns black and rotten within 5-7 days (Fig. 10.2). Under humid conditions, fruit rots rapidly, and greyish black fungal growth covers the fruit. The pulp of the diseased fruit becomes brown and soft. The pathogen incites a soft-rot with the aid of pectinolytic and cellulolytic enzymes (Pathak and Srivastava 1969; Pathak and Prasad 1969).

The fungus is a weak parasite that enters through wounds. The dead twigs and bark of mango-trees harbour abundance of pathogen, and with the onset of rains, the atmosphere gets contaminated with fungus spores and subsequent infection occurs through stem-ends or wounds (Pathak and Srivastava 1969).



Fig. 10.1. *Botryodiplodia*-rot on mango-fruits

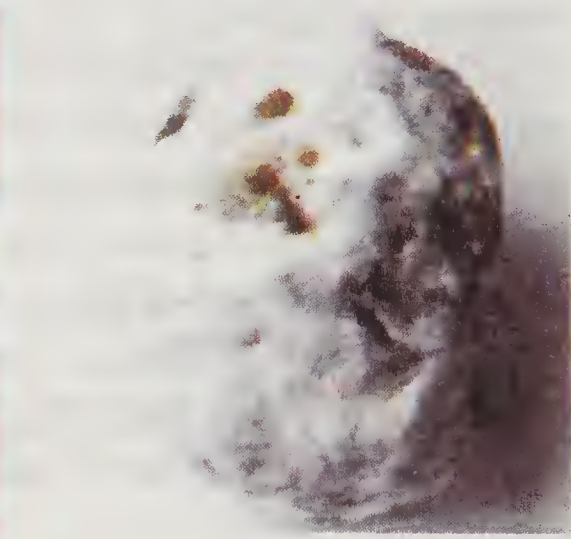


Fig. 10.2. *Botryodiplodia*-rot (Advanced stage) on the fruit

Control measures : The orchard and the surroundings should be made clean by removing dead branches and also other sources of natural infection. Injuries to fruits should be avoided at all stages of handling. Packing of mango-fruits with dried banana leaves is to be avoided, as they serve as the source of infection (Alicbusan and Schafer 1958).

Dipping of mango-fruits for five minutes in hot water at 50°C + 1% common salt is an effective control measure (Saxena and Rawal 2004).

Chemical control. Pre-and post-harvest treatments with calcium chloride and calcium nitrate (both at 5,000 ppm) were reported in reducing storage rots due to *Colletotrichum* and *Diplodia* (Kaiser *et al.* 2001). Protection of fruits with growth regulators has also been reported.

The disease can be controlled by dipping mango-fruits in Aureofungin 200 ppm or in 6% borax solution at 43°C for three minutes (Dharm Vir *et al.* 1967; Thomas and Dalal 1968). Dipping in the systemic fungicide Carbendazim 0.1% for four minutes was found effective (Sharma *et al.* 1994).

Five minutes dip in benzoic acid (50 ppm) protected against *Diplodia* stem-end-rot and anthracnose (Nair 1999).

Biocontrol. *Trichoderma viride* showed inhibition of *B. theobromae* under *in-vitro* conditions when cultures were placed at equal distance on the potato dextrose agar medium. Under *in-vivo* conditions also mango-fruits inoculated with *T.viride* remained free from infection of *B. theobromae*, *Pestalotia*, *Colletotrichum gloeosporioides*, *A.niger*, *A.flavus*, *R.stolonifer* and *M.phaseolina*, thus indicating their suppression by *Trichoderma* (Bhuvanewari and Rao 2001).

Pandey and Pandey (2005) evaluated biocontrol efficiency of *Trichoderma harzianum* against storage diseases of mango : stem-end-rot, anthracnose and black-rot in dual cultures under *in-vitro* conditions. *T.harzianum*, because of its ability to sustain under a wide range of environmental conditions, showed mycoparasitism and parasitized colonies within 5-7 days; mode of action is coiling and penetration.

With bacteria. Post-harvest dip with *Bacillus licheniformis* (isolates B 250, B 251) has been found effective in controlling anthracnose and stem-end-rot in mango-fruits (Korsten *et al.* 1993). Ripened mangoes inoculated previously with 0.5 ml suspension of *Bacillus* isolate B₄ (10^9 cfu/ml) and kept at $28 \pm 2^\circ\text{C}$ showed no symptoms on inoculation with mycelial cultures of *L. theobromae* (Jadeja and Bhatt 2008).

Non-antibiotic producing yeast in combination with chitosan was also used. Addition of chitosan enhanced efficiency of yeast in controlling post-harvest decay (Agnihotri *et al.* 2008).

Fruit coatings. Krishnaiah *et al.* (1987) tried food grade fruit coatings (FGFC) approved by the Environmental Protection Agencies (EPA) at 0.4% dilutions; no rotting symptoms were observed up to 15 days by fungi like *C.gloeosporioides*, *L.theobromae*, *A.alternata* etc.

Anthracnose, c.o. *Glomerella cingulata* (Stonem.) Spauld. & Schrenk.

Conidial state : *Colletotrichum gloeosporioides* Penz.

Anthracnose is an important cause for losses in mangoes all-over the world. It was reported from India (Tandon and Singh 1968), and was recorded from the USA also (Mc Millan 1984; Splading and Reader 1986), West Indies (Gordillo and Hernandez 1980), South Africa (Jacobs *et al.* 1973), Malaysia (Lim and Wai 1986), Philippines (Daquioag and Quimio 1979) and Australia (Fitzel and Peak 1984). It was observed to be responsible for 29.6% decay of total post-harvest spoilage (Sharma *et al.* 1994). *C.gloeosporioides* and *Gleosporium mangiferae* have been reported to cause heavy post-harvest losses to mango-fruits.

Symptoms : Ripe-mangoes are infected with anthracnose; symptoms appear as brownish irregular spots on the fruit-surface. The spots become sunken and coalesce to form large dull brownish areas on the peel (Fig. 10.3). The pulp beneath the affected peel becomes discoloured. The pathogen is reported to remain quiescent on the peel in the form of hyphae and appressorium (Daquioag and Quimio 1979) till the fruit matures, and then causes damage during transportation, storage and marketing.



Fig. 10.3. Anthracnose on mango-fruits

Symptoms of *B.theobromae* and *C.gloeosporioides* are common. But both produce clearly discernible symptoms without mingling (Philip, 2002). Awasthi *et al.* (2004) from West Bengal studied reaction on 20 cultivars to *Diopldia* and *Colletotrichum* fruit-rot and observed several cultivars resistant against both the diseases.

Survey conducted in the mango orchards of Karnataka by Prasanna Kumar *et al.* (2007) revealed that Neelesham showing maximum anthracnose and *Alternaria*-rot incidence compared to other varieties.

Control measures : Hot-water treatment of fruits at 53°C for 10 minutes or hot-water brushing at 60°C for 20-35 seconds or hot-water dip at 60°C for 20-35 seconds reduced anthracnose and stem-end-rot incidence without alterations in physical and chemical characters (Esguerra *et al.* 2004).

Chemical control. Anthracnose and stem-end-rot can be easily controlled by pre-inoculation dips to mango-fruits in Benlate 1,000 ppm (Pathak and Shekhawat 1976), and with four minutes in Thiabendazole (TBZ) 0.1% and Carbendazim 0.1% respectively (Sharma *et al.* 1994). Mancozeb(0.2%), Copper oxychloride (0.5%) and Prochloraz (0.1%) are reported as effective control measures for anthracnose from Australia (Johnson *et al.* 1989) and copper oxychloride (0.5%) from South Africa (Lonsdale 1993).

Treating mango-fruits in hot-water (50°C) + 1% common salt (sodium chloride) gave maximum control over storage rots. Use of hot-water (50°C) with half the dose of recommended Methyl thiophenate (0.05%) and Carbendazim (0.05%) reduced fruit-rots (Kaiser *et al.* 2001; Saxena and Rawal 2004). This treatment was effective for *Botryodiplodia* and *Aspergillus* rots also.

Wax coating. Haden mango-fruits dipped in Benomyl (1g/lit) or Benzalkonium chloride (2g/lit) with clean wax coat (18.5-20.5% Carnauba wax and acrylic resin) and stored at 13 ± 1°C and 80-90 % relative humidity remained free of infection up to 21 days. Waxing also increased general appearance of fruits (Fonesca *et al.* 2001, 2004).

Use of radiations. Lonsdale and Droomer (1994) claimed one-minute exposure to short-wave infrared radiation, followed by 20 seconds dip in Prochloraz (0.1%) as an effective control measure for anthracnose and other fruit-rots. Gamma radiations (0.8 or 1.0 Krad) have also been reported to be effective in increasing shelf-life of mango-fruits (Durigan *et al.* 2004).

Biological control. Use of plant extracts. These extracts are reported to have fungicidal effect against storage pathogens of mango. Bautista *et al.* (2002) observed that leaf and stem extracts of *Dyospiros ebenaster* possess antifungal activity against *C.gloeosporioides*. The solid soluble concentration (SSC) and loss of fruit mass varied with plant extracts. But the extracts did not affect fruit quality.

Antagonistic fungi. Biological control with an antagonistic fungus *Fusarium* sp. has also been recorded. Mango-fruits inoculated with locally isolated *Fusarium* sp. remained free of infection from *C.gloeosporioides* (Bhuvanewari and Subba Rao 2003). Control with *Trichoderma harzianum* was also reported under *in-vitro* studies. Myco-parasitism by coiling and penetration over pathogenic fungus was noticed in dual-culture experiments (Pandey and Pandey 2005 a).

Black mould-rot, c.o. *Aspergillus niger* Van Tieghm.; *A.aculeatus* Lizuka

Black mould-rot is common in India (Verma and Kamat 1951; Srivastava 1968; Bhargava and Singh 1975; Pandey *et al.* 1980; Cheriyan 1987). The disease caused occasional problems in Philippines also (Quimio and Quimio 1974). Patel (1972) observed 16-17% post-harvest losses due to different species of *Aspergillus* from Gujarat. Jadeja and Vaishnav(2000) recorded *Lasiodiplodia theobromae* and *A.niger* as the important post-harvest pathogens from Gujarat.

Due to the infection, quantity of ascorbic acid in fruits was reduced nearly to half (Gosh *et al.* 1966).

Symptoms : Greyish or pale-brown spots appear anywhere on the fruit-surface, which becomes soft and sunken with whitish growth and later is covered with a sooty mass of black spores. Stalk-end infection results in premature fruit drop. Injuries on the fruit-surface favour infection.

Control measures : Treating fruits with hot-water at 55°C for five minutes (Pathak and Shekhawat 1976) and with hot-water + 1% sodium chloride gave good control (Saxena and Rawal 2004).

Dipping fruits in Benlate at 1,500 ppm was reported to control rot (Bhargava and Singh 1975).

Biocontrol with antagonistic fungi. *Trichoderma viride* introduced by wound inoculation to mango-fruits inhibited *A. niger* growth. Control of *Aspergillus*-rot with a potential antagonist, *Fusarium* sp., was also reported (Bhuvanewari and Subba Rao 2001, 2003).

Yeast isolates used in food processing are potential antagonists. Sharma (2003) observed *Saccharomyces cerevisiae* Meyer ex Hansen isolate S 4 (@ 10^8 cfu /ml) and four species of *Kluyveromyces* as highly effective against fruit-rot of mango caused by *Aspergillus niger*. Wounds were made in the mango-fruits and were treated with 20 ml of yeast suspension. After drying of wound, each wound was challenged with 20 ml of *A. niger* (10^4 spores /ml). It is assumed that competition for nutrients played an important role in control of fruit-rot of mango caused by *A.niger* (Sharma and Nigam 2000; Sharma and Gosh 2000).

Black-blotch, c.o. *Aspergillus flavus* Link. ex Fries

The disease was reported by Majumder and Modi (1980).

Symptoms : The disease is characterized by blackening of peel and softening of tissues of ripe mangoes. Due to infection, three-fold decrease was noticed in total reducing sugars (Majumder and Modi 1980). Cheriyan (1987) recorded water-soaked lesions with greenish-yellow fungal growth. Then fruits became soft and juicy.

Soft-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs *R. arrhizus* Fischer

The disease is widespread in India, and has been recorded from Andhra Pradesh, Punjab, West Bengal and Kerala (Thakur and Chenulu 1970a; Laxminarayana and Reddy 1975; Garcha and Singh 1980; Cheriyan 1987; Philip 2002). Injuries favour Infection. At low temperature (7-8°C), disease development is of low intensity and is slow, and it is fast between 20° and 40°C (Thakur 1972).

Symptoms : The pathogen incites a type of soft-rot; growth of the fungus is fast. Fruit-peel turns black and in the advanced stages, pulp beneath the peel collapses; profuse leakage is also noticed.

Control measures : Dipping mangoes in 6% Borax solution at 43°C or hot-water (52°C) was effective (Thomas and Dalal 1968). Thakur and Chenulu (1970) observed protection of mango-fruits against soft-rot by *R.arrhizus* for 20 days by dipping fruits in 2-aminothiazole + 2-aminopyridin (at 5% concentration each).

Antagonistic nature of *Fusarium* sp. against *Rhizopus* sp. has been reported (Bhuvanewari and Subba Rao 2003).

Black soft-rot, c.o. *Phomopsis mangiferae* Ahmad

Sharma *et al.* (1994) recorded this disease along with several other pathogens. The fungus produces discrete and discoloured areas all-over the fruit. Infected areas turn dark brown to black on maturity. Occasionally, several spots coalesce to form large patches. The underlying tissues get sloughed off and turn into a soft juicy mass. Black fruiting bodies are clearly visible on these spots (Laxminarayana and Reddy 1975).

Black-rot, c.o. *Alternaria alternata* (Fries)

From West Bengal, brown-rot due to *A. tenuissima* was also recorded (Mukherjee and Bhattacharya 1969). This disease is of particular significance in Israel, where it is more common than anthracnose (Prusky *et al.* 1983). The fungus penetrates into the lenticels of immature fruits, and enters into a latent or quiescent stage soon after when the initial stages of infection are complete. After harvest, fruits as they mature lose their resistance and pathogen resumes growth and active lesions are seen on the fruit-surface (Pathak 1997).

The possibility of assessing latent infections as the basis for control of post-harvest disease was tried. The spores could be detected from fruits as well as during the entire period of fruit growth. Based on this, pre- and post-harvest treatments can be manipulated (Prusky *et al.* 1983).

Combination of hot-water spray and hot-water brushing (HWB) for 15-20 seconds with Prochloraz (225 µg/ml) was most effective treatment in reducing quiescent infections of *A. alternata* (Prusky *et al.* 2002).

Storage-rot, c.o. *Sclerotium rolfsii* Sacc. (*Corticium rolfsii* Curz.)

The affected fruits show grey, irregular lesions, scattered all-over the fruit-surface. Fruit-skin becomes soft and discoloured (Dharm Vir and Sharma, 1965; Cheriyan 1987).

**Sooty-mould, c.o. *Capnodium* sp.
Meliola sp.**

The disease causes dark blemishes on the fruit-surface (Philip 1998) (Fig. 10.4). Insect infestation and deposition of honeydew favours disease.

Bleaching solution (0.05-0.1%) is reported to be appropriate for cleaning fruit-rind (Dalvi *et al.* 2002).

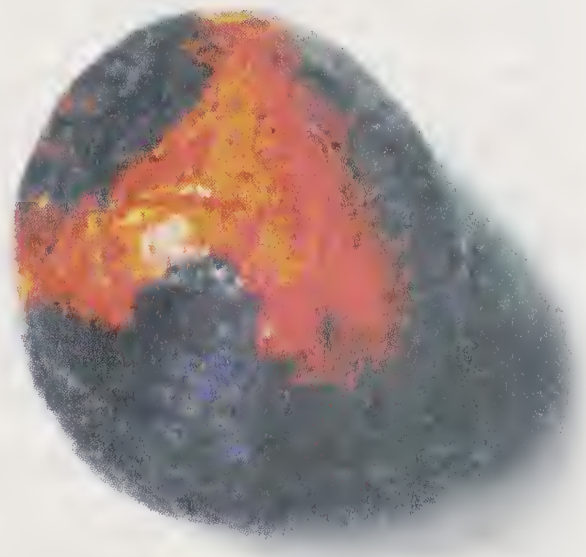


Fig. 10.4. Sooty-mould on mango

BACTERIAL DISEASES

Bacterial black-spot/mango bacterial canker,

c.o. *Xanthomonas campestris* pv *mangiferae indicae*
(Patel, Moniz & Kulkarni) Dye

Bacterial black-spot was recorded from India (Rao *et al.* 1977; Bose and Singh 1980), and from hot-humid climatic areas of South Africa (Kotze *et al.* 1976; Manicom 1986), Australia (Mofett *et al.* 1979) and Taiwan (Lia 1975).

Symptoms : Small, dark lesions appear on the peel with a sunken centre and raised margin. During the wet weather, bacteria wash down from the tree top

and can infect sound immature fruits through lenticels and stomata. The disease symptoms appear at fruit ripening. Sinha and Hinda (1988) observed severity of canker in popular mango varieties like Malgoa, Alphonso, Neelum, Rumani and Baneshan in south India.

Control measures : In Lucknow, dipping fruits in streptocycline (200 ppm) was reported to be effective against canker (Mishra and Om Prakash 1992). Disease management by leaf-based liquid pesticides showed promising results. *Azadirachta* sp., *Pongamia* sp. and *Aegle marmelos* based liquid preparations were effective in reducing disease intensity; it was observed to be on a par with streptocycline treatment (Kishun 2008).

Bacterial-rot, c.o. *Pseudomonas mangiferae indicae*
(Patel *et al.*; Bergy *et al.*)

The disease is noticed in all mango-growing areas. It attacks mango leaves and fruits. Fruit losses are very serious and sometimes whole crop is damaged. In the initial stages, tiny, water-soaked dark-brown spots appear on the leaves, panicles and fruits. The spots gradually increase in size and become slightly raised. At this stage, if it rains, the disease will take an epidemic form. Affected tissues exhibit deep longitudinal cracks and gum exudation. Such fruits drop prematurely and are unfit for consumption. Shekhawat and Patel (1975) observed fruit rotting before harvest as well as during storage.

Control measures : Cultivation of resistant varieties such as Bombay Green is promising. Rao *et al.* (1977) suggested dipping of fruits in Agrimycin/streptomycin (250 ppm) or streptocycline (50 ppm) to be effective in reducing

OTHER FRUIT-ROTS AND CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|-----------------------------|---|-------------------------------|
| Scab | <i>Elisinoe mangiferae</i> | Bitancourt and Jenkins, 1946 |
| Sclerotium fruit-rot | <i>Scelerotium rolfsii</i> | Dharm Vir and Sharma, 1965 |
| Fruit-rots | <i>Pestalotiopsis versicolor</i> | Anon., 1967 |
| | <i>P.glandicola</i> | Ullasa and Rawal, 1989 |
| | <i>Dothiorella ribis</i> | Sharma <i>et al.</i> , 1994 |
| Corky nasal-end rot | <i>Macrophoma mangiferae</i> | |
| Powdery-mildew | <i>Oidium mangiferae</i> | Berthet |
| Black-spot | <i>Rhizoctonia bataticola</i> | Chhatpur <i>et al.</i> , 1972 |
| Dry-rot | <i>Boothiella tetraspora</i> | Tandon and Srivastava, 1974 |
| Charcoal-rot/ | <i>Macrophomina phaseolina</i> | Dhawan, 1982 |
| Blue-mould | <i>Penicillium cyclopium</i> | Palejwala and Modi, 1985 |
| Macrophomina-rot/ | <i>Macrophomina</i> sp. | Jadeja and Vaishnav, 2000 |
| Ripe red-rot | <i>Penicillium purpurogenum</i> | |
| Phyllosticta-rot | Asexual stage of <i>Guignardia mangiferae</i> | |
| Hendersonia-rot | <i>Hendersonia cereberrina</i> | |
| Sooty-blotch | <i>Gloeodes pomigena</i> | |
| Black-spot | <i>Rhizoctonia bataticola</i> | Chhatpur <i>et al.</i> , 1972 |

intensity of pustules. In Bengaluru, after fruit-set, monthly Bavistin spray (1,000 ppm), followed by Agrimycin (100 ppm) was effective in containing the disease (Anon., 1983a). Dipping of fruits in streptomycin (200 ppm) was found to be effective in Lucknow (Mishra and Om Prakash 1992).

POST-HARVEST DISEASES MANAGEMENT

Pre-harvest orchard treatments

To control anthracnose, stem-end-rot and other diseases, pre-harvest treatments, careful harvesting and proper handling are found important (McMillan 1984). Effectiveness of Benomyl application in the field was reduced due to development of resistant strains of *Colletotrichum gloeosporioides* and *Lasiodiplodia theobromae* (Spalding 1982).

In the USA, withdrawal of Benomyl from post-harvest use has been reported (Sanchez 1990). In Andhra Pradesh, pre-harvest Carbendazim (0.1%) application, three times at fortnightly intervals, followed by fruit dip at the harvest stage, resulted in lowering of disease incidence and showed higher decay reduction index (DRI) (Reddy *et al.* 2004).

Fruits ripened on the trees are not suitable for storage due to their high susceptibility to fungal infection.

Mangoes show a climacteric pattern of respiration; during ripening, pulp becomes soft and juicy with a rich aromatic flavour. Mangoes meant for storage or export should be harvested at the mature green stage, before the start of climacteric changes (Lakshminarayana 1973).

Pathak (1980) has suggested following precautionary measures, especially for controlling *Diplodia* stem-end-rot, which is the most important post-harvest disease.

- Harvesting should be done on clear days.
- Injuries should be avoided at all stages of handling.
- Care should be taken to prevent snapping off of pedicel.
- Fruits should be covered and transported to ripening houses immediately after harvest.
- It is of added advantage to coat exposed pedicel-end with Chaubattia paint.

Uniform ripening is induced by introducing gas-ethylene into ripening room (Fuchs *et al.* 1975) or fruits are dipped in ethephon to release ethylene. The process accelerates fruit ripening and improves peel colour.

The following treatments increase shelf-life of the harvested mangoes.

Storage under refrigeration

Mangoes picked-up green at the proper stage can be preserved under refrigeration for several weeks. Karmarker and Joshi (1942) and Cheema *et al.* (1950) observed that many varieties when picked fully mature and firm could be stored for 4-7 weeks at 3.9-9°C. The recommended storage

temperatures are within 10-15°C for green fruits and 7-8°C for ripe-fruits. Most varieties are stored at 5.6-7.2°C and 85-90% RH; and for some varieties, 8.9-11°C has been more suitable (Srivastava 1967). Fruits stored at 7.2-8.8°C, either immediately or after holding for two days, remained in good condition with less than 15% weight loss and spoilage for 25 days, and those stored after four days holding, could be preserved well for 15 days only (Mann and Singh 1975).

Controlled atmosphere storage at 13°C with 5% O₂ and 3.5% CO₂ was effective (Kader 1985).

Storage at 12-13°C is generally considered optimum with variations according to the cultivar and the stage of harvest maturity (Medlicott *et al.* 1990). Low temperature storage is reported to cause chilling injury (Chaplin *et al.* 1991). Pulp of Haden mangoes stored in Mexico for 37 days (13 ± 1°C and 85-90% RH) blackened in 22 days of storage. Fruits showed marked loss in weight, were less firm and showed lower concentration of malic acid (Acosta *et al.* 2001).

Hot-air/hot-water treatment

Dipping in hot-water at 50°C for 15 minutes was effective for Langra and Dasherri (Tandon and Singh 1968). For other varieties, along with this was recommended cold storage (9-10°C) for 5 weeks. But Chausa fruits could be stored without much change in general appearance and flavour up to 47 days. Pennock and Maldonado (1962) and Merino *et al.* (1985) obtained protection with high humidity hot-air vapour heat. Dipping in hot-water at 46°C for 60-120 minutes or at 48°C for 60 minutes (Spalding and Reader, 1986) as well as at 52°C for 30 minutes also offered protection (Om Prakash and Pandey 2000). In Pakistan, dipping in hot-water at 55°C, immediately followed by dipping for 5 minutes in hot-water at 50°C was reported to protect fruits from microbial spoilage (Wagan *et al.* 2001). Hot-water treatment at 52-55°C for 5 minutes was recommended for uniform ripening with minimum spoilage (Krishnamoorthy and Rao 2001). Durigan *et al.* (2004) and Esguerra (2004) reported reduced disease incidence due to hot-water treatment (53°C for 10 minutes/ hot-water brushing at 60°C for 20-35 seconds/ hot-water dip at 60°C for 20-25 seconds). Physical and chemical characters of the fruits were not influenced; the treatment was effective in reducing anthracnose and stem-end infections.

Use of radiations

Lonsdale and Droomer (1994) claimed that one minute exposure to short wave infra-red radiation, followed by 20 seconds dip in Prochloraz (0.1%) was effective in controlling anthracnose and soft-rots. Gamma radiations are reported as effective in increasing shelf-life of mango-fruits (Durigan *et al.* 2004).

Use of wrappers and plastic-film packing

Singh (1941) had suggested use of wrappers treated with double-boiled linseed oil as effective. Plastic film wrapping also offered protection. This ensured better storage and limited losses during transportation. The severity of rotting due to stem-end-rots, anthracnose and other rots was significantly reduced due to wrapping in plastic films. Wax-coating was reported to increase shelf-life of mango-fruits up to 14 days (Cheriyān 1987).

Encouraging results were noticed with mangoes stored in heat-shrinkable plastic films at 21°C for 14 days (Miller *et al.* 1983). The fruits were firm in texture and were of good colouration than non-wrapped fruits. Ben-yehoshua (1985) also recorded reduced shrinkage and extended shelf-life with mango-fruits stored in heat shrinkable polyolein films (D-955). Wrapping in plastic films, followed by incubation at 30 ± 2°C and 75-90% RH, significantly reduced rot severity (Chandra and Pathak 1992). Mango-fruits wrapped individually in polyolein films as well as in low density polyethylene film (LDPE) and stored at 12-17°C also showed increased shelf-life up to 30 days with no weight loss (Yamashita *et al.* 1997).

Individual packing reduces water loss by transpiration and thereby maintain a water saturated atmosphere and a gaseous concentration close to that of air. Reduction in metabolic activity of the storage fungi was also reported. Decay was also lesser with fruits packed with ethysord paper as lining material (Nain *et al.* 2000).

Chemical protection

Dipping mangoes in 6% Borax solution at 43°C or hot-water (52°C) was recorded as effective (Thomas and Dalal 1968).

Dipping in calcium chloride solution is also observed to be effective. Fruits dipped in cold solutions containing up to 8% calcium chloride and 0.1% Tween 20 for 2 hours, followed by storage at 15 ± 2°C, RH 90 ± 5% retarded colour development and textural softening. At 4-6% concentration, shelf-life was extended up to 9 days under ambient temperature and 14 days under cold storage (Suntharalingam 1996).

Use of antibiotics and fungicides

Post-harvest treatments with antibiotics and fungicides are commonly practised.

Various fungicides offer protection. The common fungicides include Bavistin (500 ppm), Captan (0.2%) and TBZ(0.1%) (Gadre, 1979; Gupta and Srivastava 1979; Srivastava 1984; Cheriyān 1987; Sharma *et al.* 1994). Philip and Cheriyān (1995) observed Bavistin 500 ppm as the most efficient fungicide in enhancing shelf-life up to 35 days without any residual toxicity.

Dipping mango fruits in Carbendazim(0.1%), Benomyl (500 ppm) and Thiophenate-methyl (0.1%) solution, followed by packing in bamboo baskets, deal wood boxes and ventilated corrugated fibre board boxes (CFB) was

reported as effective in increasing shelf-life of fruits (Lakshmi *et al.* 2003). Benomyl-treated fruits showed minimum weight loss and lowest post-harvest spoilage.

Haden mangoes dipped in Benomyl or Benzalkonium chloride (2 g/litre) with or without clean wax could be stored at $13 \pm 1^\circ\text{C}$ at 80-90% RH for 21 days (Fonesca *et al.* 2001 2004; Durigan *et al.* 2004).

Use of fungicide plus wax emulsion

Dipping fruits in Benomyl (1g/litre) and Benzalkonium chloride (2g/litre) alone or in combination with clean wax-coat (18.5–20.5% carnauba wax and acrylin resin) improved general appearance, firmness, brightness and delayed fruit-ripening. Physiological losses in weight (PLW) were lower in wax-coated samples and shelf-life was also extended up to 12 days (Raj Kumar *et al.* 2008).



CHAPTER 11

Papaya (*Carica papaya* L.)

Papaya is a commercial fruit-crop in India. It is rich in sugars and is a good source of vitamins A, C and minerals. Besides, it contains well-known digestive enzyme 'papain'.

Effect of the fungal infection on the content of ascorbic acid (vitamin C) of fruits was studied by a number of workers (Gosh *et al.* 1966). Prasad and Verma (1976) investigated post infection changes in papaya due to infection by *Alternaria tenuis*, *Chaetomium globosum*, *Curvularia lunata*, *Cylindrocarpon tonkinense*, *Fusarium oxysporum* and *Helminthosporium speciferum*. All pathogens caused significant reduction in ascorbic acid content. Disappearance of ascorbic acid due to pathogenesis was highest with *Cylindrocarpon tonkinense*, and was lowest with *Chaetomium globosum*. Alterations in the phenol metabolism were also noticed (Agarwal and Agarwal 1982).

FUNGAL DISEASES

Anthracnose, c.o. *Glomerella cingulata* (Stonem.) Spauld. & Schrenk.

Conidial state: *Colletotrichum gloeosporioides* (Penz.) Sacc.

This is considered an important post-harvest disease in most of the papaya-growing countries—India (Gupta and Pathak 1988; Mohan and Lakshmanan 1989), East Africa, Australia, Taiwan, Hawaii and Singapore (Wallace and Wallace 1948; Tsai 1969; Chau and Alvarez 1983; Dickman and Alvarez 1983; Lim and Tang 1984).

Five species of Colletotrichum: C.capsici, C.circinanas, C.dematium and C.papayae, besides the pathogen *C.gloeosporioides* have been reported.

Symptoms : They appear only when fruits are fully ripe (Sepiah *et al.* 1991). The fungus initially establishes on the attached immature fruits by direct cuticular penetration, and symptoms manifest on the fruit surface as chocolate spots or lesions when fruit reaches climacteric phase. In the initial stages, lesions are brown and later enlarge to water-soaked, circular and slightly sunken patches. The lesions may coalesce and scanty white mycelial growth is seen on the margins. Under the humid conditions, centre of the lesion may

show salmon-coloured pink spore mass. Fruit pulp becomes dark brown and rotten from inside.

Stem-end-rot infection may also be noticed on the harvested fruits. Leaves, petioles and stem may serve as the source of primary infection. Seed-borne nature of *Colletotrichum* is also established. High relative humidity favours fungus infection, and low or high temperature reduces disease development (Om Gupta and Neema 1979, 1979a).

C.gloeosporioides has also been observed causing infection on unripe papaya fruits (Misra and Om Prakash 1986). Very young fruits, 5-10 days old, are also infected; entire fruit-surface is covered with whitish fungal growth. Slightly bigger fruits show symptoms like cigar-end-rot with a burnt tip. White concentric rings are observed over the infected patches, and the colour changes to pink and finally turns black. Infection is also noticed at the stem-end region. This results in weakening of pedicel, followed by premature fruit drop. On the early tender fruits, 93% infection was recorded (Mishra and Kumar 1987; Mary 1998).

Control measures : Pre-harvest application of fungicides. Control of post-harvest stem-end-rots due to *C.gloeosporioides* and *Ascochyta caricae* by pre-harvest spraying of orchards at biweekly intervals using Chlrothalonil (1.7-3.4 kg ai/ha) or Benomyl (0.56kgai/ha) was recorded (Alvarez *et al.* 1977).

Post-harvest treatments. Dipping fruits in hot-water at 46-49°C for 20 minutes after harvest was recorded to give protection from stem-end-rots and anthracnose (Akamine and Arisumi 1953). Spraying whole fruit with hot-water at 54°C for 3 minutes was found effective as compared to immersion treatment. Post-harvest application of Thiabendazole (0.1%) reduced disease incidence (Couey *et al.* 1984). Low pressure storage (15 mm Hg and 10°C) was also effective for controlling the disease without damaging fruits (Chau and Alvarez 1983). Dipping harvested fruits in Maneb (0.2%) solution also offered protection (Raabe and Holtzmann 1964).

Biological control. Plant extracts. Crude leaf and stem extracts of *Carica papaya* possess antifungal activity and inhibited *Colletotrichum* fruit-rot completely (Bautista *et al.* 2002).

With yeast. Dipping fruits in 2% sodium bicarbonate incorporated wax formulation and coating with biocontrol agent *Candida oleophila* are commercially accepted as an alternative to chemicals for post-harvest control of anthracnose (Gamagae *et al.* 2004).

Phytophthora-rot, c.o. *Phytophthora palmivora* Butler

P. capsici Leonian

P. parasitica Dastur

The disease was reported from Brazil (Trindade and Politronieri 2002).

It is common in homestead farms of Kerala during south-west monsoon (Philip 2002).

Symptoms : The disease originates as small water-soaked discoloured spots on the mature fruits. The fungus causes a soft watery rot, and under the warm humid conditions, fungus development can be noticed on the fruit surface. On mature fruits, lesions may occur on any part of the fruit. Green fruits are resistant to infection.

Control measures : Spraying trees at weekly or biweekly intervals with Difolatan (0.25) as well as Dithane M-45 (0.2%) gives control against infection of fruits by *P.palmivora* (Wang and Chien 1975). Regular application of Mancozeb (0.2%) help control storage rots.

Hot-water treatment (49°C for 20 minutes) is generally practised for controlling *Phytophthora* fruit-rot. *P. palmivora*, *P. nicotiane* var. *parasitica* as well as *P. capsici* are tolerant to high temperature (Aragaki *et al.* 1981). Dipping harvested fruits in hot-water maintained at 50°C for five minutes protected fruits.

Rhizopus fruit-rot/watery-rot/soft-rot,

c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.

R. arrhizus Fischer

This fungus causes destructive rot in papaya, and losses by this have been reported from Hawaii (Akamine and Arisumi 1953; Hunter *et al.* 1969) and from different parts of India (Tandon and Mishra 1969; Mishra and Kumar 1987; Vyas *et al.* 1993).

Symptoms : They appear on the fruit-surface as irregular water-soaked lesions, which gradually enlarge and get covered by white fungal growth (Fig. 11.1). Infection spreads rapidly and the fruit may collapse within 2-3 days with exudation of sap and foul smell. The rot spreads to other fruits also. Fruit-fly puncture increases disease incidence (Hunter and Buddenhagen 1972). Even slightly bruised fruits may suffer. Some yeast may also infect *in situ*, which results in still faster rate of decay (Das Gupta and Mandal 1989). A fermentative odour may persist.

Ascorbic acid content of fruits reduces to the maximum by *R. nigricans* (Ghosh *et al.* 1966). Reduction in sugar content was also recorded. Vyas *et al.* (1993) observed role of cell-degrading enzymes and toxins in pathogenesis.

Control measures : Careful harvesting and handling are essential



Fig. 11.1. *Rhizopus* fruit-rot on papaya

to prevent bruises on the peel. The disease can be checked by low temperature storage. Fruits are generally dipped in hot-water at 49°C for 20 minutes (Pathak *et al.* 1972).

Use of fungicides. Dipping fruits in TBZ (0.1%) (Arisumi 1956), DCNA (2, 6-dichloro-4 nitroaniline) at 1,000-2,000 ppm and Allisan at 1,000 ppm offered good results (Hunter *et al.* 1969). Aureofungin 1,000 ppm was also reported to be effective.

Biological control. Pre-treatment with culture filtrate of *Bacillus subtilis* protected fruits from storage decay due to *R. nigricans* for three days (Podile and Dube 1988). In dual-culture experiments, pathogen failed to produce sporangia, and mycelia were malformed.

Alternaria-rot, c.o. *Alternaria alternata* (Fr.) Keissler
A. tenuis Auck

The disease was reported from Bihar (Prasad and Verma 1980).

Symptoms : The disease is characterized by grey, brown, circular to semi-circular patches covered with mycelial growth, and is also recorded on immature fruits. Affected fruits develop typical yellowing at the infection site and show blackening of tissues with greyish mycelia when fruits are cut open. Infection occurs from the fruit centre to periphery, and fruits fail to ripen by remaining hard and are unfit for papain extraction or consumption. Plants bearing infected fruits also show severe infection on leaves.

Control measures : Spraying trees at weekly or bi-weekly intervals with Difolatan (0.25%) as well as Dithane M-45 (0.2%) gives control against fruit-rots in storage.

Dipping fruits in hot-water at 49°C for 20 minutes is effective in controlling storage-rots.

Ascochyta-rot, c.o. *Ascochyta caricae* Pat.

The disease was reported from India. The pathogen causes fruit- and trunk-rot (Chowdhury (1950). Sirdhana and Jain (1962), Ghosh *et al.* (1966), Tandon (1967), Srivastava and Tandon (1971) and Gupta and Pathak (1988) recorded fruit-rot.

Symptoms : Infection occurs on half-ripe or mature fruits, which show small circular water-soaked lesions that become sunken and brownish black. As the disease progresses, rot proceeds irregularly. Rotting becomes severe at 30°C and 100% RH.

Control measures : Pre-harvest spraying of fruits with Bordeaux mixture (2:2:50) at 21-30 days interval at the time of fruit-set contained disease. And spray with Chlorothalonil at 1.7-3.4 kg ai/ha was also effective (Alvarez *et al.* 1977).

Dipping fruits in hot-water at 48-49°C for 20 minutes was found promising (Hunter *et al.* 1969). And dipping them in 2-aminobutane carbonated solution (1-% ai) or fumigating them with 2-aminobutane were also effective. Spaying systemic fungicides like Benomyl (500 ppm) and TBZ (0.05%) (Bolkan *et al.* 1976) as well as hot water treatment (50°C) for five minutes, followed by Benomyl(500 ppm) offered protection to harvested fruits (Brodrick *et al.* 1972).

***Botryodiplodia* fruit-rot, c.o. *Botryodiplodia theobromae* Pat.**

The disease has been reported to be common in India (Siradhana and Jain 1962; Prasad and Varma 1970; Sreevastava and Tandom 1971; Philip 2002). The fungus incites stem-end-rot and fruit-rot. Symptoms of this disease can be confused with those of *Ascochyta*-rot. Temperature of 25 to 30°C with high relative humidity favour development of diseases on papaya (Om Gupta and Neema 1979).

Symptoms : They appear as water-soaked lesions around the injuries. Infection spreads to surrounding areas, and soon affected portion becomes shrivelled and turns dark-brown. Infected fruits get covered with fungal growth completely within 5-7 days,. Numerous pycnidia of the pathogen appear after seven days (Philip 2002). And infection of the fruit-stalk results in fruit drop. Infected fruits showed reduction in ascorbic acid content (Ghosh *et al.* 1966).

Control measures : Hot-water treatment at 49°C for 20 minutes protects against this rot.

***Fusarium*-rot, c.o. *Fusarium* spp.**

Raabe (1964) reported post-harvest dry fruit-rot decay due to *Fusarium solani*. This rot was recorded from Bengal (Chattopadhyay and Mustaffee 1967). *Fusarium acuminatum*, *F. equiseti* and *F. oxysporum* were recorded from Allahabad markets and orchards (Bihari Lal and Arya 1980). Gupta and Pathak (1988) observed *F. equiseti*, *F. moniliforme*, *F. oxysporum*, *F. scripi*, *F. semitectum* and *F. tabacinum* along with several other fungi causing rot. *F. equiseti* was also reported by Saxena and Saksena (1984).

Symptoms : Affected fruits show small surface lesions with profuse white hyphae. Bihari Lal and Malaviya (1994) observed severely fruit-rot affected fruits from Allahabad markets. The disease appears as water-soaked, light brown spots, which enlarge and eventually turn black. The whole fruit rots within 10 days. Pulp rotting is faster than rotting of rind; pulp turns black and emits fermented odour.

Control measures : Hot-water treatment (49°C for 20 minutes) was reported to be effective. Aureofungin (1,000 ppm) was promising in controlling the disease (Pathak and Sekhawat1976; Prasad and Verma 1980).

***Phomopsis* fruit-rot / brown crack-rot,**c.o. *Phomopsis caricae papayae* Petrak and Cif.

The disease was recorded from Madhya Pradesh (Dhingra and Khare 1971; Mishra and Kumar 1987). The fruits were infected while still on the plant. Post-infection changes in sugar content were recorded by Dhingra and Khare (1974).

Symptoms : Infection appears in storage as water-soaked lesions, which gradually increase in size. Spots then depress and turn brown to black. Whole fruit becomes soft and pulpy and cracks at the later stage. In some fruits, rotted portion gets surrounded by raised tissue, white in colour.

Control measures : Borax (2%), Benlate (500 ppm), Captan (0.2%), Difolatan (0.2%) and Dithane M-45 (0.2%) applications are effective in containing disease on the detached fruits.

Fruit-rot / hard black pimples, c.o. *Macrophomina phaseoli* (Maubl.)

The disease was reported from Punjab (Kapur and Chohan 1968, 1974) and Bihar (Mishra and Kumar 1987). The rot is responsible for 5-20% losses during summer.

Symptoms : Infection starts as small, water-soaked spots, which appear as circular specks on the fruit surface. The spots gradually enlarge and become sunken. Infected fruits turn brown to black with disintegration of internal contents. Finally, affected tissues harden, and black microsclerotia are clearly visible. Kapur and Chohan (1974 a) observed maximum decay of fruits at 30°C with 100% RH. Rotting at 30°C and at relative humidity between 60 and 90% was also severe. Pricked surface was more conducive to rapid infection and disease development compared to deeply cut or wounded surface.

Control measures : Ziram (76% zinc dimethyl dithiocarbamate), Captan (50% N-trichloro methyl thio tetrahydrophthalimide) and Ferbam (76% ferric dimethyl dithiocarbamate) were found efficient protectants against fruit-rot in *in-vitro* studies (Kapur and Chohan 1974).

Pink-rot, c.o. *Neurospora crassa* Shear & B.O. Dodge

The disease was reported from Uttar Pradesh. Infected fruits showed soft-rot on the fruit-surface. And the infected areas were pink, soft and pulpy (Tandon and Srivastava 1974). No specific control measures are available.

Fruit-rot, c.o. *Stemphylium lycopersici* (Enjoji) Yamamoto

The disease was observed on cold storage fruits in Hawaii.

Symptoms : Dark-brown sunken lesions appear with distinct reddish-brown margins. The pathogen infects fast wounded fruits, and symptoms appear usually after extended cold storage (7-21 days). Lesion size and disease incidence reduces when storage temperature decreases to 4°C (Chau and Alvarez 1983).

Control measures : Wounded fruits should not be stored. Cold storage of fruits should not be encouraged beyond 21 days. Storage at 4°C is considered effective.

***Aspergillus-* and *Penicillium*-rots**

Saxena and Sharma (1981) recorded *Aspergillus niger* and *A.flavus* while Gupta and Pathak (1988) and Philip (1998) observed *A.niger*, *A.flavus*, *A.fumigatus*, *A.nidulans*, *A.tamaritii* and *A.terreus* from infected fruits.

Symptoms : On fully ripened and injured fruits, symptoms of *A.niger* appear at first as water-soaked spots. These spots enlarge to about 2-3 cm in diameter within 2 days and their centre turns black due to the presence of profuse conidial heads, surrounded by scanty white fungal growth. The whole fruit decays within 5-7 days with profuse exudation of sap.

Penicillium spp. are also recorded to cause rotting; these include *P. funiculosum* and *P.citrinum* (Saxena and Sharma 1981), *P.islandicum* (Gupta and Pathak 1988) and *P.implicatum* (Albornettn and Sanabria 1994) and *Penicillium* sp.

Control measures : Fruits should be handled carefully to avoid wounds and bruises. Storage under refrigerated conditions help prolong storage life. Hot-water treatment as detailed under *Botryodiplodia*-rot is also applicable here.

***Corynespora* fruit-rot, c.o. *Corynespora cassiicola* Curt. & Wei.**

The disease is rarely observed in orchards. The disease was recorded by Mary (1998) from Kerala.

Symptoms : The tip of the fruit becomes dry black and shrunken resembling cigar-end disease of banana. The symptoms originate on immature fruits and are carried on mature fruits during storage (Fig. 11.2). The lesion becomes brown and the surrounding area is yellow in colour. On mature fruits symptoms are noticed anywhere on the fruit surface (Fig. 11.3).



Fig. 11.2. Fruit-rot on immature papaya (*Corynespora* fruit-rot)



Fig. 11.3. *Cornespora* fruit-rot symptoms on the mature papaya-fruit

OTHER ASSOCIATED PATHOGENS

| Pathogen | Authority |
|---|--|
| <i>Chaetomium globosum</i> | |
| <i>Curvularia lunata</i> (<i>Cochiliobolous lunatus</i>) | Prasad and Verma, 1976 |
| <i>Cylindrocarpon tonkinense</i> | |
| <i>Helminthosporium spiciferum</i> | |
| <i>H. rostratum</i> | Mishra and Kumar, 1987 |
| <i>Drechslera papendorfii</i> } | |
| <i>Paecilomyces carioti</i> } | Saxena and Sharma, 1981 |
| <i>Trichothecium roseum</i> | Saxena and Jain, 1981; Vyas, 1984 |
| <i>Memnoniella echinata</i> | Bihari Lal and Rai, 1978; Rai <i>et al.</i> , 1982 |
| <i>Hyalodendron</i> sp. } | |
| <i>Ceratocystis</i> sp. } | Arya <i>et al.</i> , 1986 |
| <i>C. paradoxa</i> | Tewari <i>et al.</i> , 1988 |
| (<i>Drechslera</i> state) | |
| <i>Cochilibolus spicifer</i> | Gupta and Pathak, 1988 |
| <i>Cladosporium</i> sp. | |
| <i>Cercospora</i> sp. } | Albornettn and Sanabria, 1994 |
| <i>Corynespora cassiicola</i> } | Quimio and Abilay, 1979 |
| <i>Guignardia</i> spp. } | |
| <i>Rhizoctonia solani</i> | |

Immature fruit rotting due to *Cladosporium oxysporum* was reported from Gujarat (Khandar *et al.* 1994). The symptoms appeared as pinkish brown growth on the fruit-stalks.

BACTERIAL DISEASES

They may cause sporadic damage to papaya-fruit. External symptoms are absent. The disease can be observed when the fruit is cut open. Purple stain is caused by pigment-producing strains of *Erwinia herbicola*. Symptoms include violet to purple streaks in vascular tissues, and in latex ducts surrounding seed cavity.

Another disease known as internal yellowing is caused by *Enterobacter cloacae*. The infected fruit-pulp becomes translucent with a bright yellow-lime green discolouration. Due to lack of external symptoms, the mode of infection and spread are not understood properly (Alvarez and Nishijima 1987).

POST-HARVEST DISEASES MANAGEMENT

The fruits have limited shelf-life, and a range of storage temperatures have been reported for different cultivars. Papayas at 10 and 15°C can be stored

for 16 days (Azi-Abou *et al.* 1975); 12°C was also recommended (Arriola *et al.* 1980). If temperature is above 20°C, fruits are liable to be infected by fungal pathogens and below 10°C may have chilling injuries. Low temperature storage (10-15°C) with controlled atmosphere (2% O₂, 5% CO₂ at 16°C) extends storage life by two weeks.

Packing fruits in a single layer in bamboo-baskets after putting sawdust as a lining material and covering fruits with a layer of paddy-straw is desirable for long distant marketing.

Wrapping in polymeric films, use of senescence inhibitors, wax-coating of fruits and gamma irradiation increase shelf-life of harvested papayas (Mitra1997).



CHAPTER 12

Peach (*Prunus persica* (L.) Batsch.)

Peaches, plums and apricots are included under drupe or stone fruits. These crops are mainly grown in Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh.

Peaches are recommended for low cholesterol, low fat and also for low sodium, and as a part of diabetic diet. It is a rich source of vitamins, calcium and potassium.

FUNGAL DISEASES

Brown-rot / blossom blight, c.o. *Monilinia laxa* (Aderh. & Ruhl.)

M. fructigena (Aderh. & Ruhl.) Honey

Symptoms : They appear as small, circular brown spots on fruits; observed frequently around wounds caused by insect bites. One to many spots may appear on a single fruit. The rot develops rapidly as fruit matures. The outline of the spots remains circular but the colour turns to light brown. And the surface remains smooth, not sunken. The rotten flesh becomes soft compared to healthy surroundings. Sooner rotten areas are covered with ash-coloured tufts of mycelia damaging fruit skin. The conidial mass gives fruit a brownish-grey appearance. The fruit rots entirely before the appearance of the first tuft, while in plum and pear it may appear within a day or two. The fruit-rot is most severe in peach compared to plum and pear.

The fruits may retain their form and remain attached to tree even after complete rotting, and then gradually dry into a firm mummy (Anderson 1956).

Control measures : Sanitation is important. Proper pruning and removal of mummified fruits attached to trees are important to be carried out periodically.

Spraying Captan 50WP (300g/100 litres of water) about three weeks before harvest helps in controlling infection during storage. Use of fungicides causes many problems like microbial resistance, environmental pollution and fruit contamination.

Dipping fruits in hot-water maintained at 60°C for 40 seconds and in sodium bicarbonate (SBC 2%) for 40 seconds is commonly practised.

Biological control with extract of herb *Coptis chinensis* (common name:

Huang Lian) at 50% concentration (EC 50) exhibited strong inhibition of *M. fructicola* (Hou Dong *et al.* 2010). Antagonistic bacterium CPA-8 (*Bacillus subtilis* species complex) at 10^7 or 10^8 cfu/ml was also effective (Cascales 2010).

Gamma radiation at a total dose of 125-150 Krad was reported to be promising (Beraha 1964).

Rhizopus-rot / whiskers-rot*, c.o *Rhizopus stolonifer
(Ehrenb.) Vuill.

This is reported to be a serious rot of peach in transit and storage. The fungus spreads rapidly through containers. Often a single infected fruit results in rotting of the entire lot if the temperature is above 50°F or 60°F.

Symptoms : Infection appears as water-soaked spots on the skin and enlarge rapidly to greater part of the fruit. In the advanced stages, fruits are covered with mycelial growth. Black fruiting bodies are produced in abundance. The mycelia can be seen extending out into spaces between fruits and container.

Control measures: Cuts and bruises on the fruit surface should be avoided.

Pre-harvest application of 2,6-dichloro-4-nitroaniline (DCNA 1,000 ppm) helps control storage rots. Dipping fruits in a solution of sodium ortho-phenyl phenate (SOPP, 0.2%) and 2,6-dichloro-4-nitroaniline (100 ppm) was effective against *R.stolonifer* (Eckert and Sommer 1967).

Peaches treated with hot-water or hot-water suspension of 2,6-dichloro-4-nitroaniline (DCNA) and Benomyl (both at 100 ppm) showed lesser symptoms of *Rhizopus* and brown-rot than those treated with unheated water (70°F). Unheated suspension of DCNA or Benomyl did not control decay. Chemicals suspended in hot-water (115°F) gave better control than hot-water treatment at 115°F (Smith 1971). Pre-cooling and maintaining low temperature (below 7°C) in transit and storage are preventive for rapid disease spread.

Biological control with bacterium (*Enterobacter coloaecae*) was reported under *in-vitro* studies. Bacterial suspension was applied to fruit-surface using a nylon bristled paint-brush. *R. stolonifer* concentration was adjusted to 10^3 - 10^5 spores/ml. Its growth was inhibited by *E.coloaecae* in 70% of the fruits, and onset of the fruit-rot slowed down in the remaining. The treatment was comparable to Dichloran application @12g/100ml of water (Wilson *et al.* 1987).

Biological control with the yeasts, *Kloeckera apiculata* and *Candida guilliermondii*, has been reported. Former yeast strain was found more effective.

Naturally infected fruits sprayed/inoculated with 10^3 sporangiospores/ml immersed in yeast *Kloeckera apiculata* suspensions @ 5×10^8 cfu/ml reduced decay due to *Rhizopus*-rots (Mc Lauglilin *et al.* 1992). It was more effective when the yeast was applied as an aqueous suspension in 2% CaCl_2 .

Powdery-mildew, c.o. (*Sphaerotheca pannosa* (Wallr.) Lev.

This is reported as the most destructive and common disease of peaches in Egypt. In India, it occurs wherever peaches are grown.

Symptoms : They appear on leaves, young shoots and fruits. On fruits, white, round spots appear. The fruits turn pinkish and finally dark-brown. Due to infection, fruit epicarp becomes leathery and hard.

Control measures : The disease can be controlled by spraying with sulphur compounds (any dithiocarbamate at 0.25% concentration) in orchard as pre-harvest spray.

Blue mould-rot, c.o. *Penicillium expansum* Thom.

Symptoms : Lesions are circular, soft and pale-brown. On peaches and apricots, there is usually a dense mass of spores.

Control measures : Prevention of physical injuries is important. Prompt cooling and storage under controlled atmosphere (CAS) helps prolong storage life.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism |
|---------------------------|---|
| Black mould-rot | <i>Aspergillus niger</i> Van Tieghm. |
| Mucor-rot | <i>Mucor piriformis</i> Fischer |
| Phomopsis-rot | <i>Diaporthe pernicioso</i> E.L. Marchal & E.M. Marchal |
| Scab | <i>Venturia carpophila</i> Fischer |
| Botryodiplodia-rot | <i>Botryodiplodia theobromae</i> Pat. |
| Pink mould-rot | <i>Trichothecium roseum</i> Link. |
| Alternaria-rot | <i>Alternaria</i> sp. |
| Grey mould | <i>Botrytis cinerea</i> Pers. |
| Cladosporium-rot | <i>Cladosporium</i> sp. |
| Pustular-rot | <i>Stigmia carophila</i> (Lev.) Ellis |
| Bacterial-rot | <i>Xanthomonas campestris</i> Dye |

POST-HARVEST DISEASE MANAGEMENT

Post-harvest storage experiments from Turkey have showed use of microwave power as a pre-storage treatment. This was found effective in controlling natural infection. The treatment caused no surface damage to fruits. And quality parameters of fruits also were not impaired (Karabulut and Baykal 2002).



CHAPTER 13

Pear (*Pyrus communis* L.)

Pear-fruit flesh contains stone cells. It is a good source of dietary fibre and vitamin C. Most of the vitamin C and dietary fibres are contained within the fruit-skin. It is a good laxative also.

FUNGAL DISEASES

Blue mould-rot, c.o. *Penicillium expansum* Link.

Blue mould is one of the most destructive rots of stored pears. It is an important disease of all pear-producing countries — USA, UK, Poland, Israel, Australia and India.

Symptoms : First soft, watery, brown spots appear, which undergo rapid enlargement between 20°C and 25°C. There is a distinct margin between the soft-rotted flesh and firm healthy tissue. In humid areas, masses of blue-green spores are noticed on the surface of lesions. The fungus can spread into neighbouring healthy fruits forming 'nests' of decay (Snowdon 1990).

Control measures : Careful handling and strict hygiene in orchards and packing houses needs to be practised. Squashed and rotted fruits should be destroyed before they become a source of infection. Washing water should be frequently changed and disinfected.

Storage under controlled atmosphere (CAS) helps prolonging shelf-life.

***Rhizopus-rot, c.o. Rhizopus stolonifer* (Ehrenb.) Vuill.**

R. oryzae Went & Prinsen Geeligs

Symptoms: Infection appears as water-soaked spots on the skin, which enlarge rapidly to a greater part of the fruit. The flesh becomes soft and watery. In later stages, strands of coarse white or grey growth cover surface of collapsing fruit.

***Mucor-rot, c.o. Mucor piriformis* Fischer**

The disease is of greater importance in Canada and USA.

Symptoms : Lesions are noticed at the stem-end or calyx-end or in core region or anywhere on the fruit. Affected fruits turn dark-brown and flesh beneath becomes soft and watery. In humid atmosphere, profuse production of mould strands is seen.

Control measures : Orchard hygiene is important. Harvesting in wet weather should be avoided. Boxes and bins must be cleaned periodically. Gentle handling is important to minimize incidence of wounds. In storehouses, 95% RH is desired, but saturated atmosphere need to be avoided.

Brown-rot, c.o. *Monilinia laxa* (Aderh. & Ruhl.) Honey

Development of small, circular spots appear on the fruit. Under humid conditions, tufts of white mycelial strands break through the skin, and fungus spreads to adjacent healthy areas.

Control measures are *detailed under Apple*.

***Aspergillus-rot, c.o. Aspergillus japonicus* Saito**

The disease is characterized by brown, water-soaked spots, which expand rapidly and disorganize fruit tissue within 4-5 days (Prasad 1938).

***Curvularia-rot, c.o. Curvularia lunata* (Wakker) Boedijn**

Cochliobolus lunatus R.R. Nelson & Haasis (1964)

Affected fruits show small, deep-brown spots, scattered all-over the surface. And the spots coalesce soon, and whole fruit is spoiled within short time.

The disease can be checked by dip treatment of fruits with sodium ortho-phenyl phenate (SOPP) at 0.25% concentration (Vir *et al.* 1975).

***Alternaria-rot / core-rot, c.o. Alternaria alternata* (Fr.) Keissler**

The disease was reported from Israel (Prusky and Ben-Arie 1981). It was identified on fruits imported from China into UK (Snowdon 1990).

Symptoms: Dark-grey mould colonizes the core cavity and proceeds to rot the surrounding flesh. Tissues that suffer physical injury are often invaded, resulting in skin blemishes. The lesions may be small black and corky or shallow dark coloured (Snowdon 1990).

Control measures: Fungicidal spray at blossoming stage *as detailed in Apple* is reported to be effective. Post-harvest dip or drenching with fungicides also help control storage rot. The fungicide Imazalil at 1,000 mg/ml inhibited development of *Alternaria-rot* in apples at 0°C and in naturally infected pears at 1°C (Prusky and Ben-Arie, 1981).

Bitter-rot, c.o *Glomerella cingulata* (Ston.) Spauld. & Schrenk.

Symptoms appear as small, brown spots on the fruit skin; they are often sunken slightly. In white-rot, flesh becomes soft and fruit may have a bleached or cooked appearance with drops of liquid on the rotted area.

Control measures are *as detailed under bitter-rot of Apple*.

Cylindrocarpon-rot, c.o. *Cylindrocarpon* sp.

The disease is of minor importance, and was reported from Australia (Mc Cartney, 1967). Lesions may occur at the calyx-end in the form of an eye-rot or anywhere on the fruit-surface. The rot is brown coloured, sunken, and has a definite margin.

Fruit-rot can be controlled by orchard spraying with fungicides *as detailed in Apple*.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|-----------------------------|---|---|
| Bull's eye-rot/ | <i>Pezicula malicorticis</i> (Jacks.) Nannf | |
| Gloeosporium-rot | Conidial state: <i>Gloeosporium Perrenans</i> Zeller & Childs | |
| Phacidiopycnis-rot | <i>Phacidiopycnis malorum</i> | |
| Phytophthora-rot | <i>Phytophthora cactorum</i> (Lebert & Cohn)Schoert | |
| Scab | <i>Venturia inaequalis</i> (CKe.) Wint | |
| Physalospora-rot | <i>Physalospora obtusa</i> | Sreevastava and Tandon, 1969b |
| Black-rot/ white-rot | <i>Botryosphaeria obtusa</i> (Schwein) Shoemaker (<i>Dothiorella gregaria</i> Sacc.) | Crosse and Bennett, 1951; Combrink <i>et al.</i> , 1984 |
| Phomopsis-rot | <i>Diaporthe pernicioso</i> El. Marchal & Em. Marchal | |
| Grey mould | <i>Botrytis cinerea</i> Pers. | |
| Mucor-rot | <i>Mucor piriformis</i> Fischer | |
| Rhizopus-rot | <i>Rhizopus oryzae</i> Went & Prinsen Geerlings, <i>R.stolonifer</i> (Ehrenb.) Vuill. | |
| Bacterial fruit-rot | <i>Erwinia aroidea</i> (Twonsend) Holland | Chakravarti and Rangarajan, 1966 |

CHAPTER 14

Pineapple

(*Ananas comosus* (L.) Merr.)

Pineapple is an important commercial fruit-crop in India. Owing to its great demand, area under its cultivation is increasing to a great extent. Next to mango, banana and citrus, pineapple is the most consumed fruit on the worldwide basis. It is a good source of vitamin C and is rich in carbohydrates, sugars and minerals (Ca, P, K). Pineapple contains proteolytic enzyme bromelain, which breaks down proteins.

FUNGAL DISEASES

Basal-rot / fruit-rot / soft-rot / stem-end rot/

Black-rot / water-rot / water blister-rot,

c.o. *Chalara paradoxa* (De Seynes) Sacc.

syn. *Thielaviopsis paradoxa* (De Seynes) Hohn.

Ceratocystis paradoxa (Dade) C. Moreau.

The disease occurs in all major pineapple-growing areas. In India, the disease was first recorded by Chowdhury (1945) and later by Jamaluddin *et al.* (1975). Singh and Prasad (1984) reported a similar fruit-rot from Nagaland. The disease was reported from the Philippines, Fiji (Campbell 1926), Australia (Dickson 1929; Simmonds 1931; Mc Knight 1941), Puerto Rico (Liu and Rodriguez 1973), Hawaii (Cho *et al.* 1977), Nigeria (Adisa and Fajola 1982), Sri Lanka (Liyanage and De 1982) and several other countries.

The fungus survives on plant debris in the soil in the form of thick-walled resting spores (Chalmydospores). Infection may occur before harvest through insect punctures or growth cracks. Usually fungus gains entry through cut stem or through wounds sustained during handling. Disease becomes severe when fruits are harvested after prolonged rains (Mandal 1981). Temperature around 21-32°C favours disease and below 10°C retards it.

Disease severity depends on the degree of bruising or wounding during harvesting and packing. The level of inoculum on the fruit and storage temperature during transportation and marketing are important.

Symptoms : They appear on the basal region of the leaves and on fruits (Figs 14.1, 14.2). Initially no symptoms are apparent on fruits. But when the fruit is cut open, soft decay is seen at the side or at the base. Affected tissues become water-soaked and their colour changes from dark-yellow to greyish-black (Bratley and Mason 1939). The affected fruits continue to rot. Black spores may be produced within the flesh but become prominent when cut tissues are exposed. In the final stages of rot, whole fruit gets covered with spores. Water-soaked lesions, followed by collapse of the fruit with exudation of sap are observed (Alice and Paily 1981).



Fig. 14.1. Basal-rot : Symptoms on pineapple-leaves



Fig. 14.2. Basal-rot: Symptoms on pineapple-fruits

Control measures : The disease can be checked by destroying affected plants. Suckers for propagation should be collected from disease-free areas. Since the fungus is soil-borne, timely disinfection of nursery soil with Brassicol or Vapam and dipping suckers in Bordeaux mixture (2:2:50) or Borax (6%), before planting, protects the crop (Raychaudhuri and Lele, 1970). Systemic fungicides like Benomyl (500 ppm), Carbendazim (0.1%) and Thiabendazole (0.1%) can also be used for treating propagating materials (Sridhar 1975; Cho *et al.* 1977).

Stem-end-rot of fruits can be checked by exposure of harvested fruits to sunlight for 2 hours. Benzoic acid (2.5%) in 30% alcohol and storage at 10-12.5° C was found effective (Bartely and Mason 1939). Sodium ortho-phenyl phenate (SOPP) at 1-5-2.5% as well as salicylanilide at 1% (Le-Grice and Marr 1970) and TBZ 1,000 ppm or Benomyl 2,000 ppm (Sridhar 1975) were promising treatments. Dipping cut-end of the fruit-stalk in 10% solution of benzoic acid in alcohol was reported to be effective (Pathak 1980).

The packing cases and baskets should be treated as a preventive measure. Spraying with 3% Formalin was found effective. Frossard (1978) incorporated Shirlan WS (1%), Imazalil (0.01-0.02%), Bayletan (0.02-0.04%) and Formol (3%) in packing materials, and results were promising. It is important to treat fruits promptly within six hours of harvest.

Disease control was recorded during transport and subsequent storage of fruits after harvest by application of benzoic acid (2.5%) mixed with inert Kaoline in 30% alcohol (Mallikarjunaradhya *et al.* 1979). Cheriyan (1987) and Philip and Cheriyan (1995) reported efficacy of Bavistin 500 ppm (without any residual toxicity) in increasing shelf-life of harvested pineapples up to 21 days.

Under refrigerated storage, fruits remain healthy for 28 days (Cheriyan, 1987; Akamine 1976; Zaldivar 1977). Temperature at 7.5°–12°C with relative humidity at 90-95% are recommended for storage. At 0-4°C, fruits may be stored for weeks, but they may show severe chilling injury when taken out of storage.

Controlled atmosphere conditions (CA storage with 4% oxygen) helps in reducing chilling injury. Application of fruit-wax also helps in generating higher internal concentration of carbon-dioxide (up to 5%) with reduced oxygen tension (Paul and Rohrbach 1982).

Fruitlet core-rot,

c.o. *Giberella fujikuroi* var. *subglutinans* Edward

Fusarium moniliforme var. *subglutin* Wollenw & Reinking

Penicillium funiculosum Thom.

Erwinia ananas Serrano

Pseudomonas ananas Serrano

The disease was reported from most of the pineapple-producing countries like the Philippines (Serrano, 1935), South Africa (Edmonstone, 1958), Australia (Oxenham, 1962), Malaysia (Lim, 1983), Ivory Coast (Mourichon, 1983) and from several other countries.

Symptoms : They appear as light-to-dark brown soft-rot on the axis of individual fruitlets (Fig. 14.3). In cross-section, rot appears as a brown spot in the centre of the fruitlet. The diseased tissue may appear as black and wet or dry depending upon the humidity (Edmonstone 1958).



Fig. 14.3. Fruitlet core-rot of pineapple

Fungal spores are carried into floral cavities by water splash, mites or mealy bugs. Disease incidence is more when a wet period follows a dry growing season.

Control measures : Control of mites and mealy-bugs is important as they can spread the disease from field to field. For control of mites, Malathion/ Ekalux/ Carbaryl @2ml/litre of water two weeks before harvest and for control of mealy-bugs, Chlorpyrifos (0.05%)/ Fenitrothion(0.05%)/Dimethoate (0.05%) /Monocrotophos (0.05%) are recommended as spray (Anon. 2007). Care should be taken that the spray fluid reaches base and side of the plant.

***Botryodiplodia-rot*, c.o. *Botryodiplodia theobromae* Pat.**

Tandon and Bhargava (1962) reported the disease from India. The fungus is a wound pathogen, and infection occurs through wound/cut stem-end. The fungus spreads into pulp and turns it into a brown and water-soaked mass. In advanced stage of infection, mycelial mat with abundant pycnidia is observed.

Avoid wounds and bruises on harvested fruits. Decay can be checked by storage at 10°C.

***Aspergillus-rots*, c.o. *Aspergillus niger* Van Tiegh.
A.flavus Link. ex Fries**

Johnson (1931) reported occurrence of *Aspergillus* spp. along with *Ceatocystis paradoxa* and *Pencillium* sp. from Queensland, Australia. The fungus produces dry-rot symptom. The fruit gets covered with black encrustation of the fungus (Fig. 14.4). Adisa and Fajola (1982) observed dry-rot caused by *A. niger* and *A. flavus* from Nigeria.

Control measures detailed under basal-rot are applicable for this also.

***Penicillium-rots*, c.o. *Penicillium* spp.**

Inter-fruitlet corking and leathery pocket caused by *P.funiculosum* was reported from South Africa and Hawaii (Hepton and Anderson 1968; Lim and Rohrbach 1980). In inter-fruitlet corking, individual flowers may be killed and affected fruit may take an unnatural glossy appearance with corky formations between fruitlets beneath the skin. Leathery pocket is characterized by cork formation at the deeper levels in ovaries at the base of the flowers. Mites (*Stenotarsonemus ananas*) disseminate fungus as they visit flowers. The disease is controlled by spraying an acaricide and a fungicide (Grice and Marr 1970). With the application of acaricides, pineapple fruit mite and *Penicillium*-induced fruit disease were reduced significantly.

Dry fruit-rots were also reported due to *P.claviforme* (Adisa and Fajola 1982) and *P.italicum* (Cheriyana1987). Fruits rot within seven days with visible growth of fungal spore masses on the fruit-surface.



Fig. 14.4. *Aspergillus-rot* on pineapple

Rhizopus-rot / soft-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs
R. stolonifer (Ehrenb.) Vuill.

The disease was reported by Adisa and Fajola (1982) from Nigeria, and accounted for 93% of losses along with *Ceratocystis paradoxa*. The rot was reported from Kerala also. Irregular brown lesions appear first over fruit-surface, then result in rotting of flesh.

Soft-rot due to *Mucor hiemalis* was also observed. Water-soaked lesions appear, and the fruit is completely covered with white-cottony growth. The pulp turns brown and juice leaks out with a fermented odour (Cheriyian 1987).

Control measures : Avoid injuries or bruises on fruits during harvesting, transporting and storage. Low temperature (10°C) prolongs storage life.

BACTERIAL AND YEAST DISEASES AND CHILLING DISORDERS

Bacterial soft-rot / fruit collapse, c.o. *Erwinia chrysanthemi*

The disease was reported to be indigenous to Peninsular Malaysia. Infection by bacterium occurs at flowering. Bacteria enter into the ovary via style and cause limited water-soaked necrosis at the base of the stylar canal within fruitlet core and remain quiescent for about two months without external symptoms. The latency of bacteria within the fruitlet core of young fruits is attributed to high polyphenol oxidase activity. Then rotting proceeds rapidly and fruits collapse within a day or two either before or after harvest. Varietal susceptibility was also recorded (Lim and Lowings 1979, 1979 a).

Occurrence of *Erwinia* sp. causing dry-rot of pineapple was also reported from Brazil (Melo *et al.* 1974).

Control measures : Bacteria are carried by pollinating insects. Lim and Lowings (1979 b) suggested that disease can be effectively controlled by spraying plants at the onset of flowering with Ethephon (2-chloro-ethyl-phosphonic acid). This restricts insects from visiting flowers.

Pink disease

It was originally described from Hawaii (Lyon 1915). Losses due to the disease were reported from Hawaii (Rohrabach and Pfeiffer 1976; Gossele and Swings 1986), the Philippines (Kontaxis and Hayward 1978), and several other countries. The disease so far has not been reported from India. The nature of pink-colour formation in pineapple-fruits has not been understood properly.

A myriad of bacteria associated with pineapple-plants have made identification of pink disease extremely difficult. The cycle of the disease is still unsolved. Four bacterial isolates representing three genera — *Gluconobacter*, *Acetobacter* and *Enterobacter*—cause pink disease in pineapple-fruits with slightly different symptoms. *Gluconobacter* symptoms are characterized by a 'cantaloup-like aroma' and a light to bright pinkish coloured raw fruit-flesh. *Acetobacter* infected fruits have no aroma but are light-to-dark

brown, and *Enterobacter* infected ones do not exhibit any pink or brown discolouration in infected tissues. All types produce dark browning of fruit-flesh on cooking. The *Enterobacter* was the most virulent and virulence varied significantly depending upon the harvest period, cultivars and isolates (Rohrback and Pfeiffer 1976). Attempts to identify causal agents with regard to their optional growth properties revealed the following bacteria (Cho *et al.* 1980): *Gluconobacter oxydans*; *Acetobacter aceti*; *Erwinia herbicola*.

Goossele and Swings (1986) identified *Acetobacter liquefaciens* from Hawaii and the USA to be associated with a pink-brown discolouration during canning process. But using molecular/genetical approaches, causal agent was identified as *Pantoea citrea* (Cho *et al.* 1997). The disease cycle is not fully understood.

The bacterium is transmitted through flower-visiting insects, and gains access to fruits through numerous florets. Pink disease is severe only if flowering takes place during the wet weather immediate after a long dry spell.

Symptoms : Pink-disease symptoms are difficult to observe in the field as outward symptoms are not apparent. Even on the foliage, no visible symptoms are noticed. In severe cases, translucent appearance on sub-dermal fruit tissues is observed. Common symptoms appear when infected fruit preparations are heated during canning process. Heating results in the formation of red-to-rusty brown colouration to golden yellow tissues (Kado 2003).

Biochemical basis of the red colour formation in pineapple-juice and fruit can be attributed to the ability of *Pantoea citrea* to oxidize glucose into 2, 5 di-ketogluconic acid via two-step conversion (Pujol and Kado 1988, 1999, 2000). End-product heating results in the formation of a dark-red colour.

Control measures : At present, controlling this disease is relatively expensive since multiple applications of insecticides are necessary to maintain low levels of disease incidence.

Kado (2003) gave the following suggestions.

- Plant genetic engineering strategies need to be considered. Genes are used to lower substrate that leads to 2,5-di ketogluconate formation, and genes used to inhibit growth of *P.citrea* in fruit tissues can be incorporated in transgenic pineapple.

Biological control methods. Use of bacterial species that are antagonistic to *P.citrea* can be utilized. The most promising isolate is *Bacillus gordonae* 206 IR (1); this reduced disease incidence in combination with insecticides.

Yeasty-rots

This rotting is associated with ripe-fruits. Davies (1928) had isolated *Saccharomyces* sp. from decayed pineapple-fruits from South Africa. Yeast invades fruits through injuries on the fruit-surface and results in fermentation of flesh. Due to which gas may be formed, and juice may bubble out. Internal content of the fruit becomes spongy and fibrous. Some yeasts may cause glassy

spoilage with distinct aroma (Linford 1952). Mandal (1981) reported putrefication of fruitlets into a soft spongy mass with liquid oozing out with a strong fermented odour; unidentified yeast was found associated.

Control measures : Injuries and bruises during harvesting, handling and storage are to be avoided. Exposure of harvested fruits to sunlight for 2 hours offers protection.

Chilling disorder [Black heart (Endogenous brown spot)]

The disease manifests as a chilling disorder in summer fruits following three days storage (temperature at 21°C). Storage at 25°C was found promising (Smith 1983).

POST-HARVEST MANAGEMENT

Storage at 21°C along with wax-coating increased shelf-life by 12 days in pineapple cv. Kew. Cold storage at 10-13°C and 85-90% RH has been found suitable. Controlled atmosphere storage (CAS) conditions at temperature of 10-15°C, O₂ 2.5%, and CO₂ 5-10% was effective (Burden 1997).



CHAPTER 15

Plum (*Prunus domestica* L.)

Plums are sweet and juicy, contain several antioxidants, and are known for their laxative property; attributed to the presence of dietary fibres, sorbitol and Isatin in fruits.

FUNGAL DISEASES

Brown-rot, c.o. *Monilinia fructigena* (Aderh & Ruhl.) Honey (*Sclerotinia fructigena*)

The fungus causes blossom blight, twig blight and fruit-rot.

Symptoms : They are noticeable as fruit approaches maturity. The fruit-rot is severe in peaches but is very destructive in plums. Symptoms appear as small, circular, brown spots, frequently originating on the slight wounds, caused by insects. One to many spots may appear on a single fruit. Rot develops rapidly. Rotted flesh becomes soft compared to surrounding areas but not watery as in *Rhizopus*-rot. Then rotted areas are covered by ash-coloured tufts of fungi. And pustules are numerous and cover entire surface of fruit. Pustules are pronounced in plums than in peaches. The fruit retains its form and remains attached to the tree as a 'firm mummy'.

The disease causes more damage in the storehouse than in the field.

Control measures : Sanitation in the orchards is of utmost importance. Remove mummified fruits and other sources of inoculum.

Application of Captan 0.2% to trees three weeks before harvest helps in controlling storage rots.

Plum-rot, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.

The rot was first recorded in India by Bhargava and Gupta (1957). Symptoms and control measures are as detailed under *Rhizopus*-rot of peach.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism |
|-----------------------|--|
| Anthracnose | <i>Glomerella cingulata</i> (Stonem.) Spauld. & Schrenk. |
| Blue-mould | <i>Penicillium expansum</i> Thom. |
| Grey-mould | <i>Botrytis cinerea</i> Pers. |
| Pustular-rot | <i>Stigmina carophylla</i> (Lev.) M.B. Ellis |
| Alternaria-rot | <i>Alternaria</i> sp. |
| Powdery mildew | <i>Sphaerotheca pannosa</i> (Wallr. Fr.) |

CHAPTER 16

Pomegranate (*Punica granatum* L.)

Pomegranate, also known as 'Anar' is one of the most favourite fruits of the tropical and subtropical regions. In India, it is cultivated commercially in Maharashtra, Andhra Pradesh and Karnataka. Its dried seeds are widely used as a condiment. The fruit and the peel are valued for medicinal properties. Fruits contain tannins, proteins, fats, carbohydrates and minerals like calcium, phosphorus, magnesium, iron and vitamins like thiamine, riboflavin, niacin and nicotinic acid.

FUNGAL DISEASES

***Phomopsis* fruit-rot, c.o. *Phomopsis aucubicola* (Brunaud) Grove**

The disease was noticed on the stored fruits, and it spreads through seeds (Verma *et al.* 1982).

Symptoms : The disease starts from calyx-end and gradually spreads over the entire fruit. Pycnidia are noticed in abundance on fruits.

Control measures : Remove affected fruits and shoots at periodical intervals. Spraying with Dithane Z-78 (0.2%) at bi-weekly intervals after fruit-set controls disease.

***Aspergillus* fruit-rot, c.o. *Aspergillus* spp.**

Several species of *Aspergillus* are found associated with fruit-rot on pomegranate—*A. fumigatus* Fries, *A. awamori* Nakezawa, *A. niger* Van Tiegh. (Sinha 1946 ; Anon. 1950; Srivastava *et al.* 1964). Srivastava and Tandon (1971, 1971a) recorded *A. flavus* Link. from Kanpur and Jodhpur. Philip (1979) recorded *Aspergillus*-rot due to *A. niger* from Thiruvananthapuram in the consignments delivered from Bengaluru. Sharma *et al.* (1981) observed two other *Aspergillus* spp.—*A. niveus* and *A. versicolor*.

Symptoms : The infected tissues turn soft and dark in colour. Sooner these are covered by mycelial growth and black/green spore masses. The diseased tissues shrink and get disintegrated after 15 days. The rotten fruits emit a fermented odour.

***Penicillium* fruit-rot, c.o. *Penicillium* spp.**

Penicillium fruit-rot by *Penicillium purpurogenum* was reported by

Shrivastava *et al.* (1993). Infected tissues become soft and fruit-surface gets covered with bluish powdery growth.

And fruit-rot caused by *Penicillium herquei* Bain was reported on wild pomegranate from Jammu and Kashmir (Seema and Sharma 2009).

***Cladosporium* fruit-rot, c.o. *Cladosporium oxysporum* Berk. and Curt.**

In the initial stages, diseased fruits develop orange-red to dull-brown circular spots, and infected grains become olive-brown. In the advanced stages of infection, entire fruit rots (Panwar and Vyas 1974).

Fruit- rot, c.o. *Pestalotiopsis versicolor* (Speg.) Steyart

The disease is characterized by minute brown- to rust- coloured spots on the fruits. These spots coalesce and with the advancement of disease, necrotic patches are formed. The central portion gets depressed inward with raised margins. In case of severe infection, rind is torned open and fungus penetrates deep into the fruit, causing discolouration of seeds (Utikar *et al.* 1980).

Anthracnose, c.o. *Glomerella cingulata* (Stonen.) Spauld.

The disease may appear at the distal end or at anywhere on the fruit as discoloured area. The infected areas rot within a week.

Black grain-rot, c.o. *Alternaria solani* Ell. & Martin

The disease was reported from Rajasthan. The symptoms appear as light-brown spots around cracked areas. The fruits become pulpy and the grains become black. The disease is of minor importance.

***Coleophoma* fruit-spot, c.o. *Coleophoma empetri* (Rost.) Petrak.**

The disease was reported from Maharashtra (Sherkar *et al.* 1980; Rao and Pandey 1992).

Symptoms : On fruits, symptoms develop as numerous, minute, circular tan brown spots, which turn dark in advanced stages. The spots coalesce and form irregular depression and hard necrotic lesions. Lesions are restricted to epidermis that bears black roundish pycnidia.

***Rhizopus*-rot, c.o. *Rhizopus arrhizus* Fischer**

The symptoms appear as minute spots that increase in size, coalesce and covers fruit-rind. The internal content decays into a soft pulpy mass. Fungus grows at a wide temperature range of 10-40°C, but maximum infection occurs between 20 and 30°C and at 80% relative humidity (Kanwar *et al.* 1973; Kanwar and Thakur 1974).

Kanwar and Thakur (1972) recorded effect of ammonium carbonate and sulphur as fumigants on the packing straw. Gibberellic acid (GA) and ascorbic acid, when used as a pre-infection treatment, were effective in inhibiting *R. arrhizus* growth in storage for 10 days (Thakur *et al.* 1974). Potassium

metabisulphite at pre- and post-inoculation trials and borax and sodium metabisulphite at pre-inoculation trials were effective (Kanwar and Thakur 1977).

***Drechslera* fruit-rot, c.o. *Drechslera rostrata* (Drechsler) Richardson & Fraser**

The fruit spot caused by *Drechslera* was reported by Utikar *et al.* (1976) on the variety Muscat. Fruits of all stages can be attacked.

Symptoms appear as numerous small, black spots scattered all-over the fruit-surface. Margin of the spot varies in colour from dark- green to orange. In advanced stages of disease development, spots enlarge and coalesce to form big dark spots. Mild infection is confined to fruit rind. And severe infection may extend up to seeds, and seeds may show discolouration. Lande and Utikar (1978) also made elaborate studies and observed pre-harvest spray with Dithane M- 45 (0.25%) and Captan (0.2%) as effective in checking growth and sporulation of fungus.

Fruit-spot, c.o. *Beltaraniella humicola* Rama Rao

The disease is characterized by black, circular spots, which gradually enlarge and coalesce to form big dark black spots. The infection is restricted to rind and may extend inside to pulp also (Sherkar and Utikar 1982 a).

Acremonium* fruit-rot, c.o. *Acremonium terricola

The disease appears as reddish brown spots; these coalesce together later to form bigger patches and ultimately result in fruit rotting (Mohale and Patil 1993).

BACTERIAL DISEASES

Black-spot, c.o. *Xanthomonas campestris* pv. *punicae*

Hingorani and Singh (Dye)

Symptoms: They are noticed on young fruits as numerous small, segregated, depressed and discoloured spots. The spots gradually increase in size and occasionally coalesce to form large, irregular necrotic patches. With advancement towards maturity, necrotic patches become corky, black and develop into typical cankers with prominent fissures. The cankerous lesions become very prominent on the fruit-surface (Upasana and Verma 2002).

Control measures : Spraying fruits before harvest with Biomycin (0.5%) or Bacteriomycin (0.01%) or streptomycin (0.01%) was recorded as effective in controlling black spot on stored fruits. Bordeaux mixture (1%) was also effective (Vanitha and Suresh 2001).

Streptocycline 500 ppm + copper oxide 2,000 ppm was found promising (Ravikumar *et al.* 2006).

CHAPTER 17

Sapota (*Manilkara zapota* (L.) P. Royen)

Sapota-fruits are highly perishable and cannot be stored for long. Firm fruits can be stored up to eight weeks at 3-5°C with 85-90% RH, and ripe-fruits can be stored at 2-3°C for six weeks (Singh 1969). Low storage temperature can extend shelf-life by reducing oxidative metabolism and ethylene evolution (Lakshminarayana 1980).

FUNGAL DISEASES

Black mould-rot, c.o. *Aspergillus niger* Van Tieghm

This disease occurs during hot summer on injured or over-ripe fruits (Mandal and Dasgupta 1981). Infection progresses more or less radially on the surface. Later black conidial heads cover the fruit-surface and fruits become soft and crack.

Avoid injuries and bruises to fruits. Refrigerated storage at 10°C is found promising.

Green mould-rot, c.o. *Penicillium* sp.

This fungus causes extensive decay and affected tissues become soft and water-soaked. Avoid injuries and bruises to fruits. Refrigerated storage at 10°C is useful.

Brown pedicel-end-rot, c.o. *Botryodiplodia theobromae* Pat.

The disease is considered as one of the serious rots of sapota in storage. The disease was recorded from Uttar Pradesh (Srivastava *et al.* 1964) and from West Bengal (Mandal and Dasgupta 1982).

Water-soaked brown areas appear at the proximal pedicel-end. Edible portions become soft, and juice leaks out with a characteristic fermentative odour; and whole fruit rots within 10-12 days. Maximum decay occurs at about 30°C.

Avoid injuries and bruises to fruits. The disease can be controlled by storage at 10°C. (Srivastava and Tandon 1968).

Pimple-rot, c.o. *Pestalotiopsis versicolor* (Speg.) Steyaert*P. glandicola* (Castagne) Steyaert*P. mangiferae* P. Henn

The disease was recorded from Kota (Gupta and Sehgal 1974) and Kurukshetra (Dhingra *et al.* 1980). Water-soaked brown to dark-brown lesions appear on the fruit-surface; fruit rots within 3-4 days. A small tuft of white mycelia consisting of fluffy growth studded with black acervuli becomes visible on the fruit-surface. Jain *et al.* (1981) recorded it as a minor pathogen from Madhya Pradesh.

Control measures as detailed for *Botryodiplodia*-rot are applicable for this also.

***Phytophthora* fruit-rot, c.o. *Phytophthora palmivora* (Butl.)**

Rao (1968) reported a transit and storage rot due to *P. palmivora* from Maharashtra. The disease appears as irregular water-soaked areas on the major portion of the fruit. The decay is deep, and eventually pulp disintegrates. The infected fruit becomes soft, pulpy, and emits a bad odour. Fungal mycelia are visible on the fruit-surface (Rao *et al.* 1966).

The disease is of minor importance; avoid wounds and bruises to fruits. Infected fruits should not be mixed with healthy ones. Cold storage at 10°C is effective.

Other soft-rots

Soft-rots caused by following fungi were also recorded.

Botryosphaeria dothidea (Mougeot Fries) Cesati & Denotari

B.ribis Jain *et al.*, 1981

Fusarium moniliforme Sheldon

POST- HARVEST MANAGEMENT

Storage in 100- gauge polythene bags with 1-2% vent in paper carton is found effective in enhancing shelf- life of fruits without fungal deterioration.

Cool chamber storage of fruits at $8 \pm 2^\circ\text{C}$ after vacuum filtration with CaCl_2 helps increase shelf-life by 16 days (Reddy and Nagaraju 1993).



CHAPTER 18

Strawberry (*Fragaria chilensis* (L.) Duchesne ex Weston)

Strawberry is a favoured fruit of many nations in the world, is relished for flavour and extensively used in canning industry and in preparation of ice-cream. But fruits are highly perishable in nature.

FUNGAL DISEASES

Grey mould-rot/dry-rot/brown-rot, c.o. *Botrytis cinerea* Pers.

The disease is reported to be serious, and occurs in all places where crop is cultivated. The disease was reported from Israel (Aharoni and Barkai Golan 1987). It is especially prevalent in the regions where rainfall and dew occur frequently during blossoming and fruiting. Though the disease is regarded as a fruit-rot, it often starts as a blossom-blight.

Symptoms : Infection on the berries may occur at any region. Often symptoms appear on the fruit base and originate from the infected calyx. It may appear on the side or tip also. The disease progresses downward through pedicel to main fruit stem, and finally spreads to most of the fruit-cluster. On the fruit, the rot appears as a light-brown soft area that dries later. Under damp weather, fruits get coated with a fine grey fuzzy growth consisting of spore masses with black bodies (sclerotia) in abundance. In advanced stages, fruit shrivels to form a 'mummy'.

Control measures : Sanitation and cultural practices help in controlling disease. Pre-harvest Captan (0.2%) application after flowering, followed by two more applications controlled disease successfully (Anderson 1956).

Pre-cooling and maintaining low temperature (4°C) in transit protects fruits from storage rots.

Chemical method. Dipping harvested strawberries in any of the chemicals—Captan (1,200 ppm), Sorbic acid (2,500 ppm) or Mycostatin (100 ppm), followed by storage under refrigerated conditions was reported to be effective against *Botrytis* and *Rhizopus* rots (DiMarco and Davis 1957).

Biological control. Essential oils of *Satureja* sp. and *Thymus* sp. showed inhibitory effect against fruit-rots caused by *B.cinerea*, *R.stolonifer*, *P.digitatum* and *A.niger*. The oils are often biologically active and possess antifungal and antimicrobial properties (Nabigol and Farzaneh 2008). They also have excellent antioxidant property.

Use of radiations. Gamma rays at 2×10^5 KGY alone or in combination with refrigeration markedly prolonged storage-life of strawberry and delayed development of *Botrytis cinerea* and *Rhizopus nigricans* without visible damage by radiations (Beraha *et al.* 1957).

Rhizopus-rot /leak, c.o. *Rhizopus nigricans* Trow.

R.oryzae Went & Prinsen Geerligs

R.stolonifer (Ehrenb.) Vuill.

Mucor hiemalis Wehmer

The disease was reported by Anderson (1925) during transport, storage and marketing. It is commonly called 'leak' as the juice from the diseased berries stains boxes and leaks out. In shipped berries, it often accounts for over 50% losses.

Symptoms : The disease is characterized by soft watery tissue on the fruit-surface with exudation of juice on a slight pressure. The flesh becomes soft and watery. In advanced stages, strands of coarse white or grey fungus growth can be noticed covering entire surface of the collapsing fruit.

Control measures : Use of a mulch to minimize contact with soil helps in reducing disease incidence on the harvested fruits.

Bruised or injured fruits should be discarded. Over-ripe fruits should not be used for packing.

Pre-cooling and maintaining low temperature (4°C) in transit and storage prevents rapid spread of disease.

Gamma radiations *as detailed under Grey mould-rot are applicable to this also* (Beraha *et al.* 1957).

Essential oil of *Satureja* sp. showed inhibitory effect against fruit-rot caused by *Rhizopus stolonifer* (Nabigol and Farzaneh 2008).

Ripe fruit-rot/anthracnose, c.o. *Colletotrichum fragariae* Brooks

The disease was reported causing serious losses in Australia (Sturgess 1957; Simmonds 1965) and in India (Singh 1974a).

Symptoms : They appear only on the ripe-fruits, characterized by one or more light-brown/black water-soaked lesions on the fruit-surface. As a result of the infection, tissues shrivel and form compact depressed lesions. The lesion colour changes gradually from tan to dark-brown, followed by eruption of pink spore mass from acervuli. In advanced stages, lesions coalesce and produce bigger patches. Symptoms appear only on the fully coloured ripe berries. Unripe fruits do not show any symptoms (Singh 1974a).

Control measures: Hot-water rinsing and brushing (HWRB) at 65°C for 20 seconds on the fruit-surface reduces decay. The treatment has no negative effects on the fruit colour, firmness, soluble solid content and titrable acidity.

Captan and systemic fungicide switch (a.i. Fluudioxonil + Cyprodinil) were evaluated for controlling anthracnose fruit-rot. Both were found effective, but switch was found better (Peres *et al.* 2010)

Calyx-blotch and stem-end-rot, c.o. *Gnomonia fructicola* (Arnaud.) Fall.

Conidial stage : *Zythia fragariae* Laibach.

The disease was reported from the USA, Canada, and from most of the European countries. Symptoms appear as small, brown spots.

***Aspergillus*-rots, c.o. *Aspergillus niger* Van Tieghm.**

Symptoms are noticed on the fruit-surface as small, black pinhead-like dots.

Essential oil of *Satureja* sp. showed prominent inhibitory effect even at very low concentration of 300 ml/litre (Nabigol and Farzanch 2008).

OTHER DISEASES AND CAUSAL ORGANISMS

| Disease | Causal organisms |
|----------------------------------|---|
| Leathery-rot | <i>Phytophthora</i> sp. |
| Black seed disease | <i>Mycosphaerella fragariae</i> |
| Blue-mould | <i>Penicillium cyclopium</i> |
| | <i>P. expansum</i> Westling Thom. |
| Black-mould | <i>Aspergillus niger</i> Van Tieghm. |
| Cottony-rot | <i>Sclerotinia sclerotiorum</i> de Bary |
| <i>Pestalotiopsis</i>-rot | <i>Pestalotiopsis</i> sp. |
| <i>Phomopsis</i>-rot | <i>Phomopsis obscurans</i> (Ell & EV) |
| <i>Pythium</i>-rot | <i>Pythium ultimum</i> Trow. |
| <i>Rhizoctonia</i>-rot | <i>Rhizoctonia solani</i> Kühn |

POST-HARVEST MANAGEMENT

Strawberry fruits immersed in a solution of pomegranate-peel extract with chitosan (1.25%) prolonged storage life by 1-2 days without any deterioration (Zhang *et al.* 2010).



Part – B
**MANAGEMENT OF POST-HARVEST
DISEASES OF VEGETABLE CROPS**

CHAPTER 19

Cucurbits

CUCUMBER (*Cucumis sativus* L.)

The family Cucurbitaceae includes a number of economically important crop-plants like cucumbers, squashes, marrows, melons, pumpkins, chayotes (chow-chow), bittergourd, snakegourd, bottlegourd, ridgegourd, etc. Some of these are eaten raw as salad. Storage life of cucumbers is very short and they are especially prone to moisture loss and decay (Risse *et al.* 1987). At temperature around 12°C, they lose their dark-green colour within a few days and begin to turn yellow (Kanellis *et al.* 1986), and at a very low temperature they are susceptible to chilling injuries.

FUNGAL DISEASES

Cottony-leak/fruit-rot, c.o. *Pythium* spp.

Pythium aphanidermatum (Edson) Fitzp., *P.butleri* Subram, *P.debaryanum* Hesse

Fruit-rot is a common disease of cucumbers (Alice 1969; Singh and Chauhan 1977; Sohi and Rawal 1977; Alice and Paily 1978; Sharma and Sumbali 1993; Philip 1998; Coursey and Booth 1972). It is more severe during rainy season. Even though infection starts in the field, it is important as a storage and transit disease.

The fungus subsists in the soil as oospores, and under favourable conditions infects roots and collar region of the young plants. On the fruits, infection occurs where some injury is on to the skin. *Pythium* spp. generally attack plants in juvenile stage. Tissue hardening prevents their attack and high relative humidity favours rapid disease development. Temperature between 28 and 37°C is ideal for disease development. High moisture, poor aeration and close planting extends juvenile stage of the plants and predispose them to disease (Singh 1992). Fungus growth is observed at 15-40°C but optimum growth is at 30°C.

Symptoms : Fruits in contact with soil get infected through wounds or insect bites. The affected peel portion becomes soft, dark-green with water-soaked lesions. Fluffy / woolly white mycelia grow profusely over wounded surface

(Fig. 19.1). Within 3-4 days, mycelial growth subsides and watery soft-rot develops. Thick viscous fluid oozes out with an offensive smell due to secondary invasion by bacteria.



Fig. 19.1. Cottony-leak on cucumber

Reduction in sugar content and amino acids was recorded in rotten fruits collected from Punjab (Singh and Chohan 1977 a).

Control measures : Decay of the harvested fruits can be checked by storage at 10°C or below. Fungicide spray is necessary at the flowering stage. Irrigation should be appropriately controlled. Excessive moisture favours disease development; so adequate drainage needs to be provided. Care should be taken to minimize injury during harvesting and handling. Avoidance of fruits touching the soil reduces infection. Soil disinfection with formalin in water (1: 50) by sprinkling this on the loose soil to be soaked to a depth of 4", should be adopted. About 1 gallon (4.546 litres) of the mixture will be required for 2-3 ft² (0.185-0.298 sqm) of soil.

Antibiotics and impregnated wrappers were promising for controlling cottony-leak. Pyrimidine fungicides were reported to be effective. They were specific and less phytotoxic. Milstem (Ethirimol) at 625 ppm and Milcurb (Dimethirimol) at 750 ppm showed *in-vitro* inhibition. But under *in-vivo* conditions, Milcurb alone at 3,000 ppm checked development of cottony-leak, when used as a dip treatment (Sharma and Wahab 1973; Wahab and Sharma 1974, 1976).

Sharma *et al.* (1981) reported control of the disease by soil fungi, *Acrophialophora nainiana* and *Stachybotrytis atra*, which possess antifungal activities. Under *in-vitro* conditions, a distinct zone of inhibition towards *Pythium aphanidermatum* was noticed.

Trichoderma harzianum (5×10^9 conidia/ml) mixed with wheat-bran plus peat mixture (1:1 v/v) and applied to the seed-coat controlled efficiently damping-off (Sivan *et al.* 1984).

Treating fruits with Hinkitol, a volatile oil extract from the Japanese Hika tree (*Thujopsis dolabrata*), was reported to protect at 750 ppm with no phytotoxic effects (Aharoni *et al.* 1993).

Anthracnose, c.o. *Glomerella cingulata* (Stonem.) Spauld. & Schrenk.

Colletotrichum gloeosporioides fsp *cucurbitae*

C. lagenarium (Pass.) Ell. & Halst

Serious losses due to anthracnose were reported from several countries, including the USA, Brazil (Menton *et al.* 1979) Netherlands (Arx *et al.* 1961) and India (Laxminarayana and Reddy 1976a; Amin *et al.* 1979).

Symptoms : They develop as conspicuous dark circular spots, often numerous in numbers on the fruit-surface. The lesions become sunken and sometimes fruits show cracking (Fig. 19.2). Under humid conditions, characteristic masses of pinkish spores or conidia are formed. Sometimes due to lesions, fruits may get disfigured. The



Fig. 19.2. Anthracnose on cucumber

fungus is usually confined to the fruit skin; even though the skin is subsequently invaded by saprophytic organisms. *Glomerella magna* is also found associated in certain cases, where it may form concentric rings on the peel. Colonization of the entire fruit was also observed (Jenkins and Winstead 1964).

The fungus survives dormant on the dead plant materials lying in the soil. The fungal conidia are transmitted by insects (Horn *et al.* 1957), rains or irrigation water. Infection is severe particularly after heavy rains (Amin *et al.* 1979). The spores formed on the host are washed by water, splashed by rain-drops or transported by beetles and implements. In the presence of moisture, spores germinate and penetration occurs within three days. The disease development in the fruit is in the epidemic form during heavy rains. Infection is heavy at 20-30°C, optimum being at 25°C along with RH above 90%. Under 100% relative humidity, infection is fast (Singh 1992).

Control measures : Strict hygiene is necessary in the field for effective control. All crop debris should be removed and destroyed. Seed treatment is more effective as there is evidence of disease transmission through seeds. Seed treatment with Carbendazim, followed by spraying with Thiabendazole (0.15%) gave good control (Om Prakash *et al.* 1973). Three to four sprayings with Ziram or Maneb (0.2% each) were also promising. Spray, when plants are two months old and repeat it at an interval of 10 days.

Soft-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs
R. stolonifer (Ehrenb.) Vuill.

Symptoms : Over-ripe fruits become more susceptible in comparison to semi-ripe fruits. Rotting is conspicuous as water-soaked irregular depressions and can often be mistaken as *Pythium*-rot; wounds or insect bites are a pre-requisite for infection. White cottony mycelia studded with black sporangial heads become prominent. The pulp gets softened and the whole fruit rots within 3-4 days (Philip 1998).

Control measures : Wounds and insect bites on fruits should be avoided. Cut pieces should not be kept under ambient condition for more than 24 hours. Cold storage of intact fruits at 10°C is desirable.

Choanephora-rot/soft-rot,

c.o. *Choanephora cucuribitarum* (Berk. & Rav.) Thaxter

The disease starts at the blossom-end of the fruit and develops as a soft wet-rot (Abd El-Rehim *et al.* 1964; Puscasu 1984). Under humid conditions, whitish growth of the fungus can be noticed with a metallic lustre. The colour turns from white to brown, and later on to purplish-black. Decay is rapid between 25 and 30°C. Under cool environments, mould growth is not visible on the surface, and the fruit just turns brown.

The fungus survives in the soil as zygospores (sexual state) or as resting spores (chlamydospores) (Barnett and Lilly 1956; Kirk 1984; Puscasu 1984). Sporangiospores spread by wind, water or insects, and cause fresh infection.

Since disease development is favoured by excessive moisture, care should be taken to ensure good drainage, moderate irrigation, low crop density and freedom from weeds in the fields. If wet conditions are unavoidable, fungicidal spray with Ziram (0.2%) is to be resorted to.

Phytophthora-rot, c.o. Phytophthora spp.

Several species of *Phytophthora* are found associated with rotting of cucumber-fruits; *P.drechsleri* Tucker was reported from China (Snowdon, 1991). These fungi are common soil inhabitants, causing disease under humid warm wet conditions. They produce both asexual (sporangiospores) and sexual (oospores) spores, which are spread by wind, water or insects.

Symptoms : They appear as lesions anywhere on the fruit-surface and are usually brown with an irregular margin, later becoming zoned or mottled. Under humid conditions, whitish fungal growth is observed with characteristic sporangia. Eventually skin ruptures and entire fruit decays to produce typical soft-rot. Fruits touching soil are likely to be affected.

Control measures : Fruits should be kept on the small raised platforms. Drenching soil prior to planting with copper oxychloride (COC, 0.2 – 0.3%) helps controlling disease on the fruits. Damaged fruits should not be stored with sound healthy fruits.

Soil-rot, c.o. *Thanatephorus cucumeris* (Frank.) Donk.

Sclerotial state : *Rhizoctonia solani* Kühn

The disease was found in warm, wet-growing areas. It was reported from Solomon Islands and the USA (Coursey and Booth 1972; Lewis and Papavizas 1980). It was also reported from Warangal (Andhra Pradesh) by Laxminaryana and Reddy (1976a).

Symptoms : Spots are at first firm, brown and water-soaked. Later, these enlarge into irregular shaped sunken cankers. Under warm, humid conditions, rotting is rapid and infected fruits are covered with dense greyish-brown mouldy growth. The fungus is a common soil inhabitant and has both asexual/sclerotial and sexual stages. Infection occurs on the fruits that are in contact with the soil, and rotting becomes apparent after harvesting of the crop. The optimum temperature for fungal growth is between 25 and 30°C and RH required is above 90%.

Control measures : The fruits should be kept on small raised platforms. Fruit decay can be controlled by storage at 10°C or below. Seed treatment may prove beneficial as the fungus is reported to be seed-borne as in pumpkin, bittergourd and muskmelon (Gangopadhyay and Sharma 1976; Maholay and Sohi 1982). Land can be covered with plastic sheets to avoid soil contact (Lewis and Papavizas 1980).

Brown-rot/*Botryodiplodia*-rot, c.o. *Botryodiplodia theobromae* Pat.

The disease was formerly known as *Diplodia*-rot and caused serious losses in the USA, Egypt, India and other countries (Beraha *et al.* 1976; Satour and Shinnawy 1977; Maholay and Sohi 1982).

Symptoms : They are noticed on the over-ripe and wounded fruits. Lesions may occur anywhere on the fruit-surface. And sometimes it may occur on the stem-end region also. The advancement of the disease is very fast. The affected area becomes spongy with a water-soaked margin (Wiant 1937). Greyish-white fluffy mycelia are noticed around wounds, which further spread and may cover fruit completely (Fig. 19.3). The fungus also produces a tough layer beneath the fruit peel, causing it to become severely wrinkled. Black bodies representing pycnidia are produced in advanced stages, and a sour odour accompanies decay. Invasion of seed cavity results in blackening of seeds.

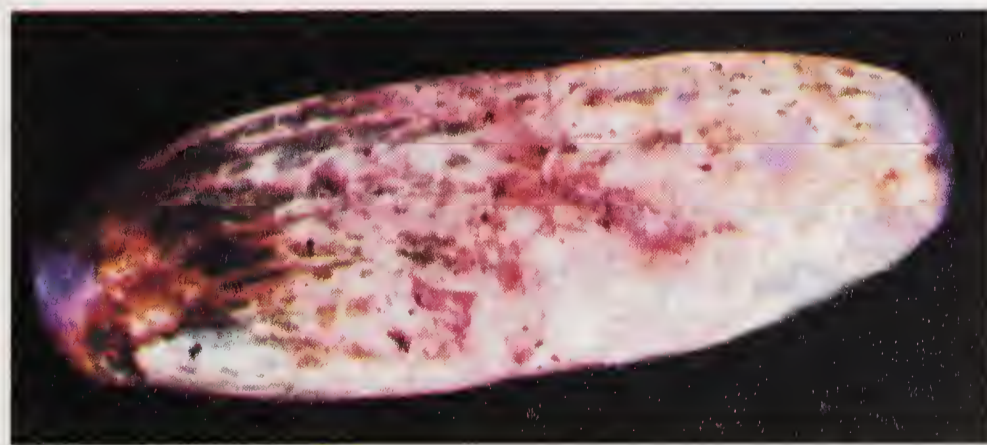


Fig. 19.3. *Botryodiplodia*-rot on cucumber

Control measures : Fungal spores are present in the soil and atmosphere. Care should be taken to avoid injury during harvest and handling as pathogen is wound-specific. Refrigeration prolongs storage life. Cut portions should not be kept under ambient condition for more than 24 hours.

Cladosporium-rot /gummosis /scab, c.o. *Cladosporium* spp.

Cladosporium cucumerinum causes losses to the crop mainly in temperate countries like the USA, Canada, Netherlands and Germany (Strider and Winstead 1960).

Symptoms : On the immature fruits, circular (up to one cm in diameter), water-soaked and deeply sunken lesions appear. They tend to exude a gummy substance, which dries and darkens. Subsequently under humid conditions, a velvety silver-grey mould develops, turning to olive-green, with the formation of a dense-mat of spores. On the mature fruits, lesions are superficial and form brown corky scab. The fungus is also reported to cause symptoms on the cucurbit leaves in Rajasthan (Maharshi 1982).

The fungus survives on plant debris in soil during wet or humid weather and produces spores, which are disseminated by air currents (Narain *et al.* 1985). Optimum conditions favourable for disease development are 20°C temperature and high relative humidity. The fungus penetrates into young fruits, but in older fruits infection takes place through wounds. Incipient infections continue to develop after harvest even under refrigeration (Wiant 1937).

Control measures : Post-harvest rotting can be controlled by dipping fruits in fungicidal solution of Guazatine (100mg a.i./litre) (Wade and Morris 1982), and also by refrigeration. Storage for longer period should be avoided.

Sclerotinia-rot, c.o. *Sclerotinia sclerotiorum* (Lib.) de Bary

The disease is common on fruits stored in cool temperature. Three to four sprays of culture filtrate of *Trichoderma viride* with Fundazole 50% (Benomyl 500 ppm) and Topsin-M (Thio phenate methyl, 0.1%) before storage were reported to be effective (Vozenilkova and Zvara 1990; Vozenilkova and Skorepa 1992).

Scanty cottony white-rot /*Fusarium*-rot, c.o. *Fusarium* spp.

The disease was reported from Bhubaneswar (Mishra and Rath 1986) and West Bengal (Dasgpta and Mandal 1989). *Fusarium equiseti*, *F. oxysporum* and *F. moniliforme* have been identified, and *F. solani* is most frequent.

Symptoms : They are pronounced on the injured fruits. Spread of the disease is very slow. Scanty white growth of the fungus appears on the infected region. Water-soaked areas may develop around the white growth. A dull-coloured liquid oozes out and entire fruit becomes wrinkled.

Control measures : Biological control was reported to be effective in reducing destructive effect of *F.oxysporum*. Seeds treated with commercial preparation of *Trichoderma* ('*Trichodermin* BL') enhanced sowing qualities and stimulated plant growth (Votika 2003).

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|-----------------------------|--|---|
| Black fruit-rot | <i>Didymella bryoniae</i> (Auersw) Rehm | Chiu and Walker, 1949; Stitterly, 1968 |
| Pink mould-rot | <i>Trichothecium roseum</i> Pers & Link. | |
| Sclerotium-rot | <i>Corticium rolfsii</i> Curzi | |
| Charcoal-rot | <i>Macrophomina phaseoli</i> (Maubl.) Ashby | |
| Alternaria-rot | <i>Alternaria</i> spp. | Sharma and Sumbali, 1993 |
| Curvularia-rot | <i>Curvularia pallescens</i> Boedijn | |
| Myrothecium-rot | <i>Myrothecium roridum</i> Tode ex Fries | |
| Helminthosporium-rot | <i>Helminthosporium</i> <i>hawaiiense</i> , Bognic. | Laxminarayana and Reddy, 1976a |
| Bacterial soft-rot | <i>Erwinia</i> spp. | |
| Bacterial-spot | <i>Pseudomonas</i> sp. | |

Seed microflora

Nazeema (1981) reported *Aspergillus flavus* from cucumber seeds. *A. niger* and *Penicillium* spp. were reported as the predominant fungi from Pakistan. Others include *Mucor* sp., *Rhizopus* sp., *Acremonium* sp., *Oospora latis*, *Geotrichum candidum* and *Cephalosporium* sp. Among bacteria, *Bacillus megaterium* and *B. subtilis* were dominant over other bacterial pathogens (Alimova *et al.* 2002).

PUMPKIN (*Cucurbita pepo* L.)

Pumpkins are grown all around the world for a variety of reasons, ranging from agricultural purposes to commercial and for ornamental sales. Phytochemicals found in them may favourably affect insulin and glucose levels in human body. Pumpkin seed oil contains fatty acids like oleic acid and linolic acid.

FUNGAL DISEASES

Anthracnose, c.o *Glomerella magna* S.F. Jenkins and N.N Winstead

Conidial state : *Colletotrichum* sp.

Marrows, squashes and pumpkin are generally resistant to this disease. The disease was recorded from the USA by Jenkins and Winstead (1964). Symptoms appear in the form of lesions with concentric rings, and sometimes entire fruit may be colonized.

Control measures are *as detailed under anthracnose in cucumber*.

***Botryodiplodia*-rot, c.o. *Botryodiplodia theobromae* Pat.**

This disease is of common occurrence in tropical countries. Affected areas become soft and loose (Satour and Shinnawy 1977). Philip (1998) observed the disease on the pumpkins stored in local markets of Thiruvananthapuram. Infection is mostly around the injuries.

Symptoms : These are similar to other *Botryodiplodia*-rots. In advanced stage, whole fruit gets covered with greyish mycelial mat. Complete rotting of fruits may be in ten days. Finally, the fruit collapses and a dark viscous fluid with an offensive smell oozes out.

Control measures : Care should be taken to avoid injuries during harvest, handling and subsequent storage. The fruits may remain intact up to two months. Refrigeration at 10°C prolongs storage period. Cut pieces should not be kept for more than 24 hours under ambient condition.

***Choanephora*-rot, c.o. *Choanephora cucurbitarum* (Berk. & Rav.) Thaxter**

This fungus caused severe losses in the USA (Barnett and Lilly 1956). The disease was reported from India also (Mustafee 1972).

At the blossom-end of the fruit, appears soft wet-rot. Under the humid conditions, luxurious growth of the fungus is noticed. Decay is very rapid between 25 and 30°C (Snowdon 1991)

***Cunninghamella* fruit-rot, c.o. *Cunninghamella echinulata* Thaxter ex Blakeslee**

The disease was reported by Grover (1965) from Punjab. Young developing fruits are vulnerable to attack and thus result in serious losses. Rotting is maximum at 28-32°C with RH of 88-100%. Neklyudova (1960) from Russia reported a disease complex on young pumpkin-fruits, caused by species of *Pythium* and *Rhizopus*, which produced symptoms similar to those by *Cunninghamella* sp.

Symptoms : They appear on young fruits, which turn dark-brown and get covered extensively with cottony mycelial growth, bearing numerous conidial heads. Either the affected fruits get detached from the plant or the rotten fruits may remain attached to the stalk, and then become shrivelled, dried and mummified.

Control measures : Field application of fungicides (4 sprays) from flowering to just before harvest with Actidione (0.25%) and Phaltan (0.15%) checked disease. Phaltan checked pectinolytic enzyme activity of the fungus (Grover 1964).

***Cottony-leak*, c.o. *Pythium* spp.**

The disease was reported from India and USSR.

Symptoms : They appear as soft, dark lesions anywhere on the fruit-surface, often at the stem-end. Infected tissues become water-soaked and pulp undergoes rapid breakdown.

Control measures are as detailed under cottony-leak in cucumber.

Spongy-rot/soil-rot, c.o. *Thanetophorus cucumeris* (Frank.) Donk.

Sclerotial stage : *Rhizoctonia solani*, Kühn
Fusarium oxysporum Schlet.

A spongy-rot due to combined infection by *Rhizoctonia* and *Fusarium* was reported by Gangapadhyay and Sharma (1976) from Kullu, Himachal Pradesh. The fungus perenates in stubbles.

Symptoms : They appear after 30 days of storage, characterized by drying of fruit and blackening of outer rind. The symptoms are both external as well as internal.

External : Deep-brown to black spongy decay on the outer surface.

Internal : Drying and sponginess of the pulp and conversion of the golden-yellow colour to black. The pulp inside becomes spongy, desiccated and juiceless. Seeds turn black due to fungal growth. Radicle of the germinating seedlings becomes black and finally dead.

Control measures: The disease has been observed mostly as seed-borne. Seed treatment with Thiram (0.2%) gives protection. Injuries during harvest and handling operations should be avoided. Refrigeration at 10°C prolongs storage.

Soft-rot/Sclerotium fruit-rot, c.o. *Sclerotium rolfsii* Sacc.

This is considered as a minor disease. Water-soaked discolouration appears on the stem-end portion of the fruit. Fruit tissues start softening and in advanced stages whole fruit is covered with mycelial mat and sclerotia (Siddaramaiah *et al.* 1982). The fungus is also reported to cause collar-rot of pumpkin seedlings (Singh and Seth 1974).

Control measures are as detailed in spongy-rot.

**Cottony white-rot, c.o. *Fusarium solani* (Mart.) Appel. & Wr.
F.oxysporum Schlet.**

Rotting due to *F.solani* f.sp.*cucurbitae* race 2 was recorded as a serious disease from the USA. A similar disease was recorded by Dasgupta and Mandal (1989) from West Bengal. On the stored ripe-fruits, the disease is with a characteristic oak-brown soft area around the injured site with flesh becoming combed-brown. Infection advances radially with distortions of the fruit-skin and shrinkage of flesh. *F.solani* is also observed to be seed-borne (Nazeema 1981), and seeds need to be treated with Thiram (0.2%), and storage of fruits under refrigeration at 10°C is promising.

Charcoal-rot, c.o. *Macrophomina phaseolina* (Tassi) Goid.

The fungus is widespread in tropics and subtropics, and causes epidemics during hot-dry season. Symptoms appear as water-soaked spots on the skin. Under favourable condition, spots rapidly enlarge and affected areas become

firm in texture with an indefinite boundary. As the decay advances, skin wrinkles, and minute spherical bodies (microsclerotia) develop in abundance; they appear powdery and black. Sometimes infected fruits become hollow shells with blackened interior (Snowdon 1991). Refrigerated storage at 10°C was found effective.

Black mould-rot, c.o. *Aspergillus niger* Van Tieghem.

The disease is of minor importance and occurs on cut pieces or rat-browed fruits. Discolouration progresses fast and sometimes seed-coat also is involved. Sporulating mass appears overnight on the surface.

Cut pieces should not be kept under ambient conditions for more than 24 hours; refrigeration at 10°C is effective.

***Phytophthora*-rot, c.o. *Phytophthora capsici* Leonian**

Pre-and post-emergence damping-off due to *Phytophthora* is a serious threat to farmers in Illinois, USA.

Symptoms : Water-soaked lesions appear on the fruit-surface. As the disease advances, whitish growth of the fungus is observed.

Control measures : Soil treatment with COC (0.2-0.3%) before planting the crop minimized *Phytophthora*-rots. Seed treatments with Mefenoxam or Metalaxyl (at concentration of 0.5mg a.i./ml) have some advantage in controlling *P.capsici*; gives protection for 5 weeks (Babadoost and Islam 2003).

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|--------------------------------|---|---------------|
| Grey mould-rot | <i>Botrytis cinerea</i> Pers. | |
| Sour-rot | <i>Geotrichum candidum</i> Link. | |
| <i>Cladosporium</i>-rot | <i>Cladosporium</i> spp. | |
| Seed-borne fungus | <i>Cephalophora irregularis</i> Thaxter <i>Rhizopus stolonifer</i> (Ehrenb.)ex Fr. | Nazeema, 1981 |

WATERMELON (*Citrullus lanatus* (Thunb.) Matsum & Nakai

The fruit contain 6% sugar and 92% water by weight. The amino-acid citrulline was first extracted from watermelon. Watermelon-fruit is mildly diuretic and contains large amount of beta-carotene. Fruit with red flesh is a significant source of lyocopene.

FUNGAL DISEASES

**Anthracnose, c.o. *Glomerella cingulata* (Stonem.) Spauld. & Schrenk.
Colletotrichum gloeosporioides Penz.**

Anthracnose disease was reported causing serious losses on watermelons (Layton. 1937; Arx *et al.* 1961; Menton *et al.*1979). A related species of

Colletotrichum (*Glomerella magna*) was recorded from the USA (Jenkins and Winstead 1964).

Symptoms, etiology and control measures are similar to those on cucumber.

Fruit-rot/cottony-leak, c.o. *Pythium aphanidermatum* (Edson) Fitzp.
P. butleri Subram.

Singh and Chohan (1977a) recorded this disease from Punjab. It is widespread, and sometimes 50% or even more of the fruits may undergo rotting after rains. It was observed to start from the blossom-end (Singh 1992).

Symptoms : The fruit-rind becomes dark-green and water-soaked. This without any aerial growth of the fungus indicates 'killing in advance' activity of the pathogen. The interior tissues become soft and watery. Decaying fruits emit bad odour due to secondary invasion by bacteria. Singh and Chohan (1977 a) studied changes in carbohydrates and soluble amino acid content due to infection; the quantity increased in chlorotic regions, and decreased in rotten areas. Drastic reduction in sucrose, glucose and fructose was also observed.

Control measures are as detailed under cottony-leak in cucumber.

Rhizopus-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs
R. stolonifer (Ehrenb.) Vuill.

The disease was reported from Israel (Barkai-Golan 1981). *Symptoms, etiology and control measures are similar to those on cucumber.*

Choanephora-rot, c.o. *Choanephora cucurbitarum* (Berk.) & Rav.) Thaxt

The disease is of minor importance (Kirk 1984; Snowdon 1991). *Symptoms, etiology and control measures are similar to those on cucurbits.*

Phytophthora-rot, c.o. *Phytophthora* spp.

Several species such as *Phytophthora cactorum* (Leb.& Cohn) Schroet and *P. nicotianae* var. *parasitica* have been reported to cause rotting in the USA (Norton and Roseberg 1954; Brown and Evans 1983). Ullasa (1984) recorded *P. nicotianae* along with *Fusarium oxysporum* from Bengaluru. *Symptoms, etiology and control measures are similar to those on cucumber.*

Alternaria-rot, c.o. *Alternaria alternata* (Fr.) Keissler
A. cucumerina (Ell.&EV.) Elliot

Alternaria-rot is common in all watermelon-producing countries. *A. cucumerina* is usually more important as a leaf-spot fungus and causes defoliation (Jackson 1959). The fungus was reported from Bengal by Gangopadhyay and Kapoor (1973).

Fruits weakened by sunscald are predisposed to be attacked by species of *Alternaria* (Kachawaha and Ali 1982). Fruits stored over long periods at low temperature with chilling injury may also be infected (Mc Colloch 1982).

Symptoms : Circular to oval lesions appear, which are sunken. Affected rind turns brown under humid conditions and is rapidly covered by fungal growth, and abundant sporulation is also observed (Simmons 1967).

Control measures : Two to three sprays of Ziram (0.2%) applied on the two months old plants and repeated at the harvest, control storage-loss. Avoid injuries on fruits at harvest, handling and storage. Refrigeration at 10°C prolongs storage.

***Cladosporium-rot*, c.o. *Cladosporium tenuissimum* Cooke**

The fungus was recorded on watermelons from Odisha (Narain *et al.* 1985). Small irregular shaped dark-brown lesions appear on the detached blossom-end. Sooner fruits wrinkle with irregular folds giving depressed appearance. Cracks are observed in larger fruits where inner pulp gets exposed. *Alternaria alternata* was also found associated with this fungus.

Rotting can be avoided by dipping fruits in a fungicidal solution of Guazatine (100 mg a.i./litre) (Wade and Morris 1982) and by refrigeration at 10°C.

***Charcoal-rot*, c.o. *Macrophomina phaseolina* (Tassi) Goid.**

This disease is of minor importance.

Symptoms : Dark-brown-to-black lesions appear. In some cases lesions are about half the size of the fruit with a large number of dot-like black bodies on the infected surface (Jhooty and Singh 1971). As the decay advances, fruit skin wrinkles and profuse minute spherical bodies, representing microsclerotia, are noticed. This superficial crust tends to rupture and expose watery flesh, which emits pungent odour and eventually turns black. Sometimes infected fruits become hollow shells with blackened interior. Epidemic during dry weather was also recorded (Reuveni *et al.* 1983).

Control measures : *Citrullus colocynthis* and *C. vulgaris* were recorded as highly resistant varieties (Singh and Chohan 1972). Seed treatment and fungicidal spray gave only partial control. When rains are infrequent, irrigate crop regularly so that plants are not weakened by drought. Refrigeration of fruits at 10°C is desirable.

***Didymella black-rot*, c.o. *Didymella bryoniae* (Auersw.) Rehm.**

Phoma cucurbitacearum (Fr.) Sacc.

This disease is of minor importance.

Symptoms : Lesions are at first water-soaked and are roughly circular. Later they zonate sometimes and become dark, sunken and cracked. Under humid conditions, whitish mould may develop. Infected tissues shrivel and give rise to minute black bodies (pycnidia and perithecia).

***Myrothecium-rot*, c.o. *Myrothecium roridum* Tode ex Fr.**

Symptoms : Dark-sunken lesions of about 1-mm diameter and fringed with

a white growth are noticed. They support discrete greenish-black spore masses (sporodochia). The lesions may coalesce into a sticky charcoal-black sheath or become dry hard and flaky. The flesh finally becomes watery.

Control measures : The disease is seed-borne. Seed treatment with Thiram (0.2%) is recommended. Field hygiene is also important. Fungicide Ziram (0.2%) spray at the onset of flowering is found promising. Refrigeration is necessary to prevent deterioration.

***Phomopsis-rot*, c.o. *Diaporthe melonis* (Beraha & O'Brien)**

Phomopsis sp.

Symptoms : The fungus infects developing fruits, and remains quiescent until melons mature. Symptoms appear as dark, raised spots.

Control measures : Post-harvest rotting can be avoided by fungicide dip (Berah and O' Brien 1979). Since pathogen is soil-borne, soil should be disinfected. Seed treatment with Thiram (0.2%) and protection of fruit from insect damage or other wounds are desirable. Refrigeration at 8-10°C enhances storage period.

***Fusarium-rot*, c.o. *Fusarium* spp.**

Several species of *Fusarium* are found associated, causing this rot—*F.equiseti*, *F.oxysporum*, *F.pallidoroseum* and *F.solani*.

Symptoms : They may appear anywhere on the fruit-surface or on the stem-end portion as white scanty growth. Surrounding area becomes water-soaked, and rotting of pulp occurs. Severe rotting in melons at Thiruvananthapuram markets was observed (Philip 1998).

Control measures : Protect fruits from insect damage/wounds. Storage at 8-10°C refrigeration is promising. Cut pieces should not be kept at ambient condition for more than 12 hours.

***Aspergillus-rot*, c.o. *Aspergillus fumigatus* Fries**

Injured fruits are invariably affected by this disease. Dasgupta and Mandal (1989) observed disease on the cracked fruits during May/June in West Bengal; sound fruits were free of infection.

Symptoms: Greenish fungal growth appears around the injury. It covers cracked surface. Rotting is slow and limited. Due to infection, red colour of the internal tissue gets faded.

Control measures : Avoid injuries to fruits. Storage of fruits at 8-10°C refrigeration is protective.

***Blue-mould*, c.o. *Penicillium* spp.**

Its symptoms and control measures are similar to those of *Aspergillus-rot*, excepting that colour of *Pencillium* lesions is blue.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organisms | Authority |
|---------------------------|--|---|
| Pink mould-rot | <i>Trichothecium roseum</i> Link. ex Fries | Rao, 1964; Singh and Bhatnagar, 1982 |
| Soil-rot | <i>Thanetophorus cucumeris</i> Frank. (Donk.) | |
| Sclerotial state: | <i>Rhizoctonia solani</i> Kuhn | |
| Sour-rot | <i>Geotrichum candidum</i> Link. | |
| Watery soft-rot | <i>Sclerotinia sclerotiorum</i> (Lib.) de Bary | |
| Grey mould-rot | <i>Botrytis cinerea</i> Pers. | |
| Bacterial soft-rot | | Dasgupta and Mandal, 1989 |

MUSKMELON (*Cucumis melo* L.)

Large number of the fruits in India are reported to get spoiled due to fungal infections during transport and marketing (Ojha *et al.* 1984; Prasad and Roy 1986).

FUNGAL DISEASES

Fruit-rot /cottony-leak, c.o. *Pythium butleri* Subram.

P. aphanidermatum (Edson) Fitzp.

The disease was reported by Prasad *et al.* (1988) from Bihar. It causes severe losses in muskmelon fruits. More than 50% rotting of fruits was observed after rains (Singh and Chohan 1977). Fruit-rot incidence was found maximum at 30-35°C and at 100% RH.

Symptoms and control measures *are as detailed under cucumber.*

Sour-rot, c.o. *Geotrichum candidum* Link.

The disease is of common occurrence in California. It was observed in 'honey dew' melons (Ceponis 1966). Yeoung and Kimhakki (1996) reported disease from Korea.

Symptoms : They appear as a soft mush-discoloured decay at the stem scar region. Maximum decay occurs at 60°F, but at 40°F, it progresses slowly. Lewis and Sinclair (1966) associated infection with deep wounds.

Control measures : Fruits stored at 5°C remain firm with longer storage life (Yeoung and Kimhakki 1996).

***Fusarium-rot, c.o. Fusarium semitectum* Berk. & Rav.**

The disease was reported by Prasad *et al.* (1988) from Bihar.

Symptoms : They *are as detailed under watermelon.*

Due to infection, reduction in total sugars, proteins and phenol content was observed. *F. semitectum* was found very efficient in utilizing sugar and protein fractions of muskmelon-fruits (Prasad *et al.* 1988).

Fruit-rot due to *Curvularia lunata* from Bihar was also recorded (Prasad *et al.* 1988).

CHAYOTE/CHOW-CHOW (*Sechium edule* (Jacq.) SW.)

The crop is grown in tropics and subtropics, including West Indies, Australia, India and parts of Africa.

FUNGAL DISEASES

Alternaria-rot, c.o. *Alternaria alternata* (Fr.) Keissler

Circular to oval lesions appear; they may become sunken in advanced stage. Affected peel appears brown or bleached out. But under humid conditions, it is covered by dark fungal growth and abundant olive-green to dark-brown spores.

Control measures are *as detailed under Alternaria-rot of watermelon*.

Anthracnose, c.o. *Glomerella cingulata* (Stonem.) Spauld. & Schrenk.

The disease is virulent on chayotes (Arx *et al.* 1961; Menton *et al.* 1979). Symptoms and control measures are *similar to anthracnose of cucumbers*.

Cottony-leak/Pythium-rot, c.o. *Pythium* spp.

Pythium debaryanum was reported on chayotes from Italy. Symptoms and control measures are *similar to cottony-leak of cucumbers*.

Fusarium-rot, c.o. *Fusarium* sp.

Symptoms: White, scanty growth appears over injured sites. Infected regions rot, and rotted tissues emit foul smell (Fig. 19.4) (Philip 1998).

Control measures: Injuries and wounds should be avoided. The fruits should be stored under refrigeration.



Fig. 19.4. *Fusarium*-rot on chow-chow fruits

Phytophthora-rot, c.o. *Phytophthora nicotianae* (Anon. 1963)

Symptoms and control measures are *similar to those of cucumbers*.

BITTERGOURD (*Momordica charantia* L. var. *charantia*)

The fruit is also known as bitter cucumber. It is common in India. Fruit pulp including seeds has a unique quality to lower blood glucose level (Pabarai and Sehra 1962).

FUNGAL DISEASES

Anthracnose, c.o. *Colletotrichum capsici* (Syd.) Butler and Bisby
C.lagenarium (Pass.) Ell. & Halst.

Om Prakash and Singh (1977) reported this disease from Bihar and Bengaluru.

Symptoms : Irregular, circular or semi-circular lesions generally appear, surrounded by water-soaked areas. These lesions coalesce sometimes and form elongated patches. Fruit cracks open longitudinally and expose abundant pink spore mass. This is followed by fruit-rot.

Control measures : Spraying of crop before harvest with Mancozeb (0.2%) or Nabam (0.2%) is effective in controlling the disease under storage.

C.lagenarium is seed-borne internally (Nazeema 1981). Dubey and Ekka (2003) observed effect of seed-dressing fungicides like Thiram, Vitavax, Topsin M, Bavistin and Captan @ 2g/kg on naturally infected seeds. Complete inhibition was recorded with Vitavax and Thiram.

Blossom-end-rot, c.o. *Macrophomina phaseolina* (Tassi) Goid.

Slight water-soaked areas appear around the blossom-end, which extend towards the stem-end. Within 7-10 days, 50% of the fruits get covered. Black pycnidia develop over and inside the infected portion. Later infection extends deep into the pulp (Singh 1975).

The disease is of minor importance.

Fruit-rot/cottony-leak, c.o. *Pythium aphanidermatum*(Edson) Fitzp.

The disease was recorded in a serious form from Maharashtra and West Bengal (Rao 1966b; Mandal and Dasgupta 1981).

Symptoms : They may appear anywhere on the fruit-surface, and the fungus forms a luxuriant woolly mycelial weft on the affected fruits, which appear as if wrapped by cotton. The disease originates as a soft-rot. On this rotting portion, fungal mycelia develop abundantly during humid conditions.

The fungus is a soil inhabitant, living as a saprophyte on the dead organic matter and induces disease on the host plants. The important pre-disposing factors are abundant moisture and high temperature. A slight injury on the peel facilitates entry by the pathogen.

Control measures : Avoid injury on the harvested fruits. Refrigeration of fruits at 10°C is protective.

Soft watery-rot, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.

The disease was reported from Karnataka and West Bengal (Hiremath and Govindu 1973; Mandal and Dasgupta 1982). On injured fruits, small water-soaked areas appear, which become yellowish-brown and are covered by a stringy coarse fungal mass. In advanced stages, fruits become soft due to tissue disintegration; and a watery-rot sets in. Mycelia invade seed-coat also.

Control measures *as detailed under Rhizopus-rot of cucumber are applicable to this disease also.*

Fuzzy yellowish-rot, c.o. *Mucor hiemalis* Wehmer

The disease was recorded from West Bengal (Dasgupta and Mandal 1989). Over the fruit-surface, scanty mycelial growth is observed due to the disease. And very soon fruits are covered with fine fuzzy, less dense, turfy yellowish mycelia. Infected fruits become soft and brown.

Control measures are *as detailed under Rhizopus-rot of cucumber.*

Grey white-rot, c.o. *Sclerotium rolfsii* Sacc.

The disease was recorded from Karnataka and West Bengal. Small, depressed water-soaked areas appear on the fruit-surface around the injury. Infected portions become ashy-yellow and soft. Finally colour turns grey or black.

Cottony white-rot, c.o. *Fusarium* spp.

Several species of *Fusarium* are found associated with this—*F. equiseti*, *F. oxysporum*, *F. solani* f sp *cucurbitarum* and *F. semitectum*. The disease was reported from several states in India (Tandon and Verma 1964; Chattopadhyay and Mustafee 1967; Hiremath and Govindu 1973; Gupta *et al.* 1982; Sharma and Sumbali 1993). Disease is noticed all year-round, particularly during summer.

Symptoms : The disease starts from the distal-end of the fruit, characterized by slightly water-soaked circular to irregular rotten patch with withered ribs and skin. Under dry conditions, fruits become hard, but during wet favourable conditions, internal tissues disintegrate in brownish shade. The reddish slimy tissue on the seed surface disintegrates and separates. White to dull scanty fluffy cottony mycelia develop on the surface in moist atmosphere. Juice leaks out from fruit but without unpleasant smell (Dasgupta and Mandal 1989).

Control measures : Treat seeds with Captan 0.2% or Thiram 0.2%. Wounds and injuries during harvesting, transportation and storage should be avoided. Cold storage under refrigeration at 8-10°C is found promising.

***Corynespora* fruit-rot, c.o. *Corynespora cassiicola* (Berk. & Curt) Wei.**

The disease was recorded from the local markets in Thiruvananthapuram, and is of minor importance. Symptoms appear at the distal-end of the fruit as minute spots, which enlarge and cover the end (Fig. 19.5). Within 3-5 days, the affected portion shrinks and rots. The rest of the fruit remains healthy (Philip 1998).

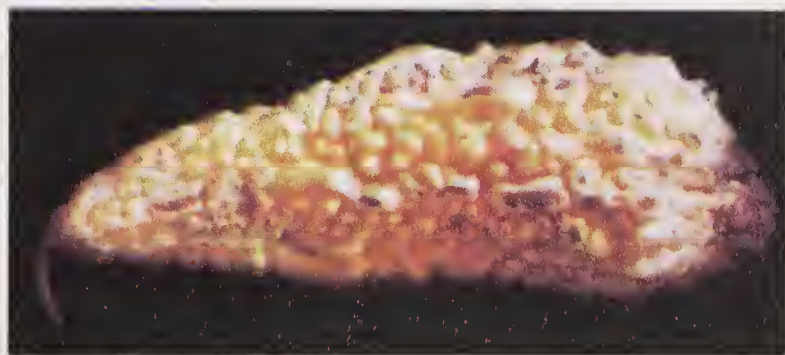


Fig. 19.5. *Corynespora*-rot on bittergourd-fruit

***Didymella* black fruit-rot, c.o. *Didymella bryoniae* (Fuckel.), Rehm
Phoma cucurbitacearum (Fr.)Sacc.**

Several names were used for the causal organism in the past, such as *Mycosphaerella citrullina*, *M.mealanois* and *Ascochyta citrullina*.

Small circular water-soaked lesions appear on the green fruits that quickly enlarge to form blackish spots within a week. Black, small, pinhead-like structures represent fungus asci and ascospores. Infected fruits contained *P. cucurbitacearum* while seeds contained both *D. bryoniae* and *P. cucurbitacearum* (Singh and Shetty 1996). The disease is of minor importance.

***Myrothecium*-rot, c.o. *Myrothecium roridum* Tode**

The disease was reported from Jodpur (Rajasthan). Small, circular olive-grey patches, which are slightly sunken, appear. The diseased area increases gradually, and is covered with copious growth of white woolly mycelia in concentric rings, followed by formation of a dark-green zone of sporodochia with viscid spore mass. Typical symptoms developed at 25°C (Vyas and Panwar 1976).

The disease is seed-borne, and seed treatment with Captan (0.2%) or Thiram (0.2%) is effective.

***Rhizoctonia*-rot, c.o. *Rhizoctonia solani* Kühn**

In the early stages, light-brown spots are visible on the ripe-fruits. Gradually fluffy mycelial growth and dark, fruiting bodies are noticed. Fruit decay is conspicuous in advanced cases (Vyas and Panwar 1976).

***Botryodiplodia*-rot, c.o. *Botryodiplodia theobromae* Pat. (Fig. 19.6)**

Symptoms and control measures are as detailed under cucumber.



Fig. 19.6. *Botryodiplodia*-rot on bittergourd at advanced stage

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|--|--|-----------------------------|
| <i>Curvularia</i> fruit-rot | <i>Curvularia lunata</i> (Wakker) Boedijn | Prasad <i>et al.</i> , 1988 |
| <i>Helminthosporium</i> fruit-rot | <i>Helminthosporium spiciferum</i> (Bain.) Nicot | Roy and Choubey, 1984 |

Seed mycoflora

Aspergillus species are commonly found externally associated with seeds. These include *A.niger*, *A.flavus* and *A.ochraceous*. Among these, *A.flavus* is found associated with embryo. Along with this, *Chaetomium microsporum*, *Botryodiplodia theobromae* and *Colletotrichum lagenarium* were also reported (Nazeema 1981).

Dehydrated samples of bittergourd showed presence of *Aspergillus* spp. and their perfect stages as the most dominant ones, followed by *Penicillium* spp. Mycotoxin patulin was also detected (Kour and Sumbali 2006).

Control measures : Moisture content of dehydrated samples should not go beyond 7%. The samples should be packed in airtight containers or sealed in polythene bags.

SNAKEGOURD (*Trichosanthes anguina* L.)

It is a subtropical vegetable, raised for its spikingly long fruits. It is low in calorie and contains little proteins, fats, carbohydrates and soluble fibres.

FUNGAL DISEASES

Rhizopus-rot, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.

The disease occurs during rainy season. Its spread is also fast during rains. It was reported from Bengaluru (Singh *et al.* 1975), north India (Sharma and Sumbali 1993) and Thiruvananthapuram (Philip 1998).

Symptoms : Water-soaked patches appear on fruits. Fruit-skin becomes soft and disintegrated. Hyphae grow outwards and cover affected portion and the adjoining areas by producing tufts of whisker-like grey sporangiophores and sporangia. Within 3-4 days, mycelia grow further, and cover rest of the fruit. The fruit decays and produces watery soft-rot. The rot appears at the pre-harvest stage and develops during storage.

Control measures : Fruits should be protected from injuries. They should be kept under refrigeration at 8-10°C. Cut fruits should not be kept for more than 24 hours under ambient conditions.

Fusarium-rot, c.o. *Fusarium* spp.

It is a common disease. Rao (1966 a) reported this disease to be serious in Maharashtra. Sahu Kritagyan and Singh (1980) observed similar rot on the pointed-gourd from Bihar. Affected fruits drop to ground. Rotting is invariably associated with different varieties and agroclimates.

Rots due to *F.oxysporum* and *F.moniliforme* were recorded under field and storage conditions from Sagar, Madhya Pradesh (Mehta and Mehta 1989). Temperature influences mode of infection. Extent of rotting is more in storage. *F.oxysprum* is more aggressive than *F.moniliforme*. These pathogens also cause

infection in brinjal-fruits. But infection starts earlier in *T. dioica* and is delayed in brinjal. But in advanced stage of pathogenesis, the extent of rotting is similar. *F. solani* was also reported (Sharma and Sumbali 1993).

Symptoms : Injured fruits, bored by larvae, decay due to this disease. Infection starts as small, water-soaked specks around injuries and progresses rapidly into tissues. The advancing margins become lavender-green while inner centre becomes white or pinkish. White flocculent mycelia develop on the infected surface. The fungus also sporulates in the hollow centre of the fruit. And the fruit cracks at the infected site.

Control measures : Treat seeds with Captan or Thiram (0.2% each). Refrigeration at 8-10°C is recommended for storage of fruits.

***Alternaria-rot, c.o. Alternaria tenuissima* Auct.**

The disease is common on the stored snakegourd.

Symptoms : They appear as grey spots. Adjoining spots coalesce and form larger lesions. Sometimes lesions are irregularly circular and are of varying sizes. Affected areas exhibit yellow or pink colour, and at maturity turn brown. Tissues below the lesions dry-up and are pulled away from healthy areas. Rotting starts from the stem-end region and proceeds downwards (Singh 1974).

Control measures *detailed under Alternaria-rot of watermelon are applicable here also.*

***Phytophthora fruit-rot, c.o. Phytophthora cinnamomi* Rand.**

Symptoms : On fruits, symptoms appear as water-soaked lesions; mostly at the stylar-end. Lesions rapidly enlarge and develop a soft-rot with extra-matrical cottony mycelial growth. Under humid conditions, fruits in contact with soil suffer more damage (Khatua *et al.* 1981). Singh *et al.* (2002) recorded an outbreak of vine and fruit-rot from eastern Uttar Pradesh; and 20-80% yield loss was observed. Lesion size varies among varieties. Minimum temperature of 20-24°C and maximum of 30°C with regular rainfall and RH above 90% favoured fruit-rot developing into an epidemic.

Control measures : If *Phytophthora* disease is suspected, soil for planting should be treated with copper oxychloride (0.2-0.3%). The fruit should not touch soil. Wrapping fruits individually with newspaper helps. Care should be taken to see that fruits are not damaged. Refrigerated storage at 10°C immediately after harvest is promising.

***Pythium fruit-rot, c.o. Pythium cucurbitacearum* Takimoto**

P. aphanidermatum (Edson) Fitzp.

Pythium-rot starts from stylar-end. Extensive mycelial growth with soft rotting of internal tissues is visible during later stages of infection. The disease was reported from West Bengal (Chaudhury 1975).

Symptoms and control measures *are similar to fruit-rot /cottony-leak of bittergourd.*

Anthracnose, c.o. *Glomerella cingulata* (Stonem.) Spauld. & Schrenk,
Colletotrichum sp.

The disease is characterized by greyish oblong to ovoid or irregular slightly sunken lesions on the fruit-surface. Lesions often coalesce and spread longitudinally towards the distal-end. Affected areas are initially light pink-green to yellow and finally become dark-brown to black. Such fruits become soft, water-soaked and completely rotten. Profuse development of acervuli is noticed on the rotten areas.

Control measures *are detailed under anthracnose of bittergourd.*

Botryodiplodia-rot, c.o. *Botryodiplodia theobromae* Pat.

Fruit-rot due to *B.theobromae* was reported from Thiruvananthapuram (Phillip, 1998). The rotting was observed on mature fruits stored for seed purpose. Disease symptoms appear as dark patches. In the advanced stage, whole fruit gets covered with greyish mycelial mat (Fig. 19.7). It may take about 10 days for complete rotting. Pycnidial encrustations are noticed abundantly with advancement of rotting.

Control measures are *as detailed under Botryodiplodia-rot of cucumber.*



Fig. 19.7. *Botryodiplodia*-rot (advanced stage) on snakegourd

Charcoal-rot, c.o. *Macrophomina phaseolina* (Maubl.) Ashby

The disease was recorded from Punjab (Jhooty and Singh 1971). Symptoms are similar to those on watermelon. The disease is of minor importance, and it occurs on the injured fruits.

Sour-rot, c.o. *Geotrichum candidum* Link.

Symptoms and control measures are *similar to those on tomato in the chapter on Solanaceous Crops.* The disease was reported by Sharma and Sumbali (1993) from north India.

BOTTLEGOURD (*Lagenaria siceraria* (Mol.) Standl.)**FUNGAL DISEASES****Anthracnose**, c.o. *Colletotrichum lagenarium* (Pass.) Ell & Halst.
C. capsici (Syd.) Butler and Bisby

This is a common disease; and sometimes becomes serious. Symptoms are observed on leaves and fruits. The disease was first observed by Mundkur in 1937. Later on, this was recorded by Rangaswami *et al.* (1970), Singh and Chohan (1972,1980) and Sokhi (1994). Infection is mainly soil-borne and pathogen survives on the diseased crop residues. It can also survive as a saprophyte on straw and stubble.

Symptoms : Lesions, circular to irregular, often oval to oblong in shape appear (Madaan and Grover 1977), and under humid conditions, pink spore masses are noticed in abundance; symptoms of scab are also observed. The fruit turns dark-brown and core becomes hollow with a few damaged seeds.

Control measures : Seed infection is superficial (external), and seed treatment with Carbendazim (0.25%) is effective. Seeds treated with systemic fungi toxicant Benomyl(0.125%) protects seedlings also for 14 days (Madaan and Grover 1979).

Foliar spray of Thiabendazole (0.1-0.15%) offers good control (Omprakash *et al.* 1973; Sokhi 1994). Field spraying with Difolatan (0.2%) or Blitox (0.5%) is observed to be effective.

Seedling-blight, c.o. *Rhizoctonia solani* Kühn

Fungal mycelia and sclerotia are observed on the seed surface (external). Infection occurs when seeds come in contact with soil. The disease was reported from Delhi (Suryanarayana 1978). Seed treatment with Thiram 0.2% is effective.

Cottony-leak, c.o. *Pythium butleri* Subram.

P. aphanidermatum (Edson) Fitzp.

The disease is widespread in bottlegourd (Singh and Chohan 1977). Fungus survives at a wide range of temperature (15-40°C), with optimum growth between 30 and 35°C.

Symptoms : They may appear anywhere on the fruit-surface, and fungus forms a luxuriant woolly mycelial web on the affected fruits, which appear as wrapped by cotton. The disease originates as a soft-rot. On the rotting portion, fungal mycelia develop abundantly during humid environment.

Control measures : Fruits should be protected from injuries during harvesting, handling and storage. Refrigerated storage at 10°C is recommended.

Fusarium-rot /cottony-rot, c.o. *Fusarium* spp.

The disease is of common occurrence and different species of *Fusarium*

have been identified—*F.concolor*, *F.equiseti*, *F. semitectum*, *F. solani*, *F.oxyspoum* and *F. dimerum* (Roy 1973; Bilgrami and Verma 1978; Singh and Chohan 1980; Garg and Gupta 1983; Sohi *et al.* 1984; Mishra and Rath 1986; Sharma and Sumbali 1993).

Symptoms : Discrete or coalescent water-soaked lesions appear on the peel of mature and ripe-fruits. Mycelial growth varies in colour from pink to white.

Control measures : Spraying plants before harvest with Nabam or Mancozeb (0.2%) is effective in reducing post-harvest rots. Avoid injuries on to the harvested fruits.

***Botryodiplodia-rot*, c.o. *Botryodiplodia theobromae* Pat.**

Fruit-rot due to *B. theobromae* was reported from Ludhiana (Punjab) by Singh and Chohan (1977). Rotting of mature fruits stored for seed purpose was also observed by Maholay and Sohi (1982) from Punjab.

Symptoms : Externally fruit-surface gets covered with ashy-grey fungal growth. Interior content including seeds also becomes black due to fungal invasion.

Control measures : Protect fruits from injuries during harvesting, handling and storage. Refrigerated storage at 10°C is found promising.

***Sclerotinia fruit-rot*, c.o. *Sclerotinia sclerotiorum* (Lib.) de Bary**

Soft watery white-rot appears initially on the infected fruits; later on it is noticed on the leaves, vines and flowers also (Pandey and Pandey 2002). The disease is of minor importance.

***Sclerotium-rot*, c.o. *Sclerotium rolfsii* Sacc.**

The disease is also known as creepy cottony-rot. Dry-rot symptoms appear on the hard-coated fruits while immature fruits become watery due to infection. On mature fruits, water-soaked lesions appear, which later get suppressed. On the infected areas, whitish mycelia spread fast. Later sclerotia develop profusely on the region. The disease was reported from Ludhiana (Punjab) (Singh and Chohan 1980) and Bengaluru (Amin and Ullasa 1981).

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|-----------------------|--|--------------------------|
| Charcoal-rot | <i>Macrophomina phaseolina</i> (Tassi) Goid. | Singh and Chohan, 1980 |
| Alternaria-rot | <i>Alternaria alternata</i> Fr. Keissler | |
| Curvularia-rot | <i>Curvularia ovoidea</i> (Hiroe and Watanbe) Munt. - Cvetk | |
| Grey-mould-rot | <i>Aspergillus fumigatus</i> Fres. | Bilgrami and Verma, 1979 |
| Fruit-rot | <i>Cylindrocarpon tonkinense</i> Bugn. | |
| | <i>Drechslera australiensis</i> Subram. & Jain ex M.B. Ellis | Roy and Ojha, 1984 |

RIDGE-GOURD (*Luffa acutangula* (L.) Roxb.)

The fruit is used as a vegetable at the tender stage. When it is fully ripe, it becomes very fibrous.

FUNGAL DISEASES

Fruit-rot, c.o. *Fusarium oxysporum* Schlet.

The disease causes premature fruit-rot. Rao *et al.* (1984) reported 50 % loss due to this disease from Mysore. Symptoms appear as yellow or brown sunken spots. The infected fruits show white tuft of mycelia with heavy sporulation. The lesions later extend gradually and result in complete drying of fruits. The inner tissues also show browning. Mishra and Rath (1986) recorded similar infection due to *F. solani* from Odisha.

Dry-rot of *Luffa cylindrica* caused by *F. solani* (Mart.) Sacc was also reported (Tandon *et al.* 1975) from Nainital, Bhowali. Scattered olive-grey coloured spots appear with white mycelial growth. The lesions ranged from 0.5 to 1.0 cm in diameter. Tandon and Kakkar (1970) reported similar fruit-rot due to *F. semitectum*.

Control measures *as detailed under Fusarium-rot of bottlegourd are applicable to this disease also.*

Cottony-leak, c.o. *Pythium aphanidermatum* (Edson) Fitzp. *P. butleri* Subram.

It was reported from Maharashtra and West Bengal (Rao 1966b; Mandal and Dasgupta, 1980). Level of soluble free sugars in diseased *L. cylindrica* fruits varied with disease development (Sharma and Wahab 1975). After complete utilization of carbon sources, fungus derives its energy from proteins and amino acids.

Symptoms and control measures *are similar to those described under cottony-leak of bottlegourd.*

Dirty grey-rot, c.o. *Rhizoctonia solani* Kühn

The disease originates from the distal-end with a depressed area of about 4-5 cm and a slightly water-soaked advancing margin. It is of minor importance. Dirty coarse mycelial mass with abundant sclerotia is noticed on the fruit-surface. Rotting is fast (Mandal and Dasgupta 1981).

Soft-rot, c.o. *Mucor hiemalis* f sp *lutens*, *M. circinelloides* Van Tiegh.

The symptoms are noticed on the damaged fruits and fruits bored by insect larvae. Affected fruits show water-soaked patches, followed by appearance of yellowish fuzzy mycelial growth. The rotten portion becomes slightly shrivelled, soft dull in colour and emits bad odour.

Protect harvested fruits from injuries. The fruits should be kept under refrigerated storage (8-10°C).

Sour-rot, c.o. *Geotrichum candidum* Link.

The disease is of minor importance. Infected fruits lose their lustre. White powdery growth appears on the surface. Infection advances radially and superficially with water-soaked margins. Infected fruits emit sour fermentative odour (Mandal and Dasgupta 1980).

Control measures are *as detailed under tomato in Solanaceous Crops*.

Charcoal-rot, c.o. *Macrophomina phaseoli* (Maubl.) Ashby

Singh and Chohan (1972a) recorded disease appearance from Punjab as light-brown water-soaked areas, usually at the pedicel-end. The rot progresses fast and may cover whole fruit. Fruits become shrivelled and internally blackened. Numerous black oval to irregular small sclerotia and a few pycnidia appear over the infected tissues. The host range of pathogen includes *Luffa cylindrica* Roem and *L. acutangula* Roxb; both are highly susceptible.

Creepy-rot, c.o. *Sclerotium rolfsii* Sacc.

The disease was reported from Rajasthan. It develops as small, localized patches with superficial, creepy, shining, white mycelial growth and abundant sclerotia. The symptoms are noticed on the damaged fruits or fruits bored by insect larvae. Infected fruits show water-soaked patches, followed by appearance of yellowish fuzzy mycelial growth. Rotten portion becomes slightly shrivelled, soft, dull in colour, and emits bad odour.

SPONGE-GOURD (*Luffa aegyptiaca* Mill.)

The plant yields a bitter tonic that is used as a diuretic and as a purgative. It is also useful in the treatment of asthma, skin diseases and splenic enlargement.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|------------------|---|-----------------------------|
| Soft-rots | <i>Fusarium scirpi</i> Lamb. & Fautr. | |
| | <i>Alternaria alternata</i> (Fries) Keissler | |
| | <i>Helminthosporium spiciferum</i> (Bain.) Nicot | |
| | <i>Curvularia lunata</i> (Wakker) Boedijin | |
| | <i>Myrothecium roridum</i> Tode ex Fries | |
| | <i>Botryodiplodia theobromae</i> Pat. | |
| | <i>Pythium aphanidermatum</i> (Edson) Fitzp. | |
| | <i>Rhizopus stolonifer</i> (Ehrenb. ex Fr.) Lind. | |
| Dry-rot | <i>Fusarium solani</i> (Mart.) Sacc. | Tandon <i>et al.</i> , 1975 |
| Mucor-rot | <i>Mucor circinelloids</i> Van Tiegh. | Tandon <i>et al.</i> , 1975 |
| Black-rot | <i>Fusarium pallidoroseum</i> (Cook) Sac. | Chitra and Arun, 2007 |

ROUND-GOURD (*Citrullus vulgaris*)

The following fungal diseases are reported on the crop.

| | | |
|--------------------------------------|---|----------------|
| Fusarium-rot | <i>Fusarium solani</i> (Mart.) Sacc, <i>F. equiseti</i> (Corda) Sacc | |
| Fruit-rot | <i>Cylindrocarpon lichenicola</i> | Sharma and |
| Pythium-rot/ Cottony-leak | <i>Pythium</i> sp. | Sumbali, 1993. |
| Sour-rot | <i>Geotrichum candidum</i> Link | |

KOVAL/IVORY-GOURD (*Coccinia cordifolia* auct. non (L.) Cogn.)
(= *C. indica* Wight and Arn.)

FUNGAL DISEASES**Anthracnose, c.o.** *Colletotrichum lagenarium* (Pass.) Ell. & Halst.

Symptoms are similar to those on other cucurbits. Dipping fruits in coprantol, thiourea or tetracycline is found effective in checking infection during storage (Hayan *et al.* 1978).

Fruit-rot, c.o. *Rhizoctonia solani* Kühn

Symptoms are similar to those on cucumber. Reddy and Reddy (1988) from Warangal studied the role of oxidases and cell-wall degrading enzymes on pathogenesis. Activity of peroxidase and polyphenol oxidase (PO and PPO) increased considerably in infected lesions.

Fruit-rot, c.o. *Bipolaris tetramera* (Mc Kinney) Shoemaker

The disease was observed from local markets of Allahabad; it caused sizable economic losses. The fruit was completely covered with fungal growth.

Dithane M-45 (250, 500, 750 ppm), Ziram (500, 750, 1,000 ppm) and Anustin (Carbendazim 50% WP at 500, 750, 1,000 ppm) as field spray were effective in disease management (Shrama 2006).

OTHER ASSOCIATED DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|-----------------------|---|-----------------------------------|
| Curvularia-rot | <i>Curvularia lunata</i> (Wakker) Boedijin | Laxminarayana and Reddy, 1976a |
| Macrophoma-rot | <i>Macrophoma</i> sp. | |



CHAPTER 20

Solanaceous Crops

BRINJAL/EGG-PLANT/AUBERGINE (*Solanum melongena* L.)

Brinjal or egg-plant is one of the most common and popular vegetable crops. Number of cultivars are grown in different parts of India. Consumer preference is based on certain characters like colour, size and shape of the fruit.

FUNGAL DISEASES

Phomopsis-blight, c. o. *Phomopsis vexans* (Sacc. & Syd.) Harter

Teliomorph : *Diaporthe vexans* Gratz.

Phomopsis-blight ranks second to bacterial wilt in causing destructiveness. It is identified as the common disease in tropical and subtropical areas. In India, it is considered as the most important disease. This disease along with leaf-spot caused by *Alternaria solani* reduced seed germination and yield up to 30-50%. Seeds that are harvested during *kharif* and *rabi* favour maximum spore load on the seed-coat than on the other seed components. Disease transmission is also more during *rabi* than in *kharif* (Thippeswami *et al.* 2005).

Although the disease is prevalent throughout the world; it is common in the tropical and subtropical areas. The disease starts with foliage blight, but its most destructive phase is fruit-rot. It was first reported by Uppal *et al.* (1953) from Maharashtra. Later on, this was recorded by Vasudeva (1960), Neema and Agarwal (1960), Ashwani Kumar *et al.* (1986), John (1991), Reeny (1995) and Rajkumar (2000). In Ranchi, *P. vexans* was observed to cause maximum losses in brinjal-fruits and recorded a loss of 11.8% (Prasad *et al.* 1989).

Symptoms : On the fruit, symptoms manifest as minute, pale-straw coloured sunken spots, which coalesce and cover 75% of the area in the long-fruited varieties. The colour deepens and ultimately becomes dark-brown to black, and whole fruit rots within seven days (Fig. 20.1). Black pycnidial spots are noticed in abundance on the lesions. The lesions are prominent on the purple/red skinned varieties also (Philip 1998). The fungus may enter through calyx, in which case whole fruit mummifies, and results in a dry-rot.



Fig. 20.1. *Phomopsis*-rot on brinjal

Duration of *Phomopsis* fruit-rot development varies in different varieties. In general, this may range from 5 to 30 days (Suga *et al.* 2002).

Temperature of 25°C and relative humidity of 90% were found conducive for development and progress of fruit-rot in Himachal Pradesh. Young fruits (10-15 days old) and an inoculum load of >120 spores/ml were ideal conditions for infection.

Synergism was reported of *Fusarium moniliforme* with *P.vexans* in causing fruit-rot (Datar 1983). Fruits inoculated with *Fusarium* showed reddish-brown discolouration on the calyx and on the stem-end region. All fruits dropped on the third day of inoculation. *Fusarium* was re-isolated. Fruits inoculated with *P.vexans* exhibited typical symptoms of *Phomopsis*-rot with brown to black discolouration that extended from the stalk-end, resulting in softening of inner tissues. But fruit drop was not observed. Fruits inoculated simultaneously with both the pathogens dropped on the third day. Fruits were sunken and tissues were softened; fruits dropping and extent of rotting indicated that pathogens exerted a synergistic effect in causing fruit-rot.

Variability in *P.vexans* isolates with regard to cultural and morphological characters is also available. Kumar and Suga (2000) and Akhtar and Chaube (2006) recorded variability among isolates collected from different geographical areas in India.

This fungus is seed-borne and subsists in soil on plant debris. Kumar *et al.* (1990) recorded 9% seed infection. The disease reduces seed germination and causes yield losses to the tune of 30-50% (Thippeswamy *et al.* 2006). The fungus is disseminated as water-borne pycniospores and requires wet weather and high temperature for their development. Chowdhury and Hasija (1979) observed temperature of 25°C and relative humidity of 75% as ideal. This fungus grows well between 21 and 32.5°C; optimum being 29°C. Storage-rot is maximum at 25°C. And 5, 10 and 40°C are unfavourable for disease development (Singh 1992).

Varietal resistance to fruit-rot was also observed. Ahamed (1987) recorded maximum rotting on fruits of Pusa Purple Long, followed by Pusa Oval Green,

Pusa Dwarf, and Annamalai varieties showed minimum percentage of rotting. Similarly, Arkakusmakar, Aurangabad Local, Annamalai, Bengal Long and certified cultivars like Early Round Market, Gondegaon Local were moderately resistant (Datar and Ashtaputre 1984, 1988). This disease in destruction ranks second only to bacterial wilt. In tropical and subtropical areas, 50% losses were recorded due to disease. Sources of resistance were reported in *Solanum xanthocarpum*, *S. nigrum*, *S. toruam*, *S. khasianum*, *S. sisymbriifolium* and in certain egg-plant lines (Kalda *et al.* 1976; Sherif and Macnab 1986; Sokhi, 1994). Ramnagar Giant and KS 233 were reported as the best varieties from Varanasi against *Phomopsis*-blight, and showed resistant to moderately resistant response at the different stages of disease development (Pandey *et al.* 2002). Punjab Barsati was considered as a disease-escaping variety.

Control measures : The disease is serious, particularly to seed-crop as it is seed-transmitted. The spore load ranges from 0.2% in the seed-coat and 0-4% in cotyledons and embryonic areas (Thippeswami *et al.* 2005). Seed treatment with Captan(0.2%), Difolatan (0.2%), Benlate (500 ppm), Calixin(1,000 ppm) was recommended (Singh and Chakrabarti 1982). Seed treatment with Thiram @ 2g/kg of seed was also effective (Kumar *et al.* 1990).

In the nursery or field as fruits touch ground, they rot irrespective of spray of chemicals. Application of chemicals, however, reduce infection on the harvested fruits. Grewal and Jhooty (1987) observed the disease to be serious for seed-crop in Punjab, and recorded Dithane M-45 as the best fungicide, followed by Bordeaux mixture and Blitox. Palo as early as 1936 and Teco in 1980 reported effectiveness of soil drenching with Bordeaux mixture (4:4:50) and a mixture of copper oxychloride (COC) and Benlate. Copper oxychloride alone was also effective. John (1991) observed spraying at fortnightly intervals with COC-50 as the best treatment in reducing fruit-rot infection in the field. Bordeaux mixture and Dithane M-45 also recorded similar results. Seed treatment with Bavistin was also effective. Mancozeb spray on the seed-crop was considered must to contain disease (Sokhi 1994). Mancozeb (0.2%), Carbendazim (0.1%) and Captaf (0.2%) inhibited seed-borne pathogens and increased seed germination (Thippeswami *et al.* 2006).

Biological control with *Trichoderma harzianum* and *Gliocladium virens* was reported. *In-vitro* studies on fruits inoculated with *P. vexans* and treated with the above cultures (@ 10^6 spores/g with talc) showed very little rotting as compared to complete rotting in control fruits (Figs 20.2, 20.3) (Rajkumar 2000).

At Ludhiana, Anju and Bedi (2004) evaluated *Beauveria bassiana* as a biofungicide for control of *Phomopsis* fruit-rot. The suspension (5×10^6 spores/ml), when applied to brinjal-plants served as an antagonist and inhibited mycelial growth and pathogen sporulation.

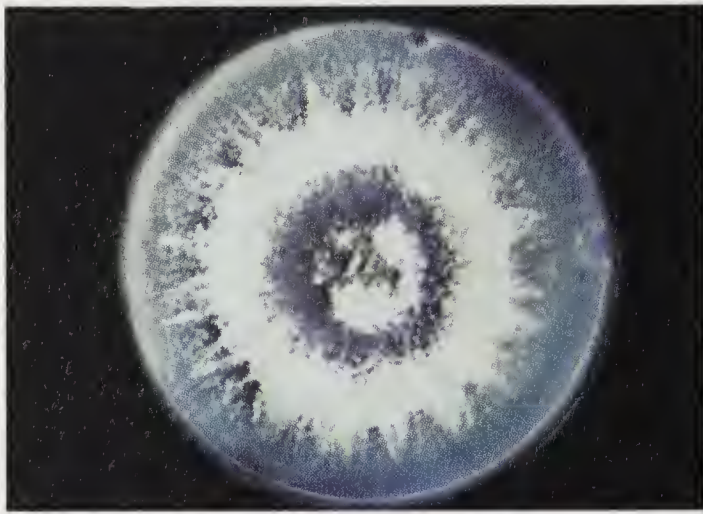


Fig. 20.2. Growth of *Trichoderma harzianum*

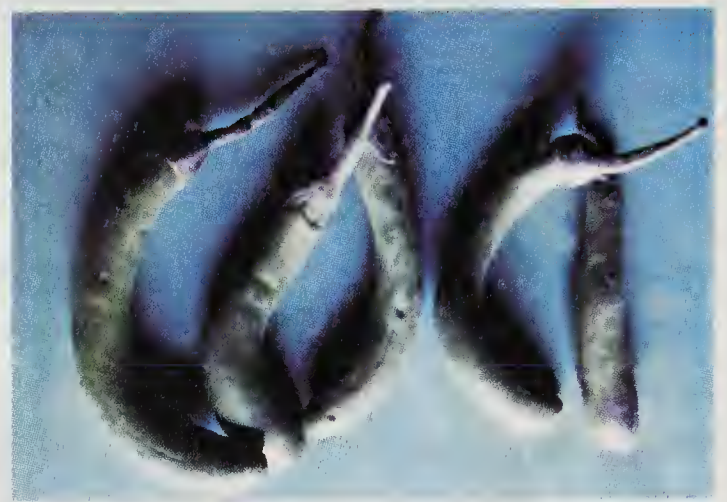


Fig. 20.3. Brinjal-fruits after treatment with biocontrol agent

***Fusarium-rot*, c.o. *Fusarium* spp.**

The disease is prevalent in field and in storage. Following *Fusarium* species have been found associated with it.

***F. moniliforme*.** This causal organism was reported earlier by Garofalo and Nuovo (1956). Datar (1980) observed brinjal variety Manjeri Gota as highly susceptible. The lesions formed are sunken and brown in colour with profuse pinkish growth on the calyx and stem-end region of the fruit. Mishra and Rath (1986) and Mehta and Mehta (1989) also recorded this pathogen from Sagar (Madhya Pradesh) under field and storage conditions. Rotting is observed more in storage than in field conditions.

***F. solani* (Mart.) Sacc.** Datar (1980), Mishra and Rath (1986) and Reeny (1995) observed it as the most virulent among the *Fusarium* species. Cultivars differed in their reaction.

***F. oxysporum* Schlet.** Laxminarayana and Reddy (1977) and Mehta and Mehta (1989) reported fungus from market samples. The fungus is seed-borne (Sharma and Sumbali 1993). It is more aggressive compared to other *Fusarium* species. Initiation of the disease takes more time with this species compared to others but in advanced stages of pathogenesis, extent of rotting is almost the same. Rot extends gradually from the stylar-end to the stalk-end of the fruit, and in a few days fruits become soft and rotten.

***F. semitectum* Berk. & Rav.** Kaur *et al.* (1984, 1985) recorded this from Punjab. The fungus causes both wilt and fruit-rot; 26-28% fruit-rot incidence was noticed in some varieties. Infected fruits are covered with white-pink fungal mycelia, and the fruit size reduces in severe infection. About 7-30% rot incidence in brinjal is due to *F. semitectum*. This fungus is recorded to be associated with seeds also.

***F. equiseti* (Corda) Sacc.** The disease was first observed by Garofalo and Nuovo (1956). Sharma and Sumbali (1993) in vegetable market survey in the north India also recorded this fungus on brinjal.

In addition to these species, an unidentified *Fusarium* sp. was reported by Alice and Paily (1978) from Thiruvananthapuram, Kerala.

Several measures including use of chemicals are suggested by different workers. Growth regulators like 2,4-D and 2, 4-5 T (750 ppm) inhibited fungal growth in brinjal-fruit (Thakur *et al.* 1974).

Fruit-rot, c.o. *Phytophthora* spp.

Phytophthora causes leaf-blight and fruit-rot in brinjal. The frequency of fruit-rot incidence is maximum during rainy season. *P. infestans* and *P. nicotiana* var. *nicotianae* were generally recorded. Maximum rotting occurred at 30°C with a relative humidity of about 80% (Jain and Bhatnagar 1978; Jain 1982). Thankamma (1983) recorded brinjal fruit-rot from Kottayam (Kerala) during south-west monsoon. *Phytophthora* sp. was also reported on brinjal-fruit reaching Thiruvanthapuram markets from Tamil Nadu (Philip 1998). The symptoms produced were of soft-rot type.

Symptoms : Brownish-black circular to oval water-soaked lesions appear on the fruits. Scrapings showed presence of sporangia. Rotting tissues on maceration yielded mycelia with disorganized spongy parenchyma. Gogoi and Rathaiah (1992) recorded dry fruit-rot from Asom, where peel became hard, sunken and discoloured.

Infection starts at the calyx as water-soaked lesions. Hardening of the fruit is a characteristic symptom. A floury-white growth occurs over lesions, and as lesions grow older, *Cladosporium* sp. can be noticed to be overgrown on them.

Control measures : As detailed in Phomopsis-rot are applicable for this also.

***Curvularia* fruit-rot, c.o. *Curvularia clavata* B.L. Jain**

This fungus causes dry-rot in brinjal-fruits. Mature fruits get infected, especially when they are wounded, and gradually lesions increase in size. The lesions are of cepia colour and measure 1-2 cm in diameter in advanced stages. The disease caused 4-7% damage to fruits in Uttar Pradesh (Tandon *et al.* 1975a). Seed-borne nature of the fungus was also reported (Sharma and Sumbali 1993).

Seed-borne infection can be controlled by treating seeds with Captan (0.2%).

***Rhizopus*-rot/soft-rot, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.**

Rhizopus fruit-rot is regarded as one of the most important diseases of brinjal in field, transit and storage. Ramakrishnan and Wilson (1968) and Alice (1969) in their surveys in Thiruvananthapuram local market recorded this fruit-rot as the most damaging one; the disease was reported from other countries also (Coursey and Booth 1972; Bilgrami *et al.* 1979, 1981).

Symptoms : They are noticed on the mature fruits as small water-soaked lesions. Soon after when the peel becomes discoloured, infected area gets darkened and extends rapidly in all directions. Peel becomes loose and tissues are sunken with considerable depression. Within 2-3 days, entire fruit becomes soft and leaky. Symptoms are also visible on fruits in the standing crop. The rotting extends to the stalk-end, and finally fruit drops to the ground (Thakur 1972). Vyas *et al.* (1978) recorded fruit-rot caused by *R. nodosus* from local markets of Sagar (Madhya Pradesh). The disease starts as a soft-rot from mesocarp portion of the brinjal-fruit. The fungus multiplies inside the fruit and causes discolouration and rotting of healthy tissues. Its hyphae appear prominent as white strands, and after 2-3 days, cottony mycelial growth and fruiting bodies develop on the entire mesocarp portion of the fruit.

Reeny (1995) observed *R. nigricans* from the local markets of Thiruvananthapuram. Water-soaked areas appeared concentrated around the injury, which was covered with mycelial growth. The mycelial mass bearing brown to black sporangia appeared profusely, especially around the margins. Brownish liquid with a characteristic odour oozed out.

Control measures : A pre-infection treatment of 2, 4-D at 500 ppm was used and was reported to be effective against *R. arrhizus* infection (Thakur *et al.* 1974).

Wet-rot, c.o. *Choanephora cucuribitarum* (Berk. & Rav.) Thaxter

The disease occurs during rainy season, and was reported from Uttar Pradesh (Dubish and Singh 1976; cit Bilgrami *et al.* 1979) and West Bengal. Symptoms may appear anywhere on the fruit-surface, but mostly originate from the distal-end. The disease progresses fast and spoils normal colour. The affected area becomes soft, foul-smelling and pulpy. Peel gets loosened from pulp with a white, scanty fibrous superficial growth.

Cottony-leak, c.o. *Pythium aphanidermatum* (Edson) Fitzp.

The disease is of common occurrence (Coursey and Booth 1972; Sharma and Sumbali 1993; Reeny 1995 and Rajkumar 2000). *P. butleri* was also reported along with *P. delians*.

Symptoms : Water-soaked lesions appear on the fruits, which gradually enlarge to sides, and fruits rot completely within 3-7 days. Ilag (1976) observed nesting of fruits during storage. The fungus is reported to be seed-borne (Suryanarayana 1978).

Control measures : Seed treatment with Captan (2g/kg of seed) eliminates seed-borne infection. Biological control with *Trichoderma harzianum* or *Laetisaria arvalis* along with Captan was reported to be effective (Jacob *et al.* 1988). Prior to sowing, seeds soaked in *Eucalyptus* leaf extract for 30 minutes offered protection.

Brown spongy-rot, c.o. *Alternaria* spp.

Several species of *Alternaria* are reported to be associated with this rot. *A. tenuis* and *A. solani* cause seedling-blight as well as leaf-spot. Fruit-rot by *A. melongenae* is common. *A. alternata* is also reported to cause fruit-rot (Sharma and Sumbali 1993). Affected fruits become yellow and drop prematurely. The disease was reported from several states in India. Prasad and Poddar (1977) reported *A. tenuis* from Bihar and observed biochemical changes during pathogenesis. Changes in carbohydrate content were recorded and were also visible in free amino acid contents. Valine and leucine were utilized completely and threonine, asparagin, tyrosine and cysteine were utilized only partially. Changes in organic acids were also noticed. Complete exhaustion of fumaric acid and an increase in malic acid were observed. And succinic acid recorded no change.

Symptoms : Small, circular spots of about 0.5-1.0 cm diameter appear with well-defined margins. Fruit-flesh becomes spongy, turns greyish to dark-tan with deep-brown to black, scanty, superficial mycelial mass, which becomes velvety due to sporulation (Dasgupta and Mandal 1989). Prasad and Roy (1979) observed maximum rotting at 26°C and 90-100% RH. Singh (1988) studied effects of N, P, K on *Alternaria* leaf-spot and fruit-rot in Kanpur, and observed that higher doses of nitrogen without P or K resulted in severe infection by *A. alternata* in the field trials, and high P or K, together or separately, reduced disease under varying nitrogen levels.

Control measures : The seed-borne nature of the disease is well established. Mancozeb (0.2%), Carbendazim (0.1%) and Captan (0.2%) are found effective in inhibiting seed-borne pathogens and in increasing seed germination (Thippeswamy *et al.* 2006). Seed treatment with 0.2% Thiram was also effective.

**Diplodia-rot, c.o. *Diplodia natalensis* Pole-Evans/
Botryodiplodia theobromae Pat.**

Ramakrishnan and Wilson (1968), Alice (1969) and Alice and Paily (1978) recorded disease from the local markets of Thiruvananthapuram (Kerala).

Symptoms : Straw-coloured lesions appear on fruits, which darken with age. In the advanced stages of infection, fruit-surface gets covered with mycelial growth. Along with this, black pycnidia are also present in abundance. At this stage, the fruit rots completely.

Control measures : Chemical treatments *as detailed in Phomopsis-rot, control this disease also*. Avoid wounds and bruises on the fruits.

Ring-rot, c.o. *Myrothecium roridum* Tode ex Fr.

Tandon and Srivastava (1963) and Ramnath *et al.* (1966) reported the disease from the local markets of Allahabad (Uttar Pradesh). Ullasa *et al.* (1976) recorded this disease from Karnataka. This fungus with *Chaetomium*

globosum caused rotting of fruit-stalks. The extent of damage was 1-2% only.

Symptoms : Stalk-skin becomes soft and loose. In the later stages, infection proceeds towards the persistent calyx, and skin gets separated from the woody stalk. Then the fruits detach easily. Symptoms are also evident as small to large conspicuous sharply defined circular to oval flattened lesions. Affected tissues become pale to black. The rot penetrates deep into the fruit. Presence of alternating narrow concentric rings of black spore masses with white mycelial growth is the characteristic symptom.

Control measures : Chemical treatments *as detailed in Phomopsis-rot* control this disease also.

Soft-rot, c.o. *Chrysosporium pruinosum* (Gilman & Abbot.) Carmichael

The disease was observed from Kurukshetra (Dhingra and Mehrotra 1980). Infection starts as light-yellow coloured depressed areas. Sooner the whole fruit surface becomes soft, pulpy and is covered by white growth. The entire fruit decays and emits foul smell.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal Organism | Authority |
|---------------------------|------------------------------------|--|
| Grey mould-rot | <i>Botrytis cinerea</i> | Coursey and Booth, 1972; Sharma and Sumbali, 1993 |
| Colletotrichum-rot | <i>Colletotrichum</i> sp. | Prasad <i>et al.</i> , 1989 |
| Cercospora-rot | <i>Cercospora</i> sp. | |
| Fruit-rot | <i>Helminthosporium spiciferum</i> | Kumar <i>et al.</i> , 1990 |
| | <i>Chaetomium eraticum</i> | |
| | <i>Dreschlera tetramera</i> | |
| Fruit-scab | <i>Cladosporium oxysporum</i> | Sharma and Sumbali, 1993 |
| Yellow mould-rot | <i>A. niger</i> | |
| Paecilomyces-rot | <i>Paecilomyces variotii</i> | Reeny, 1995 |
| Rhizoctonia-rot | <i>Rhizoctonia solani</i> | |
| Penicillium-rot | <i>Penicillium</i> sp. | |
| Pink-rot | <i>Trichothecium roseum</i> | |

BACTERIAL DISEASES

Bacterial soft-rot, c.o. *Pseudomonas fluorescens* Migula

The disease is considered as of minor importance, but occurs after rains in West Bengal. Infection occurs at any point on the fruit-surface but is mostly concentrated around the borer holes. The pulp becomes soft with skin remaining firm but turning orange-red with bluish-brown centre; the fruit smells offensive.

Dehydrated brinjal

Shelf-life of brinjal-fruits usually increases with sun-drying ; and they can be utilized in off-season. But poor handling, storage and marketing facilities often leads to microbial contamination. *Aspergillus* spp. and *Penicillium* spp. are commonly found associated. Mycotoxins, Patulin and citrinin, were detected from infected samples (Kour and Sumbali 2006).

Control measures : The moisture limit of dehydrated samples should not exceed 7%. The dried material should be kept in air-tight containers.

Seed mycoflora

Vidhyasekaran *et al.* (1980) observed fungi like *Aspergillus flavus*, *A.niger*, *A.glaucus*, *Fusarium moniliforme* and *Helminthosporium tetramera* on seed samples of brinjal. Fungi associated with brinjal-seeds were also studied by Pattnaik and Narain (2003) from Odisha; causing seed damage from 63 to 72%. Among different cultivars, higher percentage of seeds (11-30%) was predominantly infected by *Fusarium solani*, followed by *Aspergillus fumigatus* (8-20%), *Chaetomium globosum* (5-10%) and *Penicillium* sp. (6-14%). Thippeswamy *et al.* (2004) in Karnataka observed fungi like *C.capsici*, *Alternaria alternata*, *A.solani*, *F.oxysporum*, *F.solani*, *Phomopsis vexans*, *Macrophomina phaseolina* and *Aspergillus* sp.

Control measures : Seeds are to be dried up to moisture level of 8-10%. Seed treatment with Thiram at 0.2% controlled all seed-borne fungi and preserved viability and seedling vigour.

CHILLI (*Capsicum annum* L.)

Chilli is one of the valuable spice crops cultivated throughout the country. High ascorbic acid was reported in chilli-fruits (cvs Bullet and Suryamukhi). India is the second largest exporter of chillies in the world. Several varieties are cultivated all-over India. Chilli cultivation is concentrated in Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu. Chilli-crop is valued for its pungency, colour and aroma. It is a good source of vitamins C, A, and B. This also contains small quantities of proteins, fats, carbohydrates and traces of minerals. The economic importance of the fruit lies in its pungency and flavour. This is due to capsin (n-4-hydroxy-3-methoxy benzyl 8-methyl trans 6 non enamide).

The sequence of fungi associated with chilli-fruits was studied by Vijayalakshmi and Rao (2003) from Andhra Pradesh. They recorded *Alternaria*, *Fusarium* and *Cladosporium* to be always present on chilli-fruits. *Curvularia tuberculata* and *Fusarium solani* populations increased gradually as the fruits attained maturity. While *Aspergillus flavus*, *A.niger*, *A.fumigatus* and *Colletotrichum capsici* appeared only on mature fruits.

FUNGAL DISEASES

Anthracnose/ripe-rot/fruit-rot,

c.o. *Colletotrichum capsici* (Syd.) Butler and Bisby

Among the fungal diseases taking a heavy toll on chillies, anthracnose is the most important one. This is the major constraint in tropical and subtropical areas under humid conditions. The disease causes substantial reduction in yield and was reported from India by Butler and Bisby in 1918. Since then, it has been found to be serious in all chilli-growing areas. The disease becomes conspicuous only when it has already caused substantial damage to mature fruits in the field. Chowdhury (1957) reported 12-32% loss due to this disease from Asom. Crop losses ranging from 10 to 60% as well as 10 to 35% under field and storage conditions were recorded from Punjab and Haryana (Grover and Bansal 1968, 1970; Singh and Thakur 1970).

The disease causes severe damage to fruits; up to 84% in the field as well as in storage (Thind and Jhooty, 1984). Yield losses in bell-pepper during 1985-87 were estimated at 27.17% in Himachal Pradesh (Paul and Behi 1990).

Biochemical changes due to infection were recorded in different cultivars (Sharath *et al.* 2004). Due to infection, shifts occurred in amino acids, carbohydrates and capsaicin contents in red fruits. In diseased tissues, L-aminobutyric acid, asparagine and tyrosine were degraded completely. An increase in β alanine, arginine, glutamic acid, glycine and threonine was observed after 5 days of infection. Leucine remained unaffected while aspartic acid and proline catabolized considerably. Capsaicin content was reduced to half. Degradation of vitamin C and capsaicin content by *C. capsici* and *A. niger* was also reported (Das 2007). Enzymes produced by pathogens play a vital role in disease development. But inhibition of enzymes production by plant products was reported by many workers (Mahadevan *et al.* 1965; Patil *et al.* 1992). Chitra *et al.* (2001) reported effect of *Datura innoxia* extracts on pectinolytic and cellulolytic enzymes production of *C. capsici* under *in-vitro* conditions.

Colletotrichum is an economically important genus. It was established by Corda in 1931. Teliomorph stage of many *Colletotrichum* species is *Glomerella*, and both stages are widely prevalent in hot and humid areas. *Colletotrichum* spp. are mainly responsible for diseases of fruits, vegetables, sugarcane, ornamentals etc.

Several *Colletotrichum* species have been recognized. And commonly encountered, and virulent form is *C. dematium* = *C. capsici* (Verma 1973; Datar and Guhule 1987). But other species like *C. graminicola*, *C. gloeosporioides*, *C. piperatum*, *C. acutatum* have also been recognized (Ramakrishnan and Wilson 1968; Grover and Bansal 1968 ; Gupta *et al.* 1974; Thind and Jhooty 1984; Kaur and Singh 1990; Khodke and Gahukar 1990; Kardale 1990; Sharma and Sumbali 1993; Reeny 1995; Raj Kumar 2000).

In Argentina, *Gloeosporium piperatum* was observed to cause anthracnose (Laguna and Decampo 1971). Yu *et al.* (1987) recorded *C.coccodes* on *Capsicum* seeds from Korea. Detailed studies were carried out on cultural, morphological, physiological and comparative virulence (Vanan and Khirbat 2002; Khirbat and Vanan 2004; Akhtar and Singh 2007).

Epidemiological factors which help in perpetuation of disease include optimum temperature of 28°C and relative humidity of 95% (Chowdhury 1957). Besides, sunshine, age of the host also affects disease development. Fruit-rot development is maximum during rainy season in Thrivananthapuram, Kerala (Reeny 1995).

Symptoms : They appear on leaf (leaf-spot), shoot (die-back) and on fruit (fruit-rot). On mature, green fruits, they appear as small, black circular spots that spread in all directions. With advancement, the spots diffuse and become black or dirty grey. On the lesions, fungus acervuli are noticed in abundance. Grover and Bansal (1968) recorded over-wintering of *Colletotrichum piperatum* on red ripe-fruits and occasionally on green fruits, forming circular to elliptical lesions, which coalesce and cover 1-2 cm or more on fruit (Figs 20.4, 20.5). Later, lesions become depressed, sunken and turn dirty-yellow to pinkish, and finally turn brown due to ageing. *C.gloeosporioides* appears as depressed, sunken, regular discoloured circular to irregular spots. This fungus infects semi-ripe and ripe-fruits but fail to infect green fruits (Kardale 1990). Thind and Jhooty (1984, 1990) observed symptoms caused by *C.gloeosporioides*, *C.capsici* and *C.piperatum*.

Gloeosporium piperatum was reported to cause ripe-rot of chilli-fruits (green or ripe) in Punjab, Haryana, Himachal Pradesh and Rajasthan. It attacks both spice and vegetable varieties. In Solan, disease appears in a severe form. In moist weather, small circular sunken spots appear on the green or ripe-fruits. Lesions are sunken, dirty-yellow to pinkish, turning brown with age. Acervuli are formed on infected lesions in concentric circles. Conidia cause disease spread through splashing of rain-drops or wind (Suryanarayana 1978).



Figs 20.4, 20.5 *Colletotrichum* fruit-rot on chilli

Histopathological and ultrastructural studies on *C. capsici* were conducted by Muthumary and Jayachandran (1994). The conidium ontogeny was well understood by employing scanning (SEM) and transmission electron microscopy (TEM) (Gehlot and Purohit (2001).

Seeds also show symptoms of infection. In advanced stages, seeds are covered by a thick mat of fungal hyphae. The pathogen survives for a short time in the soil. Infection was reported to be seed-borne (Grover and Bansal 1968; Suryanarayana 1978; Hingole and Kurundkar 2005). Varietal differences were also considerable (Grewal and Grover 1974; Yu *et al.* 1987). In general, seed germination is reduced by more of pre-emergence mortality than post-emergence mortality.

Control measure: *Management of fruit-rot resistant lines.* Kadu *et al.* (1978) studied field reaction of chilli germplasm to anthracnose and recorded several lines to be immune as well as resistant and moderately resistant to diseases from Maharashtra. Several entries were screened and resistant lines have been evolved for different geographical areas (Ullasa *et al.* 1981; Singh *et al.* 1990; Jayalakshmi and Seetharaman 1998; Hegde and Anahosur 2001a; Kaur *et al.* 2005).

Seed treatment with chemicals. In anthracnose, infection is seed-borne, and pathogen survives in the seed for a short period. And during storage, seed viability is lost due to seed-borne fungi. Treatment of seeds with fungicides prior to storage offers protection (Pillayarasamy *et al.* 1973). Treated seeds are pelleted with *maida* and used for sowing later. The trial proved to be effective in eliminating seed-borne infections.

Seed treatment with Captan (0.2%) reduces the disease in the nursery. Seed treatment with Ceresan, Thiram (0.2%) and Brassicol (0.25%) by weight of seeds was found suitable in eliminating seed-borne infections (Suryanarayana, 1978). In sweet-pepper, seed treatment with Captan(0.2%) reduced disease in the nursery (Sokhi 1994). Seed treatment with Bavistin (0.1%), Thiram(0.2%), Captan (0.2%) as well as Thiram (0.2%) + Carbendazim (0.1%) was reported to be effective in increasing seed germination and reducing disease incidence in the field (Kumar and Mahmood 1986; Perane and Joi 1989; Hegde and Kulkarni 2001; Hingole and Kurundkar 2005 and Pawar *et al.* 2005). Captan and Thiram were effective in preventing fungal colonization and increasing seed germination, followed by Carboxin, Carbendazim and Mancozeb. Tridemorph and Ridomil were not very effective (Singh *et al.* 2006).

Pelleting of seeds offers good scope for inclusion of bio-ingredients, fungicides, growth regulators in small quantities. Dried seeds treated with Goucho at 5g/kg of seeds showed good results.

In-vitro effects of *Trichoderma harzianum*, *T. viride*, *T. viride E* and *T. virens* (*Gliocladium virens*) were evaluated for their antagonistic potential

against *C. capsici* using dual culture and poison technique at Palampur (Kaur *et al.* 2006). *T. viride* was found most effective in reducing seed infection. Untreated and infected seeds gave rise to rotten seedlings and showed necrotic lesions on primary leaves. Seed treatment with *T. viride* was effective and eradicated completely seed-borne pathogens including *C. dematium* in pea (Kumar *et al.* 2000). Culture filtrate and volatiles produced by *T. viride* suppressed spore germination and reduced mycelial growth (Iqbal *et al.* 1994; Umamaheswari and Ramakrishnan 2000).

Seed treatment with biocontrol antagonists like *Pseudomonas fluorescens*, *Bacillus subtilis*, *Trichoderma viride* and *T.harzianum* at 10^8 cfu/ml controlled damping-off caused by *C. capsici* (Hegde and Kulkarni 2001). The treatment was found on a par with Captan @ 3g/kg of seeds. Similar results were also recorded by Srinivas *et al.* (2006). Pure culture of *P.fluorescens* was effective in reducing *C.capsici* infection, followed by *T.harzianum* and fungicide-treated seeds. Inhibitory effects of leaf extracts against *C. capsici* were also reported (Gomathy and Kannabiran 2000). Leaf extracts of *Solanum toruvum*, *Datura metel* and *Prosopsis julifora* were found promising. Inhibition of conidial germination and mycelial growth of *C.capsici* was observed with aqueous leaf extract of *Datura metel* (Asha and Kannabiran 2001).

Field application of chemicals. Fungicides, Blitox (0.5%), Mancozeb (0.25%), Thiophenate methyl (0.5%), Carbendazim (0.5%), Zineb (0.2%), Captafol (0.2%), Copper oxychloride (0.25%), Iprodine (0.2%), Dithane M-45 and Dithane Z-78 (0.2% each) were found effective in controlling the disease in different agroclimatic regions (Viswakarma and Sitaramaiah 1985; Datar *et al.* 1989). In Karnataka, Carbendazim and Propiconazole were reported to be effective (Hedge and Anahosur 2001 b).

Carbendazim (0.2%) and Chlorothalonil (0.2%) recorded maximum inhibition of mycelial growth of anthracnose in *in-vitro*-grown bell pepper (Rao and Patil, 2000). *In-vitro* studies on *C.capsici* showed that Iprobenphos (Kitazin), Captan (Captaf) and Copper oxychloride (Blitox) were effective in different concentrations (0.2, 0.1 and 0.05%) (Singha and Senapoty 2006). Iprobenphos was superior compared to others.

Dipping harvested fruits in Carbendazim 1,000 ppm or Zineb or Captafol was also recorded effective in Marathwada (Datar and Guhule 1987).

Biological control in field. Use of antagonistic microorganisms. Isolates of *Trichoderma* spp., *pseudomonas fluorescens*, fluorescent pseudomonads, *Bacillus subtilis* and an yeast *Saccharomyces cerevisiae* were screened against *C.capsici* *in-vitro* and *in-vivo*. Yeast (5×10^5 spores/ml) and *Bacillus subtilis* (10^9 cfu/ml) caused maximum reduction in fruit-rot intensity and die-back, followed by *T. viride* (when sprayed 105 and 120 days after sowing) (Jayalakshmi *et al.* 1998). Hegde and Anahosur (2001 b) observed positive

results with *P. fluorescens* and Nimbiciden. There was reduction in disease development. The treated chilli-fruits also recorded maximum capsaicin, ascorbic acid and total sugars.

In addition to fungi and bacteria, yeasts and actinomycetes also serve as biocontrol agents. Singh and Bora (2006) from Manipur isolated *Streptomyces* S.124 possessing high antifungal activity against *C.capsici*, *C.pisi* and *F.oxysporum*.

Use of plant products. Shivapuri *et al.* (1997) reported that ethanol extracts of *Azadirachta indica*, *Datura stramonium*, *Ocimum sanctum* and *Polyalthea longifolia* at 5% concentration in *in-vitro* were toxic to *Alternaria brassicicola*, *C.capsici*, *Fusarium oxysporum*, *Rhizoctonia solani* and *Sclerotinia sclerotiorum*. Palmarosa (*Cymbopogon martini*) oil was found effective in reducing fruit-rot infection (Jayalakshmi and Seetharaman 1998). Leaf extract of *Ocimum sanctum* and neem oil (*Melia azadirachta*) also protected the crop. Choudhary *et al.* (1998) reported bitter temru fruit (*Diospyros cordifolia*) preparation as the best growth inhibitor for *B.capsici*, *Alternaria alternata*, *Fusarium udum* and *Helminthosporium maydis*. In *in-vitro* studies with bitter temru fruit and *datura* (*Datura stromonium*), leaf extracts inhibited maximum *C. capsici* growth (Bagri *et al.* 2004) .

Use of root extracts. Kumaran *et al.* (2003) observed hyphal thickening, vacuolar formation and swellings at the tip of hyphal strands of *C.capsici* with ethanol extract (at 5% concentration) of *Abrus precatorius* and *Rauvolfia tetraphylla* roots. The extract showed higher control compared to Mancozeb (0.2%) treatments. This was supported by the findings of Sariah (1995) in *C.capsici* and *C.gloeosporioides*, suggesting that this may be due to fungal toxic compounds present in the extract.

Integrated pest management. In this, biological antagonists are included along with fungicides and regular cultural practices. Sharma *et al.* (2004) compared 3 different pest management modules—biological, chemical and IPM, and observed IPM to be superior to others in managing chilli die-back and fruit-rot on two selected cultivars. *Trichoderma harzianum* as seedling-dip worked as a substitute for chemical control in nurseries.

Black ripe-rot/blight/fruit-rot, c.o. *Alternaria alternata* (Fr.) Keissler

The disease was reported from the USA, Italy and India. This fungus causes blighting of leaf tissues. Dark spots appear on leaves; and they die prematurely and drop. Fruit-rot is an important phase of this disease, and it causes appreciable losses during transport and storage (Coursey and Booth 1972; Hiremath and Govindu 1975; Sreekantaiah *et al.* 1973; Suryanarayana 1978; Uma 1981; Thind and Jhooty 1984; Sharma and Sumbali 1993; Wall and Biles 1993; Bhat *et al.* 2000; Vijayalakshmi and Rao 2003).

A number of *Alternaria* strains have been reported to initiate fruit-rot in chillies (Savulescu and Ana 1949; Thind and Jhooty 1984); including *Alternaria solani* (Ell & Eve) Jones and Grout, *A. tenuis*, *A. alternata*, *A. longipes*, *A. capsici annui* and *Alternaria* sp.

A. tenuis isolates collected from conventional chilli-growing areas of southern Tamil Nadu varied in morphological and cultural characters and in virulence (Muthulakshmi *et al.* 1994).

Symptoms : Circular, greyish-green, water-soaked sunken spots appear anywhere on the fruit-surface. Spots gradually enlarge, become tan to mouldy-brown and are covered by scanty mycelia with velvety-green sporulating mass in abundance (Mandal and Dasgupta 1981). Severe rotting of ripe-fruits was recorded from Vidarbha (Khodke and Gahukar 1990). Infected fruits showed oily, depressed, black circular to irregular lesions of various sizes. Later such fruits gave a bleached appearance. Sujatha Bai *et al.* (1993) recorded *Alternaria* fruit-rot as a malady in Tamil Nadu. The fruits get affected at maturity.

The diseased fruits ultimately turn black and rotten. Green fruits as well as leaves are not affected. Loss to the tune of 30-76% has been recorded along with depletion in content of capsaicin, ascorbic acid, colour, surface wax, protein, crude fibre, starch, oleoresin and minerals like P, K, Ca and Mg. At the time of harvest, an increase in sugar content was recorded (Wall and Biles 1993); reducing sugars increased by four times.

Control measures : *A. tenuis* is a wound parasite, and mechanical injuries as wounding due to tight packing will increase fruit infection. Infection is seed-borne as well as soil-borne. Affected seeds fail to germinate as embryos are damaged. Seed treatments with Thiram (0.2%), Captan (0.2%), copper oxide (0.5%) and Mancozeb (0.2%) are effective (Khodke and Gahukar 1990). Sufficient care needs to be taken to avoid bruises during harvesting, transporting as well as storage. The fruits are to be stored in airy warm places to check rapid fungus development.

Soft-rot, c.o. *Fusarium* spp.

Soft-rot is recorded as a common disease all-round-the-year from India and elsewhere (Micoso and Ilag 1977; Uma 1981; Sokhi 1994). Infection occurs on both green and ripe-chillies. But green chillies are more susceptible. High humidity favours the disease incidence.

Fruit-rot was reported to be due to *F. solani* and *F. diversisporum* infection (Sharma *et al.* 1980). *F. solani* produces light-yellow colour at the infection site. With further advancement of rotting, tissues become soft. At this time mycelia are externally visible; and fruits smell foul and watery secretion oozes out. Finally tissues turn yellow and soft. *F. diversisporum* degrades fruit within five days of inoculation. Pedicel infection results in milky juice secretion. Rots due to *F. moniliforme* and another unidentified *Fusarium* sp. were reported

by Uma (1981) from Nigeria, Datar and Guhule (1987) from Marathwada, Khodke and Gahukar (1990) from Vidarbha and Vijayalakshmi and Rao (2003) from Andhra Pradesh. Infection by *F. solani* increases gradually as fruits attain maturity. *F. oxysporum* was also reported by Adisa (1985) from Nigeria and Mishra and Rath (1986) from local markets of Bhubaneswar all-round the year. *F. equiseti* was also recorded.

Fusarium-rot was also reported on bell-pepper. *F. equiseti* and *F. semitectum* were isolated from naturally infected bell-pepper fruits (Shukla and Sharma 2000). The ideal temperature for storage of bell-pepper is between 10 and 15°C. Disease development is higher at 25°C with *F. semitectum* and 30°C with *F. equiseti*.

Fusarium-rot on sweet-pepper was reported from Canada also. At the time of harvest, disease appeared on mature fruits as soft patches or necrotic spots at the calyx or anywhere. Seeds were also covered with orange-pink spore masses (Utkhede and Mathur 2003).

Symptoms : Small water-soaked brownish areas originate from the stylar-end with scanty mycelial growth on the surface. Rotten fruits become soft and milky juice oozes out of them with an offensive smell. Under humid conditions, fluffy mycelial growth covers fruit-surface. The whole fruit becomes soft and yellow within 2-3 days.

Control measures : *Measures recommended for black ripe-rot (Alternaria alternata) are also applicable to this disease.*

Biological control of *F. solani* through seed bacterization with *Pseudomonas fluorescens* resulted in increased plant biomass and yield, and reduced disease intensity (Gehlot and Purohit 2002).

Fruit-rot, c.o. *Phytophthora capsici* Sensus Late

The disease is of common occurrence in many parts of India, and was reported by Rao (1966 b), Coursey and Booth (1972) on hot and sweet pepper also (Sokhi 1994; Jana and Khatua 2006).

Symptoms : Greyish-brown discolouration appears and advances slowly. Within 3-5 days whole fruit rots and its internal content converts into a soft mass. Sometimes *Pythium* sp. may also be found associated, and together with *Phytophthora* may cause damping-off in nurseries. Attacked seedlings suddenly topple over as their bases are rotten. The problem is severe in waterlogged as well as poorly aerated nursery beds.

The disease is also common in bell-pepper (*C. annum* L.). Heavy losses due to fruit-rot and leaf-blight were recorded from Himachal Pradesh (Sharma and Bhardwaj 1976). Dark-green, water-soaked spots appear, which enlarge quickly and cover whole fruit-surface. Under high humidity, fruits get covered with a thick mat of fungal spores and mycelia. The pathogen is identified as *P. nicotianae* var. *nicotianae* (Breda de Haan) Waterhouse.

Due to infection, significant decrease in total phenols and increase in ortho-di-hydroxy phenols were recorded. Sugars also was depleted (Mc Comb and Winstead 1976; Bhardwaj *et al.* 1985).

Control measures : Seed treatment with Thiram (0.2%) protects seeds and seedlings from infection. Providing good drainage and avoiding thick sowing reduce disease incidence. Soil sterilization of nursery beds with copper oxychloride (COC, 0.2-0.3%) was found promising.

Soft-rot/wet-rot/Rhizopus-rot, c.o. *Rhizopus* spp.

Several species of *Rhizopus* were reported from chilli-fruits (Coursey and Booth 1972).

Symptoms : Water-soaked lesions appear. Fungus produces a wet-rot and entire fruit gets covered with mycelia within 2-3 days. Reduction (96.2%) in ascorbic acid content was observed due to infection by *R. stolonifer* (Tandon *et al.* 1974).

Control measures : Storage of fruits under high humidity (above 90%) needs to be avoided. For household storage, fruits are to be washed with water, dried and stored under refrigerated conditions at 10°C wrapped in newspaper in packets of 100 g. This retains freshness and quality of fruits up to 10 days.

***Mucor-rot, c.o. Mucor hiemalis* Wehmer**

Affected portions of fruits become water-soaked and depressed. Fluffy white mycelial growth becomes visible. The tissues become soft and watery, and a viscous liquid oozes out (Reeny 1995).

Control measures *as detailed under Rhizopus-rot are applicable for this also.*

***Choanephora-rot / soft-rot, c.o. Choanephora cucurbitarum* (Berk. & Rav.) Thaxter**

The disease was reported on hot-and-sweet pepper (Sokhi 1994). **Symptoms :** They are noticed anywhere on the fruit, affected tissues become soft and decayed. The fungus produces enzymes, pectin methyl esterase (PME), depolymerase (DP) and protopectinase (PP), but not polygalacturonase (PG). Activity of enzymes in chilli-fruit is more compared to that in brinjal-fruit. Changes in amino acids, ascorbic acid and carbohydrates were also reported (Chahal and Grover 1972).

Control measures : *As detailed under Rhizopus-rot are applicable for this also.*

Dry fruit-rot/Botryodiplodia-rot, c.o. *Botryodiplodia theobromae* Pat.

The disease was formerly described as *Diplodia-rot*, and was reported from the local markets of Maharashtra and Kerala (Rao 1965; Ramakrishnan and Wilson 1968; Alice 1969; Alice and Paily 1978). Roy (1974) also recorded the disease from Jorhat (Assam).

Symptoms : Small lesions are visible on the fruit-surface, which gradually get depressed and irregular. And surface becomes pale and later turns greyish to almost black/green on which pycnidia are formed in abundance. The complete fruit is covered with mycelial growth and eventually fruit dries and rots.

Control measures *detailed under Rhizopus-rot are applicable for this also.*

**Brown-rot, c.o. *Ceratocystis paradoxa* (Dade) C. Moreau
Thielavopsis paradoxa (De Seym) Hohn.**

Disease was reported from West Bengal (Mandal and Dasgupta 1989).

Symptoms : Infected fruits show brown to deep-brown discolouration with depressed appearance. Brown sporulating colony can be noticed in abundance. The fruit becomes soft. Sporulating area advances, and may cover entire fruit, emitting a characteristic smell. The disease is of minor importance.

Phoma-rot, c.o. *Phoma capsici*

Initially light-brownish discolouration appears. Affected tissues become water-soaked with a light-brown border. Later tissues become ashy-grey, sunken and leathery, but they are firm. Numerous pycnidia with dirty white mycelial growth are also formed. Internal discolouration is not evident (Reeny 1995). The disease was also recorded by Rao (1966 b) from Maharashtra.

A fruit-rot by *Phoma sorghina* (Sacc.) Boer Dorenb was also reported by Khare *et al.* (1995). The fungus causes longitudinal and round spots, which are brown in colour.

Seed-rot and damping-off, c.o. *Rhizoctonia* spp., *Pythium* spp.

Infection is seed as well as soil borne. Infected seeds show only external symptoms. Seedlings show dark-brown spots and finally get blighted. It is a common nursery disease.

Control measures : Seed treatment with Thiram (0.2%) and Brassicol (0.25%) is effective in controlling seed-borne infection.

Seed treatment with talc-based formulations of *Trichoderma viride* and *Pseudomonas fluorescens* reduced pre-and post-emergence damping-off in chilli seedlings (Manoranjitham *et al.* 2000). Similar results were also reported by Gosh (2002) with *T.viride*, *T.harzianum* and *Gliocladium virens* in managing damping-off, caused by *Pythium aphanidermatum*.

Two isolates of *T.harzianum* (1.6×10^5 , 3.6×10^4 cfu/g of soil), one isolate of *T.hamatum* (3.3×10^4 cfu/g of soil), five isolates of *Bacillus subtilis* (4.2×10^6 , 4.6×10^6 , 3.8×10^5 , 4.0×10^5 , 6.2×10^5 cfu/g of soil), and one isolate of *Streptomyces* sp. (1.9×10^4 cfu/g of soil) were observed to be effective in reducing damping-off as compared to seed treatment with chemicals (Bohra *et al.* 2006).

Seed treatment with two *neem* formulations (*neem* oil 50% and kernel extract, 1,500 ppm azadirachtin) at 0.5% for an hour showed lesser damping-

off and higher dry biomass compared to treatment with Ridomil MZ 72 at 0.25% concentration (Bohra *et al.* 2006).

Cladosporium-rot, c.o. *Cladosporium* spp.

The disease is not of common occurrence. *C.oxysporum* was reported from Jodhpur. Olive-green to blue-green large circular spots appear on the ripe-fruits in storage. These spots soon turn ash-coloured and become dry and papery. The fluffy mycelial growth becomes visible on the lesions (Panwar and Vyas 1974). *C. herbarum*, *C. sphaerospermum* and *Cladosporium* sp. were also reported (Coursey and Booth 1972; Adisa 1985, Sharma and Sumbali 1993; Reeny 1995; Vijayalakshmi and Rao 2003).

Periconia-rot, c.o. *Periconia byssoides* Pers.

The disease is not of common occurrence. Kanaujia and Verma (1979) recorded the disease from Faizabad. Small, spherical to irregular spots of light-brown colour appear on the affected surface. They gradually enlarge and subsequently merge to form continuous dark-brown to black patches on the fruits.

Dry fruit-rot, c.o. *Neocosmospora vasinfecta* E.F. Smith

Mature fruits are susceptible to infection; 5-8% loss was reported from Nainital, Bhowali, and adjoining areas (Tandon *et al.* 1975). Lesions appear, ranging from 1.0 to 1.5 cm in diameter. Diseased tissues appear as ochraceous tawny-coloured soft areas. The lesions appear to be dry. But get covered by mycelial growth. When the fruit is cut open, dirty white mycelial mat can be seen covering seeds adjacent to necrotic areas.

Stem-and fruit-rot, c.o. *Sclerotinia sclerotiorum* (Lib.)de Bary

Fruit-rot, caused by *S.sclerotiorum*, may assume status of a potentially serious disease of bell-peppers (*Capsicum annum* Linn.), affecting both seedlings and mature plants in Ohio, United States. Management options of the disease are limited as information is not available on its resistance. Several accessions were screened and promising lines were evaluated (Yanar *et al.* 1996; Yanar and Miller 2003). The disease is of minor importance.

Fruit-rot, c.o. *Curvularia lunata* (Wakker) Boedijin, *Curvularia* state of *Cochliobolus lunatus* Nelson & Haasis

The disease was noticed by Jamaluddin and Tandon (1976) during survey of markets and storage places of fruits and vegetables at Allahabad. Fruits of *Capsicum annum* var. Grossum Wild were found infected. Small saccardo's olive lesions, oval to irregular in shape, appeared on the diseased areas. The infection penetrated inside the fruits and caused moulding. The rot is dry in nature. Seeds are also infected; and slightly different symptoms were observed by Reeny (1995) from Thiruvananthapuram(Kerala). Vijayalakshmi and Rao (2003) also observed *C. tuberculata* on mature fruits.

Fruit-rot, c.o. *Chaetomium globosum* Kunze ex Fr.

The disease was recorded by Jamaluddin and Tandon (1976) from Allahabad. On *C. annum* var. *Grossum* Wild, symptoms appear on the stalk or on the persistent calyx. Within a few days, they are visible on the stalk-end of the fruit also. The lesions are brownish-olive in colour and develop into a soft-rot. Losses of 5-8% were noticed due to disease.

***Aspergillus*-rot, c.o. *Aspergillus* spp.**

Several species of *Aspergillus* are found associated, including the following—*A. carbonarius* (Alice 1969); *A. niger* Van Tieghem (Datar and Guhule 1987); *A. flavus* Link. ex Fries (Adisa 1985 and Sharma and Sumbali 1993).

Symptoms : With *A. carbonarius* and *A. niger*, symptoms appear at first as water-soaked areas. After 24 hours, small, black pinhead-like fungal growth can be noticed on these areas.

With *A. flavus* symptoms are similar, but fungal growth is green in colour.

Control measures : They are detailed under storage studies of red chillies.

Seed treatment with Captan (0.2%) or Thiram (0.2%) controls disease incidence.

***Penicillium*-rot, c.o. *Penicillium italicum* Wehmer**

The disease is not of common occurrence.

Symptoms : Light-brown discolouration appears and advances to form oval-shaped lesions. Fruits become soft and leaky with bluish-green spore mass, concentrated mostly at the region of the fruit-cap. Internal brown discolouration is also observed.

Control measures : They are as detailed under *Aspergillus*-rot.

Seed-rot, c.o. *Macrophomina phaseolina* (Tassi) Goid.

The disease was reported by Khodke and Gahukar (1990). Kaur *et al.* (2004) reported efficacy of fungal and bacterial antagonists. Seed treatment with potential isolates of *Trichoderma* and fluorescent *Pseudomonas* (commercial formulation) reduced disease incidence and increased plant bio-mass.

Seed-rot due to *Cephalosporium curtipes* Sacc. (Mittal, 1984), *Dreschlera australiensis* (Datar and Guhule 1987) and *D. tetramera* was also reported.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|-------------------------|--------------------------------|-------------------------------|
| Fruit-rot | <i>Botrytis cinerea</i> | Coursey and Booth, 1972 |
| | <i>Aureobasidium pullulans</i> | Suryawanishi and Deokar, 2000 |
| | <i>Myrothecium roridum</i> | |
| | <i>Nectria haematococca</i> | Jarvis and Barrie, 1994 |
| Verticillium-rot | <i>Verticillium psalliotae</i> | Uma, 1981 |

BACTERIAL DISEASES

Bacterial spots, c.o. *Xanthomonas campestris* pv. *vesicatoria* Doidge and Dye

This is the most common bacterial disease of chilli in India. The disease appears on leaves and fruits. Shekhawat and Chakravarti (1977) observed loss of 8-16% in the fruit yield due to this disease alone.

Symptoms : On green fruits, small, water-soaked spots appear, which are raised and are with a greenish-white halo, and they enlarge to about 3-6 mm in diameter. Sooner halos disappear and spots become brown to dark and get slightly sunken with a rough surface, and epidermis of the fruit rolls back. The bacterium over-winters on contaminated seeds, on the infected plant debris in the soil and on the weeds and other hosts. It penetrates leaves through stomata and fruits through wounds (Agrios 1969). Splattering rains are the main source of local dissemination and ideal temperature requirement for disease spread ranges from 22 to 34°C along with high humidity. The disease becomes prominent after heavy rains.

Infection is seed-borne. Even a small percentage of infected seeds can initiate severe disease incidence under favourable conditions.

Control measures : Control with an antagonistic bacterium associated with bacterial lesions was attempted (Shekawat and Chakravarti, 1977). Seed treatment was carried out to check infection. Hot-water treatment (HWT) for 30 minutes at 52°C, followed by seed dressing with Thiram (0.2%) was found promising (Suryanarayana 1978).

Seed-borne infection of bacterial wilt (*Ralstonia solanacearum*) in *Capsicum* sp. was also reported (Aggarwal and Sood, 2004).

Bacterial-rotting, c.o. *Erwinia carotovora* (Jones) Holland (Arsenjevic and Stojic 1973)

Precooling at 10°C was reported to be effective in delaying infection (Sherman *et al.* 1982). But this did not stop infection completely.

Storage studies of red chillies

Foliar application of calcium chloride before harvest was reported from Korea to improve storage quality of red sweet-pepper (Park *et al.* 2001). Harvested chilli-fruits are to be properly dried before storage. Sunlight drying is considered as the best method for getting healthy and quality fruits. After drying, fruits are stored for 4-6 months in different containers.

Hegde and Anahosur (2001) recorded effect of common salt (sodium chloride) on disease development, quality and biochemical constituents of chilli-fruits. Fruits were dipped in a saturated solution of common salt for 30 min, followed by drying under sunshine for 30 days, followed by storage in gunny-bags. The treated fruits retained colour and had high capsaicin, ascorbic acid and total sugars. Sharath *et al.* (2004) also recorded high ascorbic acid

and capsaicin in chilli-fruits (cultivars Bullet and Suryamukhi) dehydrated at 65°C. For storage of dried chillies, gunny bags are commonly used as they are cheap and easy for handling and transportation, and also provide adequate aeration.

Hegde and Anahosur (2001 b) observed stored sundried fruits had least development of disease, while healthy fruits mixed with infected fruits and stored in gunny-bags recorded maximum spread and development of disease.

Stored chilli-fruits exhibited varying degrees of decay like discolouration, breaking of pericarp, detachment of pedicel, and spore dust formation within and outside the fruit.

The microflora associated with dried chilli-fruits were studied in detail by Senappa *et al.* (1980) and Tripathi *et al.* (1984). Infection occurs through crevices caused by mechanical injury. When it is stored under high RH, fungal flora changes completely; *A. flavus* alone predominates at 95% RH and no fungal growth was observed at 70% RH.

The extent of colonization due to different *Aspergillus* species is correlated with prevailing temperature and humidity. Infection by *A. flavus* was common on stored dry chilli-fruits during rainy season from May to August under Kerala conditions (Philip, 1998). Prasad *et al.* (2000) observed varying degrees of decay, discolouration, breaking of pericarp and fungal flora from different parts of India. Among the fungi, *Aspergillus* spp. predominated; including *A. flavus*, *A. candidus*, *A. niger*, *A. sclerotiorum* and *A. terreus*. Other fungi were *Fusarium moniliforme*, *F. sporotrichoides*, *Syncephalastrum racemosum*, *Paecilomyces varioti* and *Penicillium coryophilum*. Capsaicin content was also found decreased due to infection.

In-vitro studies with terpenoids like citral, citronellal, eugenol, feresol and nerol at 0.5% concentration showed their absolute toxicity against *A. flavus* and *A. niger*. Citral, eugenol and feresol exhibited broad spectrum of toxicity against all fungi.

Seed mycoflora

In chilli, all important diseases are seed-borne: including anthracnose and die-back (*Colletotrichum capsici*), seedling-blight (*Rhizoctonia* sp. and *Fusarium* spp.), damping-off (*Pythium* spp. and *Phytophthora* spp.), blights (*Alternaria* spp.) and bacterial leaf-spot (*Xanthomonas vesicatoria*). In addition to these, several other pathogens are also observed.

The following seed-borne fungi of chilli are reported from different agroclimatic regions of India. Khulbe *et al.* (1991) observed *Didymella lycopersici* and *Diaporthe phaseolorum* in seed samples of red pepper and bell pepper in a mild to abundant form from Kumaon and Nainital. External as well as internal seed infections were also noticed. The fungi presence could be seen on the seed-coat, endosperm and embryo.

Sokhi (1994) recorded *Colletotrichum capsici*, *Phytophthora* spp.,

Choanephora cucurbitarum and *Fusarium* spp. as seed-borne on sweet-pepper from Punjab.

Thippeswamy *et al.* (2004) from Karnataka observed on seed samples of chilli, brinjal, tomato and okra, pathogens like *C.capsici*, *A.alternata*, *A.solani*, *F.oxysporum*, *F.solani*, *Phomopsis vexans*, *Macrophomina phaseolina*, *Aspergillus* spp., *Phoma* sp., *Curvularia lunata* and *Rhizopus* spp.

Hingole and Kurundakar (2005) observed *Fusarium moniliforme*, *Colletotrichum capsici*, *A. niger*, *Alternaria* and *Curvularia* sp. from Parbhani, Marathwada.

Singh *et al.* (2006) recorded 14 species belonging to 10 genera—*Alternaria solani*, *A.tenuis*, *Aspergillus flavus*, *A.niger*, *Aspergillus* sp., *Chaetomium* sp., *Colletotrichum capsici*, *Curvularia lunata*, *Fusarium oxysporum*, *F.solani*, *Helminthosporium* sp., *Penicillium notatum*, *Penicillium* sp. and *Rhizopus nigricans* from Faizabad and Chanchal. The common variety Jwala harboured maximum pathogens.

Pattnaik and Narain (2000) recorded *Colletotrichum capsici*, *Curvularia lunata*, *Aspergillus flavus* and *A.niger* from infected seeds from Odisha. Higher percentage of seeds was having *C.capsici* and *C.lunata*.

POTATO (*Solanum tuberosum* L.)

It is a starchy tuberous crop and world's fourth largest food crop, preceded by rice, wheat and maize. Potato contains vitamins and minerals as well as assortment of phytochemicals such as carotenoids and natural phenols.

FUNGAL DISEASES

Dry-rot, c.o. *Fusarium* spp.

This disease is of worldwide occurrence (Bilgrami *et al.* 1979; Khanna and Chandra 1980; Gallenberg 1989; Singh *et al.* 1989). And it develops usually during storage. The following species of *Fusarium* have been reported.

- Fusarium oxysporum* Mishra and Rath, 1986; Shashireka and Narasimham, 1990; Sharma and Sumbali, 1993; Singh *et al.*, 2004
- F. moniliforme* Gaur and Chenulu, 1982; Kassim, 1986
- F. solani* Shakywar and Pathak, 2006
- F. solani* var. *coeruleum* Gindrat 1984; Mishra and Rath, 1986
- F.solani subglutinans*
- F.culmorum* Grindrat, 1984a
- F.graminacearum*
- F.chlamydosporum*
- F.poa*
- F.sambucinum* (*Gibberella pulicaris*) Peters *et al.*, 2001; Malyuga, 2002
- F.roseum* var. *arthrosporoides*
- F.roseum culmorum*

Singh *et al.*, 2004

F.roseum var. *graminearum* (*Giberella zeae*)

F.sulphureum Langerfield, 1984

F.avenaceum Gindrat, 1984a

F.equiseti Sharma and Sumbali, 1993

F.trichothecioides

Of these, *F.solani*, *F.sambucinum* and *F.avenaceum* are known throughout the world as pathogens of potato. *F.oxysporum* and *F.culmorum* are considered as dominant species causing dry-rot in Australia (Chamber 1973). Malyuga (2002) from Russia reported *F.sambucinum* (*Giberella pulicaris*) and *F.sambucinum* var. *minus* (*G.pulicaris* var. *minus*) as the most prominent dry-rot causing organism. Nasr (2006) recorded *Fusarium* dry-rot as the most devastating disease in Turkey. In India, *F.oxysporum* is the most prevalent one, followed by *F.solani* and *F.equiseti* (Shakywar and Pathak 2006).

Symptoms : Infected tissues become light-brown to deep-brown, shrunken with crinkled peel often covered with a scanty, white fungal growth. Affected tissues become moist. Lesions are circular to oval and may enlarge up to 2-3 cm in diameter. Several lesions coalesce to form large wrinkled patches with deep discolouration inside. Under humid conditions, tubers may completely rot. Scanty, white fungal growth is also noticed in decaying portions (Fig. 20.6) (Philip 1998).



Fig. 20.6. *Fusarium*-rot on potato

Gindrat (1984) observed correlation of lesion development with storage temperature. At 5°C, most of the pathogens were inactive but, their activity increased at 20°C and above. Reust *et al.* (1984) recorded losses ranging from 12 to 61%. Maximum rotting was observed with tubers stored at higher CO₂ concentration. The infective capacity of different species of *Fusarium* varies depending upon the varieties (Langerfield 1984), depth of wound and inoculum (Tivoli *et al.* 1986). Tivoli and Jouan (1981) recorded maximum rotting at 25-30°C with *F. culmorum* and at 15°C with *F. solani* var. *coeruleum*.

Control measures : Gaur and Chenulu (1982) observed complete control against rotting by *F.moniliforme* as well as *Cladosporium sphaerospermum*, *Pestalotia versicolor* and *Rhizoctonia solani* with Bavistin at 1,000 ppm. Sodium metabisulphite and salicylic acid at 1,000 ppm protect against decay. Weedicide 2, 4-D at 500 ppm is also effective. Kassim (1986) observed Antracol (0.2%) as well as Benlate (0.2%) to be effective for pre-infection treatments. Singh *et al.* (1989) observed Boric acid (2%) dip, followed by Thiabendazole (0.1%) and Emisan 6 (0.25%) as effective at pre-cooling stage.

Dipping seed-tubers in aqueous solutions of trace elements like iron, copper and zinc decreased sprouting as well as microbial spoilage during storage at ambient conditions (Sashirekha and Narasimhan 1990).

Thiabendazole (0.2%) was also reported to be effective. But Peters *et al.* (2001) from Canada reported Thiabendazole-resistant isolates of *F. sambucinum*. Resistant isolates of *Fusarium* were also reported from Europe and US.

Late-blight, c.o. *Phytophthora infestans* (Mont.) de Bary

Late-blight is a highly destructive disease of potato and causes heavy yield losses under favourable weather. Irish famine of 1845 is an example where thousands of people died of starvation and several others migrated to US and other countries.

In India, disease was reported from Nilgiri hills in 1870, and then from West Bengal, Uttar Pradesh and Asom (Baruah *et al.* 1985). Yield losses are due to reduction in photosynthetic capacity of plant through destruction of foliage and tuber infection. Though it is generally considered as a field disease, tubers stored also get infected by potato collected from blighted fields. Invasion of tubers by sporangia or zoospores from infected leaves or through soil causes dry- or wet-rot, according to the prevalent moisture and temperature. The fungus survives in a wide range of temperature and relative humidity.

Degree of susceptibility to late-blight varies with varieties. Use of resistant varieties such as Kufri Sherpa, Kufri Badshah and Kufri Himalini was promising for the north-western plains and hilly tracts (Singh 1992). The basis of resistance includes factors like host attribution components (Singh and Bhattacharya 1995), compatible and incompatible interactions at the cellular level (Singh *et al.* 1992) as well as structural basis of the late-blight resistance (Mahajan *et al.* 2003).

Symptoms : In storage containers, wet-rot phase is common unless ideally cool and dry conditions are maintained. In moist atmosphere, tubers get rotten fast. White tufts of mycelia and sporangiophores appear on the tuber surface. Rotten tubers may be further attacked by secondary bacteria, resulting in a slimy, soft decay.

Control measures : Disease incidence is more with increased irrigation frequency. Adjustment of irrigation and chemical desiccation of potato foliage 2-3 weeks prior to harvest of tubers were reported to be effective in reducing late-blight incidence (Dennis *et al.* 2003).

Diseased seed-tubers are the principal source of inoculum. Tubers should be intact, free of wounds and should be stored in cool, dry, well-aerated store-houses. Temperature at 15-25°C and high inoculum density favour infection. Avoiding wounding of tubers and rapid cooling of storage-bins at 10°C help in disease control (Salas *et al.* 2000).

Chemical treatments are given usually after harvest to reduce pathogenic decay of fruits and vegetables during transit, storage and marketing. These also eradicate established infection. Treatment of tubers with TMTD (Thiram 0.2% and Mancozeb 0.2%) protects tops and tubers against *P. infestans* (Kotikova and Gerasimova 1980). Seed treatment reduces risk through seed transmission and enhances seed establishment and plant vigour (Powelson *et al.* 2002).

Thakur and Chenulu (1974) reported protection of tubers for 60 days by dipping seed-tubers in commercial formalin (0.3%), and 2, 4-D and 2, 4, 5-T at 0.01% concentration each. Treatment of tubers and sprouts with systemic fungicide Ridomil MZ (Metalaxyl) 0.2% was also reported (Singh and Pundhir 2004).

Biocontrol agents like *T. viride* and *Bacillus subtilis* (commercial formulations @ 4g/kg) and fungicide Captan (4g/kg) reduced post-emergence damping-off in the field. Tuber yield was also high (Lakra 2003).

Pink-rot, c. o. *Phytophthora erythroseptica* Pethybr., *P. cryptogea* Pethybr & Bafferty, *P. drechsleri* Tucker; *P. megasperma* Drechsler

Symptoms : Infected tubers become brown or blackened. Decayed tissues appear wet and spongy. The rotted tissues become pink-to-brown and later black.

Control measures : Use of resistant varieties. Salas *et al.* (2003) assessed several cultivars from North Dakota, USA, for resistance of tubers to pink-rot and leak by *Pythium ultimum*. Only cv. Atlantic showed some resistance to infection and colonization by *P. erythroseptica*.

Disease-free seed material should be planted. Application of Metalaxyl (0.2%) during growing season as a protectant fungicide was reported.

Seed treatment with biocontrol agents has also been evaluated as a sustainable management option for controlling pink-rot. In New Zealand, Tate and Cheah (2003) used *Trichoderma*-based commercial products. The bio-control products provided an organic/non-chemical alternative for controlling tuber decay through root colonization. And also assisted the crop to withstand nutritional and environmental stress.

Soft-rot, c.o. *Rhizopus* spp.

Soft-rot is a major disease, affecting stored potatoes in India. In Delhi, *R. arrhizus* was found responsible for causing decay in 8-25% of stored potatoes (Chenulu and Thakur 1968; Thakur and Chenulu 1974; Prasad *et al.* 1989). *R. stolonifer* (Balasubramonian 1972) and *R. oryzae* (Mandal and Dasgupta 1981) were also reported from Delhi, Maharashtra and West Bengal. Dipping in commercial formalin (0.3%), as well as 2,4-D and 2, 4, 5-T each at 0.01% concentration protected infected tubers for 60 days.

Watery wound-rot/leak, c.o. *Pythium butleri* Subram.*P. debaryanum* Hesse*P. ultimum* var. *ultimum* Trow.*P. deliense* Meurs

Symptoms : Irregular lesions appear, and the affected areas may be bordered by black line visible externally and internally. Sometimes symptoms are not visible externally. The outer tissue remains firm, enclosing the fluid; which leaks out, potato becomes hollow, hence the alternative common name is shell-rot. At temperature above 25°C, infected tubers decay completely; at 10°C and below, rotting is in check.

Control measures : Any seed protectants (Thiram, Dichlone, Ziram, Zineb, Maneb or Captan all at 0.2-0.25%), applied as a dust or as a dip treatment to seed pieces of potato-tubers, control seed decay (Walker 1975). In addition to seed treatment, soil treatment is also important. Formalin dust (15 parts with 85 parts of charcoal ash) mixed thoroughly and applied to soil at 30g/ft² to a depth of 3" was reported to be effective (Singh 1983).

Target-rot/early blight, c.o. *Alternaria alternata* (Fr.) Keissler*A. solani* Ell. & Martin

The disease has long been known in Europe and the USA. In India, seed-potatoes are affected and are the primary source of inoculum. Khanna and Chandra (1980) reported the disease from Uttar Pradesh.

Symptoms : Infection starts as brown pinhead-shaped lesions on the tuber surface. Several spots enlarge and coalesce to form target lesions of 1-2 cm diameter and 1-cm deep. Storage of tubers at 15.6°C for 3 weeks, before final storage at 10°C results in a few smaller lesions than instant storage at 10°C or 4.4°C or pre-storage for varying periods (Nodu *et al.* 1982).

Control measures : Antracol and Benlate at 0.2% concentration when used as a post-harvest dip proved promising (Rai 1978; Kassim 1986). Three sprays of Ridomyl MZ 0.25% (Metalaxyl 8% + Mancozeb 64%) as well as Melody Du 66.75 WP (Iprovalicarb 5.5.% + Propineb 61.25%) at 1.5, 2.0, and 2.5kg/ha were effective in controlling early blight as well as late-blight during storage (Singh 2008).

Black scurf, c.o. *Rhizoctonia solani* Kühn*Thanatephorus cucumeris* (Frank) Donk.

Rhizoctonia solani causes stem canker in the field and black scurf on the stored potatoes (Cayley *et al.* 1983; Harris *et al.* 1988).

Symptoms : Black crust appears on the peel due to sclerotia formation. The sclerotia are normally skin-deep. Due to insect or mechanical injuries, the fungus may grow in injured tissues and cause rot (Singh 1992). Spores released may cause subsequent infection to healthy tubers in the storehouse.

Field and greenhouse testing confirmed occurrence of both tuber-borne and soil-borne inocula. Tuber-borne inoculum affected sprout and emergence and soil-borne damaged stolon (Frank and Leach 1980).

Control measures : Pre-and post-storage treatment of seed-tubers with Imazalil (200 ppm) and Thiabendazole (0.2%) decreased the disease (Cayley *et al.* 1983; Tsrer and Petretz Alan 2002). Seed treatments with Tolclofosmethyl/Prochloraz (0.25% solution), maganese chloride or mixtures were successful in commercial use for control of stem canker and black scurf (Harris *et al.* 1988).

The pathogen usually remains in seed or soil. Kalisena (commercial bioformulation of *Aspergillus niger*) applied as seed treatment reduced *Macrophomina phaseolina* and *R.solani* infections in the soil and increased yield (Sen 2000). Similar results with *Trichoderma viride* and *Pseudomonas* spp. like *P.maltophila* and *P.fluorescens* were also reported from Haryana against black scurf (Arora and Somani 2001; Gandhi and Kumar 2006).

Black scurf was significantly reduced (72-42%) by treating tubers with freshly prepared bioformulations of *T.viride* (@ 1×10^7 cfu/mg) and *Bacillus subtilis* strain B₅ and *B.cereus* strain B₄ (both @ 1×10^{10} cfu/mg) either applied alone or in different combinations (Somani and Arora 2010).

Gangerine/skin-spot, c.o. *Phoma* spp.

Oospora pustulans Owen & Wakef.

The disease is widespread in the world. Its occurrence was reported by Prasad (1977), Smith and Wilson (1978), Cayley *et al.* (1983) Langerfield (1984) and Gindrat (1984) and Elphinstone *et al.* (1983).

Phoma species found associated with the disease include: *P.exigua*, *P.exigua* var. *foveata*, *P.eupyrina* and *P.herbarum* (Janke and Zott 1983; Gindrat 1984; Hamilton 1985).

Symptoms : Small, circular, shallow, brown-to-grey depressions appear. Such spots may crack off in favourable conditions. The spots may enlarge superficially to about 2-4 cm and develop a shallow rot. Sometimes rot may be restricted to a small area with deep and extensive rotting of internal as well as superficial tissues. Rotted areas are demarcated by a dry and grey zone. In deeper rots, button-holes may develop containing pycnidia and fungal mycelia. In the final stage of infection, tubers may be reduced to a dry shell. No rotting was observed at 15-20°C or at low relative humidities; few rots were noticed with increased relative humidity (Nonodu *et al.* 1982).

Control measures : In storage, disease was controlled by treating tubers with Imazalil (200 ppm) and Thiabendazole (0.2%) soon after lifting them and retreated them before planting (Cayley *et al.* 1983). Fumigation of potato-tubers stored in boxes with 2 aminobutane was also promising.

Charcoal-rot, c.o. *Macrophomina phaseolina* (Tassi) Goidanich

Charcoal-rot is observed under moist, warm climates, and was reported from Bihar (Thirumalachar 1955) as a major disease. The disease was also reported from Uttar Pradesh, Punjab and West Bengal (Paharia 1960; Mandal and Dasgupta 1981). Severe losses due to this disease were reported also from Palestine. Losses ranging from 10 to 70% are generally observed, depending upon the variety and pre-disposing conditions. The fungus enters from the soil into tubers through proliferated lenticels.

Symptoms : Cloudy or black blotches appear near the eyes, followed by extensive blackening. The inner tissues develop a dry or semi-watery rot, become greyish to tan yellow; turn pinkish buff and finally become black. Sometimes cavities may develop near the eyes. Maximum decay was observed at 27°C and at 100% RH. Disappearance of amino-acids was also recorded on the 20th day of inoculation (Rao and Usharani 1985).

Control measures : Fungal and bacterial antagonists were found promising to control charcoal-rot. Kalisena (commercially prepared bioformulation based on *Aspergillus niger*) introduced to soil through seed treatment retarded *M. phaseolina* in potato-planting by 79% (Sen 2000). Isolates of *Trichoderma* and fluorescent *Pseudomonas* were reported to be effective (Kaur *et al.* 2004).

Creepy white-rot/*Sclerotium*-wilt, c.o. *Sclerotium rolfsii* Sacc.

Sclerotium-wilt is an important disease of tropics and subtropics. It was recorded from Karnataka and West Bengal (Hiremath and Govindu 1975; Dasgupta and Mandal 1989). The disease was serious in Satar region (Maharashtra) in 1968, with an average incidence of 5%. In northern Karnataka, 1-40% wilting of plants and up to 25% tuber infection were recorded.

Symptoms : The affected tubers show small, sunken, yellow to tan-coloured spots. White mycelial growth is noticed over the tuber surface in a fan-shaped outline with dark-brown coloured sclerotial bodies. Tubers shrink, and gradually affected tissues become soft, watery and rots. Congregation of tubers in storage leads to rapid spread and deterioration of tubers. Affected tubers when cut open show discolouration from margin to inner tissues.

Control measures : *In-vitro* studies with *Trichoderma* spp., *Pseudomonas fluorescens* and *Gliocladium virens* showed complete inhibition of *S. rolfsii* growth by them. Tubers treated with *T. viride* or *T. harzianum* prior to planting at 4g/kg of seed-tubers reduced *Sclerotium* wilt in storage (Anahosur 2001).

Green mould-rot, c.o. *Penicillium* spp.

The disease is of seasonal importance, and was reported from Delhi (Thakur and Chenulu 1970), Madhya Pradesh (Chauhan and Sharma 1977), West Bengal (Mandal and Dasgupta, 1981) and Bihar (Prasad *et al.* 1989). *P. cyclopium*, *P. harqui* and *P. auranteogriseum* (Sharma and Sumbali, 1993) are the commonly encountered species with this disease.

Symptoms : On the tubers stored under cool conditions, depressed areas of 2-3 cm in diameter appear proceeding vertically through eye-end. The peel remains intact but internal tissues become soft, irregular, brown and separated from healthy tissues. Greenish growth of fungus occurs within the cavity.

Control measures : Seed prtectants *detailed under watery wound/ leak are applicable for control of Penicillium-rots.*

Eye-end rot, c.o. *Aspergillus* spp.

Khanna and Chandra (1980) reported the disease caused by *A. fumigatus* from Uttar Pradesh. *A. niger* was reported by Kassim (1986). Severe rotting due to an unidentified species of *Aspergillus* (Prasad *et al.* 1989) and *A. flavus* (Sharma and Sumbali, 1993), and dry-rot due to *A. terreus* (Rao and Usharani, 1985) were also reported.

Symptoms : Water-soaked lesions appear on the skin near the eyes. Rot develops fast and involves a major portion of the tuber, forming a soft-rot with a foul smell.

Control measures : Seed prtectants *detailed under watery wound/ leak are applicable for the control of Aspergillus-rots.*

Waxy-rot, c.o. *Geotrichum candidum* Link.

Khanna and Chandra (1980) reported the disease during the rainy season from Uttar Pradesh.

Symptoms: The symptoms may appear anywhere on the tuber surface in the form of a wet-leaky rotting with a waxy growth and a foul odour (Dasgupta and Mandal 1989). The disease is severe at 20-30°C and RH 90-100%.

Control measures *are as described under the waxy-rot in tomato of Solanaceous Crops.*

***Botrytis*-rot/soft-rot, c.o. *Botrytis cinerea* Pers.ex Fr.**

Teliomorph : *Botryotinia fuckeliana* (de Bary) Whetzel

The disease is usually observed in temperate regions. It produces pit-rot on stored tubers, which appear as soft, wet and extensive with a distinct edge. When cut open, affected tissues can be seen to be soft and water-soaked with a pale-brown or occasionally a yellow margin. A faint vinegary odour could also be smelt in certain cases. The disease is usually found associated with potatoes stored under low temperature for seed purpose (Choiseul and Carnegie 2000).

***Phomopsis*-rot, c.o. *Phomopsis tuberivora* (= *Phacidiopycnis tuberivora*)**

The disease was observed by Rai (1983) from Manali, Himachal Pradesh. Infection starts at the stem-end and gradually progresses towards healthy tissues, resulting in mummified tubers. Longitudinally cut tubers show dark-brown corky tissues with a distinct margin. No specific control measures are available.

Tuber-rot, c.o. *Gilmaniella humicola* Barron

The symptoms observed on the tubers are of late-blight differentials. Minute brownish necrotic spots are noticed around lenticels and eyes. Tubers stored at 15-25°C are found infected. Necrotic lesions ranging from 2-4 mm near the lenticels to 3-6 mm at the eyes are noticed. Sometimes 2-5 lesions are observed around the lenticels, which coalesce and form large lesions. Infection does not develop deep into the tissues, and tubers remain firm and dry during storage. All eyes die making tubers unfit for seed purpose (Sahai 1967). No specific control measures are available.

Tuber-rot/internal black-rot, c.o. *Pestalotiopsis versicolor* (Speg.) Steyaert

Soft-rot causing 2% loss was recorded from New Delhi (Gaur and Chenulu 1981). The disease incidence was high during July when the climate was warm and humidity was high. Light-brown patches appear around injuries. On cutting open tubers, white mycelial mat and black, shining cushion-shaped acervuli with dark-coloured conidia are seen.

Any seed protectants, Thiram or Captan at 0.2-0.25%, when applied as dust or dip treatment to cut seed pieces of potato-tubers, controlled decay.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|--|------------------------------------|---|
| Internal patch-rot | <i>Doratomyces stemonitis</i> | Mandal and Dasgupta, 1981 |
| Tuber-rot | <i>Cladosporium sphaerospermum</i> | Gaur and Chenulu, 1982 |
| Black-dot | <i>Colletotrichum coccodes</i> | Cayley <i>et al.</i> , 1983 Hamilton, 1985; Harris <i>et al.</i> , 1988 |
| Skin-spot | <i>Polyscytalum pustulans</i> | |
| Watery soft-rot, c.o. <i>Sclerotinia sclerotiorum</i> | | Ginoux <i>et al.</i> , 1984 |
| Mucor-rot <i>Mucor</i> sp. | } | Rao and Usharani, 1985 |
| Tuber-rot <i>Trichurus spiralis</i> | | |
| Dry-rot <i>Phacidipycnis tuberivora</i> | | Rai, 1983, |
| Silver scurf <i>Helminthosporium solani</i> | | Harris <i>et al.</i> 1988 |
| Dry-rot <i>Chaetomium globosum</i> | } | Sharma and Sumbali, 1993 |
| Brown-rot <i>Scopulariopsis brevicaulis</i> | | |
| Gliocladium-rot <i>Gliocladium roseum</i> | | |

BACTERIAL DISEASES**Black-leg / bacterial soft-rot, c.o. *Erwinia carotovora* subsp. *carotovorum* Vanhall 1902, Dye 1969**

Soft-rot is a common storage and transit disease. The bacteria also cause black-leg and wilt of plants in fields. The most destructive soft-rots are caused

by the bacterium of the genus *Erwinia*. Of these, *E. carotovora* has been recorded as the most prevalent one (Elphinstone *et al.* 1983; Colyer and Mount 1983; Panno and Kohler 1984; Cappellini *et al.* 1984; Hussian *et al.* 2002). In India, the disease was investigated in detail by Trivedi and Patel (1972). The soft-rot of tubers may occur in the field when soil is moist and temperature is high or it may occur during transit and storage.

Symptoms : Small, water-soaked lesions appear, which enlarge rapidly. Tuber surface becomes discoloured, depressed and wrinkled. And the tubers are transformed partially or totally, slowly or quickly into a soft, decayed pulpy mass (Fig. 20.7). The mass is held together by a corky epidermis, which is resistant to attack by the pathogen. Kushalappa and Zulfiquar (2001) observed lesion development at 16°C after storage for 60 days. Campos *et al.* (1982) observed 13% and 45% incidence due to *E. carotovora* pv. *carotovora* and *E.*

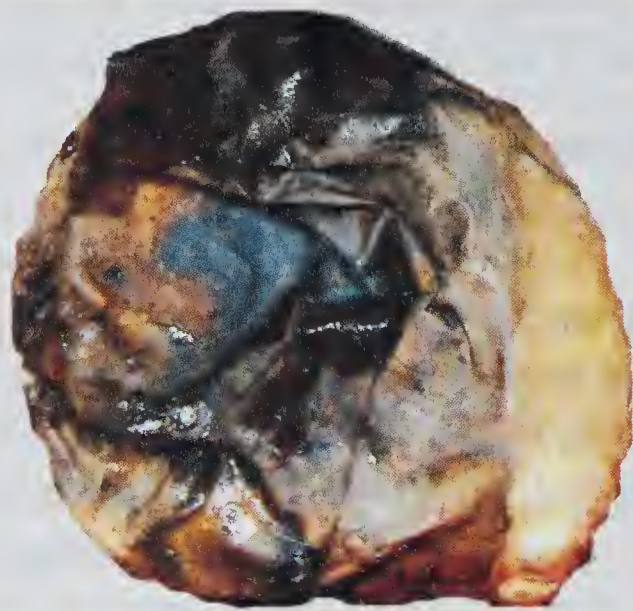


Fig. 20.7. Bacterial-rot on potato

carotovora pv. *atroseptica*, respectively. In addition, they also observed certain pectolytic clostridia. Workman and Holm (1984) reported that black-spot and soft-rot both were caused by *E. carotovora* subsp. *atroseptica*. They compared tubers of 11 clones for various characters like Redox potential (R), ascorbic acid (A), dry matter (DM) and potash (K) for different storage periods, and observed significant differences among clonal types.

Bacteria produce pectolytic and cellulolytic enzymes, causing breakdown of pectic substances of middle lamella and cell wall, resulting maceration of cell tissues. Mahmoud *et al.* (1981, 1981 a) studied susceptibility of potato-tubers to soft-rot and black-leg pathogens, and observed their rotting ability in relation to enzymes secreted. *E. atroseptica* isolate showed high depolymerase (DP) and cellulase (CX) activity than *E. carotovora* isolates, and reverse was the situation with glucosidase activity. But dehydrogenase activity was similar in all isolates.

When a soft-rot tuber is cut open, colourless putrid mass turns pinky-red on exposure to air, and rapidly becomes brownish-red to brown-black. The cut tubers have only a slight smell. But due to secondary bacteria, that gain entry into the rotting mass, a strong repulsive smell is felt. The organisms survive saprophytically on diseased tubers left in the field. The disease severity is maximum at 20-23°C (Bartz and Kelman 1984). Clonal variation is also significant. The bacterial and the plant gene expression is also well understood (Yang *et al.* 1989). The stored tubers are infected through insects, which crawl on them and bacteria may enter through wounds. Elphinstone *et al.* (1983)

studied sources and pathways of contamination during grading, and observed that susceptibility increased with early harvesting of crop and *vice versa* was the case with resistant ones. The chief source of primary inoculum in the storage is the infected tubers. The bacteria also survive, both internally and externally on the vectors, *Drosophila melanogaster* and *D. busckii*; they enhance longevity of nonspore-forming *Erwinia* cells. The pupae as well as maggots act as the source for field and storage phase, and bacteria enter through injuries sustained during harvest as well as insect and freezing injuries.

Tubers cool stored at 3-6°C had elevated levels of reducing sugars, and developed more soft-rot compared to tubers stored at 21-29°C (Otazu and Secor 1981).

Control measures : They include surface sterilization of seed-tubers with 10% chlorine bleach (Colyer and Mount 1983) and treatment of tubers with TMTD (Thiram 0.2% and Mancozeb 0.2%) (Kotikova and Gerasimova 1980). Dipping seed-potatoes in aqueous solutions of trace elements like iron, copper and zinc decreased both sprouting and microbial spoilage during storage at ambient conditions (Sashirekha and Narasimhan 1990).

Water extracts of plants *Cannabis sativa*, *Calotropis procera*, *Cenchrus ciliaris* and *Solanum surratense* were observed to have antibacterial activity in *in-vitro* studies against the rot-producing bacteria—*E. carotovora*, subsp. *atroseptica*, *E. carotovora* subsp. *carotovora* and *E. chrysanthami* (Pal and Jalali 1990).

Brown-rot/bacterial-wilt/ring disease,

c.o. *Pseudomonas solanacearum* (Smith 1896)

(*Ralstonia solanacearum* (Smith 1896) Yabuchi *et al.* 1996)

This bacterium has been reported from several countries. Paul (1998) in a study on the dry temperature zone of Himachal Pradesh observed bacterial wilt to the tune of 2-12%, and found it to be introduced through seed.

Symptoms : The bacterium causes wilting, stunting and yellowing of foliage, followed by collapse of the plant. The name 'ring' disease denotes brown ring that is formed in tubers due to discolouration of vascular bundles. The skin of the tubers is often discoloured. In severely affected tubers, eye-buds blacken. Ciampi Panno (1984) observed vascular ring-rot in stored tubers caused by race 3 of *P. solanacearum* from Chile. The infected tubers when cut across and squeezed release greyish-white bacterial ooze. The pathogen survives in seed-tubers. The infected tubers on storage continue to rot and hence become unsuitable for seed purpose. Infected and surface contaminated seed-tubers serve as the primary source of infection in the field (Singh 1992).

Control measures : The disease can be controlled by planting clean tubers and seed material. In epidemic areas, seed-tubers should be treated with 0.2% streptocycline for 30 min after giving 5-mm deep cut. No resistant varieties are available.

Common scab, c.o. *Streptomyces scabiei* (Thaxter) Lambert and Loria, 1989

Scab is a common field disease. But may spread in storage under favourable environment. The greatest loss due to the disease is the reduction in the market value of the tubers due to rough-and-blemished skin.

The disease is reported as a problem to seed-potato production in the north-western zone of India; 80-100% of tubers were found severely infected. The disease is introduced into new areas and fields through infected seeds (Vashisth 1977).

Symptoms : Two types of lesions are generally seen. They are shallow and deep lesions. In shallow scab, the affected tubers show superficial roughened areas, and sunken below often is the plain of healthy tissue. The lesions consist of corky tissues that arise from abnormal proliferation of periderm cells due to pathogen attack. In deep-pitted scab, lesions are 1-3 mm or more in depth and are darker in comparison to shallow scab. These lesions are corky and may coalesce to cover entire surface.

The disease is significantly reduced when soil pH is brought below 5.2. Watering suppresses disease by increasing activities of antagonistic bacteria (*Bacillus subtilis*). Green manuring with soybean or by including it in crop rotation also increases population of antagonistic bacteria. Superphosphate also reduces scabbiness.

Control measures : In India, no resistant varieties are available. Tubers with deep lesions should not be used for seed purpose. Tubers can be disinfected by keeping in 0.25% suspension of a mercurial fungicide like Emissan-6 or Agallol-6 or Aretan for 10 min. Elemental sulphur application to soil reduces pH and hence is recommended for use. Penta chloro nitro benzene (PCNB/ Brassicol at 20-30 kg/ha) is also effective in controlling scab as well as black scurf. Resistance to common scab has been observed in red-skin varieties like Kufri Sindhuri and in some hybrids of *Solanum andigena* × *S. tuberosum* (Singh 1992).

Seed-potatoes infected with scab (*Streptomyces acidi scabies*) were disinfected with streptomycin (200 ppm) and copper fungicide (0.5%). This combination was also reported to be effective for controlling seed-potato scab, caused by *S. turgidi scabies* (Souma *et al.* 2002).

Cool chamber technology has been identified as a low-cost storage technique to preserve freshness of farm products. Total inhibition of sprouting in potatoes for three months with minimum physical loss in weight was achieved through treatment with iso propyl N-(3-chloro phenyl carbonate) at 50-100mg/kg of potatoes before storage in the cool chambers (Anon. 1997).

TOMATO (*Lycopersicon esculentum* Mill.)

Tomato contains carotene and most powerful antioxidant, lycopene. Lycopene offers protection against sunburn and harmful ultra-violet rays.

Storage losses in tomato are caused by rotting, senescence and physiological loss in weight. About 20% of loss is estimated to be caused by fungal diseases. Tomato fruit-rots are of global occurrence. They were reported from Florida (Gonzalez and Owen 1962), Texas (Ashworth and King 1962), Nigeria (Adisa 1985), and from many states in India.

FUNGAL DISEASES

Buck eye-rot, c.o. *Phytophthora nicotianae* var. *parasitica*

The disease was reported from several parts of the world. Critopoulos (1954) recorded symptoms due to three species of *Phytophthora*—*P. capsici*, *P. drechslera* and *P. parasitica*. Of these, *P. capsici* is considered the most vigorous type, as it affects rapid decay by forming a compact tuft of sporangia and mycelia over the fruit-surface. The disease was serious in Solan (Himachal Pradesh) (Jain *et al.* 1958), Bengaluru (Sohi and Sokhi 1972), Ooty (Sokhi and Sohi 1974) and Ranchi (Gupta *et al.* 1989). Madaan and Ullasa (1990) in a survey on farms, markets and processing units in Karnataka observed buck eye-rot as the major disease.

The fungus also causes damping-off in the nursery and collar-rot as well as blossom-blight on the adult plants in Himachal Pradesh (Sharma and Sohi 1975). Symptoms are common on the fruits that are in close proximity to soil, and appear subsequently on to the fruits above the ground level. Infection is caused by water-splash or by contact with soil. Lesion development on fruits coming in contact with soil was common in Mexico (Fernandez *et al.* 2003).

Symptoms : Brownish circular spots are formed on the immature fruits at the blossom-end. The concentric rings resemble markings on a buck eye-nut. The spots may be small or may cover a major portion of the fruit-surface. There is no rotting of peel, but internal pulp may be discoloured up to the core. The fruits remain firm and retain their shape till they are spoiled by saprophytic fungi (Sokhi and Sohi 1982; Singh 1992). Variation in symptoms is also common. Grey-coloured lesions surrounded by water-soaked areas are common on tomato-fruits. When green fruits are attacked, they show brownish circular spots at the blossom-end, and subsequently they get shrunk and mummified.

Buck eye-rot of tomato does not occur in the dry weather (Sharma *et al.* 1980). High soil moisture is required for disease development. Infection occurs only when the host cells are gorged with water. Fruits in contact with the soil, which has been saturated for about 12 hours, get infected. The fungus attacks at a temperature as low as 13°C and as high as 35°C; the optimum is between 24 and 30°C. At Solan (Himachal Pradesh), it was observed that local temperature during cropping season was not important. The disease incidence was affected with the amount of rainfall. Fruit-rot occurs only when fruits come in contact with the infested soil. After infection, spores produced on

fruits are carried by wind, water and other agencies to other fruits. The disease is not generally seed-borne, although fruits are infected. But, Sharma and Sohi (1975) observed mycelia remaining viable inside the seed for more than 1 and 1½ years. Infected seeds do not germinate. Alcock (1931) also reported seed-borne nature of *P.parasitica* on tomato.

Control measures : Certain cultivars are resistant to fruit-rot. Buck eye-rot on tomato is a serious disease in the hilly areas of Tamil Nadu, Himachal Pradesh and Karnataka. Accessions LA 22.05 and LA 1428 were recorded as resistant (Kumar *et al.* 1997). The disease resistance is reported to be controlled by a dominant gene (Rattan and Saini 1979; Sokhi 1994). High soil moisture favours infection. The fungus remains viable for more than 2 years in the soil (Sharma *et al.* 1980), and this is correlated with high ascorbic acid content of fruits. Spraying crop with Difolatan (0.3%) is effective in checking disease incidence (Sokhi and Sohi 1982). Fungicides impregnated wrappers did not show promising results (Ullasa 1990). Fungicidal sprays with Ridomil MZ (0.2%) and Dithane M-45 (0.25%) (Verma *et al.* 1994) and copper oxychloride (0.2%) (Bhardwaj *et al.* 1995) were reported to be effective.

Fusarium-rot, c.o. Fusarium spp.

The disease was recorded on leaves and stems also. Preston (1943) recorded *Fusarium* occurrence on the stems of tomato-plants from the UK. Later Stevens and McColloch (1947) recorded fruit-rot from the USA. Thirumalachar and Misra (1953) also recorded leaf-spot of tomato from Bihar. Damping-off in the nursery was also recorded (Ganesan and Sinha 2002).

Madaan and Ullasa (1990) considered this as the major fruit disease, next to buck eye-rot in Karnataka. *F. moniliforme* was reported as early as 1936 by Wollenweber and Hochapfel and later by Khanna and Chandra (1975a). Several species of *Fusarium* have been found associated with ripe and stored tomatoes—fruit-rot due to *F. nivale* (Thakur and Yadav 1971), *F. semitectum* (Bilgrami and Verma 1979; Nedumaran and Vidhyasekaran 1982), *F. solani* (Garg and Gupta 1979; Sharma and Sumbali 1993), *F. roseum* (Thomas *et al.* 1981); and dry-rot due to *F. equiseti* (Adisa 1985; Sharma and Chaudhary 2004). But in Solan under storage, Thapa and Sharma (1976) observed negligible losses by fruit-rot, caused by *Fusarium* sp. *F. solani* and *F. oxysporum* were recorded usually on the fruits reaching Thiruvananthapuram markets (Kerala) from Bengaluru and Coimbatore (Reeny 1995). *Fusarium* sp. was also recorded during storage (Pandey 2006).

Symptoms : Water-soaked lesions are initiated anywhere on the fruit-surface. They gradually increase in size and the tissues beneath them become depressed and sunken. Sometimes irregular cracking of fruits is also observed. Dirty white mycelia are seen along the cracks. Older lesions show white mycelia along the cracks. White to salmon-coloured cottony growth of the fungus consisting of profusely branched hyphae with spores is also noticed. As the

disease progresses rapidly, inner tissues lose their turgidity, disintegrate, and a yellow juice with an unpleasant odour leaks out.

Tomikawa and Kobayashi (1990) reported that in varieties resistant to fruit-rot, caused by *F. oxysporum*, fungus was not able to reach the ovary, as styles had dropped off much earlier.

Control measures : Khanna and Chandra (1976a) studied effect of 1-200 potencies of several homeopathic drugs on the spore germination of *F. roseum*, and observed its complete inhibition. Tomato-fruits given pre-and post inoculation dips with homeopathic drugs, Kali iodide 149 and *Thuja occidentalis* 87 showed no rotting on subsequent storage. Paper-liners impregnated with Carbendazim (Bavistin), Mancozeb and Captan and stored at $25\pm 1^\circ\text{C}$ were effective against rots caused by *F. pallidoroseum* and *F. equiseti* (Sharma 2006; Singh and Jain 2007).

Phoma-rot, c.o. *Phoma* spp.

Phoma destructiva Plowr causes fruit-rot in cold climate and fruit-rot as well as stem-blight in warm climate. Transit-and-storage rot was recorded by Srivastava and Tandon (1966), Hasija and Batra (1979) and Pankaja (1983). *P. exigua* and *P. sorghina* were also recorded (Reddy *et.al.* 1980, 1984; Adisa, 1985). Along with *Rhizoctonia solani*, *P. exigua* was found aggressive and reduced complex carbohydrates to simple sugars within 6-8 days. *Didymella lycopersici* Kleb (Anamorph *Phoma lycopersici* Cook and *Phoma destructiva*) was also recorded as a causal agent of stem canker and fruit-rot (Jones and Burch 1988, 1988 a; Sharma and Chaudhary 2004).

Symptoms : Firm sunken lesions occur on any part of the fruit, but are mostly concentrated at the stem-end region as small, slightly depressed spots. Infected tissues become brown and later black. Minute black bodies representing pycnidia are produced over the peel, and in humid conditions, white or pinkish spores (conidia) ooze out in large numbers. The fungus persists in soil and on crop debris. Initial infection takes place when spores are splashed on to plants with irrigation. Lesions typically develop at the wound sites on the stem. Infection of fruits takes place via cracks formed on the stem and or through injuries, and results in rapid rotting and fruit-rot. Lesions on ripe-fruits are more conspicuous than on green fruits. In the field, lesions develop as small, circular, depressed water-soaked areas. Later, they become leathery with prominent pycnidia (Grover 1965). Fruits shortly before harvest appear healthy and sound but when packed, lesions develop during transit and storage.

Disease development is favoured by temperature between 15 and 35°C , maximum being at 25°C . Rate of rotting increases with increased relative humidity. Uninjured fruits are rarely attacked (Hasija and Batra 1979).

P. lycopersici Kleb was also reported as a storage pathogen (Sharma 2006). Vitamin C content as well as reduction in sugars and amino acids were

recorded in fruits infected by *P. exigua* (Reddy *et al.* 1980, 1984). Production of cellulolytic enzymes (cx) was also recorded. Maximum quantity of enzyme was recorded on the 9th day on fruits inoculated with *P. destructiva* that were kept at 10-30°C. Infection is seed-borne. The pathogen persists in diseased crop debris also.

Alternaria-rot, c.o. Alternaria spp.

The disease was recorded from most tomato-growing countries like Canada, France, USA, Germany etc (Mc colloch and Worthington 1952; Stinson *et al.* 1981; Blancard *et al.* 1984). The disease was reported from India also (Rao 1965; Kassim 1986; Gupta *et al.* 1989; Sharma and Chaudhary 2004; Sharma *et al.* 2004). The fungus causes dark olive-green spots on tomato. It also causes early blight symptoms on leaves. Storage-rot due to *A. solani* Soraeur was reported by Rao (1965), Mehta *et al.* (1975) and Kore and Gole (1990). Sharma and Sumbali (1993) conducted extensive surveys at whole sale, retail markets and at consumer level to assess various vegetable-rot causing fungi in parts of north India, and reported *A. alternata* to be responsible for causing dark olive-green rot on tomato. In Himachal Pradesh, Sharma *et al.* (2004) also observed 4.8-11.75% fruit-rot due to *Alternaria-rot*. Temperature range of 20-25°C was reported ideal for growth and sporulation, and no infection was observed at 0-5°C. The fungus is a common inhabitant of soil and air, and survives on plant debris. Infection generally occurs through dead flower parts, insect injuries, cracks at the stem-end or on tissues weakened by sunscald, chilling injury etc.

Variability among isolates of *Alternaria* was also reported. Varma *et al.* (2007) reported morphological, pathological and molecular variabilities by random amplified polymorphic (DNA RAPD) technique.

Symptoms : Lesions may appear anywhere on the fruit-surface. Mostly they are concentrated at the stem-end or the blossom-end as black, circular or oval-sunken spots (Fig. 20.8). The inner tissues turn soft and become dark-brown to black with a cylindrical dry-core (Pearson and Hall 1973, 1975). Lesions of different diameter were also recorded by Zeitter and Wein (1984). Under humid conditions, dense, velvety olive-green spore masses were visible. Profuse sporulation of *A. alternata* was also noticed (Philip 1998).



Fig. 20.8. *Alternaria-rot* on tomato

Mehta *et al.* (1975, 1975 a) observed temperature of 28°C, RH 100% and 4-8 days old inoculum as most effective for disease incidence. Metabolic changes as well as changes in the composition of sugars, organic acids, amino acids and phenolic substances were also reported.

Control measures : Storage at 10-15°C offers satisfactory results. Chemical methods are available for controlling fruit-rot. Dharam Vir *et al.* (1967) observed efficacy of Aureofungin as a fruit-dip and a wrap-treatment in controlling fruit-rot during transit. Kassim (1986) reported use of Antracol (0.2%) and Benlate (0.2%) as pre-infection treatment. In general, non-systemic fungicides are recorded to be superior than systemic fungicides. Ruchisood and Sharma (2002) observed Indofil M-45 (at 250, 500 and 1,000 ppm) as the best protectant and eradicant, followed by Ridomil (0.2%) or Captan (0.2%) against fruit-rot.

Bavistin + Dithane M-45@100 ppm each, followed by Bavistin @ 200 ppm was effective in inhibiting fungal growth in Latur. *Trichoderma harzianum*, *T. viride* and *T. hamatatum* were effective, but *T. harzianum* was the best in managing tomato early blight (Throat *et al.* 2005).

The fungus is seed-borne. Khulbe and Sati (1987) from Kumaon area identified on tomato-seeds several species of *Alternaria*, besides the common *A. solani*. This included *A. tenuis*, *A. alternata*, *A. raphami* and *A. brassicae*. The pathogen may survive on the infected crop residue. Since it is seed-borne, seed treatment is effective in eliminating infection.

Chandravanshi *et al.* (1994) made *in-vitro* studies with the commonly available non-systemic and systemic fungicides. Results showed that Carbendazim (0.2%) persisted for 90 days.

Rhizopus soft-rot, c.o. *Rhizopus* spp.

The disease is of worldwide importance. But is commonly reported from tropical areas along with bacterial soft-rot and sour-rot (Mc Collach *et al.* 1968). *R. stolonifer* and *R. arrhizus* are the common pathogens (Thakur 1972; Thakur *et al.* 1974; Sonoda *et al.* 1982; Okoli and Erinle 1990; Sharma and Sumbali 1993; Reeny 1995; Sharma and Chaudhary 2004). *R. nigricans* produces characteristic nests of rotted fruits (Eckert and Kolbezen 1962).

Symptoms: Disease symptoms may appear anywhere on the fruit-surface but concentrate mostly around injuries. The tissues become soft and water-soaked but not discoloured. Decay spreads throughout the fruit, which often ruptures with profuse leakage. Coarse white fungal growth with globular spore heads also appear profusely. Later entire fruit becomes ash-coloured. Humid conditions support copious growth of the fungus. The fruit collapses soon and a thick, viscous fluid oozes out (Philip 1998).

Control measures : Thakur *et al.* (1974) recorded 2, 4-D at 500 ppm as an effective pre-infection treatment in inhibiting *R. arrhizus* growth. Use of growth regulators in low concentrations is also effective. Control with coconut oil, groundnut oil, palm-kernel oil as well as pure vegetable oil and liquid paraffin was also reported by Adisa (1955) from Nigeria. Mature ripe or half ripened tomatoes dipped in 75% palm-kernel oil and stored at 15°C gave protection against spoilage by *R. oryzae*, *P. sorghina*, *C. lunata* and *F. equiseti*.

**Soft-rot/ Mucor-rot, c.o. *Mucor hiemalis* Wehmer
Mucor sp.**

Mucor was reported by Reeny (1995) from Thiruvananthapuram. Soft-rot due to *Mucor* was also commonly noticed. Moline (1984) and Moline and Kuti (1984) made comparative studies with *Mucor* spp. from Czechoslovakia. They recorded *M. piriformis* on mature green and ripe- red tomatoes. The fungus causes maximum decay within 2-3 days, accompanied by a watery ooze.

Symptoms : Water-soaked lesions are noticed on the fruit-surface. They are later covered by white cottony growth of fungus. The disease causes extensive damage to tomatoes in storage.

Control measures : *As detailed under Rhizopus soft-rot are applicable to this disease also.*

Cottony-leak/damping-off, c.o. *Pythium* spp.

The disease was recorded from all the tomato-growing areas. *Pythium aphanidermatum* was recorded from the USA (Pearson and Hall 1973) and other countries including India (Tripathi and Grover 1977). Other *Pythium* species involved include *P. myriotylum*, *P. arrhenomonas* (Sonoda 1973) and *P. butleri* (Sharma and Sumbali 1993).

Ganesan and Sinha (2002) and Pandey and Pandey (2005) recorded *Fusarium oxysporum* f sp *lycopersicum*, *Sclerotium rolfsii*, *Rhizoctonia solani*, *Alternaria solani*, *Colletotrichum capsicii* and *Macrophomina phaseolina* in addition to *Pythium* in tomato nurseries as causal agents of damping-off.

Symptoms : Soft, water-soaked lesions may occur anywhere on the fruit-surface. The lesions enlarge rapidly until entire fruit is infected. Skin splits and profuse leakage occurs. The fungus is present in the soil, and infection occurs during wet-warm weather. The rotting is maximum at 25-35°C. During transport and storage, infected tomatoes undergo a wet collapse (Ilag 1976).

Control measures : Seed and soil application of *Trichoderma* spp. and *Gliocladium virens* managed successfully damping-off of vegetables *as is detailed in cucumber, pea* (Sivan *et al.* 1984; Lifshitz *et al.* 1986; Sawant and Mukhopadhyay 1990; Hazarika and Das 1998). The biocontrol potential of *Trichoderma viride* as well as *T. harzianum* and *G. virens* of Asom and Tamil Nadu was evaluated against *P. aphanidermatum*, incitant of damping-off. Seed treatment with Asom strain of *T. harzianum* recorded highest seedling stand (Hazarika *et al.* 2000). Anandh and Prakasam (2001) reported effect of activated *Trichoderma* formulation in managing damping-off in tomato.

Rammoorthy *et al.* (2002) observed enhanced resistance in tomato and hot pepper to *Pythium* through seed treatment with fluorescent pseudomonads. *Pseudomonas fluorescens* applied along with neem-cake recorded 50% increase in seed germination (Ganesan and Sinha 2002).

Thiruvadainambi *et al.* (2004) also recorded disease control through seed treatment with *P. fluorescens*, followed by soil application with farmyard manure.

Biological control with different species of *Trichoderma* showed *T. viride* as the best against *F. solani*, *S. rolsfii* and *P. aphanidermatum* in tomato, followed by *T. virens*. In soils with mixed infection, *T. konengii* and *Bacillus subtilis* resulted in best seedling emergence (Pandey and Pandey 2005).

Soil-rot/*Rhizoctonia* fruit-rot, c.o. *Rhizoctonia solani* Kühn

The disease occurs on the fruits which are in the close proximity of the soil; and infection occurs during transport and storage also (Gonzalez and Owen 1962). The injuries sustained during harvest, transit and storage play a key role in the development of symptoms during storage. Thapa and Sharma (1976) recorded negligible losses from Solan, while Rajkumar (2000) recorded this fungus to be frequently associated with fruit-rots in the Thiruvananthapuram markets.

Symptoms : Lesions formed are circular with a dark border and a pale centre. Within two days, splitting of fruit-skin occurs in all directions and the fruit-surface gets covered with dense flocculent mycelia (Fig. 20.9). Profuse growth of sclerotia is also noticed. Inner tissues also become soft and watery. Reddy *et al.* (1980, 1984) and Reeny (1995) recorded fungus from rotten tomato-fruits also. Changes in the levels of sugars, amino acids and vitamin C were also observed.



Fig. 20.9. *Rhizoctonia* fruit-rot

Control measures : Care should be taken that fruits do not touch the soil. Ashworth and King (1962) observed reduction of damping-off caused by *R. solani* in nurseries raised on beds covered with polyethylene sheets.

Sour-rot, c.o. *Geotrichum candidum* Link.

Butler (1960) reported high losses due to this disease. Mc Colloch *et al.* (1968) recorded the disease to be common in the tropical regions. The fungus was reported on many other fruits, besides tomatoes (Shankhpal and Hatwalne 1974). In India, the disease was reported by Jamaluddin *et al.* (1971, 1975); Shankhpal and Hatwalne (1976); Madaan and Ullasa (1990); Okoli and Erinle (1990); and Sharma and Chaudhury (2004). The morphology, pathogenecity and aggressiveness of the two isolates—*G. candidum* and *G. penicilliarum*—were studied by Mall and Mall (1982) and Moline (1984). *G. candidum* was observed to be virulent and pathogenic even though fungus was considered a weak parasite that colonized broken/ruptured fruits.

Symptoms : At first, water-soaked lesions appear, mostly around the stem-end region. After 2-3 days of infection, fungal growth is observed in the form of white-waxy powdery growth that causes typical star-shaped cracks (Fig. 20.10). The fungal spores are carried to healthy fruits by common fruit-fly, *Drosophila melanogaster* (Butler 1961; Philip 1998; Rajkumar 2000).

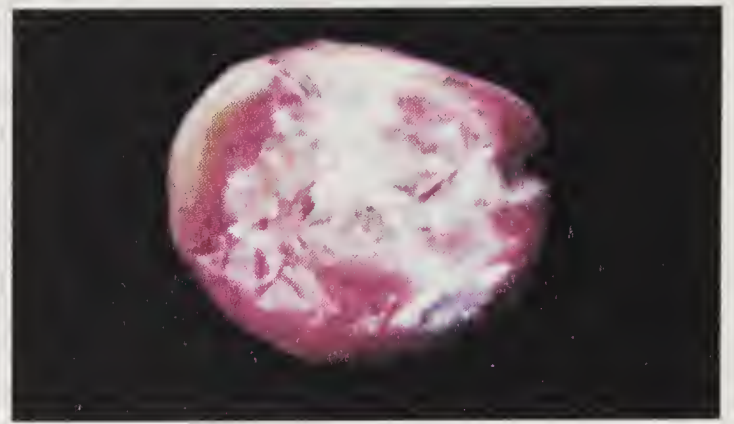


Fig. 20.10. *Geotrichum*-rot (advanced stage) on tomato

The fungus survives at a temperature range of 10-35°C with a maximum rotting at 25°C; minimum or no rotting at 10°C and below (Tandon *et al.* 1974).

Control measures : The latex of *Euphorbia hirta* has been found effective against this fruit-rot and fruit-fly *Drosophila buskii*, which carries spores to healthy fruits. The latex acts as a repellent (Purnima and Saxena 1990).

***Aspergillus*-rot, c.o. *Aspergillus* spp.**

The disease due to *A.niger* is common under tropical conditions and is observed on the fully ripened fruits (Kassim 1986). The disease spreads through contact.

Symptoms : Water-soaked lesions appear on the affected fruits. The affected skin ruptures and produces open lesions, which are covered with black spores. The inner tissues become soft, develop rot and convert into a soft pulpy mass. Rotting was also observed (Pandey 2006).

Rotting due to *A.flavus* was recorded by Reeny (1995). Initially, the rot starts as water-soaked lesions that rupture the skin and juice with a fermentative odour leaks out (Fig. 20.11). The tissues become soft and mycelia with greenish sporulation are observed on the infection site. From Nigeria, infection due to *A. flavus* and *A.fumigatus* was recorded by Adisa (1985) and both moulds *in vivo* were



Fig. 20.11. *Aspergillus*-rot on tomato

found to produce pectinolytic enzymes, polygalacturonase and pectin methyl transeliminase. Similarly, they produced amylases and cellulolytic enzymes. Maximum production of both enzymes by *A. flavus* was at 25°C and pH 6.8 and by *A. fumigatus* at 35-40°C and pH 7.0.

Control measures : The crude water extract of *Withania somnifera* was recorded as effective. The extract showed potentiality of controlling fungus and its vector *Drosophila buskii* (Purnima and Saxena 2002).

Ring-rot/Myrothecium-rot, c.o. *Myrothecium roridum* Tode ex Fr.

Ring-rot usually causes losses in outdoor and greenhouse crops. The disease was recorded to cause losses in Cuba, Mexico, USA etc. Madaan and Ullasa (1990) reported the disease from Bengaluru, Karnataka along with several other fungi.

Symptoms : The disease appears on the fully ripened tomato-fruits. The diseased area gradually increases in size and gets covered by copious growth of concentric circles of white woolly mycelia, followed by dark-green zone of sporodochia with viscid spore mass. The junction between the healthy and diseased areas remains clearly well defined (Tandon and Srivastava 1963; Gaur and Pathak 1979).

Tomato is an important source of vitamin C (ascorbic acid), and reduction in ascorbic acid content was noticed due to infection by *M. roridum* (Jamaludeen *et al.* 1974). Kapoor and Tandon (1969) observed similar results with tomato infected by *Drechslera australiense*.

Control measures : Seed treatment with Captan/Thiram (0.2%) controls seed-borne infection.

***Sclerotium-rot, c.o. Sclerotium rolfsii* Sacc.**

In Gaya (Bihar), a loss exceeding 10% in yield was recorded. Fruits remaining in contact with the soil are mostly affected.

Symptoms : The fruit is covered by white mycelial fungal growth. Soon the mycelia get blighted, turn brown and produce sclerotia in abundance. By this time, the fruit becomes soft and cracks open with a watery exudate. Rotting is restricted to narrow zone of the green fruit. Temperature range of 25-30°C was recorded as optimum for rotting (Prasad *et al.* 1984, 1988) under conditions prevailing in Gaya. It was also recorded by Ganesan and Sinha (2002) and Sharma and Chaudhary (2004).

Control measures are as detailed under *Soil-rot/Rhizoctonia fruit-rot*. Fruits should not be allowed to touch the soil.

***Cylindrocladium-rot, c.o. Cylindrocladium scoparium* Morgan**

Jamaludeen *et al.* (1974 a) and Jamaludeen (1977) observed disease in a serious form from the local markets of Allahabad. About 20-25% of the fruits rotted within 10 days of infection. Under natural conditions, the infection is observed through stem-end as well as from skin-cracks in the ripe fruits. The disease is severe from December to March.

Characteristic disease symptoms, small, circular soft areas appear on the fruit. As the decay progresses, some light-brown mycelia changing to dark-brown with age as well as hyaline conidia appear over the infected areas. The entire fruit gets covered within two weeks. The mycelial coating becomes compact on the fruit-skin, and the inner tissues turn soft and ultimately fruits shrivel and rot. Rotting of fruits is most severe at 25-28°C. The growth and

sporulation of the fungus is favoured by the vitamin, thiamine. The disease is of minor importance.

Cladosporium-rot, c.o. *Cladosporium* spp.

Several species of *Cladosporium* are found associated with storage-rot. These include *Cladosporium oxysporum*, *C. herbarum*, *C. sphaerospermum*, *C. cladosporioides* and *C. fulvum* (Coursey and Booth 1972; Singh *et al.* 1987; Sharma and Sumbali 1993; Sharma and Chaudhuri 2004). *C. herbarum* was recorded on tomato from Italy and Norway and on peppers in the USA (Ramsey and Heiberg 1952).

Symptoms : Lesions on the fruits are at first circular, firm, sunken and jet-black with sharply delimited pale-brown border. Under humid conditions, copious growth of brownish green to black spores is noticed. Maximum infection is recorded at 30°C and 95% relative humidity.

Control measures : Pre-infection treatments with Captafol (0.2%), Captan (0.2%), Benlate (Benomyl) 500 ppm and Blitox-50 (0.5%) were found effective in reducing storage-rots by 75%. Spraying fruits with different oil-soap emulsions is also recorded as effective in maintaining firmness of fruits and also freshness for 5-10 days longer. Differential toxicity of oils to fungi was also reported.

Irregular target-spot, c.o. *Phomopsis fusiformis*, N.C. Mandal and M.K. Dasgupta sp.nov.

The perfect stage of *Phomopsis*, viz. *Diaporthe phaseolorum* var. *sojae* (Lehmann) Wehmeyer was reported on tomato from the USA (Lutterell 1947). *Phomopsis* spp. was recorded by Coursey and Booth (1972) also.

Symptoms : Soft-water soaked lesions appear near the pedicel-end and later enlarge up to 3-4 cm in diameter. The centre becomes pale to amber and occasionally brown to dark-brown. Irregular zonations are observed. The affected fruit becomes shrivelled, slightly wrinkled and cracked. Fungus growth is visible on the infected surface (Mandal and Dasgupta 1984). The disease is of minor importance.

Watery soft-rot, c.o. *Sclerotinia sclerotiorum* (Lib.) de Bary

Ginoux and Blancard (1984) reported the disease from France. Lesions appear anywhere on the fruit surface. Under warm moist conditions, lesions are enveloped sooner by white fungal growth. At first, white, irregular shaped bodies representing sclerotia develop with white exuding drops of liquid. Later they become black, dry and hard. The fungus is present in the soil. The disease is not common in Indian conditions.

Fruit-spot, c.o. *Corynespora cassiicola* (Berk. & Curt.) Wei

The fungus generally causes leaf-spots on tomato. Fruit infection is also common. Winds and rains perpetuate the disease. Lesions on fruits appear as

small necrotic pits or freckles (Volin and Pohronezny 1989). The disease was reported from Florida also.

Control measures *as detailed in Cladosporium-rot are applicable here also.*

Botrytis-rot, c.o. *Botrytis cinerea* Pers.ex Fr.

This is considered as a major disease in the temperate countries. The disease is also known as ghost-spot (*Botryotinia fuckeliana* de Bary Whetzel, Anamorph: *Botrytis cinerea*). The disease was reported from the UK, US and Netherlands. Barkai-Golan *et al.* (1990) observed stimulation of ethylene production in fruits by *B. cinerea* and *Geotrichum candidum* infection in normal and non-ripening tomatoes. Inoculation of fruits at the time of harvesting with the above-mentioned pathogens stimulates ethylene production, which in turn hastens the development of symptoms.

Symptoms : Pale circular haloes are noticed on the shoulder of the fruit. At the centre of each halo, a dark point often raised may be apparent. Numerous lesions are visible. The conspicuous symptom is the roughness of skin.

Control measures : Fallikk *et al.* (2002) from Israel reported hot-water rinsing (52°C) and brushing (HWRB) effective in reducing decay and chilling injuries. The treatments also enhanced resistance of fruits against *B. cinerea*. Application of hexanoic acid to tomato-plants was reported to be effective in post-infection control of *B. cinerea* (Leya *et al.* 2008).

The fungal antagonist *Ulocladium atrum* has been recorded as a promising candidate for control of *B. cinerea* (Kohl and Molhoek 2002).

Pink mould-rot, c.o. *Trichothecium roseum* Link. ex Fries

The disease is generally considered as of minor importance. Occasional losses in greenhouse crop were reported from the USA (Welch *et al.* 1975). It was reported by Jamaluddin and Tandon (1976) from Allahabad. The infection starts from the stalk-end of the fruits and causes pale-vinaceous pink growth on the surface. In the final stage, fruits become pulpy, and spore-laden juice with a disagreeable odour oozes out. Nearly 10% damage was recorded in Red Currant.

Choanephora-rot, c.o. *Choanephora cucurbitarum* (Berk. & Rav.) Thaxter

Star-shaped cracks appear on fruits in the early stages of infection. Centre of the infection becomes depressed and soft. The skin gets easily loosened from the pulp with a white scanty superficial growth. As the lesions advance, secondary infection by saprophytic fungi occurs (Reeny 1995).

Control measures *as detailed under Rhizopus-rot are applicable to this disease also.*

Septoria leaf-spot/fruit-rot, c.o. *Septoria lycopersici* Speg.

The disease is of worldwide distribution. It causes defoliation and fruit-rot. The fungus is seed-borne. It also persists on the infected crop refuse. Seed

treatment and foliage spray was reported to keep disease under check (Suryanarayana 1978).

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|---------------------------|---|---|
| Fruit-rot | <i>Drechslera australiense</i> | Kapoor and Tandon, 1969, 1969a, 1970 |
| | <i>Chaetomium brasiliense</i> | Rath <i>et al.</i> , 1990 |
| | <i>Monoascus rubber</i> | |
| Anthracnose | <i>Colletotrichum capsici</i> (Syd.) Butler and Bisby | Thapa and Sharma, 1976; Gupta <i>et al.</i> 1989; Sharma and Choudhary, 2004; |
| | <i>C. phomoides</i> (Sacc.) Chester | Pandey, 2006 |
| | <i>C.gloeosporioides</i> Penz. | |
| Pleospora-rot | <i>Pleospora lycopersici</i> | Coursey and Booth, 1972 |
| Stemphylium-rot | <i>Stemphylium vesicarium</i> | Bartz, 1962; Chary <i>et al.</i> , 1980; Blancard, 1992 |
| | <i>S. botryosum</i> Wallr | |
| Nigrospora-rot | <i>Nigrospora (Khuskia)</i> (Berk. & Br.) Petch | Chary <i>et al.</i> , 1980 |
| Curvularia-rot | <i>Curvularia lunata</i> (Walker) Boedijin | Adisa, 1985 |
| | | |
| Blue mould-rot | <i>Penicillium digitatum</i> | Kassim, 1986; Shrivastava <i>et al.</i> , 1993; Pandey, 2006 |
| | <i>P. auranteogriseum</i> | |
| | <i>Penicillium</i> sp. | |
| Bipolaris-rot | <i>Bipolaris spicifera</i> | Sharma and Sumbali, 1993 |
| Cylindrocarpon-rot | <i>Cylindrocarpon tonkinense</i> | Jamaluddin, 1976 |
| | | |
| Stem-end-rot | <i>Didymella lycopersici</i> Kleb | Sharma and Choudhury, 2004 |

BACTERIAL DISEASES

Bacterial soft-rot,

c.o. *Erwinia carotovora* (Jones) Holland (Arsenjevic and Stojic 1973)

Pseudomonas aeruginosa, *P. marginalis* and *P. syringae* pv. tomato

Symptoms : Lesions on the fruits are initially soft and slightly depressed with water-soaked margins. Rotting becomes rapid and skin crumbles and splits with profuse leakage. The bacteria are found in soil and in plant debris and are disseminated by wind, water, insects and human-beings. Infection may occur through wounds in the skin or through cut-ends. Heavy rains increases likelihood of infection. Water condensing on the packed fruits results in increased bacterial decay, as that helps in easy dissemination.

Control measures: Vigneault *et al.* (2000) observed tomato-fruits hydro-cooled with a suspension of *E. carotovora* subsp. *carotovora*, containing

50-200 mg of free chlorine/litre at pH 7 free of decay for ten days at 20°C storage.

Bacterial fruit-rot, c.o. *Corynebacterium michiganense*
(E.F. Smith) Jensen

Symptoms : The bacterium causes brown streaks on the stem and necrotic lesions on the leaves, wilting of the plants and cankerous lesions on the fruits, which ultimately rot. On green fruits, infection causes water-soaked spots, which get surrounded with a halo, resulting in fruit-rot in transit and storage. Local dissemination occurs from open cankers.

The bacterium is seed-borne, and 7% infection was recorded (Nedumaran and Vidhyasekaran 1982a). Infected seeds showed less viability (7-15% reduction) with reduced seedling vigour. The infected seeds when sown in a non-infested soil, spread pathogen in the new area, and may survive in the soil for several years (Neergaard 1977).

Control measures : Rotation with non-solanaceous crops is useful. Keep the fields free of weeds by cultivating. Avoid overhead irrigation; instead use drip irrigation or soaker hoses for watering.

Bacterial-spot, c. o. *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye

It is an important disease of tomato and pepper, grown under warm humid conditions (Goode and Sasser 1980; Ramoss and Volin 1987).

Symptoms : Dark, raised spots appear on the infected tomato-fruits and each spot is surrounded by a water-soaked border. As lesions enlarge, margins acquire a lobbed appearance. Meanwhile the centre disintegrates and sinks down to form a fibrous pit. The bacterium attacks all the above-ground parts, including fruits.

Distribution of pathogenic groups and races in *X. campestris* pv. *vesicatoria* in India was studied in detail by Chand *et al.* (1994), and categorized isolates into two pathogenic groups—3.4 % belonged to tomato group (XCVT) and 96.6 % to pepper tomato group (XCVPT). All XCVPT isolates from tomato and pepper were specific to tomato and produced cankerous lesions.

Control measures : Three applications of Agrimycin-100 (15% streptomycin and 1.5% terramycin) are effective in reducing disease intensity. Seed treatment is also effective (Patel *et al.* 1950; Kishun and Sohi 1982).

Small spots on fruits caused by *Clavibacter michiganensis* subsp. *michiganensis* were also reported.

Seed microflora

Stored tomato-seeds carried a wide spectra of fungal spores (Nazeema 1981). Alimova *et al.* (2002) recorded *Aspergillus* spp. and *Penicillium* spp. in abundance on seed-coats. *Fusarium oxysporum*, *Stemphylium*, *Oospora*

latis, *Sclerotinia sclerotiorum* and bacterial spores of *Pseudomonas* sp. and *Erwinia* sp. were also recorded.

Control measures : *Trichoderma harzianum* was recorded with high antagonistic activity against all the above-mentioned pathogens. Greatest growth inhibition was observed after three days. Seed treatment with *T. viride* @0.4% (2×10^9 cfu/g), *T. harzianum* @1.0% (10^9 cfu/g), *P. fluorescens* @ 1.0% (10^9 cfu/g) and a mixture of *P. fluorescens* and *A. niger* @ 0.8% (3.28×10^8 cfu/g) as well as Thiram (0.2%) reduced post-emergence mortality and increased plant vigour and yield (Hooda *et al.* 2008).

POST-HARVEST DISEASES MANAGEMENT

Enhancement of resistance in fruits through the induction of defence-related enzymes involved in the phenyl propanoid pathway is being attempted against *Pythium* in tomato and in hot-pepper.

- Providing good drainage in the nursery beds, avoiding thick sowing, and soil sterilization by steam, dry heat, formalin (40% formaldehyde) are common practices. Soil solarization by exposure to sunlight helps controlling soil-borne diseases.
- Cool-chamber technology is identified as a low-cost storage technique, which helps preserve freshness of farm produce (Anon. 1997). Cool chambers help to increase shelf-life of tomatoes. Physiological loss in weight (PLW) is also less compared to low temperature storage.
- Fruit-rots caused by *R. oryzae*, *Curvularia lunata*, *Phoma sorghina* and *Fusarium equiseti* are controlled by storage at 10-15°C (Adisa 1985).
- Hydro-cooling before storage, followed by storage at 10°C for seven days, are reported to be effective.
- Hot-water rinsing and brushing (HWRB) is assuming importance in Israel, as it reduces chilling injury and enhances resistance against *Botrytis cinerea* in freshly harvested tomatoes (Fallik *et al.* 2002).
- Seed treatment with Thiram (0.2%) protects seedlings against the attack of soil-borne pathogens. Kassim (1986) observed Antracol and Benlate (0.2% each) to be effective for pre-infection treatments. Singh *et al.* (1989) proved efficacy of Guzatine (100 mg a.i./litre) as a fungicide of low mammalian toxicity with no residual hazards.
- Fungicide impregnated paper-liners protect against storage-rots caused by *Colletotrichum gloeosporioides*, *Cladosporium oxysporum*, *Fusarium pallidoroseum*, *F. equiseti*, *Geotrichum candidum*, *Phoma lycopersici* and *Sclerotium rolfsii*. Fruits kept in wooden boxes with Carbendazim (Bavistin) 500 ppm or Mancozeb (Indofil M-45) impregnated tissue-papers and stored at $25 \pm 1^\circ\text{C}$ also showed promising results (Sharma 2006).

- The biocontrol potential of *Trichoderma* spp. in damping-off disease has already been recorded. It has been documented that seed and soil application of *Trichoderma* spp. and *Gliocladium virens* managed damping-off on vegetables, cucumber, pea and tomato.
- Application of *Pseudomonas fluorescens* along with neem-cake recorded increased seed germination (Ganesan and Sinha 2002). Pandey and Pandey (2005) observed variable responses to biocontrol agents against soil pathogens in tomato.
- A combination of Bavistin (0.05%) + stay fresh was found most effective in improving shelf-life and maintaining fruit quality for 17 days (Barua *et al.* 2010).



CHAPTER 21

Legume Crops

With the growing demand for nutritional security, legumes are becoming important as a plant-based source of proteins for human nutrition. Legumes are made up of 20-25% proteins and are rich in dietary fibres with little or no oil. Protein component of legumes is rich in essential amino acids like lysine and methionine, making them nutritionally complementary to cereals, which are deficient in these two amino acids. The important legumes-crops include the following.

GARDEN-PEA (*Pisum sativum* L.)

FUNGAL DISEASES

***Mycosphaerella/Ascochyta*,**

c.o. *Ascochyta pinoides* (Berk. & Blox)

Mycosphaerella pinoides (Berk. & Blox) Stone.

The disease is of worldwide importance and may pose serious threat to garden-pea if weather conditions are favourable to it during the cropping season. Walker (1975) described three diseases of garden-pea—*Mycosphaerella*-blight, *Ascochyta*-leaf and pod-spot and *Ascochyta* foot-rot. The disease has been known in Europe for centuries. In the United States, *Mycosphaerella*-blight and *Ascochyta* foot-rot are most important. *A. pisi*, *A. pinodella* and *M. pinoides* were reported from Czechoslovakia (Moravick 1982).

Antigenic relationship among isolates of *A. raibei* (Uma Devi *et al.* 1991) and their variability (Singh and Madendra Pal 1993) were studied. Presence of five races in *A. raibei* on the basis of disease reaction on different host genotypes was reported.

Symptoms : Round, tan-brown spots, up to 9 mm in diameter, appear on the leaves, stems and pods. Spots on the pods are surrounded by a black and thickened edge having pale-brown centre. The fungus penetrates into seeds also. Heavily infected seeds remain small and shrivel up. Infection is seed-borne. *A. pinodella* produces brown to purple, round spots on the pods, leaves and stems. The spots in this case are fewer with clear zonations. *A. pisi* also produces symptoms on the pods. All fungi are seed-borne, but can also survive

on the diseased crop debris. When seed germinates, seedling tip dies and this serve as the substrate for fungal growth and subsequently produces pycnidia and conidia for further spread.

Cold weather with abundant moisture on leaves favour disease development. Frequent rains help building up of inoculum/epidemics. Relative humidity above 90% is most conducive. Elimination of seed-borne inoculum and destruction of crop refuse are of utmost importance.

Control measures : Seed infection can be controlled by soaking seeds in 0.2% Thiram/ Captan suspension for 24hr at 30°C (Suryanarayana 1978). *Trichoderma harzianum* (Chaudhary and Gangwane 1989) and seed treatment with Captan, Thiram (all at 0.2%) or with organomercurials give protection against seed-borne fungi (Hwang *et al.* 1991; Singh, 1992).

Cottony white-rot /collar-rot, c.o. *Fusarium* spp.

Fusarium-rot was reported from Kurukshetra and Karnal (Dhingra and Mehrotra 1980). Collar-rot disease of pea (*Fusarium solani* f.sp. *pisi*) causes heavy reduction in yield of green pods and grains (Maheswari *et al.* 1983).

Symptoms : Pods are infected with yellowish to creamy watery lesions, which become suppressed, and after 3-4 days are covered with white, fluffy growth. *Fusarium semitectum* Berk and Rav was isolated from infected lesions. Dasgupta and Mandal (1989) observed water-soaked bleached areas on pods during late winter due to *F.oxysporum*, which later turn greyish. The seeds become soft with brown markings on the seed-coat. White floccose fungal growth develops on the surface as well inside the pods. The rotten material produces offensive smell.

Control measures : Collar-rot could be controlled by integration of biological and chemical methods (Kumar and Dubey 2001). Isolates of *Trichoderma viride*, *T. harzianum* and *Gliocladium virens* (at 10⁶ spores/ml/10 g seed) along with seed-dressing fungicides were used. Seeds treated with Captan (1 g/kg) + *T. harzianum* recorded good germination and least disease incidence along with highest green pod yield, which was similar with seeds treated with *T. harzianum* alone, *T. harzianum* + Thiram, Carboxin + *G. virens* and *G. virens* alone. Mishra *et.al.* (2002) observed chlamydospore based formulation of bioagents to be superior in shelf-life and bio-efficacy against soil-borne pathogens, including *F.oxysporum*.

For integrated management of pea diseases, Kapoor *et al.* (2004 , 2006) reported use of two local bioagents, *T.koningii* and *T.harzianum*. Their concentration was maintained at 1-2 × 10⁷ cfu/g of the formulation. For soil application, the bioagent was used @ 2.5kg/65kg of FYM/ha. Integration of seed treatment with neem-based biopesticide Wanis (0.2%) and *T.koningii* reduced pea root-rot/wilt disease complex (RRWC) at Palampur(Himachal Pradesh). *T.harzianum* was more effective against white-rot. Wanis (0.1%) was

highly effective against *F.oxysporum* f sp *pisi* and *F. solani* f sp *pisi* and *Sclerotinia sclerotiorum*.

Soft-rot, c.o. *Rhizopus oryzae*

This disease was recorded from West Bengal (Mandal and Dasgupta 1981). It appears on physiologically weak and half-filled seeds. The decay appears in patches and starts on the pod, which becomes water-soaked, bleached, white and coarse with stringy mycelial growth on and within the pod. The seeds become soft and pods emit a soury fermentative odour. Sprinkling water on the green pods favours disease incidence. *R.stolonifer* was also reported on peas (Sharma and Sumbali 1993).

Pod-rot/white-rot, c.o. *Sclerotinia sclerotiorum* (Lib.) de Bary *Sclerotium cepivorum* Berk.

White-rot is rated as the most important disease, as it causes heavy losses in yield in different pea-growing areas of Himachal Pradesh and Rajasthan. Under favourable conditions, it causes total crop failure also.

Symptoms : White growth appears on the pods. Rotting of pods and seeds is common. The fungus was reported by Sharma and Sumbali (1993). Sharma and Kapoor (1997) recorded important epidemiological aspects of white-rot. Disease symptoms appear between 10 and 25°C (with optimum at 20-25°C). The sclerotia survive for more than a year in the soil.

Control measures : Seed treatment with Bavistin (0.1%) + Thiram (0.2%) in 1:1 at 2.5g/kg, and three fortnightly sprays with Bavistin, starting at flower initiation, provided excellent control (Suga 2000). Seed treatment with *T.harzianum* mixed with Carbendazim(0.1%) @ 2g/kg of seed protected seedlings from pre and post emergence phase of mortality, resulting in 100% final stand of plants. And *T.harzianum* in combination with Captan (0.2%) or Mancozeb (0.2%) also recorded similar results (Khan *et al.* 2004).

Adams and Ayers (1981) recorded *Sporodesmium sclerotivorum* functioning as a biocontrol agent to *S.sclerotiorum* and *S. cepivorum* under natural field conditions. They observed that 100 spores/g of soil brought decline of *S. sclerotiorum* and *S.cepivorum* sclerotia under field conditions.

T. viride, *T. hamatatum*, *T. viride* isolate B and isolate E were mass multiplied on wheat-bran agar and spore suspensions were used for the study. The volatile and non-volatile metabolites of *Trichoderma* spp. significantly reduced mycelial growth and germination of *S. sclerotiorum* in the field (Kapil and Kapoor 2005).

Wanis, the neem-based biopesticide, at 0.5 and 0.1% concentration was effective in controlling *S. sclerotiorum* in fields.

Anthraco nose, c.o. *Colletotrichum pisi* Pat.

This is considered as a minor disease. Brown spots appear on the leaves,

stems and pods. The causal fungus survives on crop debris and seeds. The optimum temperature for infection is 20-24°C. Control measures recommended for *Ascochyta-blight* are applicable to this disease also.

Powdery-mildew, c.o. *Erysiphe polygoni* DC, *E.pisi* DC

It is a common disease in several pea-growing areas of India, and was recorded from Maharashtra, Karnataka, Uttar Pradesh, Delhi and Himachal Pradesh.

Symptoms : Powdery white-spots appear on the upper side of the leaves and the corresponding portions underneath become chlorotic. Upper leaves fail to develop fully. Infection appears on pods, which shrivel and dry-up. The fungus survives as dormant mycelia below the seed-coat. Pre-soaking of seeds in cold-water for six hours, followed by hot-water treatment at 50°C for ten min have been suggested to check seed-borne infection (Suryanarayana 1978).

Control measures: Powdery mildew causes more damage to seed-crop than to vegetable-crop. Seed treatment with Carbendazim and sowing in October and November reduce disease incidence. Manipulations of sowing time are reported to reduce disease incidence in different localities (Sokhi 1994). Swarnamutki is considered as a powdery mildew resistant high-yielding garden-pea variety.

In Himachal Pradesh, the disease was controlled by field application of Bayleton (0.025%) or Contaf (0.025%) at the time of disease appearance, followed by 2-3 sprays of Karathane (0.05%). Seed treatment only delayed disease appearance (Banyal 2000).

Downy-mildew, c.o. *Peronospora pisi* Sydow

The disease is common in the Indo-Gangetic plain. It is also reported from Europe and North America.

Symptoms : They appear on leaves and on pods. The patches are pale-green, more or less elliptical with blotches on the sides of the pods and irregular elongated lesions are along the dorsal sutures of the pods. The seeds beneath the lesions are undersized and aborted. And the disease is primarily soil-borne.

Control measures : The primary inoculum is in the soil. Sanitation and crop rotation will help in reducing primary infection. Oospores present in the soil can be inactivated if rotation of two to three years is followed.

Seed treatment with Fosetyl aluminium or Metalaxyl (0.2%) protect crop from early attack (David 1990).

***Alternaria* blight, c.o *Alternaria* spp.**

The fungus is seed-borne. Dark patches are noticed on the seed-coat. Similar lesions on the cotyledons are also noticed. The radicle blights eventually. Reduction in germination is also noticed. Thiram (0.2%) soak treatment is effective in reducing seed infection.

Seed-rot, c.o. *Aspergillus flavus* Link. ex Fries (Rati and Ramalingam 1974)

This is responsible for non-emergence of seedlings. Seed-rot by *Pythium* spp. was also reported.

Control measures : Seeds should be dried to a moisture level of 7%. Seed treatment with 0.2% Captan or Thiram is effective.

Seed-rot of pea in soil infested with *Pythium* spp. or *Rhizoctonia solani* is controlled with *Trichoderma hamatum* (10^5 conidia/millilitre). The conidial suspension in water with a spreader and sticker is applied to seeds (Harman *et al.* 1981). Similar studies with *Penicillium oxalicum* against pre-emergence damping-off by the application of conidia (harvested from Zapek-Dox agar medium and applied directly to seeds) were also reported (Windels 1981).

Seed treatment with culture filtrate of *Trichoderma* (collected from the cultures grown on malt extract, washed with sterile water, sieved through cheese cloth and centrifuged) containing 3×10^8 conidia per millilitre was also reported as effective in controlling pre-emergence damping-off in peas (Liftshitz *et al.* 1986).

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|-------------------------------|--|--------------------------|
| Brown-rot | <i>Humicola grisea</i> | Sharma and Sumbali, 1993 |
| Yellow-mould | <i>Aspergillus flavus</i> | |
| Powdery-mildew | <i>Erysiphe</i> spp. <i>Oidium</i> spp. | |
| Phytophthora-rot | <i>Phytophthora nicotianae</i> var. <i>parasitica</i> | Snowdon, 1991 |
| Helminthosporium-rot | <i>Helminthosporium victoriae</i> | |
| Septoria blight/blotch | <i>Septoria pisi</i> | |
| Yeast-spot | <i>Nematospora coryli parasitica</i> | |

BACTERIAL DISEASES

Bacterial blight, c.o. *Pseudomonas syringae* pv. *pisi* (Sackett) Young *et al.*

The disease was reported from the UK also (Ball and Reeves 1992). The disease is seed-borne, and is widely distributed throughout the world; up to 25% losses have been reported.

Symptoms : Water-soaked spots appear on the pods. The lesions retain their water-soaked or greasy appearance with little change in colour. The bacteria survive on crop residues and seeds, and are carried by irrigation water and water splashes created by rainfall or blown by moist-wind, and perpetuate disease.

Control measures : Avoid use of early-maturing varieties, as they are susceptible. Wide spacing between plants, proper drainage, removal of weeds and restricted irrigation help minimizing disease incidence.

VIRAL DISEASES

Pea mosaic, c.o. Pea mosaic virus (Osborn 1935),

Common pea mosaic virus, Red clover mosaic virus
Zaumeyer (Raychaudhuri and Nariani 1977).

Symptoms : The diseased plants look pale, weak and stunted, and flowering is delayed. Comparatively fewer pods are formed on the affected plants, which remain small in size and contain a few seeds (Sreenivasan and Nariani 1966).

Control measures : The virus is not carried through seeds. Losses due to the disease can be minimized by growing pea varieties, Cannons Perfection, Horal, Hundredfold and Little Marval, which are resistant (Raychaudhuri and Nariani 1977).

Another viral disease of pea has been described from Uttar Pradesh. Its characteristic symptoms are streaking and necrosis of different plant parts. Pods developed during the period have purple spots or pits with a few underdeveloped seeds or none at all. Pods are smaller, generally underdeveloped, seedless and malformed. Association of Pea streak Carla virus was also recorded (Singh 1998).

Seed mycoflora

The following fungi are observed on the seeds.

| | | |
|---|--|-----------------------------|
| <i>Cladosporium</i> sp. | | Chapentie and Nicot, 1978 |
| <i>Aspergillus</i> spp. | | |
| <i>Penicillium</i> spp. | | |
| <i>Ascochyta</i> sp. | | |
| <i>Fusarium solani</i> f sp <i>pisi</i> | | Harman <i>et al.</i> , 1981 |
| <i>Alternaria alternata</i> | | |
| <i>Gliocladium virens</i> | | |
| <i>Cladosporium cladosporioides</i> | | |
| <i>C. herbarum</i> | | |
| <i>Rhizopus stolonifer</i> | | |
| <i>R. nigricans</i> | | |
| <i>Pythium aphanidermatum</i> | | |
| <i>P. ultimum</i> | | |
| <i>Absidia cylindrospora</i> | | |
| <i>Alternaria alternata</i> | | |
| <i>Aspergillus flavus</i> | | |
| <i>A. niger</i> | | |
| <i>Penicillium</i> sp. | | |
| <i>P. chrysogenum</i> | | |
| | | Verma and Dohroo, 2005 |

COWPEA (*Vigna unguiculata* (L.) Walp.)

Cowpea is cultivated throughout the country as a vegetable-pulse crop. During rainy weather, diseases attack all the aerial parts of the crop, and affect adversely pod quality and yield.

Maheshwari and Mathur (1987) observed changes in proteins and in the content of the reducing and non-reducing sugars due to infection under different temperatures and relative humidities. In general, deterioration was maximum at higher temperature and relative humidity. Also infection by *A. nidulans* was more deleterious in comparison to *A. terreus*. Studies on the nitrate reductase (NR) and urease (UR) activities with seedlings raised from seeds infected by *A. niger* and *A. flavus* were made by Dayal *et al.* (2001); their activities had lowered significantly.

FUNGAL DISEASES

Dry root-rot, c.o. *Macrophomina phaseoli* (Tassi) Goid.

The fungus causes failure of seed germination and the seedling blights. The pathogen is seed as well as soil-borne.

Management of pea charcoal-rot was attempted using biocontrol agents and plant products by Ushamalini *et al.* (1997). Soil application with neem-cake (*Azadirachta indica*) @ 150 kg/ha and farmyard manure (10 tonnes /ha) reduced charcoal-rot incidence significantly and increased yield by enhancing antagonistic activity of the native microflora. They observed increased seed germination by soaking in 10% leaf extracts of *Adenocalyma allinaceum* and *Vitis negundo*. Neem showed medicinal, antifungal and pest-control properties (Desai and Kulkarni 2001).

Pelleting of cowpea seeds with *Trichoderma viride* either alone or in combination with Carbendazim inhibited *M. phaseoli* growth. The treatment increased germination and reduced post-emergence mortality under pot-culture experiments (Algarsamy and Sivaprakasam 1988). Seed treatment with *Trichoderma viride* and *T. harzianum* is also effective in addition to the above in reducing root-rot incidence.

***Myrothecium*-rot, c.o. *Myrothecium roridum* Tode ex Fries**

Severe decay of cowpea pods was recorded from the local markets of Bhagalpur. The disease caused about 5-11% loss. The disease is common on moth-bean (*Vigna aconitifolia*) also (Singh and Srivastava 1989).

Symptoms : They appear as scattered discoloured lesions, that later cover the entire pod. The whole pod becomes rotten within 5-7 days. Heavily infected pods bear no seeds or less number of seeds that are smaller in size.

Control measures : Spraying Bavistin 0.1%, starting with flower initiation, controlled the disease.

Anthracnose, c.o. *Colletotrichum lindemuthianum* Br.& Cav.

(= *Glomerella lindemuthianum* (Sacc. & Mag. Shear)

Serious attack due to anthracnose was reported from Bengaluru (Sohi and Rawal 1977, 1984); disease affected adversely pod quality and yield.

Symptoms: They are noticed on the emerging cotyledons as sunken black spots. Infected seedlings get blighted. Stems and leaves are also affected. Black stem cankers develop on the adult plants. Lesions appear on the pods, which later spread and cause pod-rot. Seeds get infected. Badly affected seeds show dark lesions and lightly affected show only discolouration. Lesions on seeds are not clearly visible on the varieties with dark seed coats. The disease organism is seed-borne, and fungus persists in the infected crop residues.

Control measures: Seed-borne infection can be partially controlled with Thiram or Captan (Suryanarayana 1978). Spraying Bavistin (0.1%), Benomyl (0.1%) and Difolatan (0.3%) was found effective; this reduced infection and increased yield (Sohi and Rawal 1977).

Adebanjo and Bankole (2004) from Germany recorded biological control with isolates of *Trichoderma viride* and *Bacillus subtilis*; this reduced significantly seedling infection from the anthracnose-infested seeds in the pot-culture experiments.

Pod-rot, c.o. *Choanephora cucurbitarum* (Berk. & Rav.) Thaxter

The disease was reported from Kerala, India (Wilson and Jose 1968).

Symptoms : Water-soaked areas appear on the pods, which later develop wet-rot symptoms during storage. Young as well as mature pods are infected. Fungal whitish luxuriant growth is noticed in the advanced stages of infection. Black pinhead-like structures representing sporangia are also present in abundance. The disease is of minor importance.

Cottony-leak, c.o. *Pythium butleri* Subram.

The disease was recorded from the local markets of West Bengal. Rotting starts anywhere on the pod surface as water-soaked areas.

Symptoms : Affected pods turn slightly dull and coppery. Infection progresses very fast and pods may be affected overnight. Sprinkling of water by vendors over stored cowpea heaps to retain freshness accelerates decay. White fluffy mycelia wrap over heap. Seeds also become soft and rotten (Dasgupta and Mandal 1989).

Control measures : Refrigerated storage at 10°C is effective. Rotted materials should not be mixed with healthy pods.

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|---------------------------|------------------------------|-------------------------------|
| Leaf-spot | <i>Cercospora canescens</i> | Suryanarayana, 1978 |
| Snuffy mould-rot | <i>Aspergillus aculeatus</i> | Das Gupta and Mandal, 1989 |
| Cottony pink-rot | <i>Fusarium moniliforme</i> | |
| Fuzzy brownish-rot | <i>Mucor hiemalis</i> | |

Seed mycoflora

Cowpea seed mycoflora has been studied from the different parts of the world. From Kerala, Nazeema (1981) observed *Aspergillus niger*, *A. flavus*, *A. ochraceus* and *Botryodiplodia theobromae* as externally seed-borne and also frequently associated. But fungi like *Drechslera rostrata*, *Penicillium* sp. and *Rhizopus stolonifer* were internally seed-borne. Nazeema *et al.* (1982) recorded 38% inhibition of cowpea seed germination on treating with culture filtrate of *D. rostrata*.

The following fungi were also reported.

| | | |
|--------------------------------|---|---|
| <i>Curvularia</i> sp. | } | Kanapathi Pillai, 1982 from Malaysia |
| <i>Drechslera</i> sp. | | |
| <i>Diplodia</i> sp. | | |
| <i>Chaetomium</i> sp. | | |
| <i>Pestalotiopsis</i> sp. | | |
| <i>Aspergillus</i> sp. | | |
| <i>Macrophomina phaseolina</i> | | |
| <i>Colletotrichum</i> sp. | | |

Aspergillus parasiticus produced the potent mycotoxin (Aflatoxin B₁) in cultures (Seenappa *et al.* 1983) from Tanzania.

| | | |
|--------------------------------|---|--------------------------------|
| <i>Aspergillus flavus</i> | } | Maheswari <i>et al.</i> , 1985 |
| <i>A. fumigatus</i> | | |
| <i>A. nidulans</i> | | |
| <i>A. niger</i> | | |
| <i>A. terreus</i> | | |
| <i>B. Fusarium moniliforme</i> | | |

Seeds infected by *Aspergillus flavus* showed depletion of non-reducing sugars and increase in reducing sugars (Maheswari and Mathur 1985).

| | | |
|---|---|--|
| <i>Aspergillus</i> spp. | } | Muthe Gowda and Sullia, 1987 |
| <i>Penicillium</i> spp. | | |
| <i>Penicillium chrysogenum</i> | | |
| <i>Alternaria alternata</i> | | |
| <i>Fusarium</i> spp. | } | Saad Shama <i>et al.</i> , 1988 |
| <i>Aspergillus flavus</i> , <i>A. niger</i> | | |
| <i>Curvularia lunata</i> | | |
| <i>Penicillium</i> sp. | | |
| <i>Macrophomina phaseolina</i> | } | Ushamalini <i>et al.</i> , 1998 from Tamil Nadu |
| <i>Fusarium oxysporum</i> fsp. <i>tracheiphilum</i> | | |
| <i>Alternaria alternata</i> | | |
| <i>Curvularia lunata</i> | | |
| <i>Aspergillus flavus</i> , <i>A. niger</i> | | |
| <i>Rhizopus stolonifer</i> | | |
| <i>Penicillium</i> spp. | | |

Among the different fungi associated, *M. phaseolina*, *F. oxysporum*, *A. flavus* and *A. niger* were predominant in terms of intensity and occurrence.

| | | |
|--------------------|---|---------------------------------|
| <i>A.flavus</i> | } | Kritzinger <i>et al.</i> , 2002 |
| <i>A.niger</i> | | |
| <i>F.oxysporum</i> | | |
| <i>F.equiseti</i> | | |
| <i>A.flavus</i> | | Usha <i>et al.</i> 2008 |

Use of essential oils (thyme and clove) on storage fungi, germination and emergence of cowpea seedlings recorded inhibition of growth of all associated fungi at 500 and 1,000 ppm level (Kritzinger *et al.* 2002).

BACTERIAL DISEASES

Bacterial-blight/bacterial-spot/bacterial-canker,

c.o. Xanthomonas axonopodis pv. vignicola

The disease is prevalent in India under the natural conditions. Infection starts from leaf margins, indicating entry of bacteria through hydathodes. This is followed by typical blight symptoms.

Symptoms : In case of severe infection, brown cankerous lesions are noticed on the stem, peduncle and inflorescence. Pods may show discolouration in the affected regions. The diseased pods produce smaller, wrinkled and infected seeds. Seeds show symptoms on the emerging cotyledons. The affected cotyledons turn reddish and wrinkled, followed by necrotic lesions on the stem and leaves. Growing tip of the plant dies resulting in the death of the plant.

Control measures : Infection is seed-borne. It is both external and internal. Variability in growth and pathogenicity of bacteria was recorded by Singh *et al.* (2000). Resistant varieties are not available. Use of healthy seeds is the only practical remedy.

VIRUS DISEASES

Cowpea mosaic virus

This virus produces yellow green patches on leaves. Mottling is conspicuous and affected plants get stunted. Some strains of this virus are seed-transmitted also. Exposing seeds for four days at 30°C, inactivate virus in the seeds (Suryanarayana 1978).

Mali and Kulthe (1980) made comparative studies on the seed-borne virus isolates from cowpea, and identified them as BYMV, a member of poty virus group, based on the host range, physical properties and electron microscopic studies. Seed transmission ranged from 14 to 41%. Cowpea is known to be affected simultaneously by several other viruses, including seed-borne viruses (Kühn 1964; Harrison and Gudauskas 1968).

Mali *et al.* (1983) made extensive studies on the transmission through seeds of the bean yellow mosaic (BYMV), cowpea aphid borne mosaic (CAMV) and cucumber mosaic virus (CMV) in 23 cowpea varieties, collected

from Badnapur (Maharashtra). The extent of seed transmission was observed through visual symptoms together with the identity of the viruses and was checked through their reaction on test plants by serological tests. Cowpea varieties recorded positive as well as negative seed transmission. Mali *et al* (1989) also made sero-diagnosis of six cowpea seed-borne viruses from Maharashtra. Seed transmission was confirmed, and they were identified as (i) Sunnhemp mosaic tobamo virus, (ii) Cowpea mild mottle virus (iii) Southern bean mosaic sobemo virus (iv) Pea aphid-borne black eye cowpea mosaic poty virus, (v) Black eye cowpea mosaic poty virus and (vi) Cucumber mosaic cucumo virus. It may be noted that many viruses, including stable ones, occurring in high concentration in leaves are not transmitted through seeds. For true seed transmission, virus must enter and survive in the embryo. A strain of cowpea mosaic virus not transmitted through seeds was also recorded. This virus was unable to move into cotyledons due to obliterated passage; in the dried seed tissues, virus was absent due to dehydration (Singh and Singh 1984).

Control measures : Use of resistant varieties like Co1 is promising. Spraying Malathion (50 EC) 2% is recommended for controlling aphids. Biopesticide, neem garlic emulsion (stock solution prepared with neem oil 200 ml + garlic 200g crushed and mixed with 300 ml water + 30g soap mixed with water), is used. Solution diluted to a concentration of 10% is used for spraying plants (Anon. 2007).

Cowpea mild mottle virus

The virus is seed-borne. Deformed and discoloured seeds show highest virus transmission. Virus is detected in testas, cotyledons and embryo (Sawant and Nahre 1994). Another seed-borne virus, cowpea seed-borne mosaic virus (aphid borne, poty group) was observed to the tune of 15-20% from Pune (Summanwar *et al.* 1994).

Seed-borne virus can be eliminated by soaking cowpea seeds in 5% trisodium phosphate (TSP) solution for 24 hours before sowing, followed by spraying TSP 3% + Ekalux 3 ml/litre to the standing crop.

COMMON BEAN /RAJMASH/FRENCHBEAN

(*Phaseolus vulgaris* L.)

All beans coming under genus *Phaseolus* have been included.

FUNGAL DISEASES

Anthracnose,

c.o. *Colletotrichum lindemuthianum* (Sacc. & Magn.) Brios & Cav.

The disease is of worldwide importance and occurs wherever crop is grown. It is absent in drylands or surface irrigated fields. The fungus infects vegetable-beans and cowpea.

Epidemiology of anthracnose on Frenchbean was worked out by Sindhan and Bose (1981). The fungus is essentially seed-borne and subsists on the diseased crop debris in soil. Relative humidity of 90% and above is essential for infection. Water is required for dissemination of spores. Kumar *et al.* (1999) investigated recurrence and development of anthracnose in Himachal Pradesh by *C. lindemuthianum* on kidney-beans with weather variables. Heavy and frequent rains with moderate temperature (19-25°C) and relative humidity above 70% favoured disease in its vertical and horizontal spread. They also screened 60 genotypes under field and artificial epiphytotics for disease resistance, and recorded two accessions as resistant to all races.

Symptoms : Fungus attacks all aerial parts of the plant. On seedlings, cotyledons show small to large, brown to black sunken spots, which may bear pink-spore masses of fungus in the wet weather. On pods, spots are first small but later enlarge with purple borders (Fig. 21.1). Similar lesions may develop on the stem also. Mature seeds from diseased pods may or may not be stained. If stained, various shades of brown are seen. Seedlings emerging from such seeds may show typical lesions on cotyledons (Singh 1992).



Fig. 21.1. Anthracnose on common beans

Control measures : Disease incidence and severity was more in highly susceptible cultivar, Jawala. And seed-borne infection caused more yield losses compound to background contamination. Pod infection exerts direct affect on the seed yield. Reduction in seed number per pod and seed weight was also observed (Sharma *et al.* 2008). In healthy seed crops, disease is delayed by 4-6 weeks. Seed treatment with organo-mercurials like Agallol, Aretan, Emisan (0.25% each) or with systemic fungicides, Bavistin, Vitavax (0.5%) or Ziram (0.2%) reduces seed-borne inoculum. Seed treatment with Carbendazim (0.1%) or Carbendazim 50 WP + Thiram 75WP (0.2%), followed by foliar spray of Mancozeb (0.25%) after 45, 60 and 75 days after sowing (Sharma and Suga 1995), was recommended. Bavistin, Thiram, Dithane M-45 and Hexacap were reported to be effective in improving seed germination and seedling vigour (Paul 2002).

Khatai and Hooda (2006) tested several genotypes, and observed IPR 96-4 possessing multiple resistance against *C. lindemuthianum*.

Brown-rot/*Fusarium*-rot, c.o. *Fusarium* spp.

Several species of *Fusarium* found associated are *F. equiseti*, *F. semitectum* and *F. solani* (Tandon and Verma 1964). Sharma and Sumbali (1993) recorded *F. oxysporum* on garden-beans.

Rio *et al.* (1991) from Puerto Rico reported *F. equiseti* as predominantly seed-borne. They observed internal infection. *F. semitectum* (*F. pallidoroseum*) was also observed along with several other fungi. Presence of *Fusarium* spp. is noticed specifically on the freshly harvested crops.

Symptoms : Dasgupta and Mandal (1989) observed circular spots with black centre and brown margins on the infected pods. The spots are small, sunken, water-soaked that coalesce later and form blighted patches. Under humid conditions, abundant sporulation appears and rest of the period, only scanty mycelial growth is visible. A brown tint is noticed on the seed surface but no discolouration is observed during early stages of infection. The disease spreads through contact among pods. Mixed infection is also noticed.

Control measures : Seed treatment with Captan (0.2%) or Thiram (0.2%) is effective in controlling seed-borne infection.

***Ascochyta* pod-spot, c.o. *Ascochyta* spp.**

This is a minor disease of lima-bean and some other species of *Phaseolus*. The disease occurs on many other vegetables—okra, pepper and egg-plant. The fungus mostly causes leaf-spots but may also infect stem and pods. *Ascochyta fabae* was also noticed on faba-beans.

Symptoms : On pods, lesions are elongated, and on them fewer fruiting bodies are produced. The fungus was also reported causing seed-and pod-rot in butter-beans in Bengaluru (Maholay 1982). On pods, circular zonate rings of light-brown discolouration appear. Pathogen is seed-borne. Partially infected seeds are orange and heavily infected seeds are buff-coloured with leathery soft tissues.

In Bengaluru, Sharma and Sohi (1980) observed on Frenchbean symptoms of pre-and post-emergence mortality, collar-rot, stem-canker and pod-rot. Seeds on artificial inoculation recorded maximum pre- and post-emergence mortality. The fungus is seed-borne and soil-borne. The disease is favoured by mild rains and relatively low temperatures. Fungal growth occurs at 20-24°C, and optimum temperature for reproduction is 27.5°C.

Control measures : Seed dressing with Thiabendazole(0.1%)/Metalaxyl (0.1%) coupled with a post-emergence spray was recorded to be effective (Jellis *et al.* 1988).

***Rhizoctonia* disease/ collar-rot,**

c.o. *Rhizoctonia bataticola* (Taub.) Butler
(*Macrophomina phaseolina* (Tassi) Goid.

This is an important field disease of Frenchbean, and has been reported to cause heavy losses in Bengaluru and Himachal Pradesh. Its severity ranged from 15 to 25% (Sharma and Sohi 1980; Banyal *et al.* 2002). Dillard and Wallis (1986) reported *R. solani* from New York.

Symptoms : The fungus causes pre-and post-emergence mortality, collar-rot, stem-canker and pod-rot (Sharma and Sohi 1980; Banyal *et al.* 2002). Seed transmission of *R. solani* was reported on *P. vulgaris* and *P. lunatus* (Leach and Pierpont 1956, 1958).

Control measures: Use of resistant varieties. IPR 96-4 has been identified as a resistant genotype against *R. solani* and *Fusarium* spp. (Khatai and Hooda 2006).

Seed treatment reduces disease in the field and increases plant stand (Mukhopadhyay 1994). Seed treatments with Captan (0.2%), Carboxin (5g/kg seed), Benomyl (500ppm) and Thiram (0.2%) were reported to be effective (Oliveira *et al.* 1997).

Bioagent-based integrated management of collar-rot of Frenchbean has been reported from Jharkand. Seed treatment with Vitavax (0.1%) + *Trichoderma viride* (19×10^3 /cfug) @ 2g/kg of seed resulted in maximum seed germination and minimum disease incidence (Dubey 2002). Kumar and Dubey (2002) in their studies on web-blight (*Thanatephorus cucumeris*/*Rhizoctonia solani*) of winged-bean (*Psophocarpus tetragonolobus*) observed integration of seed treatment (*G. virens* @ 10^6 spores/ml/10g seed + Vitavax @ 1g/1kg of seeds) and spraying Tilt (Propiconazole) giving minimum disease incidence and high pod yield in fields.

White mould /Sclerotinia-rot/soft-rot,

c.o. *Sclerotinia sclerotiorum* (Lib.) de Bary

Gupta *et al.* (1997) observed the disease from Himachal Pradesh. Water-soaked lesions are noticed on leaves, stem and branches. Infected portions on pods show white mycelial growth. The disease is severe in wet and cool weather. Pods in contact with the soil are seriously damaged. Under *in-vitro* studies, *Trichoderma harzianum* showed highest radial growth after two weeks of incubation on 1.5% water extract of farmyard manure. In fields also, seeds treated with *T. harzianum* along with 0.05% Carbendazim in 1.0% FYM amended soil reduced disease incidence (Gohain and Das 2006).

The fungus is reported to cause 'nesting' on bean-pods and other vegetables in transit and storage at a very low temperature. The mycelia grow superficially on the substrate and bind decayed material together into a cottony mass. Chief diagnostic characteristic of soft-rot is conspicuous mycelia in the early stages and profuse sclerotia in the later stages. The host tissues become soft and watery as the disease progresses, and finally gets desiccated.

Angular leaf-spot of beans, c.o. *Phaeoisariopsis griseola* (Sacc). Ferr.

Isariopsis griseola Sacc.

The disease was first reported from India (Sreenivasan 1953). It is widely present on Frenchbean, which is an important *kharif* pulse and vegetable crop in the hilly terrains of India, and has been reported from Nilgris, Karnataka,

Himachal Pradesh and Uttar Pradesh (Sohi *et al.* 1963; Bose and Sindhan 1973; Singh and Sharma 1975 and Ponnappa *et al.* 1976).

Symptoms : The disease damages extensively foliage and pods in all commercial varieties; 40-70% loss in green pods yield was reported (Singh and Saini 1980). Angular leaf spots ranging from 5 to 8.5 mm are noticed. Round lesions appear on unifoliate leaves and pods also. It is observed that higher temperature gives rise to small spots and lower temperature to large spots and occurrence is optimum at 15°C. The lesions cease to appear above 30°C (Verma and Sharma 1984).

Control measures : Almost all-grown varieties are highly susceptible. Singh and Sharma (1975) and Gupta *et al.* (2000) observed certain lines to possess good degree of resistance against angular leaf spot under natural epiphytotic conditions. These lines could be exploited for resistance breeding against the disease. Brock (1951) from Australia also reported resistant lines.

Seed treatment followed by spraying with Carbendazim (0.1%) was reported to be effective (Bhardwaj and Thakur 1992). Rajappan and Yesuraja (1999) evaluated efficacy on seed germination of talc-based formulation of *T. viride* (obtained from TNAU, Coimbatore) @4g/kg of seeds. The treatment improved seed germination, reduced angular leaf spot, and recorded highest green pod yield; on a par with Carbendazim (Bavistin 50%) @2g/kg of seeds.

Black-rot, c.o. *Alternaria alternata* (Fr.) Keissler

This is one of the common diseases of broad-bean (*Vicia faba*), observed during February-March. Infection is carried from the field. The disease was reported by Vasudeva (1960) and Mandal and Dasgupta (1981).

Symptoms: The spots are circular to irregular, measuring 0.5-2.0 cm in diameter with a brown outer rim, which gradually enlarge and coalesce. Grey to brown mycelia and abundant spores appear over lesions. Under humid conditions, surface becomes black, and infected bean emits a characteristic bad odour. Seeds also become soft.

Mode of perpetuation and spread of *Alternaria*-blight was reported by Dubey and Patel (2000). The fungus remains viable in infected seeds up to 15 months under laboratory conditions and 13 months in the soil. Infected seeds serve as the primary source of inoculum for the pathogen and the secondary spread is through air-borne conidia.

Damping-off, c.o. *Pythium* spp.

Bhargava and Gupta (1957) surveyed on the market diseases of fruits and vegetables in Kumaon and reported cottony-leak of beans, caused by *Pythium* sp.

Symptoms: They appear on Frenchbean pods. Damped-off pods contain oospores which serve as an inoculum source for damping-off on to the ground (Devaki and Bhat 1992). A cottony-leak due to *Pythium aphanidermatum* was also recorded on garden-beans (Sharma and Sumbali 1993).

Control measures : Fluorescent pseudomonads and certain *Bacillus* spp. are known to control fungal and bacterial-rot diseases in common-bean. Ahmadzadeh *et al.* (2003) observed fluorescent *Pseudomonas* to be effective against seed-rot, caused by *P. ultimum* in Iran.

Phoma-rot, c.o. *Phoma medicaginis* Malbr.& Roum

The disease was recorded from Kumaon (Dhyani *et al.* 1989). The fungus infects leaves, pods and seeds. Seed treatment with Thiram (0.2%) and Captafol (0.2%) offers protection.

Pod-blemish, c.o. *Cladosporium tenuissimum* Cook.

Brownish blemishes are noticed on damaged pods. Blackish-green spore-balls are also seen in masses. This is accompanied by rotting. Seeds decay into a black mass (Dasgupta and Mandal 1989).

Seed treatment is as *detailed* in *Rhizoctonia disease/collar-rot*.

**Soft-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs
Mucor sp.**

Soft-rot is one of the major diseases, noticed during humid period. Infection can originate anywhere on the pod surface as water-soaked discoloured areas. Later, the beans can be seen adhering or clinging together and forming a 'nest rot' (Philip 1998); and these pods give fermentative odour. The disease is very common in the markets of Thiruvananthapuram during rainy season when gunny bags packed tightly with beans coming from Bengaluru are loosened and distributed for sale.

Control measures : The beans should not be packed tightly. They should be spread out with sufficient ventilation.

***Diaporthe* pod-blight,**

c.o. *Diaporthe phaseolorum* (Cook. and Ellis) Saccardo

This disease was reported on Lima-beans (*Phaseolus lunatus*). Older pods are frequently attacked. Lesions on maturing pods may occur on any point. As the pods mature, lesions spread in all directions. By this time, the pods turn black and the plant starts wilting. If infection occurs before seed formation, pods may be seedless or if seeds are formed, they may get dark and shrivelled. The fungus perpetuates through seeds and on the crop refuse left in the field. Affected seeds do not germinate normally. Even if germination occurs, seedlings die soon. Rapid infection occurs at 25.5-30.5°C (Singh 1992).

Seed treatment with Thiram (0.2%) and Captafol (0.2%) was effective.

Black mould-rot, c.o. *Aspergillus niger* Van Tiegh.

The disease was reported on injured beans. Water-soaked areas appear; their progress is very slow, they are up to 2-3 cm in diameter. Black conidial

heads appear over the fruit-surface and affected area becomes dull. Secondary invaders were also found associated (Dasgupta and Mandal 1989). Sharma and Sumbali (1993) recorded this fungus on garden-beans. *Aspergillus* spp. were reported in stored seeds by Kalakutski *et al.* (1988) from the USSR. *A. repens* spread was most rapid, followed by *A. sydowii*, *A. candidus* and *A. versicolor*. Seed treatment is effective in eliminating all seed-borne fungi (Sharma and Sugha 1995).

Seed treatment with Thiram (0.2%) and Captafol (0.2%) protected the crop.

Seed-rot, c.o. *Aspergillus flavus* Link. ex Fries

Aspergillus flavus was reported as pathogenic to germinating seeds and seedlings of different crops. Seeds of *Phaseolus vulgaris*, *Dolichos lab lab*, *Vigna catjang* etc were found heavily infected by *A. flavus*. The fungus spreads from seed-coat to cotyledons and to other parts, depending on the stage of the emergence, and leads to following types of infections (Rati and Ramalingam 1974).

- **Seed-rot.** All parts of the seeds, excepting seed-coat get liquefied. Rotting seeds show abundant sporulation on the seed-coat with no sign on the radicle or the plumule.
- **Non-emergence of cotyledons.** Due to the formation of mycelial mat, cotyledons fail to emerge resulting in death of the seedling.
- **Infection of plumule.** The fungus sporulates in the cotyledonary cavity and infects plumule, resulting in death of seedling.
- **Cotyledonary infection.** The infected cotyledons show circular, sunken brown spots of various sizes, visible on both the sides of the cotyledons. The fungus sporulates and infected cotyledons fall-off earlier than healthy ones. Different species of *Aspergillus* were reported by Nazeema(1981) from Kerala. *A. flavus* produces also potent toxin, aflatoxin B₁.

Control measures : The disease is seed-borne. Hence seed treatment with Captan 0.2% or Thiram 0.2% was found effective. Seeds are to be dried properly; their moisture content should not exceed 7%.

***Myrothecium-rot, c.o. Myrothecium verucarria* Alb. & Schwein**

Bihari Lal and Chaturvedi (1994) reported disease from the local markets of Allahabad. The disease appears on the lateral side of the fruits and is prevalent from November to February. Small, nearly circular spots are initiated with a light brown centre surrounded by a dark brown band. The decay is confined to the fruit skin in the initial stages, but later penetrates deep into the mesocarp. Dark-green sporodochia appear on the infected area after 9-10 days.

BACTERIAL DISEASES

Bacterial blight/fuscous blight, c.o. *Xanthomonas phaseoli* (Smith)

X. axonopodis pv. *phaseoli*

Bacterial blight of common-bean (*Phaseolus vulgaris*) was first described from the United States. The causal organism was described by E.F. Smith in 1897. The disease is widespread in the US and Canada and in all states of India. Symptoms appear as irregular red to brown spots that coalesce to form large patches. Affected leaves become shrivelled, distorted, and are shed prematurely. Young developing and infected pods also become shrivelled and dried-up. Systemically invaded and fully developed pods show water-soaking along the sutures and affect also the funiculus. Local infections on the pod-walls appear initially as small, water-soaked spots, which later enlarge and become depressed and turn brown. Seeds from severely diseased pods shrivel (Patel and Jindal 1972). Walker (1975) also reported shrivelling and discolouration, depending upon the extent of infection.

Infection is seed-borne. It is present on the seed-coat. Even 0.5% seed infection can start an epidemic. Bacterial blight continues as a major problem in the high rainfall areas. Sources of resistance to *X. axonopodis* have been reported in *Phaseolus coccineus* and *P. acutifolius*. Transfer of resistance was from these species to Frenchbeans by interspecific hybridization (Kaushal and Kumar 2000; Kumar *et al.* 2005).

Rapid plaque methods have been developed for detecting scanty infections. Seed treatment with antibiotics like streptomycin (100 ppm) reduces seed-borne infection. Use of certified disease-free seeds is effective in containing disease.

Use of resistant varieties has been recorded. The genotype IPR 96-4 was reported to possess multiple resistance against *X. campestris* pv. *phaseoli* (Khatri and Hooda 2006).

Integrated management strategies for fuscous blight and floury leaf spot of rajmash with *Pseudomonas fluorescens* strain RPB 14 were suggested by Mondal (2004). Foliar application of bacteria at the seedling stage (10^7 cfu/ml) and flowering stage (10^6 cfu/ml), followed by a single spray of Carbendazim (50 WP (0.05%)) at the pod-development stage helped protecting plant from both the diseases. The treatment also increased seed yield.

Halo-blight, c.o. *Pseudomonas phaseolicola* (Berk.)

The disease is widespread in the United States and Canada. Patel and Jindal (1972) reported occurrence of bean common blight and bean halo blight on *Phaseolus vulgaris* from India also. Its symptoms are similar to those of bacterial blight. The disease is introduced through the infected seed. When the seed is infected, bacteria develop in the seed-coat of the germinating seed and contaminate surface of the expanded cotyledons, penetrating through rifts in the cuticle and progress intercellularly until reach vascular system. The

disease develops under relatively cool environment. Pods are infected locally or by systemic invasion and halos may appear around spots on pods. The formation of halos occurs most strikingly at 20°C or below (Walker 1975).

VIRUS DISEASES

Bean mosaic virus. Causal virus : *Phaseolus virus 1*. Infected plants are stunted and are bushy in appearance. Leaves develop mottling blisters and lamina curls downwards. Most of the flowers were shed and setting of pods was delayed (Yaraguntaiah and Nariani 1963). The virus is sap-transmissible as well as carried through seed.

Another virus (Rubbery bean, *Phaseolus coccineus*, mosaic virus) was also reported on Frenchbean. This virus is also seed-borne.

Seed-borne viral diseases

The mosaic disease of beans was first observed by Iwanowski from Russia in 1899. The disease incited by seed-borne virus is now known as common mosaic. It is found throughout the United States and in many parts of the world and causes severe yield reductions.

On the susceptible varieties, common mosaic on leaves causes in varying degree vein clearing and mottling. Pods show ordinarily no symptoms, but under certain conditions, chlorotic spots may appear, and sometimes a glossy sheen (hydrosis) of immature pods is noticeable. The virus affects seed quality also. More than 50% of seeds can be infected (Walker, 1975). Jimenez and Nelson (1986) identified two viruses on *Phaseolus vulgaris*—southern bean mosaic virus (SBMV) and cowpea chlorotic mottle virus (CCMV). Both viruses were isolated from seed and field collected bean tissues. Davis and Hampt (1986) also observed CMV isolates to be seed-borne in *P.vulgaris*, and seed transmission varied depending upon the varieties. In India, Suryanarayana (1978) recorded yellow bean mosaic virus (*Phaseolus virus* No.1/common bean mosaic virus) affecting different species of *Phaseolus*, *Dolichos* bean, peas and soybean. The virus is seed-borne but is transmitted through aphids and also through sap. Another virus (Runner bean, *Phaseolus coccineus* mosaic virus) also affects Frenchbean. The virus is up to 42% seed-borne on runner bean. Development of tolerant or resistant varieties is the only possible means for control.

Seed microflora

Trichothecium roseum Pers. on Faba-bean

Fusarium equiseti (Corda) Sacc.

F. semitectum Sacc. (*F. pallidoroseum*)

Aspergillus spp.

Penicillium spp.

Rio *et al.*, 1991

Chaetomium sp.

Mucor sp.

Bacillus licheniformis

Flavobacter sp.

Flavobacter sp. and *Fusarium* spp. were observed on the freshly harvested seeds, and *Bacillus* spp. and *Aspergillus* spp. were recorded from stored seeds. The composition of the microflora serves as a good indicator and is used in testing seed quality in Honduras (Rio *et al.* 1991).

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism |
|-------------------------------|--|
| Rust of beans | <i>Uromyces appendiculatus</i> |
| Sclerotium-rot | <i>Corticium rolfsii</i> |
| Helminthosporium-rot | <i>Helminthosporium victoriae</i> |
| Septoria-blight/blotch | <i>Septoria pisi</i> |
| Yeast-spot | <i>Nematospora coryli parasitica</i> |
| Phoma-rot | <i>Phoma medicaginis</i> Dhyani <i>et al.</i> , 1989 |

CLUSTERBEAN (*Cyamopsis tetragonoloba* (L.) Taub.)

Clusterbean popularly known as *guar* is an important crop, cultivated throughout India all-round the year for feed, fodder and vegetable purposes. The crop assumes great industrial importance owing to the presence of gum in its endosperm. The gum has diversified uses in many industries.

FUNGAL DISEASES

Seed-rot/damping-off, c.o. *Sclerotium rolfsii* Sacc.

The disease causes considerable losses in yield. *Sclerotium rolfsii* is a soil-borne parasite with a wide host range (Aycook 1966); survives in the soil for more than four years as dormant sclerotia (Anil Kumar and Gowda 1984). Survival of sclerotia in the soil for a long time and extensive host range make difficult to control this fungus by crop rotation.

Symptoms : The pathogen causes seed-rot and damping-off of seedlings. At later stages of plant growth, infected plants exhibit foot-rot near the soil line and results in wilting of the host-plant.

Control measures : Soil fumigation was recorded to be effective (Hersenzon and Palti 1958). But was not economical for low-income group (Harrison 1961). Studies conducted by Ganesan (1997) at Bengaluru recorded soaking of seeds in 0.2% solution of Dithane M-45 to be effective in controlling the disease. Brassicol applied twice as soil drench, four days prior to sowing along with Foltaf and Dithane M-45 and Brassicol was also found effective.

Macrophomina-rot, c.o. *Macrophomina phaseolina* (Tassi) Goid.

Jaiman and Jain (2004) recorded this disease from Rajasthan. Though it is seed-borne, the pathogen appears at the seedling stage, and at maturity causes losses in yield. The disease was also reported by Bhatia *et al.* (1998).

Seed treatment with fungicides, Bavistin(0.1%), Topsin (0.1%), Captan (0.2%), Indofil M. 45 (0.2%) and Thiram (0.2%), improved germination.

Black mould-rot, c.o. *Aspergillus niger* van Tiegh.

The diseased fruits show black conidial heads at the injured site, surrounded by water-soaked areas. The inner tissues become moderately soft and blackened.

BACTERIAL DISEASES

Bacterial soft-rot, c.o. *Pseudomonas fluorescens*

The disease manifests as a water-soaked area, which starts mostly from the pedicel-end. But the symptoms may occur elsewhere also on the fruit-surface. Pinhead-like black dots are noticed on the infected area.

Bacterial-blight, c.o. *Xanthomonas campestris* pv. *cyamopsidis*
(Patel *et al.*)Dye
X. axonopodis pv. *cyamopsidis* (Patel) Vauterine

Bacterial blight is considered a serious disease of *guar*, limiting profitable production of seed and fodder. It is known to be internally seed-borne (Srivastava and Rao 1963), and provides primary inoculum for secondary spread (Lodha and Gupta 1981).

Control measures : Gandhi *et al.* (1978) and Lodha (1984) evaluated several genotypes from Jodhpur and found none to be resistant. But Mitter *et.al* 1997 recorded field resistance in certain varieties. Seed treatment and spraying of streptomycine at 35 and 49 days after sowing was advocated for the disease control (Lodha and Ram 1993). The treatment proved effective in reducing disease intensity and in increasing grain yield of *gaur*. Lodha (2001) observed antagonistic potential of a white sterile fungus and of a bacterium *Bacillus subtilis* isolated from the phylloplane microflora in managing bacterial-blight. The antagonist cultures were multiplied on potato dextrose broth for 10 days, homogenized, diluted with water and used for spraying on to plants. This resulted in reduced disease incidence.

Dipping of clusterbean seeds for three hours in streptomycine aqueous solution (0.02%) was very effective in controlling bacterial-blight (Rathore 2000).

Garlic-clove water/ethyl acetate extract (at 1, 10, 100, 1,000, 10,000 mg/ml) provided maximum inhibition of the bacterium at all concentrations (Sunilkumar *et al.* 2002).

Bacterial-blight has also been reported from Karnataka (Chakravarthy *et al.* 2004), where the crop is grown for vegetable and seed purposes. The disease occurred in a serious form and caused about 58% yield losses. Survey of the seed samples in the major clusterbean-growing districts during *kharif* 2002 and 2003 showed bacterial incidence in 70% of the seed samples. Plants raised from naturally infected seeds were diseased.

Seed mycoflora

The mycoflora associated with clusterbean seeds from Haryana was recorded by Karwasra and Singh (1982). This included the following.

| | |
|-------------------------------|------------------------------|
| <i>Aspergillus</i> spp. | <i>Helminthosporium</i> spp. |
| <i>Alternaria cyamopsidis</i> | <i>Fusarium</i> spp. |
| <i>Chaetomium</i> spp. | <i>Penicillium</i> spp. |
| <i>Curvularia</i> spp. | <i>Rhizopus</i> spp. |

The bacterium included *Xanthomonas cyamopsidis* (*X. axonopodis* pv. *cyamopsidis*)

Bhatia *et al.* (1998) recorded following fungal species—*Alternaria*, *Aspergillus*, *Cladosporium*, *Colletotrichum*, *Curvularia*, *Drechslera*, *Fusarium*, *Gliocladium*, *Macrophomina*, *Myrothecium*, *Penicillium*, *Phoma*, *Pleosporium* and *Rhizopus*.

En-Nagerabi and Elashafie (2001) at Sudan with the Sudanese *gaur* seeds noticed *Aspergillus* spp. as the prominent group, followed by *Rhizopus* and *Curvularia*. However, they could not detect any aflatoxin in *Aspergillus*-infected seeds.

Seed samples of clusterbean recorded *X. axonopodis* pv. *cyamopsidis* (Chakravarthy *et al.* 2004).

Jaiman and Jain (2008) recorded the following fungi.

| | |
|--------------------------------|------------------------|
| <i>Macrophomina phaseolina</i> | <i>Pleosporium</i> |
| <i>Alternaria alternata</i> | <i>Phoma</i> sp. |
| <i>Cladosporium</i> sp. | <i>Gleocladium</i> sp. |
| <i>Colletotrichum</i> sp. | <i>Myrothecium</i> sp. |
| <i>Curvularia</i> sp. | <i>Penicillium</i> sp. |
| <i>Fusarium</i> sp. | <i>Rhizopus</i> sp. |

Shivanna *et al.* (1992) observed seed treatment with Thiram (0.2%) effective when used individually or in combination; followed by Carbendazim (0.1%) and Zineb(0.2%). Carbendazim was effective against *Fusarium* and *Phoma* was least effective against *Alternaria*.

Captan (0.2%) and Zineb(0.2%) reduced significantly *Alternaria*, *Cladosporium*, *Colletotrichum* and *Myrothecium* sp. Seed treatment with Benomyl was also recommended. Movement of Benomyl from seeds to seedlings was also reported (Claramma *et al.* 1984).

WINGED-BEAN/GOA-BEAN/FOXTAIL-BEAN

(*Psophocarpus tetragonolobus* L.)

This is considered an underutilized pulse vegetable. Its protein content varies from 22 to 25%. The crop is not affected by many diseases.

FUNGAL DISEASES

Web-blight, c.o. *Thanatephorus cucumeris* (Frank Donk) Kühn

Anamorph : *Rhizoctonia solani*

The disease occurs in a severe form (7-70%), and this limits crop cultivation. Sharma and Sohi (1980) reported this for the first time. Its symptoms are similar to other *Rhizoctonia* diseases.

Fungicides, Vitavax, Bavistin, Blitox-50, Contaf, Tilt, Captaf and SAFF all at the recommended doses as well as seed treatment with *Gliocladium virens* (10^6 spores/ml) + Vitavax (1g/kg of seed) and spraying of Tilt (Propiconazole) minimized disease incidence and increased pod yield (Kumar and Dubey 2002).

DOLICHOS-BEAN/INDIAN BEAN

(*Dolichos lab lab* L.)

Dolichos-bean is one of the important pulse crops, grown extensively in the south Gujarat during *rabi* season. Diseases inflict heavy losses on the crop. Like other crops, it is attacked by many fungal, bacterial and virus diseases (Naik and Sabalapara 2006).

FUNGAL DISEASES

Pod-rot, c.o. *Botryodiplodia theobromae* Pat.

Severe pod-rot of dolichos-bean was recorded from the College of Agriculture, Vellayani, Thiruvanthapuram (Philip and Menon 1974). Infection was confined mainly to pods nearing maturity. The pods show brownish discolouration and become dark-brown to black. Infected pods shrivel and ultimately dry-up. Fungal pycnidia appear during storage. Vines bearing infected pods show die-back symptoms also.

Fusarium-rot, c.o. *F. oxysporum* Schlet.

The disease was recorded by Mishra and Rath (1986) from Bhubaneswar. The disease occurs on stored beans after harvest.

Phoma-rot, c.o. *Phoma herbarum* Westend

The disease was reported from Sagar, Madhya Pradesh (Chile *et al.* 1992). The fungus causes brown spots. Diseased parts become soft and watery. Seeds inside the pods are also affected.

Pod-rot, c.o. *Geotrichum candidum* Link.

The disease was observed from Gwalior markets. White, sunken spots appear with light-yellow margin. With advancement of infection, pods shrivel at the infected and diseased portions on the pods; exhibiting white powdery appearance. Inside seeds are also infected (Saxena *et al.* 1983).

Soft-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs

The decay appears in patches as water-soaked areas. Later these areas are covered by white stringy mycelial mat. Sprinkling water on the pods favours infection and results in 'nest rot' like symptoms (Fig. 21.2).



Fig. 21.2. *Rhizopus*-rot/nest rot on dolichos-bean

BACTERIAL DISEASES

Fuscous-blight, c.o. *Xanthomonas phaseoli* var. *fuscans*

This disease spreads through seeds. The disease was reported by Patel and Jindal (1972).

Symptoms : On leaves, stem and pods dry and necrotic spots appear, but they sometimes are water-soaked or have translucent border. Lesions on pods are raised and brown. The bacteria and the phages of *Xanthomonas* are widely distributed in India and manifest through infected seeds, diseased plant materials and soil (Jindal and Patel 1981).

Control measures : Seed treatment with solar heat/hot-water (52°C for 30 minutes), followed by chemical treatment (streptomycin 0.1% + Captan 0.2%) before sowing coupled with a spraying schedule was reported to be effective from Ludhiana (Thind and Kumar 1985) in increasing grain yield in contrast to seed treatment/ foliar sprays carried out separately.

Seed mycoflora

Aspergillus flavus is commonly recorded from seeds. Abundant sporulation is noticed on the seed-coat, and is reported to be responsible for non-emergence of seed (Rati and Ramalingam 1974).

Control measures are as detailed under seed-rot (*A.flavus*) in common beans (*Phaseolus vulgaris*).

SWORD-BEAN (*Canavalia gladiata* (Jacq.)DC)

FUNGAL DISEASES

Black-rot c.o. *Coleophoma empetri* (Rostr.) Patrak

The disease was reported from Warangal(Andhra Pradesh) by Laxminarayana and Reddy (1976). The disease starts initially as dark-brown

to black spots on the fruits, which coalesce later to form irregular lesions. In advanced stages, lesions assume bigger size and small, round, black bodies are embedded on them.

Pink-rot, c.o. *Trichothecium roseum* (Pers.)

Singh and Shrivastava (1979) reported this disease from Bihar. Dark brown to black, shallow spots are seen to be scattered over the fruit-surface. These are later covered with light pink velvety spore masses and fungal hyphae. The decay is confined to fruit skin in the early phase of infection. As the disease advances, symptoms spread to deeper zones of fruits.

Collar-rot, c.o. *Sclerotium rolfsii* Sacc.

The decay was noticed at the collar region of the plants. Samraj and Jose (1969) reported the disease from the College of Agriculture, Vellayani.

Symptoms : The rotting results in complete bark decay at the soil level. In bush-type varieties, sword-beans are seen touching the ground. Since fungus is soil-borne, chances of fruits getting infected and their further decay during storage is likely to occur; even though not reported.

Control measures : Fruits should not be touching the soil.



CHAPTER 22

Cole Crops

CABBAGE [*Brassica oleracea* (L.) con var. *capitata* (L.)
Alef. var. *capitata*]

Cabbage-head may be round or flat with smooth leaves. This vegetable is a source of vitamin B₄, B₅, B₆ and vit. C. Minerals like iron, calcium, magnesium and potassium are also present. Anticancerous properties have also been recorded.

FUNGAL DISEASES

Target-spot c.o. *Alternaria brassicae* (Berk.) Sacc.

Leaf-spot *A. brassicola* (Sch.) Wittish

Black curd-rot, *A. alternata* (Fr.) Keissler

The disease was reported from Karnataka (Hiremath and Govindu 1975), West Bengal (Mandal and Das Gupta 1981), Haryana (Duhan and Suhag 1990) and Kerala (Philip 1998).

Symptoms : Infection starts as small lesions on leaves, and develop into zonate spots or large rots depending upon the weather. If rotten leaves are not removed, whole head gets rotten and blackened within 8-10 days. Under high humidity, spots spread quickly. The symptoms are prominent on the outer leaves. Rotten head gives out a characteristic smell (Figs 22.1, 22.2). Vendors usually remove outer scales before marketing the heads.

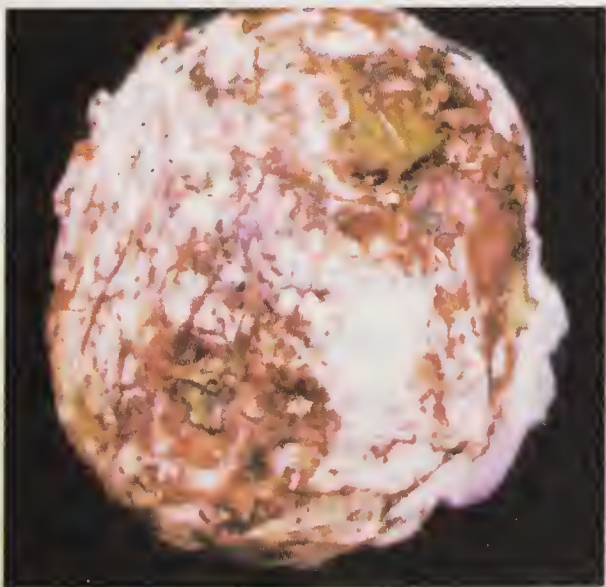


Fig. 22.1. *Alternaria*-rot on cabbage



Fig. 22.2. *Alternaria*-rot on detached leaf of cabbage

Dew or rain consistently for 9 hours caused infection, and optimum temperature was 26°C (Singh 1992). All *Alternaria* species are seed-borne pathogen. Inoculum of *Alternaria* spp. remains lodged deep into cabbage and cauliflower seed tissues (Richardson 1970; Maude and Huperson-Jones 1978, 1980. Mohd *et al.* (1994) recorded all three species of *Alternaria* to be pathogenic. Mehta *et al.* (2000) evaluated 59 *Brassica* genotypes comprising different groups under epidemic conditions against *A. brassicae* and observed that all genotypes were susceptible. Disease infection on pods is found to be favoured by high relative humidity, intermittent drizzling and moderate temperature (Duhan and Suhag 1990).

Variability among different isolates of *A. brassicae* was also recorded (Kumar *et al.* 2002). Isolates were distinguished based on the thermal sensitivity. Differential sensitivity of *A. brassicae* isolates to fungicides was also recorded from Hisar (Srivastava *et al.* 2002). *A. tenuis* was occasionally reported. Pathogen produces spots on heads as well as blacken them.

Control measures : Hot-water treatment at 50°C for 30 min is effective for seed-borne inoculum.

Pre-harvest treatment with fungicides reduces decay during storage. The heads are to be sprayed with Mancozeb (0.2%) or Folpet (0.2%) in the fields and later kept under cool-storage conditions at 0-1°C. Tasca and Trandaf (1984) observed it to be effective up to 136 days in Romania. Spraying on the heads with Emisan 6(0.25%) or Ridomil MZ-72 (0.2%) was also recommended as all isolates were highly sensitive to these chemicals (Srivastava *et al.* 2002).

Curd-rot is also considered a disease syndrome. It includes four different types of rot. It is initiated by *Fusarium equiseti*, followed by other fungi and bacteria, including *Rhizopus stolonifer*, *Pythium aphanidermatum*, *Alternaria brassicae*, *Erwinia caritovora*, etc (Chakrabarty 1990).

***Rhizoctonia-rot*, c.o. *Thanatephorus cucumeris* (Frank) Donk.**

Sclerotial stage: *Rhizoctonia solani* Kühn

The disease was reported on cabbage from Germany, USA and many other countries (Williams and Walker 1966; Abawi and Martin 1985), and also on Chinese cabbage from the USA, South Korea and West Indies (Rajnauth 1987).

Symptoms : In the bottom-rot phase, elongated, sunken black lesions develop on the under surface of the mid-ribs, and circular spots appear on the lower parts of the leaves. Small, irregular shaped lesions are also recorded on the top of the heads. These gradually coalesce and darken resulting in head-rot. As decay progresses, dark web-like fungal growth spreads over the surface, giving rise to a mass of flat, brown, resting bodies (sclerotia).

Control measures : Seedling diseases have been managed by seed treatment and soil amendment. Seed treatment with *Trichoderma harzianum* multiplied

on sorghum and dried @ 10g/kg of seed + soil application of *T.harzianum* @ 20g/pot or when it was directly applied to seed-beds enhanced seed germination as well as growth of cabbage seedlings. Since the disease is soil-borne, control measures also include sterilization of seed-bed, followed by careful management of field and crop rotation. After harvesting, infected plant material should be promptly destroyed.

Ring-spot, c.o. *Mycosphaerella brassicicola* (Duby) Lindau

The disease is widespread and important in cold, temperate countries — USA (Nelson and Pound 1959), UK (Dring 1961), New Zealand and Australia (Wicks *et al.* 1987). It is prevalent in India also. Infection occurs over 12 to 28°C; optimum is between 16 and 20°C.

Symptoms : The spots are conspicuous on leaves. Circular spots may show small irregular lesions of brown and grey concentric zones with a well-defined border. Occasionally affected areas are irregular and are uniformly dark with leathery texture. Presence of large spots on the heads reduce their market value (Singh 1992).

Control measures : The disease is seed-borne. Seed treatment with Captan (0.2%) or soaking seeds for 24 hr in a suspension of Thiram (0.2%) at 30°C was found promising. Seed treatment along with strict hygiene in seed-bed and field is necessary. Refuse of the previous crop is a potential source of inoculum and should be properly disposed. Pre-harvest application of fungicides as is detailed in *Alternaria*-rot, followed by prompt cooling and low temperature storage after harvest helps minimizing decay.

**Grey mould-rot, c.o. *Botryotinia fuckelina* (de Bary) Whetzel
Botrytis cinerea Pers.**

Grey mould is of major importance in cool, temperate countries— UK, USSR, USA (Tahovonen 1981; Brokenshire and Prudie 1984; Davies and Heale 1985).

Symptoms : Brown, water-soaked areas develop on leaf or stem tissues. In humid conditions, whitish growth develops, which may later darken and give rise to a dense mass of brownish-grey spores. The disease is usually more after harvest. Pre-disposing factors include freezing damage, mechanical injuries and prior infection. Once established, grey-mould subsequently progresses into the sound healthy tissues also and produces 'nest rot' in store. Optimum growth temperature for the fungus is approximately 20°C; significant decay occurs at very low temperature also. The fungus was reported to produce ethylene gas in storage, which hastens ageing and pre-disposes cabbage to further infection. The factors affecting post-harvest infection of stored cabbage were studied by Yoder and Whaler (1985).

Control measures : Pre-cooling before storage and maintaining storage and transit temperature as near as to 0°C has been recommended as essential.

Fusarium-rot, c.o. *Fusarium* spp.

The disease was frequently recorded on stored cabbage from Canada and USA (Adair 1971). *F. equiseti*, *F. moniliforme* and *F. oxysporum* were also recorded from Kumaon (Harbola and Khulbe 1994). *F. roseum* was also reported.

Symptoms : The fungus produces a yellow pigment on the surface of the infected tissues. Due to infection, rapid ageing occurs. Decay cannot be checked by modified atmosphere storage.

Control measures : Storage losses can be minimized by spraying Mancozeb (0.2%) or Folpet (0.2%) on heads in the fields, and later storing them at 0-1°C (Tasca and Trandaf 1984).

***Pythium*-rot /damping-off, c.o. *Pythium* spp.**

Damping-off is a major seedling disease in the nurseries. It was recorded as early as 1925 by Drechsler from the USA. Several *Pythium* species were reported to be associated. Infection takes place through wounds or in contact with wet soil. The progress of the disease is usually rapid.

Symptoms : Tissues become water-soaked, loosen cohesion, and liquid exudes as in bacterial soft-rot. The fungus is intracellular and inconspicuous in the early stages of decay. Later it produces characteristic soft/wet decay. Eventually fluffy or depressed white, aerial mycelia appear on the surface of the decayed tissues. The rot is likely to be masked by secondary bacteria, which cause soft-rot.

Control measures : They are as detailed under *Fusarium-rot*.

Brown-head, c.o. *Phytophthora porri* Foister

Semb (1971) and Geeson (1976) recorded *Phytophthora* sp., and reported the disease from the UK.

Symptoms : The outer wrapper leaves show desiccated appearance. The centre becomes dark-brown with discolouration advancing upwards from the stem base. Sometimes scanty mycelial growth may appear within stem cavities and in between heart leaves.

Control measures : They are as detailed under *Fusarium-rot*.

**Head-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs
R. stolonifer(Ehrenb.) Vuill.**

The disease was reported from Karnataka (Hiremath and Govindu 1975) and West Bengal (Dasgupta and Mandal 1989).

Symptoms : The leafy heads turn brown and rot. Floccose growth of the fungus is also noticed (Fig. 22.3).

Control measures : Sanitation of the storage room is important. Debris should be removed promptly and walls, floors and containers should be disinfested before the crop storage. Since bruises act as portal of invasion, care in



Fig. 22.3. Mixed infection (*Rhizopus*, *Alternaria* and bacteria) on cabbage

harvesting and handling is crucial, and regulation of storehouse temperature is also essential. The normal procedure is to raise storehouse temperature to 28-32°C for 2 weeks and then lower down to 5°C (Walker 1975).

**Black-leg, c.o. *Phoma lingam* (Tode ex Fr.) Desm.
Leptosphaeria maculans (Desm.)**

It is a common disease in the USA and Australia, and is also reported from Maharashtra. The disease was introduced into India through imported seeds.

Symptoms : The plants may get infected from seed-beds or at anytime during their growth. Ash-grey spots studded with tiny black dots are noticed on the leaves and stems. Girdling of stem is noticed, as a result of which plant wilts and dies. On seed stalks and pods of seed-plants, lesions are elliptical.

Control measures : The fungus is seed-borne. Fungicidal dust treatments generally are not effective in eliminating seed-borne infection. Hot-water treatment at 50°C for 30 minutes is effective; fresh vigorous seeds alone can withstand the treatment. Thiram-soak treatment (dipping of seeds in Thiram (0.2%) solution for 24 hours at 30°C) is recommended (Suryanarayana 1978).

Efficacy of pre-harvest treatment of heads with Mancozeb (0.2%) or Folpel (0.2%) in the field, followed by pre-cooling before loading and storage at 0-1°C was reported as effective (Tasca and Trandeaf 1984).

Watery soft-rot, c.o. *Sclerotinia minor* Jagger

The disease was reported from Italy, USA (Davis, 1925; Dillard and Hunter, 1986), Australia and India. In Australia, *Sclerotinia minor* tends to prevail in inland areas during summer when a dry period is followed by rains or irrigation. *S. sclerotiorum* is more prevalent under cool moist conditions (Letham *et al.* 1978).

Symptoms : Lesions at first appear pinkish-brown and water-soaked. Under dry conditions, the rot may remain firm, but is usually soft, and breakdowns

with much leakage. Small black bodies (sclerotia) develop on and within the tissue. The optimum temperature for decay is approximately 20°C. Crops grown for seed are particularly susceptible to attack. Seeds may be infected internally or may be contaminated with sclerotia.

Control measures : Use of disease-free seeds and weed control are important. Recommended cultural measures include removal of infected leaves at weekly intervals and mulching with pine-needles or sunflower-head residues (Sharma and Sharma 1986). The disease can be held in check by pre-cooling and maintaining storage and transit temperature at 0°C.

Powdery-mildew, c.o. *Erysiphe cruciferarum* Opiz ex Junell

Conidial stage : *Oidium* sp.

Powdery-mildew is common in semi-arid regions such as Middle East (Al-Hassan 1973; Oran 1974) but causes occasional losses in temperate countries after a warm dry spell (Walker and Williams 1965).

Symptoms : In susceptible cultivars, small patches of whitish growth may be seen on the upper leaf surface. Finally, entire leaf gets covered. In partially resistant cultivars, symptoms are noticed as minute black flecks on the leaves. Although primarily is a field disease, it may cause serious post-harvest losses also.

Control measures : The disease is to be controlled in the field itself. Dusting with sulphur is commonly practised as it acts both as an eradiant and protectant. Spraying with Karathane (Dinocap) at 0.1% is also effective. Three to four sprays at 10 days interval, starting when the first symptom appears is reported to be effective (Nene and Thapilyal 1982).

OTHER DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|------------------------|---|---------------|
| Light leaf-spot | <i>Pyrenopeziza brassicae</i> Sutton & Rawl. <i>Cylindrosporium concentricum</i> Grev. | |
| Anthracnose | <i>Colletotrichum hugginsianum</i> } | |
| Cercospora-spot | <i>Cercospora brassicae</i> } | Snowdon, 1991 |
| Choanephora-rot | <i>Choanephora cucurbitarum</i> | |

BACTERIAL DISEASES

Black-rot, c.o. *Xanthomonas campestris* pv. *campestris* (Pammel.) Dowson

This was reported on cabbage for the first time in 1929 in India. The disease is important in tropical, subtropical and humid continental regions (Williams 1980).

Symptoms : Yellow brown V-shaped lesions appear at the leaf region. When cut transversly, a ring of black dots becomes visible.

This is essentially a field disease but predisposes crop to infection by secondary soft-rot bacteria. Since the bacteria require moisture for infection, it is important to ensure that harvested crops are dried sufficiently to withstand long-term storage.

Control measures : Use of post-harvest fungicide dips for cabbage results in retention of liquid between the leaves. This should be avoided and replaced by efficient ventilation (Snowdon 1991).

The pathogen is seed-borne (Archana *et al.* 2008). Hot-water treatment at 50°C for 30 minutes, followed by seed dressing with Thiram (0.2%) are required. During storage viability of cabbage-seeds falls rapidly. After a year of storage, viability falls from 58 to 5%. Hot-water treatment, followed by dip in streptocycline (100 ppm) were promising (Singh 1992).

**Soft-rot/ stalk-rot, c.o. *Erwinia carotovora* subsp. *carotovoa*,
E. carotovora subsp. *atroseptica***

Losses due to stalk-rot in the stored cabbage may reach up to 30%. Infection occurs from soil (Keller and Knosel 1980). High nitrogen doses in the field enhances stalk-rot in the stored cabbage (Mirow and Knosel 1982).

Symptoms : Water-soaked lesions appear. Tissues become extremely soft, followed by a slimy decay. Secondary bacteria impart disagreeable odour to decayed tissues. Hot-humid weather is particularly conducive for infection (Kikumoto 1980; Ho 1985). Insects are also carriers of bacteria (Fritz and Honma 1987).

Control measures : They include field hygiene and application of balanced fertilizers. Copper fungicides also protect the crop (Brokenshire and Robertson 1986). Insect control is necessary (Kikumoto 1980). Care should be taken to avoid injuries during harvesting and storage.

**Bacterial-spot, c.o. *Pseudomonas syringae* pv. *maculicola* (Mc Culloh)
Young *et al.***

Symptoms : At first, spots are water-soaked and circular; turn brownish-grey with dark border later. Then they are irregularly angular and coalescent. The disease appears during wet season and infection occurs through natural openings. Suggested control measures include crop rotation and use of healthy seeds.

Cold storage was reported to increase incidence of spotting disorders due to bacterial soft-rot in Ontario, Canada (Warner *et al.* 2003).

OTHER BACTERIAL DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism | Authority |
|------------------------------|--|--------------------------------|
| Slimy soft-rot | <i>Pseudomonas marginalis</i> pv. <i>marginalis</i> (Brown) Stevens | Brocklehurst and Lund, 1981 |
| Bacterial zonate spot | <i>Pseudomonas cichori</i> (Swingle) Stapp. | |

CAULIFLOWER [*Brassica oleracea* (L.) con var. *botrytis* (L.)Alef. var. *botrytis*]

Cauliflower is low in fat and carbohydrates but high in dietary fibre and vitamin C. Sulforaphane, a compound released when cauliflower is chopped or chewed, offers protection against cancer.

FUNGAL DISEASES**Black curd-rot/dark leaf-spot/*Alternaria*-rot, c.o.***Alternaria brassicicola* (Schw.) Wilts.*A. brassica* (Berk.) Sacc.

The disease is common in many parts of the world. *Alternaria alternata* was recorded from the USA, Germany, Finland and many other countries. In India, the disease was reported from Karnataka (Hiremath and Govindu 1975), West Bengal (Mandal and Dasgupta 1980; Duhan and Suhag 1990) and Kumaon, Himachal Pradesh (Harbola and Khulbe 1994). Three species of *Alternaria* — *A. brassicae*, *A. brassicicola* and *A. alternata* are recorded as pathogens of seed-borne nature (Mohd *et al.* 1994). Survey of *Brassica* seeds showed that 60% of the samples were infected with *A. brassicicola* and 10% were with *A. brassicae*. Significant differences among isolates were recorded. *A. tenuissima* was also reported from Kumaon.

Symptoms : Infected curds show erratic dark-brown patches, which finally become blackish and soft, extending to deeper tissues and emit bad odour. Water sprinkling over curds aggravate the disease. Sporulating mass is noticed around advancing margins only (Fig. 22.4).

A. brassicicola produces small black spots (up to 1 cm in diameter) on leaves, stems and pods. In humid weather, spots may coalesce together to form bigger circular lesions. Concentric rings are also seen on these spots. When lesions appear on the tips

of the pods, they split. The fungus from pods penetrates inside them and reaches seeds. Affected seeds are shrivelled. The disease is important on the seed-crop as the pathogen attacks pods and seeds. Infected seeds fail to germinate or produce diseased seedlings (Wu and Lu 1984; Dauhan and Suhag 1989).

This disease has become a major constraint for successful cultivation of cauliflower for seed. The disease symptoms on pods are favoured by high relative humidity, intermittent drizzling and moderate temperature (Duhan and Suhag 1990). The inoculum remains lodged deep into the seed tissues



Fig. 22.4. *Alternaria*-rot on cauliflower

(Richardson 1970, Mohd *et al.* 1994). It reduces seed quality, causes seedling mortality, leaf spot, curd blight and seed infection. Siliqua infection reduces number of seeds/siliqua. Heavy yield losses are also reported. The fungal mycelium is also recorded in different parts of the seeds (Prasad and Vishunavat 2002, 2003, 2006). Seed yield losses were maximum in mid-maturing variety Pant Shubhra.

Control measures : Hot-water treatment of seeds at 50°C for 30 minutes is effective (Sokhi 1994). Thiram applied as dust to seeds (8.5 g/kg) eliminates superficial infection, but not deep-seated infection. Thiram suspension maintained at 30°C is effective in eliminating deep-seated infections (Suryanaryana 1978). Spraying crop with copper oxychloride (0.5-0.75%), Maneb (0.2%), Zineb (0.25%) was recommended (Singh 1992).

Srivastava *et al.* (2002a) tested efficacy of 10 fungicides with 12 isolates of *A. brassicae* and observed all of them highly sensitive to chemicals, including Emisan-6 and Ridomil MZ-72.

Biological control of seed-borne *Alternaria* on cruciferous plants with powdery preparation of *Streptomyces* was reported from Finland (Tahvenen and Avikainen 1987).

Damping-off, c.o. *Pythium aphanidermatum* (Edson) Fitzp.

Rhizoctonia solani Kühn

Damping-off due to *P. aphanidermatum* was reported by Shyam *et al.* (1987) and Harbola and Khulbe (1994).

Symptoms : The fungi causes pre-emergent and post-emergent damping-off in nurseries.

Control measures : Bhardwaj *et al.* (1987) studied effect of seed and soil treatments on the incidence of damping-off and black-rot in cauliflower seedlings. Mishra *et al.* (2000) recorded soil solarization effective in reducing significantly pre- and post-emergent damping-off in nurseries. Sen (2000) controlled the fungus by a combined treatment of seed and soil with commercial preparations of *Aspergillus niger* (Kalisena SD and Kalisena SL).

Effect of seed treatment with biotic agents and biotic elicitors on the reduction of damping-off was also recorded (Sharing and Socin 2005).

Lower disease incidence was recorded with Bion treatment, followed by *Trichoderma harzianum* (labortatry formulation), Kalisena SD (commercial preparation of *A. niger*) and Bavistin (0.1%). Efficiency of *T. harzianum* and *A. niger* on plant vigour index was higher than that of chemicals.

Soft curd-rot, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.

Fusarium equiseti (Corda),

F. semitectum Sacc.

Soft-rot causes heavy losses. The disease was reported from Karnataka (Hiremath and Govindu 1975). It is common when there is a glut in the market and produce is subjected to rough handling.

Symptoms : The rot may be partial or total; surface becomes discoloured. Decay appears in patches, progresses fast and involves whole curd that starts emitting bad odour (Fig. 22.5). *R. stolonifera* produces brown soft decay accompanied with extra matrical stringy mycelia. *Fusarium* spp. are often observed as secondary invaders.

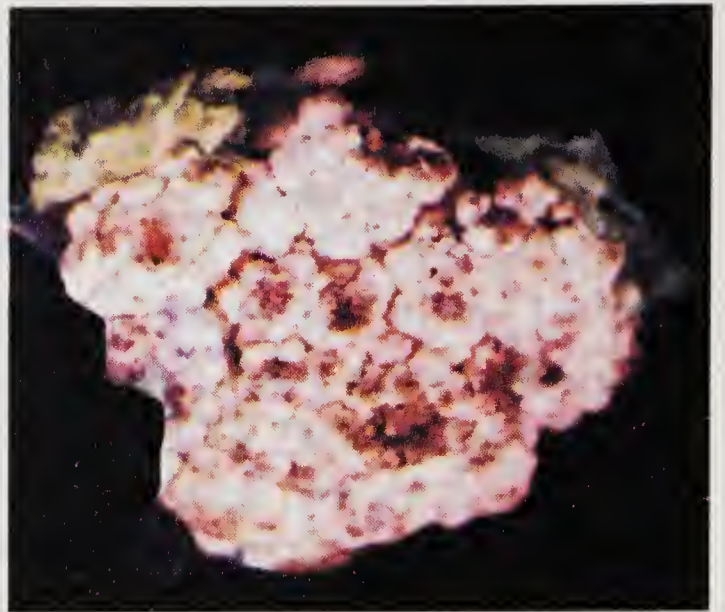


Fig. 22.5. Mixed infection (*Alternaria* and *Rhizopus*) on cauliflower

Control measures : Sanitation of storage rooms is important. Debris should be removed promptly and walls, floor and containers should be disinfected before storage of curds. Since bruises become portal of invasion, care in harvesting and handling is important. Cold storage at 5°C is recommended.

***Sclerotinia* stalk-rot/white-rot, c.o. *Sclerotinia sclerotiorum* (Lib.) de Bary**

The disease is considered as one of the most destructive diseases of the vegetables in the cold and moist areas of the world and occurs on cabbage, cauliflower, kale, brussel's sprouts, broccoli and chinese cabbage. It is mainly observed in Himachal Pradesh. Losses are more than 30%, and average seed yield also decreases considerably (Verma and Sharma 1999).

Symptoms : Symptoms are noticed on leaf, stem and curd. When curds are affected, rotting results in, and this gives rise to large cavities, which are lined inside by fluffy mycelia and fungal sclerotia. The rotting may start from any point, but usually it starts from the centre. In the seed-crop, fungus attacks inflorescence, on which mycelia and sclerotia can be noticed.

Sharma *et al.* (1984) observed high protease activity and synthesis of protein. Khare and Bompix (1976) also observed similar symptom with *S. sclerotiorum* in mustard.

Control measures : Soil solarization has been reported to be effective in disease management (Quais *et al.* 2002). Benlate (0.2%) was also found promising. Enzyme production was under check in plants sprayed with Benlate.

Seed-crop production was threatened by this disease in Himachal Pradesh. Singh and Gangopadhyay (1984) observed 0.1% spray of Methyl Benzimidazole Carbamate (MBC) at 10 days interval effective. Bavistin was also reported effective. Maximum reduction in disease incidence was recorded with Bavistin 50% (1.5g/litre) (Quais *et al.* 2005). Even though fungicides are effective, chemical control measures are not economical and also not ecofriendly because of their residual toxicity.

Application of farmyard manure was reported to reduce white-rot (Sokhi 1994). Hybrid seeds of cauliflower infected by *S. sclerotiorum* could be saved by application of Kalisena SL (commercial preparation of *A. niger*) in the sick fields after harvest (Sen 2000). Culture filtrates of *Trichoderma harzianum* were also recorded to be effective in reducing disease incidence; seed yield increased with its treatment. Integrated disease management with Kalisena, *T. harzianum* + *A. niger*; Booty (*T. viride*) + Kalisena and Booty alone was found promising in increasing seed production (Quais *et al.* 2005).

Cauliflower heads could be successfully stored at zero energy chambers; this recorded lower physiological loss in weight (Mangal *et al.* 2000).

Rhizoctonia-rot, c.o. *Thanatephorus cucumeris* (Frank) Donk.

Rhizoctonia solani Kühn

The disease has been reported from several countries. Management of seedling disease through seed treatment and soil amendment was reported. Its symptoms and control measures are as described under *Rhizoctonia-rot in cabbage*.

Choanephora-rot, c.o. *Choanephora cucurbitarum* (Berk. & Rav.) Thaxter

The disease has been reported to cause post-harvest rot during transit and storage (Pavgi and Singh 1970). In the field, greyish-brown spots appear on leaves, which are later covered with a silvery bloom of mould growth. The curd may undergo a soft wet decay. Mandal and Dasgupta (1985) observed a watery-rot from West Bengal. The rot was observed in cool atmosphere.

Control measures : Storage of cauliflower heads at zero energy chambers has been recorded to be effective.

Curd-smudge/Cladosporium-rot, c.o. *Cladosporium* spp.

The disease has been reported from several countries, including India (Chakraborty *et al.* 1989). In Taiwan, the causal organism identified was *Cladosporium tenuissimum*, and it was observed to be seed-borne. Superficial colonization of cauliflower curd tissue was reported from California. Curd smudge caused by *Cladosporium* has been reported from temperate countries also (Laemmlen 1986).

Symptoms : Infection results in small, circular, black mycelial aggregations over the curd surface. Fungal growth occurs in cool weather with light rains, followed by several days of heavy dew.

Control measures : The disease can be controlled by using jet sprays of chlorine water, followed by chlorine dip (100-400 ppm).

Grey mould-rot, c.o. *Botryotinia fuckeliana* (de Bary) Whetzel

Botrytis cinerea Pers.

Grey mould-rot is of major importance in cool temperate countries — UK (Brokenshire and Prudie 1984; Davies and Heale 1985).

Symptoms : They appear on the curds. Under humid conditions, whitish mould develops that darkens subsequently and gives rise to a dense mass of brownish-grey spores. Once established, the fungus penetrates into sound healthy tissues and produces severe 'nesting'.

Control measures : Pre-cooling before storage and maintaining storage and transit temperature near to 0°C have been recorded as effective.

***Nigrospora-rot*, c.o. *Nigrospora sphaerica* (Sacc.) Mason**

The disease was recorded from Egypt. Symptoms include brown patches on the curd and on the stalklet as elongated sunken blackish-brown spots with raised edges.

***Downy-mildew*, c.o. *Peronospora parasitica* (Pers.) de Bary**

The disease was reported on cauliflower heads from Kumaon (Chakraborty *et al.* 1989). Seed treatment with Metalaxyl before sowing gives promising results. Spraying with Mancozeb and Ridomil MZ-72 (0.25%) each at 10-14 days interval in the field reduces post-harvest rot.

***Ring-spot*, c.o. *Mycosphaerella brassicicola* (Duby) Lindau**

Oblong or irregular spots may occur on seeds, stems and siliqua. Phytosanitary measures coupled with appropriate crop rotation keep disease in abeyance. Carbendazim (0.1%), Ridomil MZ (0.25%) and Mancozeb (0.2%) are found effective in controlling the disease in the field.

***Powdery mildew*, c.o. *Erysiphe cruciferarum* Opiz ex June, *Oidium* sp.**

The disease is common in semi-arid regions such as the Middle East (Al-Hassan 1973). Symptoms and control measures are as detailed under *Powdery mildew in cabbage*.

***Light leaf-spot*, c.o. *Pyrenopeziza brassicae* Sutton & Rawi
Cylindrosporium concentricum Grev.**

Seed mycoflora

Absidia orchidis

Alternaria alternata, *A. brassicola*

Aspergillus flavus, *A. nidulans*, *A. niger*

Fusarium solani

Penicillium chrysogenum

Sharma and Sach Dev, 1984

Rhizoctonia solani

Rhizopus oryzae

Torula herbarum

Xanthomonas campestris

Actinonmycetes

Occurrence of *Alternaria*, *Aspergillus* and *Rhizopus* was more on deformed seeds. Surface disinfection resulted in increased germination.

Other fungi reported include the following.

Chaetomium globosum

Fusarium equiseti

F. lateritium

Phoma tropica

Rhialophora sp.

Cordana musae

Chakraborty *et al.*, 1989

Harbola and Khulbe, 1994

BACTERIAL DISEASES

Black-rot/bacterial-rot, c.o. *Xanthomonas campestris* pv. *campestris*

This is an important disease having worldwide distribution. In India, it is reported from Himachal Pradesh. It is quite serious in seed-producing centres, and is prevalent in India since 1949 (Patel *et al.* 1949).

Symptoms : They occur near leaf margins. Infection is systemic and affects inflorescence, pods and seeds. In seeds, it is present in the seed-coat. Seeds are also externally contaminated and infection is reported to be active for three years. The disease symptoms may also occur at the base of the curdlet, where vein-rot appears (Dasgupta and Mandal 1989) (Fig. 22.6). Cauliflower heads gets discoloured due to infection.



Fig. 22.6. Bacterial-rot on cauliflower

Control measures : The disease is internally seed-borne and is difficult to be controlled under glasshouse conditions. Treatment of seeds with hot-water at 50°C for 30 minutes, followed by seed dressing with Thiram (0.2%) are recommended. This is also effective for controlling other seed-borne fungi like *Alternaria*, *Fusarium*, *Chaetomium*, *Aspergillus*, *Penicillium* and *Rhizopus* (Suryanarayana 1978). Bharadwaj *et al.* (1987) studied effect of seed and soil treatments on the incidence of damping-off and black-rot in cauliflower seedlings and observed control by sowing hot-water treated seeds (52°C for 30 min) in 2% formalin-treated soil. Hot-water treatment was also recorded as effective in disinfection of black-rot bacteria (Sokhi 1994). Dipping seeds for 3 hours in streptomycin (0.01%) + Mancozeb (0.25%) was most effective and resulted in disease control. Integrated seed treatment with streptomycin (0.01%) + Mancozeb (0.25%) for 3 hours and foliar sprays coupled with a mulch of eucalyptus leaves also resulted in 60% disease control (Jarial and Shyam 2003).

Bacterial soft-rot, c.o. *Erwinia carotovora* ssp *carotovora**E. carotovora* ssp *atroseptica* Van Hall 1902

Cauliflower curds are especially vulnerable to attack. Secondary bacteria impart disagreeable odour to decaying tissues. Hot-humid weather is particularly conducive for infection (Kikumoto 1980). Insects are also responsible for carrying and introducing bacteria through wounds (Fritz and Honma 1987). Infection can also occur during harvesting and handling through cut stem or through wounds. Infected tissues are stimulated to produce ethylene.

Symptoms : Water-soaked lesions appear, later tissues become extremely soft, followed by slimy decay.

Control measures : They include field hygiene along with destruction of insects. Care should be taken to avoid injuries during harvesting and handling. Cultivation of resistant cultivars should also be encouraged.

Bacterial-spot, c.o. *Pseudomonas syringae* pv. *maculicola*

The spots are at first water-soaked and circular. Later they turn brownish grey with dark borders, irregularly angular and coalescent. The disease occurs in wet season and infection takes place through stomata. Control measures include crop rotation and use of healthy seeds.

Soft-rot, c.o. *Pseudomonas viridiflava* (Barkh.) Dowson.

The disease was reported from Newzealand. Irregular dark-green water-soaked lesions appear. In advanced stages, tissues become brown, soft and watery and emit putrid odour (Wilkie *et al.* 1973).

KNOL-KHOL/KOHL-RABI[*Brassica oleracea* (L.) con var. *acephala* (DC.)Alef.var. *gongylodes* (L.)]

The crop is cultivated in Europe and in parts of India, especially in Kashmir. Its leaves are used as a vegetable in soup preparation. It is rich in minerals, calcium, magnesium, potassium, sodium and sulphur.

FUNGAL DISEASES***Alternaria-rot, c.o. Alternaria brassicae* (Berk.) Sacc.,***A. brassicola* (Sch.)Wittish *A. alternata* (Fr.) Keiss.

Symptoms and control measures are as detailed under *Alternaria-rot of cabbage*.

Watery soft-rot, c.o. *Sclerotinia minor* Jagger

Symptoms and control measures are as detailed under Watery soft-rot of cabbage.

Damping-off, c.o. *Pythium* spp.

Rhizoctonia solani Kühn

Seed treatment with commercial preparation of *Trichoderma viride* (2g/100g of seeds along with soil drenching by Captan (75% WP) 1.5-2.5g ai/litre of water) reduced disease incidence.



CHAPTER 23

Root Crops

BEET ROOT/ SUGARBEET (*Beta vulgaris* L.)

The chemical process to obtain sugar from sugarbeet roots was developed by the German Scientist Margyraf in 1747. The modern beet sugar factories have come into existence in the first quarter of the 20th century. In India, sugarbeet is an introduced crop from Europe.

FUNGAL DISEASES

***Sclerotium* root-rot/creepy white-rot, c.o. *Sclerotium rolfsii* Saccardo**

Walker (1975) recorded the disease from the USA as Southern blight or *Sclerotium*-rot. The disease is not so important in countries where beet root matures in falling down temperatures. In India, this disease is one of the limiting factors for successful cultivation, and is recorded as the most destructive disease (Srivastava 2004). It can be serious if maturity period of the crop coincides with hot weather. Increase in disease incidence caused corresponding decrease in root yield. Infection of more than 10% root area caused significant decrease in sucrose content (Sharma and Pathak 1994).

In north India, symptoms appear in the latter part of February till March-April when weather warms up. In the early stages of infection, symptoms are not visible on the aerial parts.

Symptoms : With the advancement of disease, symptoms appear on the roots, and leaves show yellowing and wilting. Such plants can be easily pulled out. The fleshy root can completely or partially decay. White strands of fungal mycelia and numerous brown sclerotia are noticed on the decaying root parts. The inner red tissues become dull, flaccid or even dry or shrivelled. Under humid conditions, entire root rots, and within 2-3 days forms 'nests' within the heap. Seedling-blight was also reported from India (Mukhopadhyay and Sharma 1968).

Sclerotium rolfsii has a wide host range and survives as saprophyte on the crop refuse. *Sclerotia* left in the field on contact with any plant residue germinate at temperature above 28°C (Singh 1992). The physiology of the fungus was studied in detail by Mathur and Sarbhoy (1976).

Control measures : Certain cultivars like Resista Poly, Cerco Poly and Extra Poly were found moderately resistant under artificial epiphytotic conditions. (Mukhopadhyay 1976).

Nitrogen (160 kg) in the form of ammonium sulphate or calcium ammonium nitrate significantly reduced root-rot in the field. Soil drenching with Chloroneb or Quintozene @ 12kg/ha after planting was found effective. Brassicol (15kg/300 litres of water) as a soil drench around roots and Bavistin at 10 g/kg of seeds were also promising (Singh 1992).

The effectiveness of certain chemicals which are known to induce defence mechanism in plants against their potential pathogens is well understood (Sinha, 1989). Based on this, management of fruit-rot through seed soaking with non-conventional chemicals has also been reported. Root-rot was reduced maximum when seeds were pre-soaked in 2, 4, 5 trichloro phenoxy acetic acid solution (10^{-4} M viz, 7.59 %), followed by zinc chloride (10^{-4} M viz., 12.08%) or chitosan (0.3%); they were also reported to be effective in producing maximum root yield, foliage growth and sugar yield (Das and Raj 2004). These chemicals have no phytotoxic effect. Chitosan, a polymer of glucose amine, increased chitinase activity and degraded chitin content of fungal cell walls (Marek *et al.* 2000).

Wells *et al.* (1972) isolated antagonistic microflora from diseased sclerotia of *S. rolfii* and later developed techniques for controlling pathogen in the field by using *Trichoderma harzianum*. Backman and Rodriguz (1975) reported diatomaceous earth granules impregnated with 10% molasses to be suitable for growth and delivery of *T. harzianum*. Mathur and Sarbhoy (1978) recorded disease control under *in-vitro* conditions. *T. viride* and *T. harzianum* cultures multiplied on sand with maize meal medium (9:1) v/v with water were applied to sugar-beet plants. Soil application of *T. harzianum* cultures to the field was also reported (Upadhyay and Mukhopadhyay 1986). *T. harzianum* directly attacked and lysed mycelia and sclerotia of *S. rolfii*. The type of interaction was through hyphal coiling. *T. harzianum* applied in the form of sorghum culture to *S. rolfii*-infested soil gave 76-88% disease control. Penta chloro benzene(PCNB) at low concentrations when integrated with *T. harzianum* also showed similar results.

Dry root-rot/*Rhizoctonia* root-rot, c.o. *Rhizoctonia solani* Kühn

Thanatephorus cucumeris (Frank) Donk.

The disease is important as it causes dry-rot of fleshy roots. It consists of a brown spongy decay, starting at the root surface and extending several centimetres deep into the flesh. As the roots grow up, open cankers are formed on them. The disease is detailed under potato. *R. solani* also causes post-emergence damping-off. The treatments offered for *Sclerotium*-rot are applicable to this disease also (Singh 1992). Planting of seeds that have been primed and/or treated with *Rhizobacteria* (Suslow and Schroth 1982) may reduce disease incidence in the field. Integrated control of *Rhizoctonia* crown-

and root-rot through fungicides and an antagonistic bacteria (*Bacillus* sp. strain MSU-127) was promising. The bacteria was grown in the cultural broth at 28°C, centrifuged, decanted and used at a concentration of 10⁸ cfu/ml. This applied in combination with fungicide Azoxystrobin (76 gai/ha) reduced disease incidence and gave good root and sucrose yields (Sebastin *et al.* 2001).

Damping-off and seedling diseases

Seedling diseases are caused by a number of soil- and seed-borne pathogens, including *Phoma betae* (Heilberg and Ramsey 1948), *Rhizoctonia solani* (Afansiev 1948, 1956), *Sclerotium rolfsii* (Mukhopadhyay and Sharma 1968), *Alternaria* spp. (Ilyaletdinov and Agatev 1970), *Aphanomyces cochliodes* (Lewis and Papavizas 1971), *Pythium aphanidermatum* and *Fusarium* spp.

A survey of seedling diseases of sugarbeet in India by Sen *et al.* (1974) revealed that seedling-blight, black-leg, collar-rot and damping-off syndromes are incited by *S. rolfsii*, *R. solani*, *R. bataticola*, *Fusarium* spp. and *Alternaria* spp. Of these, the first three were noticed to cause acute mortality and reduction in sugarbeet stands in the field.

Control measures : *S. rolfsii* and *R. solani* could be controlled by seed treatment with Penta chloro nitro benzene (PCNB) 5.0g/kg of seeds. Incorporation of this fungicide as seed pellet was superior. Pelleting with Brassicol @ 10g/10 kg of seeds was most effective. Bavistin (5-10 g/kg of seeds mixed with Bentonite clay as base and methyl cellulose as sticker) as seed pellets was also effective (Singh *et al.* 1982).

Biological control of *P. aphanidermatum* with *T. harzianum* also was recorded (Mukhopadhyay and Chandra 1985). In dual-culture experiments, *T. harzianum* (50 µg/ml) exhibited antagonism towards sugarbeet isolates of *P. aphanidermatum*. *P. aphanidermatum* stopped growing on contact with the mycelia of *T. harzianum*. *T. harzianum* hyphae were found coiled around those of *P. aphanidermatum*, and their protoplasm was disintegrated completely. A synergistic effect leading to enhanced control of damping-off was also observed when both *T. harzianum* and Metalaxyl were used in combination. Seedling diseases can be effectively managed through seed treatments; seed polishing and seed pelletting with biocontrol agents, and cultural practices. Pelleting of seeds with Bentonite clay as base material and methyl cellulose as sticker was found effective. Pelleting with fungicides protects against seedling diseases in comparison to conventional seed treatments (Srivastava 2004).

Cottony white-rot, c.o. *Fusarium* spp.

The disease was recorded from Maharashtra, Karnataka, West Bengal, etc. It was also recorded on beet roots coming to the local markets of Thiruvananthapuram (Kerala) from Bengaluru and Coimbatore (Philip 1998).

Symptoms : On uninjured roots, white powdery growth is noticed. Infection appears as water-soaked patches with scattered whitish growth. Under humid conditions, entire root surface is covered with whitish cottony fluffy growth (Fig. 23.1).

Control measures : Storage of roots at 4-13°C is effective in controlling infection and in increasing storage life (Musa and Saleh 1988).



Fig. 23.1. *Fusarium*-rot on beet root

***Rhizopus* root-rot, c.o.**

Rhizopus oryzae Went & Prinsen Geerligs

The disease is of a common occurrence in North America. In India, the disease was recorded from Lucknow (Srivastava and Misra 1972).

Symptoms : In nature, the disease starts as a soft-rot and progresses infecting rapidly healthy tissues. Later, it covers entire root surface with profuse fungal growth. Complete rotting takes place within 10-15 days. The diseased tissues turn yellowish brown and emit unpleasant odour. In fields, increased atmospheric temperature has been observed to enhance incidence of the disease.

Control measures : Storage of roots at 4-13°C is effective in controlling infection and in increasing storage life (Musa and Saleh 1988).

***Macrophomina* root-rot, c.o. *Macrophomina phaseolina* (Tassi) Goid.**

Karadimos *et al.* (2002) reported root-rot from Thessaloniki in Greece. Diseased plants appear in patches in the field. Rotted roots showed white yellow mustard coloured lesions in the internal surface. In advanced stages, tissues become mummified.

Control measures : Storage of roots at 4-13°C is found effective in controlling disease.

***Cercospora* leaf-spot, c.o. *Cercospora beticola* Sacc.**

It is a common disease, particularly in the warm parts of the world. In the plains, disease appears in February-March and in hills during August and September on seed-crops. Lower leaves near the ground are attacked first. Infection is seed as well as soil-borne. Seed-borne infection is both superficial as well as deep-seated.

Three years rotation, deep ploughing, irrigation and fertilizer applications are recommended to control the disease. If the disease appears late in the season, it may not warrant any costly treatment. However, if losses are expected, 3-4 sprayings with a fungicide like Dithane M-45 @ 2.5 kg/ha at

10 days interval are recommended (Singh 1992). Seed-borne infection can be reduced by using aged seeds. Thiram-soak treatment is also effective in checking the disease.

Black-leg/*Phoma* leaf-spot, c.o. *Phoma betae* (Oudemans) Frank.

It is an important disease recorded from Europe, UK and the USA; and in India it is recorded from Punjab, Uttar Pradesh and Kalpa Valley in Himachal Pradesh. When infected seeds are sown, seedlings may die even before emergence or they may get blighted after emergence. The fungus attacks flower-stalks and seed-clusters. Under favourable conditions, pathogen spreads downwards and reaches roots, and such roots decay in storage.

Thiram-soak treatment (soaking in Thiram 0.2% for 24 hours in water kept at 30°C), followed by Prochloraz treatment (0.25 ml of 25% solution/100g of seeds) resulted in reduction of infected seedlings accompanied by lessening of storage-rot (Bugbee and Cole 1981). Proper spacing and drainage are also recommended.

Rust, c.o. *Uromyces betae*

The disease is common in Europe, Canada, Australia, New Zealand and South Africa. It is also common in the plains of northern India. Leaves are the main target of attack. Pustules appear on seed-stalks and also on seed-clusters.

Seed mycoflora

Sugarbeet seeds harbour a number of fungi, which are known to cause considerable damage to flowers, seeds and seedlings. It includes many seed-borne pathogens — *Cercospora beticola*, *Phoma betae*, *Rhizopus oryzae*, *Alternaria alternata* and *Fusarium* spp. Among these, *P. betae* is the most important seed-borne pathogen, causing damping-off, leaf-spot, stem-, crown- and storage-rots. The population of these fungi can be minimized by seed treatment with Organo mercurials, Thiram, Chloroneb, Carboxyl, Metalaxyl, PCNB, Carbendazim etc. Treatment with a combination of fungicides is better than use of a single fungicide (Srivastava 2004).

CARROT [*Daucus carota* (L.) subsp. *sativus* (Hoffm) Arcang.]

Carrot is a valuable dietary item. Its orange colour is due to the presence of betacarotene, the precursor of vitamin A; besides vitamin A, it contains vitamins B and C. It is also rich in sugars.

FUNGAL DISEASES

Watery soft-rot, c.o. *Sclerotinia sclerotiorum* (Lib.) De Bary

The disease was first reported from Belgium by Coemans in 1860 on carrot fields and by Rostrup in 1871 on stored carrots. Both authors observations indicated *S. sclerotiorum* as the parasite responsible for rotting of carrots. But it was Anton De Bary (1886) who confirmed pathogenecity

of this fungus. Since then it has been reported from at least 20 carrot-producing countries. The disease has assumed importance because of its sporadic and devastating nature and lack of effective control measure (Kora *et al.* 2003).

The disease occur at the post-harvest stage and affects crop's shelf-life in storage. Transit and market losses of 30-50% were recorded from US and other countries. Every infected root has the potential to develop as the source of inoculum for new infection. Infection occurs at a wide range of temperature (0-23°C).

Control measures : Pre-harvest cultural practices are important in reducing susceptibility during long-term storage. Balanced fertilizers with adequate potassium are important.

- Excess use of nitrogen is to be avoided.
- Mechanical injuries during harvest should be minimized.
- Pre-cooling before storage as well as maintaining a transit-and-storage temperature at 0°C are effective.

Biological control measures. The coelomycete fungus *Coniothyrium minitans* is hyperparasitic on *S. sclerotiorum*. Foliar application on the crop with a commercial bio-fungicide containing fungus was reported as effective (Turner and Tribe 1976).

- Several *Trichoderma* spp., including *T. harzianum* have demonstrated biocontrol activity against soil-borne pathogens including *S. sclerotiorum*.
- Mycorrhizae (*Glomus intra radices* and *Glomus etunicatum*) inoculations on carrot at seedling stage help provide protection during storage.
- Soil amendments have a suppressive effect. Amendment of field soil with an organic formulation of the fermented agricultural wastes or allyl alcohol, suppressed germination of sclerotia, enhanced colonization by *Trichoderma* spp. (Huang *et al.* 1997).
- Chitosan, the naturally derived polysaccharide, possesses antifungal properties to *S. sclerotiorum*, and is used for post-harvest treatment of *Sclerotinia* root-rot of carrot in storage (Cheah *et al.* 1997).
- Non-ionizing ultraviolet (UV-C radiation) can effectively elicit accumulation of antifungal phytoalexin in carrot roots and can induce systemic resistance to subsequent infection by *S. sclerotiorum* (Mercier *et al.* 1993).
- Ozone treatment was reported to have some fungistatic effect on *S. sclerotiorum*, and has been proposed as an alternative disinfectant to stored carrots (Liew and Prange 1994).

Cottony white-rot, c.o. *Fusarium* spp.

Cottony white-rot is a very serious disease of carrot all-over the world under field and storage. In India, *F. oxysporum* was recorded from Uttar Pradesh (Srivastava *et al.* 1964) and Karnataka (Hiremath and Govindu 1973), *F. solani* from West Bengal (Dasgupta and Mandal 1989) and *Fusarium* sp. from Maharashtra (Rao 1966) and Thiruvananthapuram (Philip 1998). During

the rainy season, the disease was noticed on the roots that were brought to the local markets of Thiruvananthapuram from Coimbatore.

Symptoms : Symptoms may appear anywhere but are usually noticed on the distal-end as water-soaked areas. Gradually, lesions enlarge and become circular to irregular patches. The tissues putrefy. On the surface, scanty white mycelial mass develops (Fig. 23.2). Infected tissues emit a characteristic smell. Seeds are infected when they come in contact with the contaminated soil.

Control measures : Infection is seed as well as soil borne. Seed treatment with 0.2% Thiram is effective in reducing infection. Storage of carrot roots at 4-10°C protects crop from infection.



Fig. 23.2. *Fusarium*-rot on carrot

***Rhizoctonia* root-rot, c.o. *Rhizoctonia carotae* Rader**

This disease on carrot was first reported from the USA (Rader 1948). Walker (1975) recorded a semi-soft rot from Wisconsin. Niza *et al.* (1981) observed disease from the local markets of Thiruvananthapuram. Small whitish growth is observed, and the tissues become soft. The pith enlarges and tissues beneath them become watery and emit foul smell. The rot develops rapidly and within a week root gets putrified.

Sour-rot, c.o. *Geotrichum candidum* Link.

This is considered a serious post-harvest disease of carrot in the USA (Wright *et al.* 1964). In India, it was recorded from West Bengal (Mandal and Dasgupta 1980) and from Haryana (Suhag and Duhan 1979). Losses as high as 80% were observed in 'Chanteney type' carrot (introduced from Holland) as compared to 50% in the local varieties of Haryana.

Symptoms : The first indication of the disease is the appearance of the irregular or circular water-soaked patches on the roots within 10 days. White cottony mycelial growth tends to spread by making conspicuous grooves within root tissues, which disintegrate and cause leaves to topple over and die. On injured roots during and after rains, the disease appears as water-soaked patches and spreads rapidly. Tissues emit sour offensive smell, and powdery white or scum-like growth is noticed over the root surface. Yeast is also found associated. Fungus disseminates with the aid of fruit-fly *Drosophila melanogaster* as well as through contact (Philip 1998).

Infection is observed on roots kept under ambient conditions (28 ± 2°C) after 5-6 days of storage.

Control measures : Storage of roots at refrigerated conditions of 4-5°C is beneficial. Control measures as detailed *under sour-rot of tomato, under Solanaceous crops is applicable here also.*

Soft-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs
R. stolonifer (Ehrenb.) Vuill.

Soft-rot was recorded from Karnataka (Hiremath and Govindu 1973) and West Bengal (Mandal and Dasgupta 1982).

Symptoms : The disease occurs extensively on the injured roots during rains. The rot develops at the injured site; water-soaked areas appear, and within 24 hours roots will be covered completely with fungal mycelia.

Control measures : Sanitation of the storage-room is important. Debris should be removed promptly, and walls, floor, and containers should be disinfected before crop storage. Since bruises are portal of invasion, care is essential in harvesting and handling. Cold storage at 10-15°C was found promising.

Black-rot, c.o. *Alternaria alternata* (Fr.) Keissler, *A. dauci* and
A. tenuis Aunet

This is a seed-borne disease. Leaf-blight caused by *A. dauci* was reported from the UK, Europe and the USA. In India, it is common in Asom, Maharashtra and Karantaka. The fungus survives on the infected crop debris in the soil. Infected seeds often fail to germinate. Sometimes seedlings emerge, which soon get blighted. On the lower part of the stem, long chestnut-brown to black stripes appear. Later on, whole stem rots and dries up. On carrot roots also black sunken lesions are produced, which under improper storage enlarge causing rotting of the tissues. Inflorescence, fruits and seeds are also infected.

Seed infections can be controlled by Thiram (0.2%)-soak treatment (Suryanarayana 1978).

OTHER FUNGAL DISEASES

| | |
|---|----------------------------|
| Sclerotium-rot, c.o. <i>Sclerotium rolfsii</i> Sacc. | Mandal and Dasgupta (1982) |
| Thielaviopsis-rot, c.o. <i>Thielaviopsis basicola</i> , <i>T. thielavioides</i> (<i>Cereatocystis paradoxa</i>) | Weber and Tribe (2004) |
| Crater-rot, c.o. <i>Athelia orachnidea</i> | } Snowdon (1991) |
| Grey-mould, c.o. <i>Botryotinia fuckeliana</i> | |
| Conidial state, <i>Botrytis cinerea</i> | |

BACTERIAL DISEASES

Bacterial-blight/root-scab, c.o. *Xanthomonas campestris* pv. *carotae*

The disease was recorded to be severe on the seed-crop. The bacterium is seed-borne and thus gets disseminated to far and wide places. Fleshy roots are damaged. The symptoms are first noticed on leaves. The inflorescence in a seed-crop dies if infection occurs before unfolding of the umbel. The bacterium requires dew or rain for spread. The optimum temperature for

infection is 25-30°C. Between crop seasons, the bacterium survives in soil or on crop-refuse and seeds.

Symptoms : Bacteria are washed down from foliage to soil and infect fleshy roots. Brown to maroon lesions are formed on the fleshy roots, which later develop into slightly raised or depressed laterally expanded pustules, showing flakes of dead tissues. When these pustules crack open, bacterial ooze comes out.

Control measures : They include selection of site, long crop rotation and hot-water treatment of seeds at 50°C for 15 minutes (Singh 1992).

Bacterial soft-rot, c.o. *Erwinia carotovora* (Jones) Halland (Arsenjevic and Stojic 1973)

This was recorded by Agrios (1969). The disease is found all-over the world, and causes serious damage to carrots, potatoes, raddish, onion, hyacinth, iris etc. It develops during transit and storage, and results in higher losses than any other bacterial disease.

Symptoms : Serious decay occurs within a few hours in storage or during marketing. Soft-rot causes severe economic losses by reducing market value of the produce. Chand and Kishun (1989) observed water-soaked brown spots on the lower parts of the roots. Spots develop rapidly and spread to the core of the root, from where they progress from inside to outside. In advanced stages, infected parts become soft due to maceration of the tissues and emit foul smell.

Control measures : Avoid wounds and bruises during harvesting, handling and storage. Roots should be dried under shade before storage; storage at 4-5°C was reported effective.

OTHER BACTERIAL DISEASES AND THEIR CAUSAL ORGANISMS

| Disease | Causal organism |
|--------------------------|--|
| Soft dark-rot | <i>Pectobacterium carotovorum</i> , <i>Erwinia</i> sp. |
| Light soft-rot | <i>Xanthomonas</i> sp. |
| Watery brown-spot | <i>Pseudomonas</i> sp. |
| Dry crush spot | <i>Erwinia</i> sp. |

RADISH (*Raphanus sativus* L.)

It is an edible root vegetable that was domesticated in Europe in pre-Roman times. It is pungent or sweet in taste with a lot of juice. It is rich in ascorbic acid, folic acid and potassium.

FUNGAL DISEASES

Waxy-rot, c.o. *Endomyces reessii*

Mandal and Dasgupta (1980) observed the disease from West Bengal. The disease is recorded during humid weather. Rot generally appears from tapered

end. The root becomes gradually soft and cortex gets separated from the stele, but the fibro-vascular system remains intact. It also emits characteristic foul smell. Powdery or slimy growth appears over the infected surface. The infection spreads by contact. The disease is of minor importance.

Charcoal-rot, c.o. *Macrophomina phaseoli* (Maubl.) Ashby

The disease was reported from India (Pavagi and Singh 1970; Mandal and Dasgupta 1980). During rains, freshly harvested roots carry severe infection of charcoal-rot, and decay is observed in storage.

Seedling-blight and leaf-spot, c.o. *Alternaria* spp.

The disease occurs in plants kept for seed-purpose (Sokhi 1994). When too many spots are on the leaves, they die prematurely. Infection is seed-borne. In soil, pathogen survives on the infected crop residue. Seed-borne infection may be external as well as internal.

Seed treatment with fungicides gives only partial control. Hot-water treatment at 50°C for 20 minutes, followed by protective treatment at 50°C with Thiram 0.2%, have been recommended (Suryanarayana 1978).

***Fusarium*-rot, c.o. *Fusarium* sp.**

Symptoms and control measures are as detailed under carrot (Fig. 23.3).

White-rust, c.o. *Albugo candida*

The disease is worldwide in occurrence. It is common in India also. Symptoms are noticed as blisters on leaves, stems and inflorescence. Inflorescence becomes hypertrophied and sterile with oospores.

Use of clean seeds or seeds collected from disease-free areas help eliminating disease.

Seed mycloflora

The following fungi have been recorded

Alternaria alternata

Aspergillus flavus Sad et al., 1990

A. niger

A. quadrilineatus

Curvularia lunata

Fusarium oxysporum

Rhizoctonia solani

Srivastava et al., 2002



Fig. 23.3 *Fusarium*-rot on radish

Seed treatments with fungicides like Bavistin (Carbendazim), Ridomil, Captan, Dithane M-45 (Mancozeb) and Thiram were promising.

CHAPTER 24

Bulb Crops

ONION (*Allium cepa* L.)

Onion is an important vegetable-crop in India. India is the second largest producer of onions in the world. But nearly 40% of the produce is lost during post-harvest handling; microbial spoilage alone constitutes 15-20% of the total loss (Pantastico and Banstista 1976). Out of Rs 31,700 lakh earned in 1994 as foreign exchange from fruits and vegetables, 1,900 lakh were earned from fresh onions alone (Sokhi 1994).

Genus *Allium* consists of around 450 species; many of which are widely used as spices from time immemorial. Onion is used as a salad or in the cooked, fried, boiled or baked form like flakes, powder, paste etc. Small onions have better medicinal value than common 'savala' onions. They are medium in calorific value and have low amount of proteins and vitamins.

Onions contain chemical compounds with potential anti-inflammatory, anti-cholesterol, anticancerous and antioxidant properties. As onions are sliced or eaten, the allyl propyl disulphide present in them, comes in contact with the air and produces allyl sulphide. This compound irritates the skin, mucous membrane and eyes.

Storability of bulbs vary from region to region. Storage life is correlated with dry matter content. The mean temperature during storage has profound influence on sprouting and subsequent loss in weight. Weight loss in onion increases with sprouting (Karmarker and Joshi 1941; Ward 1976).

FUNGAL DISEASES

Black mould-rot, c.o. *Aspergillus niger* van Tiegh.

Black mould-rot is considered as one of the common diseases all-over the world (Venkatanarayan and Delvi 1951; Coursey and Booth 1972; Curtis *et al.* 1974). Quadri *et al.* (1982) reported spoilage as high as 80%. *A. niger* being a soil saprophyte is ubiquitous in nature and attacks onions by producing enzymes/toxins and gets established on the bulb or other tissues. Periodic survey of onion storage by Gupta and Srivastava (1984) showed 30-40% rotting due to pathogenic organisms under favourable conditions (temperature about 30°C and RH 99%). Of this, 20% loss was by *A. niger* alone. High

temperature prevailing during harvest, followed by ill-ventilated storage increases susceptibility, and the disease attains high severity (Ahir and Maharshi 2008). Virulent nature of the fungus during transport and storage was recorded from Odisha (Narain and Omprakash 1968), Bengaluru (Sohi 1977), Haryana (Dang and Singh 1982), West Bengal and Meghalaya (Dasgupta and Mandal 1989), Tamil Nadu (Rajam 1992) and Karnal (Srivastava *et al.* 2001).

The toxic nature of the metabolites of *A. niger* and their role in onion-rot disease is also well understood. The cultural filtrate reduces spore germination and disorganizes succulent scales and green leaf tissues of onion varieties, Red Globe, Red Patna and White Globe. The toxic principle is thermostable and acts as a protoplasmic poison to host tissues. Studies conducted in Uttar Pradesh by Sharma and Roy (1978) showed that the fungus appeared to be confined only to outer dry scales, and caused dry-rot.

Symptoms : In general, symptoms appear both as dry and wet rot. White mycelia develop in the initial stages, followed by black spores formation (Fig. 24.1). In about 10 days, bulbs become shapeless, turn black and pulpy. With a little pressure, entire bulb gets crushed. *A. aculeatus* was also reported from West Bengal. In dry-rot phase, black thin lines appear between the outermost scales as well



Fig. 24.1. *Aspergillus*-rot on onion

as on the stalk region. Both red and white scaled cultivars are affected (Dasgupta and Mandal, 1989). Similar type of symptoms were also recorded by Philip (1998) on onion varieties in the local markets of Thiruvananthapuram from Kerala. During rainy season, problem is acute. Infected bulbs become soft and emit offensive odour. Infection causes reduction in pungency also. Sometimes disease is observed in combination with bacterial-rot. Association of *A. flavus* was also reported (Sharma and Sumbali 1993).

Control measures : Srinivasan and Shanmugam (2006) reported curing of onion-bulbs by wind or row method, and storage by hanging method was effective in reducing disease incidence.

Evaluation of cultivars for resistance to *A. niger* was studied by Naik *et al.* 2008. Severity of black-mould infection varied among genotypes. Among the genotypes, Arka Kalayan and Arka Pitamber showed less severity (<10%) to black-mould till 30 days after storage and reached 20% severity by 45 days and thereafter increased steadily and reached 35-40% by 90 days after storage.

Studies conducted in Ethiopia with Shallot bulbs (*Allium cepa* var. *ascalonicum*) showed that storage materials had significant impact on the keeping-quality. The bulbs stored in sacks, lost weight and had highest rate of sprouting and rotting (Jemal 1999). Sreenivasan *et al.* (2002) recorded that

higher doses of calcium in the form of gypsum (400 kg/ha) and lower dose of nitrogen in the form of urea (50 kg/ha) application to the field and advancing harvest of onion-bulbs by 15 days to be effective in reducing bulb spoilage in storage. Kosweesuak *et al.* (2002) developed a Bordeaux mixture screening protocol for effective control.

Curing of onion for five days in the field, followed by five days drying under shade and storage in crates was also practised for minimizing storage losses. Brice *et al.* (1997) reported storing of onions in nets. This helps to lengthen storage life. For storage, bottom and side ventilated storage structures (with sidewalls made of bamboo and plastered with clay and cowdung) were also used (Anon. 2003). Bottom ventilated single-row storage structures with thatched roof were recorded as the best for small farmers due to low severity (15-25%) of onion moulds.

Chemical and biological control. Carbendazim (0.1%) applied as foliar spray to the standing crop recorded maximum reduction of *A.niger* during storage (Raju and Naik 2006). Double spray was also found better. In addition, post-harvest fumigation of onion-bulbs with sodium metabisulphite, which released sulphur dioxide for four hours or dipping bulbs in acetic acid (0.4%) markedly reduced disease incidence.

Companion (Carbendazim + Mancozeb 0.2%), Rovral (Iprodiome 0.2%) and Indofil M 45, Mancozeb (0.2%) along with bioagents *T. harzianum* and *T. viride* (spraying cultural filtrate directly to plants) were observed to be effective in reducing disease incidence (Ahir and Maharshi 2008).

Essential oil of *Cymbopogon flexuosus* was reported to have fungi toxicity against major storage pathogens like *A. niger* and *F. oxysporum*. The oil when used as a fumigant at 500 ppm killed a wide range of fungi harboured on the scales (Dixit and Tiwari 1994). *Cymbopogon* oil also showed absolute inhibition at the lowest concentration of 250 ppm.

**White soft-rot/basal-rot, c.o. *Fusarium* spp., *F. solani* (Mart.) Sacc.
F. oxysporum Schlet.**

The disease was reported from several parts of the world. Marlatt (1958) reported basal-rot of onion due to *Fusarium oxysporum* f. *ceapae* from Arizona. Since then it has been reported from several countries. Mathur and Sankhla (1963) observed disease in a severe form from Kota(Rajasthan). Coursey and Booth (1972) also recognized basal-rot caused by *Fusarium oxysporum* Schlet and *Fusarium* spp. The disease was also reported from Haryana (Dang and Thakur 1972; Dang and Singh 1982), Madhya Pradesh (Rao and Agarwal 1977), Karnataka (Hiremath and Govindu 1975), New Delhi (Gupta and Srivastava 1984), West Bengal (Dasgupta and Mandal 1989) and Karnal (Srivastava *et al.* 2001). *F. proliferatum* was reported on onion-bulbs from Washington (Toit *et al.* 2003). Salmon-pink discolouration was prominent on the outer 3-4 layers. The disease was recorded from India also.

Symptoms : They start with yellowing of leaves from tip downwards, which shrivel later with or without necrosis along with the retarded root system. Affected plants could be easily pulled out. Wet- or dry-rot is noticed on bulbs beginning from the base of the outer scales and progressively advances towards the tip. In plants showing complete collapse of leaves, the bulbs becomes rotten, while others with partial rotting continue to rot during storage. The pathogen invades only through injuries. This fungus failed to infect *Allium sativum*.

The infected portion becomes macerated and soft with shrinkage and appears as pale-white. Complete internal rotting is evident within 7-10 days.

Control measures : The disease can be kept under control with fumigation. In *in-vitro* studies, ammonia-releasing fumigants (ammonium bicarbonate 0.65g, + Bentonite clay 1.26g + Talc 0.24g; ammonium sulphate 5 g +sodium carbonate 0.38g, diphenyl amine 62mg) and sulphur-dioxide-releasing materials (sodium metabisulphite (40%) + sodium carbonate (5%) kept in dessicators) were used. Pre-treatments arrested disease development in inoculated bulbs. But when applied as post-infection treatments, their efficiency decreased considerably (Dang and Thakur 1972).

Purple-blotch/-blight, c.o. *Alternaria porri* Neerg

It is a common disease occurring in several onion-growing countries, and has become a widespread problem in Punjab, causing 20-25% losses (Pandotra1964). The disease becomes a limiting factor in seed production, especially in humid areas. Initial inoculum originates from plant debris (Hussain 1960; Pandotra 1965). Sohi (1977) reported *A. solani* and *A. cepulicola* under humid conditions of Bengaluru. Gupta and Pathak(1984) assessed losses in bulb and seed yield due to the disease in onion variety 'Nasik Red' from Jaipur. The disease severity levels were assessed based on the increase in the coefficient of disease index (CODEX). Increased losses in bulb yield and seed yield were recorded with increase in the CODEX levels. More than 50% yield losses were recorded from Punjab. The relationship between disease progression and weather variables is of paramount importance in managing disease (Razdan *et al.* 2008). Maximum disease severity was observed in the variety Royal Select and minimum was in Pankaj. Disease infection rate remained high at the initial storage but declined progressively due to adverse weather conditions and lack of tissue availability.

Symptoms : Small, sunken lesions appear with a purple tint on leaves. Lesions enlarge rapidly resulting in girdling of leaves, which ultimately results in fall of inflorescence stalk. Infection spreads downwards to the bulb. Affected plants do not produce flowers. Bulb decay continues during storage also. This is considered as the most damaging disease for bulb and seed crop (Sokhi 1994).

It is generally observed that in seed-crop, flower-stalks infected with *A. porri* usually have thrip injuries that predisposes onion-plants to infection.

With artificial inoculation also, *A. porri* causes infection on onion-stalks with different grades of thrip injuries. Infection is more on stalks, which have moderate to severe thrips attack. In case of severe thrips attack, purple lesions merge with one another and form large irregular blotches (Thind and Jhooty 1982). Ajrekar as early as 1922 had reported possibility of thrip infection from Bombay (Mumbai at present).

Khare and Neema (1981, 1984) studied occurrence of the disease from Jabalpur (Madhya Pradesh). They observed epidemic form on two months old plants. The epidemiological factors that favoured infection included average temperature ranging from 22 to 25°C with relative humidity of over 90%. Maximum sporulation occurred at 8 AM under field conditions immediately after rains. Relative humidity of 100% for more than 4 hours and temperature of 22-25°C appeared optimum for infection. The interaction of temperature and relative humidity determines severity of purple blotch (Boelema and Ehlers 1967). Disease outbreak is also dependent on the amount of initial inoculum.

Control measures : Captan, Thiram and Aureofungin gave good control against storage rots (Sohi 1977). Field sprays with Blitox (0.3%), Dithane M-45 (0.2%) and Difolatan (0.3%) were effective in controlling disease incidence/intensity, and thereby increasing seed yield (Gupta *et al.* 1985). From Rajasthan, Mathur and Sharma (2006) reported effectiveness of Mancozeb as seed and foliar spray in reducing seed-borne infection; 4-5 sprays of Mancozeb (0.25-0.3%) + Metasystox (0.05%) + Sandovot as sticker were reported to be effective for purple-blotch and *Stemphylium*-blight.

Charcoal-rot, c.o. *Macrophomina phaseolina* (Tassi) Goid.

The disease was reported from Madhya Pradesh (Garg and Chauhan 1981). Externally both healthy and diseased bulbs appear similar, but diseased bulbs show ashy discolouration. On close examination, after peeling outermost dry scales, dark charcoal coloured blemishes with pinhead-like sclerotial bodies on one or two scales below the outer dry papery scales can be noticed. The scales become papery, dry, brittle later, and slough off easily. Infection starts with a white discolouration which gradually increases, followed by formation of jet-black sclerotial bodies after a week. Chandra and Tandon (1965) reported the fungus on garlic-bulbs also.

Control measures *detailed under purple-blotch are promising for this also.*

Grey-mould/neck-rot, c.o. *Botrytis allii* Munn/*Botryotinia* spp.

The first description of onion neck-rot was that of Sorauer from Germany in 1876. Since then the disease has been reported from the USA and UK. It at present has been reported from many countries. David and Irene (1966) reported it from Israel. Walker (1975) distinguished three species of *Botrytis*. But the most common is grey-mould species, *Botrytis allii*. The pathogen also

infects shallot (*Allium ascalonicum* Linn.) and garlic. Ramsey and Lorbeer (1986) recorded 'Flower blight' on onions kept for seed purpose. All florets or seed capsules were blighted due to infection. Infection occurs near the flower base. The cardinal temperature varies with species. Three isolates (*B. allii*, *B. cinerea* and *B. byssoidea*) were recorded. *B. porri* was also identified on onion-seed samples from Canada (Toit and Derie 2002).

The disease is found common on bulbs after harvest. Onions for seed production are damaged. Infection takes place through neck tissues or through the stem-end or wounds.

Symptoms : Softening of the affected scale-tissues occurs first, which take on a sunken and cooked appearance. This remains characteristic of the advancing region of decay, which is separated from the healthy tissue by a definite margin. Mycelial presence on the outer zone of the decaying tissue is scanty, but increases gradually in older diseased areas; tissues become greyish and a dense mycelial mat develops soon over the surface of scales. Under moderately humid conditions, conidial production is fast. The disease progresses rapidly down to scales which were infected originally at the neck. The spread from scale to scale proceeds slowly. The advancing margins have a distinct water-soaked appearance. Older tissues continue to decay and sclerotia appear first as whitish compact mass of mycelia, which become darker with age until assuming appearance of hard black, rounded kernel-like bodies, which are spherical, oblong or irregular and vary from 1 to 5 mm in length. They are usually formed on the outer surface of the scales or are slightly embedded in the host tissue. At this stage, bulb undergoes desiccation, followed by premature sprouting. The older decayed bulb gives 'mummy' appearance. The fungus may cause white necrotic lesions on leaves and seed-stalks. It may also damage seeds.

The fungus over-winters as sclerotia in the soil or bulbs. Decayed bulbs may serve as a source of inoculum. Blast or leaf spotting during growing season may also be incited. Neck-rot is an extremely spasmodic disease as it is favoured by cool, moist weather. Conidial production, germination and mycelial growth occur over a wide temperature range. Infection and post-infection decay of bulbs are favoured at 15 and 20°C. Succulence of the neck tissue at harvest time is important in determining infection. Rapid drying out of decayed neck tissue may check further disease progress. White-bulb varieties of onion are more affected than coloured varieties. It has been observed that certain phenolic substances in the dry, outer coloured scales are antibiotic to *B. allii*. Since these materials are contained chiefly in the outer scales and only in the outer epidermal cells of the succulent scales, infection may occur when succulent neck tissue is exposed at harvest. Infected umbels do not produce seeds (David and Irene 1966).

Control measures : It is advised to grow only coloured varieties and also avoid wounding during harvesting. Artificial curing of the bulbs should be

done. Warm dry air is forced through bulbs in bins until outer scales are quite free from moisture. This process reduces neck-rot as well as smudge and bacterial soft-rot. The blast phase of the foliage can be reduced by spraying Ferbam 0.2% (Walker, 1975). Spraying of fungicides as detailed under purple-blotch is applicable here also.

Smut, c.o. *Urocystis cepulae* Frost

Onion smut made its first appearance in Europe. A specimen of the fungus in the Persoon herbarium in France, collected around 1834, leaves no doubt about its European origin. The disease was introduced into the USA, India, Egypt, New Zealand and Canada. In the USA, the disease was reported from northern states (Walker 1975). The fungus is restricted to genus *Allium*, within which there are considerable number of susceptible species. Common hosts, besides onion, are *A. porrum* and *A. fistulosum*. The disease has also been reported from India.

Symptoms : Streaks appear on the leaves. Spots are seen even on cotyledons. On older leaves, spots are formed from tip to base. These lesions after sometime rupture and expose spores, which look-like black powder; infected plants die. In India, *desi* varieties are commonly attacked. Infection is through spores present on seeds and bulbs. Spores (chlamydospores) survive in soil for several years (Suryanarayana 1978).

Raut *et al.* (1984) observed symptoms due to severe infection in stored onions from Vidarbha on both white and colored onions. But conspicuous symptoms occurred only on white varieties. Onion scales show presence of smut. Black spore masses in sori contain teliospores. When such onions are planted, emerging seedlings contact disease *in situ* and serve as the primary source of inoculum. Infection in storehouses occurs through infected bulbs carried from the field, and spreads during cleaning operations. Storage under high humidity favours disease spread. No symptoms are observed during summer period.

The optimum temperature for teliospore germination, hyphal fragment germination and vegetative growth is between 13 and 22°C. Above 25°C, there is reduction in germination (Walker 1975). Disease initiation by seed-borne inoculum is doubtful, although spores are noticed on seeds as well as on bulbs. Seeds appear to be a means of spreading disease into newer areas.

Control measures : Seed treatment with Thiram (0.2%) is found promising (Larson and Walker 1953). Captan, Hexachlorobenzene (HCB) or Folpet (all at 0.2% concentration) are being used as substitute for Thiram. Granule formulation of fungicides (Thiram, Captan or Phaltan 50% a.i.) mixed with an insecticide and applied to soil by dribbling into furrows along with seeds has been found effective (Newhall and Brann 1960). Seed treatment with Thiram (0.2%) or Captan (0.2%) along with furrow application was also recommended (Singh 1992).

Onion-smudge, c.o. *Colletotrichum circinans* Berkley

The disease was first described by Berkley from England in 1851. It is common in Europe and United States. It occurs primarily on white-bulb varieties. Slight shrinkage and premature sprouting occurs in storehouses.

Symptoms : They are confined to scales and lower portions of unthickened leaves. Minute fungus stromata appear just beneath the host cuticle. They are dark-green at first and later with age become black. The stromata may be scattered promiscuously over the bulb surface or they may be congregated in smudgy spots around a few infection centres. The spots are roughly circular. On underlying scales, similar spots are seen surrounded by yellowish borders. Under humid conditions, pinkish fungal growth becomes visible on black stroma. In addition to *C. circinans*, other species, *C. chardoniana* Noila and *C. allii* Averena were also recorded to be pathogenic (Singh 1992). Optimum temperature for conidia germination is 26°C. The disease can develop from 10 to 32°C. Moisture is essential for conidial germination, and rain-drop splashes help in dispersal.

Control measures : Use of coloured onion varieties is the best method for control of onion-smudge as well as neck-rot. These varieties are resistant due to the presence of protocatehuic acid and catechol. Rafika *et al.* (2006) from Tunisia reported red onions with longer storage life than white ones. Storage life is correlated with dry-matter content.

The crop may be protected with fungicidal sprays (Zineb or Maneb @ 0.2%) to reduce inoculum load. Drying of bulbs before storage with hot-air at 37-48°C is a pre-requisite. Chemical treatment of bulbs before storage with 0.2% Thiram/Captan/Difolatan was also found promising. Artificial curing and storage environment are same as described under onion neck-rot.

The fungus was reported to cause severe curls or twister disease of onion seedlings from Patna (Sinha and Singh 1994). Whitish spots were observed on leaves, followed by acute chlorosis. The leaves curl or twist several times and result in stunting of plants. The disease was reported to be serious from Brazil and Nigeria. Seedling disease was controlled by two sprayings of Mancozeb (0.25%) at 15 days interval.

White-rot, c.o. *Sclerotium cepivora* Berk.

Berkley first described the disease from England in 1841. The first authentic record of white-rot was from North America in 1918. Since then it has been reported from Europe, Egypt, India, Ceylon, Australia, South Africa and New Zealand (Swaminathan *et al.* 2002). The host range includes shallot (*A. ascalonicum*), leek (*A. porrum*), welsh onion (*A. fistulosum*) and wild garlic (*A. canadense*), besides onion and garlic.

Chandra and Tandon (1964) recorded soft-rot of stored onions from Allahabad. The disease was found throughout the year. Symptoms appeared as dirty white-spots on the outer scales giving a water-soaked appearance to

affected area. Gradually spots increase in size and spotted region becomes soft. Finally whole bulb becomes pulpy.

Symptoms : They may appear at any time during the growing period. Fungus germination is stimulated by a thermo-stable substance released from *Allium* roots. Initial symptoms appear as yellowing and die-back of leaves, beginning at the tip and progressing downwards. A gradual decline of the plant may continue for some days or weeks. Coinciding with early symptoms, the disease appears on subterranean portions of the host-plant also. Roots and scales succumb to infection and become covered with white superficial fluffy mycelia.

A semi-watery decay destroys root and scales. By this time, black spherical sclerotia of pinhead size appear on the surface or are embedded within the decayed tissue. If bulbs are infected late, disease continues as a storage-rot (Walker 1975). Dhyani and Chauhan (1975) recorded heavy losses from Madhya Pradesh. An acid reaction of pH 6.0 and a soil moisture of 25% favour infection. Sohi (1977) observed incidence (up to 60%) in onion-bulbs (cvs Nasik Red, Bellary Red and Pusa selection) from Bengaluru.

Control measures : The disease can be controlled by containing sclerotial liberation from diseased bulbs. Disinfection and heavy manuring of soil helps in controlling disease in field conditions. Captan (0.2%), Thiram (0.2%) and Aureofungin (100 ppm) showed good control against storage-rot with 25% spoilage against 50% in control. Liming of soil reduces incidence.

S. rolfii is a non-specialized soil pathogen with a host range of over 500 species (Punja 1988). Storage utility is dependent on varieties.

Successful biocontrol of *S. rolfii*/*S. cepivora* with cultures of *Trichoderma* spp. was reported (Sreenivasa Prasad and Rao, 1993; Desai and Schlosser, 1999). The sclerotia were exposed to infection by *Trichoderma* spp isolates. by placing 40-50 sclerotia at the outer periphery of colonies grown on potato dextrose agar (PDA). After 24 hr of incubation at $25 \pm 1^\circ\text{C}$, *Trichoderma* overgrew sclerotia. Isolates of *T. harzianum*, *T. hamatatum* and *T. koningii* killed all sclerotia by penetration, followed by colonization and death of sclerotia.

Soft-rot, c.o. *Cephalosporium curtipes* Saccardo

This disease occurs on stored onions. The fungus produces dark-brown coloured rotting that spreads to interior tissues. Scales separate easily with application of a little pressure. Scales maintain their form, but rotting beginning becomes evident by the secretion of yellowish brown liquid (Sharma and Roy 1978). The disease is of minor importance.

Downy mildew, c.o. *Perenospora* sp.

Mirakhur *et al.* (1977) reported downy mildew from Kashmir. The disease is common in the north-eastern areas adjoining Himachal Pradesh and Jammu and Kashmir. Devlash and Sugha (1977) reported downy mildew and its impact on yield from Himachal Pradesh.

The disease is severe on seed-stalks than on bulb-crops. Onion-seed production was reported to be reduced by 60-70% in Punjab. The disease incidence was so high that many cultivators were compelled to abandon onion cultivation in certain pockets in Kashmir. The disease was observed to be severe after rains when temperature was $24 \pm 3^{\circ}\text{C}$ and RH was 80-85% (Gupta and Srivastava 1984).

Symptoms : They are noticed on foliage including stalks. Stalks bearing flowers wither and result in yield reduction. The bulbs become moist and spongy.

Control measures : Difolatan (0.1%) as well as Cuman (0.1%) protected standing crop against downy mildew and this increased yield.

Stemphylium-blight, c.o. *Stemphylium botryosum*
(*Pleospora herbarum* Pers. ex Fr. Rab),
S. vesicarium

Stemphylium-blight is an important seed- and soil-borne disease reported from Jharkhand and Haryana (Jakhar *et al.* 1994). *S. vesicarium* is normally a weak pathogen but assumes severe form during prolonged wet period. In Haryana, Gupta and Srivastava (2000) observed certain varieties resistant to the blight.

Control measures : Mathur and Sharma (2006) evaluated fungicides against *S. vesicarium* in Rajasthan, and observed seed treatment and foliar spray of Mancozeb (0.2%) effective in controlling the disease. Seed treatment (0.2%), root dip (0.1%) and foliar spray two times with 0.1% Hexaconazole reduced disease incidence.

Seed treatment, root-dip and two foliar sprays (0.2% each) with *Pseudomonas fluorescens* recorded lower disease index and increased crop yield. *P. fluorescens* and other bacterial epiphytes were reported to be effective for other diseases also (Barnwal *et al.* 2003).

Onion-seeds were dipped overnight in rhizobacterial formulation of *Pseudomonas fluorescens* (PF-1), prepared by suspending 20 mg of bacterial suspension in 1 ml of water. The treated seeds recorded reduced disease incidence and increase in yield.

Leaf extracts (aqueous) of plants like *Azadirachta indica* Juss and *Datura metel* Linn. were reported to be effective in lowering disease intensity (Prasad and Barnwal 2004). Effect of leaf extracts of different botanicals on the growth inhibition of pathogens *in vivo* were also reported (Datar 1994; Varshney 2001; Malick and Singh 2002).

Bulb-rot, c.o. *Geotrichum* sp.

Miller (1987) observed bulb-rot due to *Geotrichum* sp. from south Texas in United States. The inoculated bulbs developed small water-soaked translucent lesions after three days of incubation at 20°C . The disease is of minor importance in India.

***Penicillium-rot/blue mould-rot*, c.o. *Penicillium digitatum* Sac (Naik *et al.* 2008)**

This is considered as an important pathogen associated with storage-rot. *Penicillium-rot* caused by *Penicillium ducaluxi* was also reported (Gupta and Srivastava 1984).

Pre-harvest spray to the crop with SAFF (Carbendazim 12% + Mancozeb 63%) at 0.5%, 0.10% and 0.15% concentrations and Benomyl (Benlate) at 0.1-0.15% provided complete protection against blue mould. However, disease increased with storage duration (Raju and Naik 2006).

Rhizopus-rot caused by *Rhizopus stolonifer* was recorded by Gupta and Srivastava (1984) from Jaipur.

POST-HARVEST DISEASES MANAGEMENT

Post-harvest factors — field curing, grading, packing and transportation — determine quality of onion-bulbs. The length of the time required for curing depends on the weather factors. When temperature is low, bulbs are cured artificially. Onion-bulbs collected from fungicide-treated plots (sprayed with Bavistin 0.1% and streptomycin 0.02%) and stored in crates recorded minimum storage losses (Srivastava *et al.* 2001; Gupta *et al.* 2001). Pre-storage treatments with Thiram (0.2%), Ridomil Mz-7WP, Mancozeb + Metalaxyl 0.2%, and Captan (0.2%) were reported to be effective in improving seed and storage viability.

Sulphur and calcium carbonate treatments were also effective in preventing bulb-rot. High temperatures and long periods of pre-drying reduced rotting and sprouting significantly. Drying at 45°C for 48 hours at 15 days interval for 120 days was recorded promising (Lim *et al.* 2002).

BACTERIAL DISEASES

In Jaipur, highest magnitude of rotting (60% of total rotting) of onions was observed on account of bacterial rots (Gupta and Srivastava 1984).

Bacterial soft-rot, c.o. *Erwinia carotovora* f sp *carotovora*, *E. aroidea*

The disease was reported from different parts of the world, including India (Smith *et al.* 1966; Raju and Raj 1980). Onion is an important commercial crop in the Cuddapah district of Andhra Pradesh. It suffers heavy losses in storage. Rotting was common in the popular variety Bellary Big. Loss of 0.2-28% was recorded; considerable reduction in weight was also noted.

Symptoms : Two types of symptoms are noticed. In the first type, on removal of outer scales of apparently healthy onion-bulbs, rot of inner scales is noticed with large, irregular water-soaked areas (Fig. 24.2). Yellowish colour extends from neck downwards; foul smell is also produced. The rotting portions become slimy in advanced stages. And slimy liquid yielding bacteria oozes out when neck is pressed.

In the second type, on the removal of outer scales, soft-rot with large irregular dirty white water-soaked areas, extending from neck to base or *vice versa*, is observed. *Aspergillus niger* is also found associated with bacteria (Raju and Raj 1980). The disease is described in detail under soft-rot of potato and black-leg of crucifers.



Fig. 24.2. Bacterial-rot on onion

Sero-diagnosis of *E. carotovora* var. *carotovora* on onion-seed was made by Sendhilvel *et al.* (2002) from Tamil Nadu. Polyclonal antibodies specific to bacteria were produced to identify and detect pathogen by indirect ELISA.

Control measures : In the field, planting should be done in well-drained areas; by allowing sufficient space among plants for adequate ventilation. Over head irrigation should be avoided. Susceptible varieties should be rotated with cereals or other non-susceptible crops (Agrios 1969).

Debris should be removed from warehouses and walls should be disinfested with solutions containing formaldehyde, copper sulphate (1%) or mercuric chloride (1g in 1,000ml of water). Onions need to be dried properly before storage. Storage temperature should be around 4°C.

Biological control. Fluorescent *Pseudomonas* strain (FP 7) isolated from tomato rhizosphere showed promising results. Talc-based formulations of the antagonist, prepared by the method of Vidyasekaran and Muthamilan (1995), was used. In *in vitro*, *Pseudomonas* strain and *Bacillus subtilis* reduced growth of soft-rot bacteria. Seed treatment was effective in checking seed-borne *Erwinia carotovora* var. *carotovora*. Formalin at 2% concentration also checked *Erwinia carotovora* growth (Sendhilvel *et al.* 2005).

Bacterial stalk-rot, c.o. *Pseudomonas* spp.

Bacterial soft-rot of onion, caused by *Pseudomonas alliicola*/*Burkholderia gladioli* pv. *alliicola* and *P. capsici*, was reported by several workers outside India (Burkholder 1942, 1950). Hingorani and Malla (1951) from Delhi observed that most of the bulbs received in the IARI for trials were soft and emitted foul odour. On examination, they noticed bacteria, identified as *P. marginalis* (Brown) Steeven. Dowson (1941) also reported similar rots in onion and potato. Swarup *et al.* (1973) recorded stalk-rot due to *P. alliicola* (Burk.) Starr & Burk. from Uttar Pradesh, where the disease was restricted to seed-crop alone. Up to 90% of the affected plants showed rotting. Infection was noticed on onion Kalyanpur Red; 14-50% of flower-stalks recorded rotting. Ram and Swarup (1979, 1979 a) reported disease from Uttar Pradesh. The disease incidence ranged from 12.8 to 35.6% in seed-crop and 8.5-30% in bulb-crop of different onion varieties. Plant debris left in the field

acted as inoculum. The bacteria survive on bulbs and cause dry-rot during storage. Seed, soil and irrigation water do not play a role in disease cycle. Production of enzymes and toxins was also studied *in-vitro*.

Gupta and Srivastava (1984) observed that 30-40% of rotting was built in storage due to pathogenic organisms. Under favourable conditions (RH 99%, temperature around 30°C), rotting up to 80% was noticed. Among the pathogens recorded, bacterial-rot caused by *Pseudomonas* sp. was maximum, and covered 60% of the total rotting, followed by black-mould, *Aspergillus niger* (20%). Phytopathogenic species of *Pseudomonas* such as *P. tabaci*, *P. marginalis*, *P. glycinea* were also reported to produce toxins in *in-vitro* (Ceponis and Friedman 1959; Hoitink and Sinden, 1970; Srivastava *et al.* 2001).

Staglellini *et al.* (1990) from Venezuela observed bacterial disease affecting leaves and bulbs causing soft bulb-rot. The affected plants produced hollow bulbs, intermediate bulb scales and withered leaves with scorched appearance. *Pseudomonas solalacearum* and *P. cepacea* were isolated.

Control measures are as detailed under the bacterial soft-rot.

Bulb-decay, c.o. *Enterobacter coloacae*

The bulb decay was reported from Colorado (Schwartz and Otto, 2000) on sweet Spanish onion cultivars (*A. cepta* Linn.). Only mature and firm bulbs were infected. Symptoms associated with the disease are brownish discolouration and breakdown of inner scales.

Seed mycroflora

Wilcox and Balogh (1999) recorded following bacteria from onion in Nigeria — *Staphylococcus aureus*, *S. epidermis*, *Listeria monocytogenes*, *L. denitrificans* and *Micrococcus luteus*. During storage, *Listeria*, especially *L. monocytogenes*, became dominant on all cultivars. *L. monocytogenes* was frequently encountered on flesh and processed foods (Fuchs and Surendran, 1989; Hicks and Lund, 1991). In general, fungal contamination of onion cultivars was higher in the beginning of the storage. *Aspergillus*, *Rhizopus*, *Monilia* and *Geortrichum* species occurred both on the neck and body. Some potential mycotoxin-producing strains of *Penicillium* spp. viz. *P. griseofulvum*, *P. islandicum*, *P. viridicatum* and *P. cyclopium*, and *Aspergillus* spp. were also observed with prolonged storage.

GARLIC (*Allium sativum* L.)

Garlic is widely used for its medicinal importance. Red varieties are superior. Asia is the biggest producer of garlic. China ranks first, followed by Korea and India. Garlic is imported from China to meet Indian domestic demand. It is a carminative and gastric stimulant and helps in digestion and absorption of food. Besides all these, garlic is also used in reducing cholesterol

concentration in the blood, and is used in case of flatulence also. It is good for pulmonary tuberculosis, sterility and impotence, cough and red eyes (Saha 2003). It is widely used as an insect repellent.

FUNGAL DISEASES

Black mould-rot, c.o. *Aspergillus niger* Van Tieghem

The disease is reported from almost all states of India. Philip (1998) recorded it throughout the year from the local markets of Thiruvananthapuram(Kerala).

Symptoms : The fungus manifests itself with black copious growth. Dust-like fungal spores remain concealed between scales. In advanced stages, black copious mass of spores can be seen inside the bulb. The individual bulb shrivels and becomes light in weight. Infected bulbs have rotten smell. *A. niger* was also reported by Sharma and Sumbali (1993).

Control measures : Bulbs should be cured thoroughly and stored in cold storage at 60-70% RH. Irradiation of bulbs with gamma radiations(6 Krad) is suitable for long-term storage.

Rhizopus-rot/shrivelled bulb-rot, c.o. *Rhizopus oryzae* Went & Geerlings

The disease was reported from Rajasthan (Mathur and Sankhala 1963), Bhubaneswar(Rath and Mohanty 1978) and from West Bengal (Dasgupta and Mandal 1989). It causes much damage, especially during winter.

Symptoms : Affected bulbs become disfigured, shrivelled and turn into a pinkish mass. Sometimes dirty, white, fluffy mycelial mat develops on the surface. The disease is prevalent throughout the year. *R. oryzae* is a typical wound parasite and a storage pathogen. Due to infection, garlic-cloves get partially or completely rotten.

Control measures : Garlic bulbs for seed purpose are to be treated with 0.1% mercuric chloride or 0.03% formalin (if stored for table purpose) at periodic intervals of 10-15 days to avoid or minimize storage losses (Rath and Mohanty 1978).

Internal bulb-rot, c.o. *Macrophomina phaseolina* (Tassi) Goid.

M. phaseoli (Maubl.) Ashby

The rot due to *M. phaseolina* was reported from the USA (Alstatt and Smith 1943) and other countries. In India, it was reported from Uttar Pradesh (Chandra and Tandon 1965) on garlic-bulbs. Externally both diseased and healthy bulds appear similar. But on closer examination after peeling outer scales, black pinhead-like sclerotia become visible on the inner scales. Sclerotia are smooth, black and hard.

Symptoms : As the result of the infection, edible yellow fleshy portion of the scale gets reduced to a hard brown mass without usual pungent smell.

Scales become papery, dry, and slough-off easily (Garg and Chauhan 1981). Cross inoculation was successful with *Allium cepa*. The disease was also reported from Odisha and West Bengal (Rath and Mohanty 1978 a, 1989).

Control measures : Treating garlic-bulbs with 0.03% formalin or 2% boric acid immediately after harvest was promising in minimizing storage loss due to fungal infection (Rath and Mohanty 1978).

White-rot, c.o. *Sclerotium cepivora*, Berk. *S. rolfsii* Sacc.

The disease was first reported from the USA by Berkeley in 1841 (Asthana 1945). Thakur *et al.* (1962) and Kamat *et al.* (1977) recorded the disease from Uttar Pradesh and Maharashtra. The disease is favoured by a slightly acidic reaction and 25% soil moisture (Dhyani and Chauhan 1975).

Symptoms : The disease appears in the form of dirty, white-spots on the fleshy cloves. The spots increase in size with increased storage time. The cloves also turn brown, shrunken, light and hard. Tiny black sclerotia appear on cloves. This disease appears throughout the year. Severe infection is reported from July to October. It is difficult to assess correctly the loss due to hidden nature of infection.

Control measures as detailed under white-rot of onion are applicable here also.

Smut, c.o. *Urocystis cepulae* Frost

The disease was reported from Vidarbha (Raut *et al.* 1984). Severe infection on stored garlic and onion was noticed; 80% of the bulbs were infected. Bulbs (carried) from the field spread the disease during cleaning operation. No symptoms were noticed during summer. The disease spreads in stored onion under periods of high humidity only.

Seed treatment with Thiram (0.2%) is desirable. The bulbs should be cured properly.

Garlic-bulb canker, c.o. *Embellisia allii*

The disease was reported from Japan, Korea and Washington (Taniguchi *et al.* 1994; Lee *et al.* 2002; Dugan *et al.* 2004). In Australia in 1983-84, it was intercepted on garlic-bulbs imported from Hong Kong (Bertus 1984). The pathogen is not known to occur in India and pathogenicity in *Allium* spp. has not been studied. However Latha *et al.* (2007) observed interception of *Embellisia allii* on garlic-bulbs imported from China.



CHAPTER 25

Miscellaneous Vegetables

AMARANTHUS (*Amaranthus* sp.)

Amaranthus is an important leafy vegetable grown extensively in India. It is a rich source of many vitamins and minerals; serious pests and diseases are not reported on this crop.

FUNGAL DISEASES

Leaf-blight, c.o. *Colletotrichum capsici* (Syd.) Butler & Bisby

A severe leaf-blight of *A. caudatus*, locally known as Rajgira', was reported by Somani *et al.* (1976) from Akola. It is characterized by irregular, dark-brown spots on the leaf lamina, which later elongate along with the veins and veinlets. As the result of the development of the necrotic area on both the sides of the veins, leaf becomes brittle ultimately. The necrotic region becomes greyish black, on which many minute submerged pin-point acervuli are seen.

A. caudatus is widely cultivated throughout the plains of India as a garden, ornamental and pot-herb. Hill tribals cultivate this as a regular crop because of its edible grains.

Control measures are not generally practised.

Foliar-blight, c.o. *Rhizoctonia solani* Kühn

Thanatephorus cucumeris (Frank) Donk

The disease was reported from Asom (Baruah *et al.* 1985). and from Kerala on *A. tricolour* (Kamala Nayar *et al.* 1996).

Symptoms : Small, irregular whitish-cream spots appear on leaves in the greenhouse and in the field and they enlarge under high humidity. As the spots age, they become translucent and light-green with irregular margin. Severely infected leaves show shot-hole symptoms as the infected tissues get dislodged by air currents leading to defoliation. On the underside of the leaves, hymenial layer of *Thanatephorus cucumeris* is observed as a powdery mass. Infection is not visible on the plant stem (Gokulapalan *et al.* 2000).

Control measures : Green amaranth Co 1 is a resistant variety. Spray plants at weekly intervals, 14 days prior to harvest with Mancozeb@4 g/litre in cowdung supernatant (cowdung diluted with water) as fine droplets. The plants should be covered properly so that spray solution reaches undersurface of the leaves also.

The following fungi are also reported.

Alternaria alternata

Cladosporium cladosporioides, *F. moniliforme*, *Penicillium* sp.,

Phoma amaranthus, *Rhizopus oryzae* and *Trichoderma viride*

DRUMSTICK/MORINGA FRUIT (*Moringa oleifera* Lam.)

Moringa fruits at mature stage are considered a delicious and nutritious vegetable. Its flesh is rich in protein, vit. A , vit. C, minerals, crude fibres and phosphorus.

The fruit is affected by the following diseases only.

Corky lesion, c.o. *Fusarium acuminatum*

Lesions roughly ovoid, raised, and 0.2-0.3 cm in diameter appear on fully mature fruits. The upper portion is covered by carmine-red mycelial mass of fungus, and finally the rot becomes soft (Mandal and Dasgupta 1978) (Fig. 25.1).



Fig. 25.1. Mixed infection of *Fusarium* and *Rhizopus* on drumstick

Avoid injuries to the fruit at the time of harvest. Cold storage at 10°C is promising in controlling storage rots.

Distal-end rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs

Infection appears in the form of water-soaked lesions on the young fruits. Infected fruits emit out characteristic smell. Rahman *et al.* (2001) studied physico-chemical composition of healthy and diseased fruits at different maturity levels. Total sugar, starch and vit. C content were reduced due to infection. Enzyme catalase and protease activity increased but of polyphenol oxidase and ascorbic acid oxidase decreased remarkably.

Avoid injuries to the fruit at the time of harvest. Cold storage at 10°C is effective in controlling storage rots.

LADY'S FINGER/OKRA/BHENDI
(*Abelmoschus esculentus* (L.) Moench.)

Okra is a popular vegetable cultivated all-over India, and it is used in daily diet by majority of Indians. The fruits are rich in pectin and also contain iron and calcium. They are mucilaginous in nature, and are commonly used for thickening soups, stews and sauces.

FUNGAL DISEASES

Dry-rot, c.o. *Aspergillus flavus* Link. ex Fries

The disease was reported from Madhya Pradesh (Jain *et al.* 1982). Infection starts from the apical end, resulting in complete drying of the fruit within 10-12 days. The mouldy growth of the fungus is clearly visible on the fruit surface. Refrigerated storage at 10°C is promising.

Cottony-leak, c.o. *Pythium butleri* Subram.

P. aphanidermatum (Edson) Fitzp.

Mandal and Dasgupta (1981) recorded it as the most serious disease of lady's finger, prevalent in West Bengal. The infection is serious from March to September in wet weather, particularly in borer damaged or injured fruits. Philip (1998) recorded fruit-rot from the local markets of Thiruvananthapuram.

Symptoms : Water-soaked lesions appear around broken areas. The rot advances rapidly and within 3-4 days whole fruit becomes slimy and rotten. Scanty white growth of the fungus is also visible, and fruits emit offensive smell. Singh (1992) recorded *Phytophthora palmivora* also. The disease spreads fast through contact and causes decay of entire lot at high humidity, coupled with temperature around 30°C. At later stages, *Pseudomonas fluorescens*, *Erwinia herbicola* and *Enterobacter* sp. hasten rotting. The former two were recorded weakly pathogenic (Dasgupta and Mandal 1989).

Control measures : Bruised or injured fruits should not be used for storage. The fruits should not be tightly packed in gunny bags or kept in a heaped position during the wet weather. Sprinkling of water over fruits should also be avoided. The fruits should be spread out, not touching one another. Storage of fruits at 10°C is promising.

Grey blight-rot, c.o. *Sclerotium rolfsii*, Sacc.

Rhizoctonia solani Kühn

The disease was recorded from West Bengal.

Symptoms : Water-soaked dull areas appear, lacking in lustre, with white thick stranded oppressed and rough cottony mycelial growth over the host surface (Fig. 25.2). At high humidities, sclerotical knots or mustard-like reddish-brown hard sclerotia appear. Affected fruits are devoid of its natural odour. The infection spreads by contact (Dasgupta and Mandal 1989). Philip

(1998) observed similar symptoms on *bhindi* fruits in the local markets of Thiruvananthapuram during rainy season from April to July. Typical mycelia and sclerotia were observed. The fungus grows faster and covers the fruit within 3-4 days.



Fig. 25.2. *Rhizoctonia*-rot on lady's finger

Seedling blight due to *R. solani* was recorded by Suryanarayana (1978) as an important disease in India. The pathogen causes failure of germination. It also causes root-rot and blight on other parts. Sometimes seed-crop is heavily infested. The variety Pusa Sawani is highly susceptible. The disease was observed in a severe form in the seed-production plots of Karnal. Root system and the stem up to a considerable height are affected. Fruits are seriously damaged and seeds are covered with mycelia and sclerotia. Seed infection is both external and internal.

Control measures: Hot-water treatment at 50°C for 30 min, followed by protective dressing with Thiram (0.2%), are recommended. Seeds should be procured from disease-free areas. Areas with heavy infection should not be used for raising seed-crop for at least 3-4 years. Infected fruits should not be mixed with healthy fruits.

Mucor-rot, c.o. *Mucor hiemalis* Wehmer

Philip (1998) observed the disease from the local markets of Thiruvananthapuram during the south-west monsoon period. 'Nest rot' type of symptoms are noticed. Fruits can be seen clinging together in clusters. This is usually noticed when fruits tightly packed in gunny bags are released/unpacked. Fruits become water soaked and get covered with profuse mycelial growth (Fig. 25.3).



Fig. 25.3. *Mucor*-rot on lady's finger

Control measures : Fruits should not be kept in a tightly packed position. Refrigerated storage at 10°C is promising.

***Fusarium*-blight, c.o. *Fusarium* sp.**

Seed-borne infection was recorded (Suryanarayana 1978). Infected seeds often fail to germinate. If seedlings emerge, they get blighted. Seed-borne infection is both superficial as well as deep seated (Gangopadhyay and Kapoor 1977). Seed treatment with Thiram (0.2%) is effective in controlling infection.

Hema *et al.* (1991) reported Carbendazim and Triflumizole effective as slurry against *Fusarium* spp.

Patel *et al.* (2004) noticed efficacy of seed treatment with Bavistin, followed by Agrozim, Derosal and Pausin-M (@ 2g/kg of seeds) against okra-wilt under field conditions.

Seed-rot, c.o. *Phoma destructiva* Plower

Pankaja (1983) observed seed-rot due to *P. destructiva* on seed samples of *bhindi* collected from Mysore. About 8-30% infection was recorded. Considerable variation in the length of plumule and radicle was also observed.

Seed treatment with Captan (0.2%) or Thiram (0.2%) is found effective.

Pod-spot, *Ascochyta abelmoschi*

The disease was reported from the USA and Brazil. In India, it is common in Himachal Pradesh. Its symptoms appear on leaves and fruits. The disease spreads by fruit borers. Infection is seed-borne. It also survives on infected crop tissues, lying in the field (Suryanarayana 1978). An *Ascochyta* sp. causing pod-rot with an ash-grey centre was also recorded by Singh (1992). In advanced stages, fruits shrivel and dry-up.

Seed treatment with Captan (0.2%) or Thiram (0.2%) is effective.

Colletotrichum* fruit-rot, c.o. *Colletotrichum capsici* (Syd.) Butler & Bisby, *C. hibisci

Both fungi are recorded to cause fruit-rot (Singh 1992). Sanitation and spraying with Zineb, Maneb or Captan (all at 0.2%) in fields control the disease.

Seed mycoflora

Seed-borne fungal pathogens have a major role in seedling diseases and cause considerable losses to crop. The fungi include the following.

Fusarium oxysporum, *Pestalotiopsis versicolor* Pattnaik and Narain, 2000
Aspergillus tamari, *A. flavus*

Okra seeds showed infection range of 61-74%. At higher moisture levels (7.5-10%), this was more compared to seeds stored at 5% moisture level. Cell-free culture filtrates of *C. capsici*, *F. solani* and *F. oxysporum* reduced seed germination, and seedling, shoot and root growth. In controlling seed-borne fungi, fungicides Bagallol, Mancozeb and Thiram (all at 0.2%) proved effective.

Other fungi included are:

Alternaria alternata

Aspergillus columnaris, *A. flavus*, *A. fumigatus*, *A. niger*

Botryodiplodia theobromae, *Colletotrichum dematium*

Curvularia lunata, *Chaetomium globosum*

Fusarium moniliforme,

F. solani, *F. oxysporum*, *F. pallidoroseum*

Macrophomina phaseolina, *Rhizoctonia solani*

} Mashooda
Beegum *et al.*, 2003

| | | |
|--|---|-------------------------------------|
| <i>Rhizopus stolonifer</i> <i>Trichothecium roseum</i> <i>Colletotrichum capsici</i> <i>Alternaria alternata</i> , <i>A. solani</i> , <i>F.oxysporum</i> , <i>F. solani</i> <i>Phomopsis vexans</i> , <i>Macrophomina phaseolina</i> <i>Aspergillus</i> spp., <i>Phoma</i> sp. <i>Curvularia lunata</i> <i>Rhizopus</i> spp. | } | Thippeswamy <i>et al.</i> , 2004 |
|--|---|-------------------------------------|

Seed treatment with fungicides is practised for controlling seed-borne infection.

Carbendazim (Bavistin) and Chlorothalonil (all at 0.25%) were found effective against most of the seed-borne pathogens. But were ineffective for *A.alternata*. Triflumizole (0.30%) was promising against *A.alternata* (Hema *et al.* 1991).

Seeds treated with Thiram and stored in polythene bags remained viable for longer periods compared to seeds stored in cloth-bags (Vijaykumar, 2001). Dithane M-45 and Captan(all at 0.2%) are also effective in inhibiting seed-borne pathogens and in increasing seed germination.

Effect of seed treatment along with biocontrol agents was reported from Haryana. Bavistin, Benlate, Captan, Dithane M-45, Ridomil MZ, Vitavax@ 2g/kg and commercial formulation of biocontrol agent *Echoderma* (*T. viride*@ 4g/kg of seeds) enhanced seed germination and reduced seedling infection. Seed leachate and seed extract of okra are also reported to inhibit spore germination of *F. oxysporum*, *Alternaria alternata* and *A. niger*(Shrisail *et al.* 2002, 2002 a). Indofil M-45 and Captan (0.2% each) are also reported to be effective in inhibiting seed-borne pathogens — *Macrophomina phaseolina* and *A. alternata*.

The concept of plant growth promoting rhizobacteria (PGPR) for promotion of plant growth is gaining worldwide acceptance. Mashooda Beegum *et al.*(2003) reported effectiveness of PGPR isolates and tested them against seed-borne fungal diseases and evaluated their potential against seed-borne diseases of okra. Among the different bacterial isolates, *Bacillus pumilus*, *B. pasteurii*, and two strains of *B. subtilis* were observed to be effective in improving crop growth in greenhouses and in fields. The colonization of these bacterial strains reduced incidence of seed mycoflora, and thus indirectly enhanced percentage of seed germination and vigour index of seedlings.

Biological control. Continuous use of seed-dressing fungicides causes pesticidal hazards and environmental pollution. Gurjar *et al.* (2004) recorded biocontrol agents like *T. harzianum*, *T. viride*, *Gliocladium virens* and *Pseudomonas fluorescens* effective. Seeds were coated with sporulating cultures of these biocontrol agents for 2 hours, dried in shade and used for planting in the field. Treated seeds exhibited increased germination and reduced seedling mortality.

Biocontrol agents besides mycoparasitizing, also act as aggressive competitors to the pathogen. Production of antibiotics by biocontrol agents has also been reported. Mixing of seeds with biocontrol agents (commercial formulation of *Trichoderma*) helps controlling seed-borne infections.

Control of seed-borne fungi with *Pseudomonas fluorescens* and with an aqueous leaf extract of *Lawsonia inermis* was also reported. Complete inhibition of *A. flavus* and *Macrophomina phaseolina* was shown. But inhibition was less to *A. niger* and *F. moniliforme* infection (Beebi and Rasheed 2007).



CHAPTER 26

Spices and Condiments

GINGER (*Zingiber officinale* Rose.)

Ginger is one of the important spice crops of India, known for its medicinal properties. The crop is cultivated in all the agroclimatic zones from Himachal Pradesh to Kerala. A gap of 4-5 months exists between the harvesting and the subsequent planting in the succeeding season. During this period, the seed-rhizomes are stored by farmers in the conventional pits. Storing seed-rhizomes results in 34% post-harvest losses and also reduces quantity and quality of seed-ginger (Sharma and Dohroo 1982).

FUNGAL DISEASES

Soft-rot/rhizome-rot, c.o. *Pythium* spp., *Fusarium* spp.

Soft-rot of ginger is a serious disease, threatening ginger cultivation, and is reported to be of worldwide occurrence. In India, the disease was first reported by Butler (1907) from Gujarat, followed by Subramanium (1919) from Bihar and Uppal (1940) from Bombay. It was also reported from Ceylon (Park 1941). *P. aphanidermatum* is considered as the common pathogen associated with soft-rot.

The disease was recorded in 1949 from Wyanadu, Kerala (formerly Tamil Nadu) which is situated at an elevation of 1,000 m amsl (Ramakrishan 1949). The fungus was identified as *Pythium vexans* de Bary. Sahare and Asthana (1962) reported *P. monospermum* and *P. gracile* in addition to *Pythium* species, mentioned earlier. Haware and Joshi (1974a) during a survey in Madhya Pradesh observed the disease to be widespread. Pre-emergence and post-emergence damping-off were commonly observed. Isolations from infected plants were *P. deliens* Meurs, *P. zingiberum* (Ichitani and Goto 1982), *P. pleroticum* (Dohroo and Sharma 1985) and *P. myriotylum* (Mathur *et al.* 1992; Lodha *et al.* 1994). Along with *Pythium* spp., several species of *Fusarium* like *F. solani*, *F. moniliforme*, *F. oxysporum* and *F. equiseti* were also found associated (Rosenberg 1962; Dohroo 1972; Haware and Joshi 1972; Rath *et al.* 1978; Dohroo, 1988; Mathur *et al.* 2002; Dohroo 2001). Besides these, *Verticillium* and *Chlamydosporium* were reported (Dohroo 1989; Ram *et al.* 2000; Dohroo 2001).

Chauhan and Patel (1990) studied etiology of rhizome-rot and observed *P. aphanidermatum* and *F. solani* together or separately responsible for rotting. Combined infection by both resulted in rapid drying of fruit shoot, followed by rhizome rotting.

Symptoms : Initial symptoms are visible on leaves. Soon entire foliage turns yellow, followed by drying and withering. This ultimately results in plant death. Dead leaves droop and hang along the stem. The basal portion becomes water-soaked, soft and later gets shrivelled. The symptoms are also noticed on rhizomes. They become discoloured and gradually

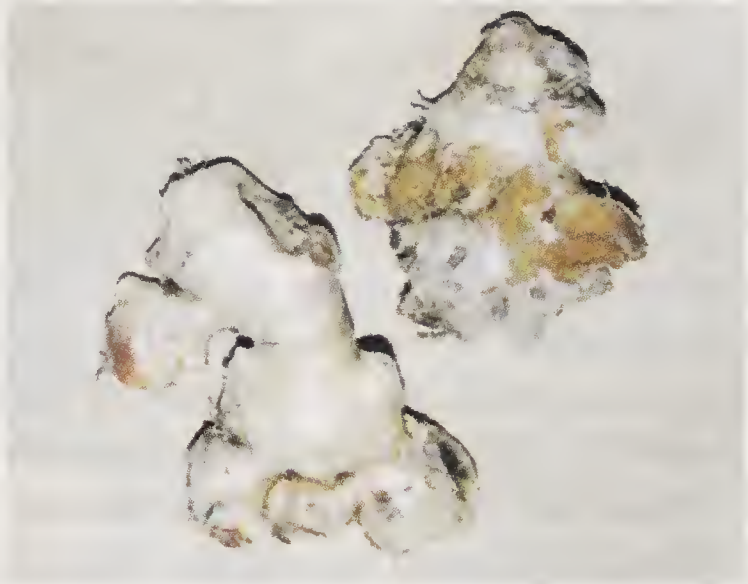


Fig. 26.1. Mixed infection of *Fusarium* and *Pythium* on ginger

rot (Fig. 26.1). The roots also show rotting. The infected rhizomes continue to rot in storage also. The disease is severe in fields where drainage is poor. Storage-rot is considered complex as it is soil-borne as well as seed-borne.

In Himachal Pradesh, conventional pits of different sizes ranging from 1 to 5 metres are used for storage. These pits are exposed to varying temperatures and relative humidities (12-18°C, 60-80% RH). It is observed that storage temperature and relative humidity are directly correlated with the rot. Three types of symptoms are generally noticed (Dohroo 2001).

- **Soft-rot**, c.o *P.ultimum*: The surface of the diseased rhizomes turns brown to black, followed by maceration of tissues, leading to decomposition of rhizome with fibro-vascular strands remaining as such.
- **Dry-rot**, c.o *F.oxysporum*: The affected rhizomes show no external symptoms. Internal tissues become brown and yellow. Discolouration is seen in the rhizome pith region. Tissues become black.
- **Red-rot**, c.o *V.chlamydosporium*: The affected rhizomes show superficial mycelial growth and internal tissues become discoloured.

Indrasenan and Paily (1982) collected rotten specimens from Amblavayal (Kerala) and studied pectic enzymes role in tissue maceration. Dohroo (1989a) observed rise in peroxidase and polyphenol oxidase activities three days after infection by *P. pleroticum* and *F. equiseti* (dry-rot), followed by a sharp decline. Polyphenol activity was not detected in healthy rhizomes.

A technique for rapid detection of vegetative hyphal body (VHB) on a selective isolation medium is also available from Japan (Shimizu and Itchitani, 1982). This helps in easy identity of an isolate for undertaking control measures.

The host range of the pathogen includes beans, peas, balsams, spinach, carnations and barley. Highly resistant or immune plants include carrot, chrysanthemum, cabbage and zinnia (Ichitani and Konyo 1981).

In the rhizome-rot of ginger as well as in turmeric, association of maggots of Dipteran fly *Mimegralla* was noticed. Etiological studies under controlled conditions indicate *Pythium* to be the primary pathogen and maggots as the secondary colonizers of dead tissues (Anandaraj and Sarma 2000).

Control measures : The pathogen is seed- and soil-borne. Disease management of rhizome-rot by soil solarization and pesticides was reported (Balakrishnan *et al.* 1994; Mathur *et al.* 2002). Disease in the field is positively correlated with its occurrence in storage. Siddiqui and Kaushal (2001) observed positive correlation between incubation period and storage-rot. Medium nitrogen and low potassium were effective in reducing disease incidence (Rao *et al.* 2004). The following control measures are also suggested.

Evolving/screening resistant varieties. Dohroo (1989) tested 10 cultivars and observed SG 66 to have the lowest disease incidence by *F. oxysporum*, which caused seed transmission, pre-emergence rot and yellows in ginger. Screening of ginger varieties against rhizome-rot complex/yellow disease caused by *F. oxysporum*, *F. solani* and *F. equiseti*, showed only variety ZO 16 to be resistant from Odisha (Senapati and Sugata 2005).

Pre-treatment of rhizomes with chemicals. Sundaram (1955) recorded efficacy of mercuric chloride and wettable ceresan as seed treatment chemicals. Seed-rhizomes treated with Dithane Z-78 (0.15%), Perenox (0.3%), BM (0.4%), Ceresan (0.25%) and mercuric chloride (0.1%) showed disease suppression in the field (Sahare and Asthana 1962). Rath *et al.* (1978) recommended seed treatment with Arasan and soil fumigation with Trizone to be effective under warm and humid storage conditions in Odisha. Due to the ban on mercury compounds, efforts are concentrated on systemic and non-systemic fungicides. Dohroo and Sharma (1983) studied efficacy of chemicals under storage experiments in pits against wet-rot caused by *P. pleroticum* and dry-rot (*F. equiseti*), and observed maximum control with Antracol (0.25%). Antracol is recommended as it is of low toxicity and is found to control both storage rots in Solan (Himachal Pradesh). Rhizomes are dipped in fungicidal solution for 30 minutes. Dipping in fungicidal suspension of Bayleton (Triadimefon), Fenaminosulf, Difolatan (Captafol), Syllit (Dodine), Ridomil (Metalaxyl) is effective in reducing infection by *P. aphanidermatum* and *F. solani*. Seed treatment with Metalaxyl formulations, followed by soil drench for about one month after sowing gave control of rhizome-rot caused by *P. aphanidermatum* (Rathaiah 1987; Ramachandran *et al.* 1989). Similar results with Metalaxyl were also reported from Gujarat. Metalaxyl formulations and Bordeaux mixture (3,000 ppm) gave best inhibition of *Pythium*-rot and *Fusarium*-rot respectively when used singly or in combination (Chauhan and Patel 1990). In Himachal Pradesh,

Dohroo and Paramer (1993) observed pre-storage treatment of rhizomes with Dithane M-45 or Captan for 60 min effective in inhibiting rhizome sprouting, surface shrivelling and discolouration.

Soil solarization and pesticides also recorded as an effective field treatment for managing rhizome-rot (c.o., *P. aphanidermatum*) (Balakrishnan *et al.* 1994; Mathur *et al.* 2002). A combination of treatments with Dithane M-45 (0.3%) + Bavistin (0.2%), followed by *T. harzianum* (slurry treatment in cowdung) were reported effective in managing storage-rots (Dohroo and Negi 2000).

Treatment of seed-rhizomes with Mancozeb (0.3%) and drenching seed-beds with cheshnut compound or with 1% Bordeaux mixture or 0.3% Mancozeb was also reported (Anon. 2007).

Biological control measures. Ghorpade and Ajri (1982) studied effectiveness of different oilseed cakes. All of them reduced disease incidence in the field and increased yield. The disease incidence was significantly suppressed by pelleting or by amendment in the field just before sowing with *Trichoderma* species. *T. viride* suppressed rhizome-rot caused by *P. myriotylum*, but was ineffective to *Fusarium solani* under *in-vitro* conditions due to activity of volatile and non-volatile substances produced by antagonists. The growth of the pathogen was inhibited completely. The oogonia formation was also inhibited.

Several biocontrol agents (BCAs) like *T. harzianum*, *T. aureoviride*, *T. longibrachiatum* and rarely *Gliocladium virens* are reported to protect through production of volatile and non-volatile diffusible antibiotics or through mycoparasitism (Lodha and Webster 1990; Lodha *et al.* 1994). Rhizomes pelleted with BCAs and sown in the field showed their establishment in the field to be several folds higher. Significantly higher number of sprouts, lower disease incidence, and higher yields were also recorded. *T. viride* was observed more effective than *G. virens*. Both *Trichoderma* and *Gliocladium* are known as potent antagonists to fungal pathogens (Papavizas 1985). The effect of resident biocontrol agents for seed treatment was also studied. Rhizosphere establishment and proliferation of BCAs applied on seeds for suppression of soil-borne diseases were also reported (Elad *et al.* 1982; Mukhopadhyay *et al.* 1992; Clique and Schffer 1996; Ram *et al.* 2000).

Balakrishnan *et al.* (1994) reported efficacy of *T. viride*, *T. harzianum* I, II, *T. hamatum* and one isolate of *G. virens* in comparison to Dithane M-45. Seed germination was uniform in all the treatments. But less disease incidence and increased yield were recorded from biocontrol-treated plots. Pre-storage treatment of rhizomes with Topsin-M as well as Dithane M-45 or Bavistin, followed by *T. harzianum* slurry treatment showed promising results (Dohroo and Negi 2000). Dohroo (2001 a) studied population dynamics of naturally occurring *T. harzianum* Rifai and observed its antagonistic potential against rhizome-rot.

Effects of *Trichoderma*, fluorescent pseudomonads and their combination in disease suppression were also reported (Beena and Sarma 2000).

The role of different chemicals, especially COC (Fytolan 0.5%), as well as use of *T. harzianum* (cfu 9.9×10^8 /g @ 5 ml injected into pots with hypodermic syringe) against management of ginger diseases (*Pythium* sp., *Fusarium oxysporum* and *Ralstonia solanacearum*) in Sikkim was noticed (Rajan *et al.* 2002).

Rhizomes treated with 0.3% Mancozeb and inoculated with native arbuscular mycorrhizae/*Trichoderma viride*/*Pseudomonas fluorescens* (commercial preparations) and planted in beds previously treated with cheshnut compound/ Bordeaux mixture (1%)/ Mancozeb (0.3%) showed good results (Anon. 2007).

An integrated strategy for soft-rot management is required. This includes use of disease-free planting material, seed treatment with chemicals/pelleting with BCAs, adoption of suitable cultural practices, isolation and destruction of infected plants, providing adequate drainage, soil solarization and chemical control measures in combination with bio-antagonists.

Ginger-yellows, c.o. *Fusarium oxysporum* Schlecht

Ginger-yellows was first recorded by Trujillo (1963) from United States. Wilting occurs due to vascular infection by the fungus. The disease is common in the ginger-growing areas of Madhya Pradesh (Haware and Joshi 1974a). It is characterized by yellowing of leaves and wilting of adult-plants, thus leading to poor yields. The fungus causes rhizome-rot and post-emergence death of seedlings. Primary infection occurs from infected rhizomes. Sharma and Dohroo (1990) recorded occurrence and distribution of fungus causing ginger-yellows from Himachal Pradesh. *F. solani* and *F. oxysporum* were also reported from Jhansi and Sikkim (Siddique and Kaushal 2001; Rajan *et al.* 2002).

Five species of *Fusarium* were recorded. Among these isolates, *F. oxysporum* is the major cause of yellows in all ginger-growing areas, followed by *F. solani*, *F. moniliforme* (*Giberella fujikuroi*), *F. graminearum* (*G. zae*) and *F. equiseti*. Variability in *F. oxysporum* f sp *zingiberi* was also reported (Dohroo and Sharma 1992); among the three isolates, Isolate I was more aggressive and caused 100% mortality of plants in the field and 87.5% rhizome-rot during storage, followed by II and III, which caused 60 and 80% mortality and 10-25% rhizome-rot under storage (after 14 and 15 days of inoculation).

Rhizome treatment with Benlate (0.25%), followed by foliar spray of Dithane M-45(0.3%), was reported to be effective in controlling rhizome-rot and pre-emergence death of seedlings (Haware and Joshi 1974a).

Creepy white rhizome-rot, c.o. *Sclerotium rolfsii* Sacc.

The fungus grows superficially on the infected rhizomes. Rarely internal infection is also noticed. Sundaram (1951, 1953) recorded the disease from Tamil Nadu and Mehrotra (1952) from Allahabad. *Fusarium roseum* Link. is also associated under Allahabad conditions. During rainy season, ginger-rhizome gets covered with white aerial growth. It is considered as an

occasional, secondary or wound invader of ginger-rhizome. The disease is reported from Maharashtra (Rao 1968) and West Bengal (Dasgupta and Mandal 1989) and from Kerala (Philip 1998). It is prevalent throughout the year and has maximum intensity during rainy season. The affected rhizomes become moderately soft and the tissues below become water-soaked, brown and sunken.

Sundaram (1955) recorded dipping of rhizomes in mercuric chloride (1: 1,000) solution and wettable sulphur promising.

Black-rot, c.o. *Memnoniella echinata*

Sharma and Joshi (1976) recorded disease from Madhya Pradesh. Infection goes unnoticed in the early stages. But the infected rhizomes soon dry-out, get shrivelled and become grey-black to jet-black with black spore masses at the infection site that present a sooty appearance. The disease is of minor importance.

**Dry-rot, c.o. *Macrophomina phaseoli* (Maubl.) Ashby
Fusarium sp.**

The disease was reported from Kasaragod (north Kerala) (Sharma and Nambiar 1974). The rot persists in storage. Affected plants have slight yellowing of leaves in the initial stages, and in advanced stages, whole plant presents a blighted appearance. Unlike soft-rot, stem base does not decay and plant does not snap away at the collar region on a slight pull. During advanced stages, rhizomes appear shrunken and inner tissues show discolouration and start disintegration. Later rhizome inner core shows dark sclerotia adhering loosely to fibrous tissues. The affected tissues does not exhibit any wet-rot; rhizomes only shrink and dry-up. Hence it is termed 'dry-rot'. Treatment of seed-rhizomes with Topsin-M (0.2%) for 60 minutes is effective in controlling infection.

Internal dry-rot, c.o. *Botryodiplodia theobromae* Pat. (*Diplodia natalensis*)

The disease was recorded on the dried ginger samples from Alleppey (Kerala). Infection of rhizome results in blackish discolouration in internal tissues. Tissues later become more or less powdery, consisting of dark-coloured fungus mycelial bits intermingled with fibrous strands of the host material. Early infection is not visible by external appearance. In advanced stages, rhizomes become shrunken and dry (Wilson and Balgopalan 1971).

Control measures : Ginger should be dried properly before storage. Moisture limit of dried ginger should not go beyond 7%.

Red-rot, c.o. *Nectria inventa*

The disease was reported from Madhya Pradesh (Sharma and Joshi 1976) and Himachal Pradesh (Dohroo and Paramar 1993). It is characterized by

small, irregular shiny light-brown patches, which turn dark-brown to brick-red. The scales become papery and peel off easily. Rhizomes become dry and shrunken.

Geotrichum-rot, c.o. *Geotrichum candidum* Link.

The disease was reported by Mishra and Rath (1998) from the local markets of Bhubaneswar (Odisha). The fungus caused complete rotting of inoculated ginger in 15 days at 25°C and 100% RH.

Grey-rot, c.o. *Trichurus spiralis*

The disease was reported from Madhya Pradesh (Sharma and Joshi 1976). Infection starts from the rhizome cut-end or other wounds, ending in dry-rot. Numerous greyish black bristle-like synnemata develop on the infected surface, and sometimes entire rhizome gets covered by fungal mass.

In addition to the above mentioned diseases, rhizome-rots due to *Acremonium killense* Grütz (Sharma and Joshi 1976) and *A. strictum* W.Gams (Sharma and Jain, 1977) were also reported from Jabalpur. Fungal rots due to *Aspergillus niger* and *A. flavus* were also reported.

BACTERIAL DISEASES

Bacterial wilt, c.o. *Ralstonia solanacearum* (Smith 1896)
(Yabuuchi *et al.* 1996)
Pseudomonas solanacearum (Smith 1896)
Smith 1914

The disease causes extensive losses in ginger production in India and many other tropical countries. Its outbreak is associated with planting of seed-rhizomes with latent infection (Indrasenan *et al.* 1982). The pathogen is recorded as seed-borne (Hayward 1991). The disease was reported from Sikkim also (Rajan *et al.* 2002). No effective chemical or biocontrol methods are available for reducing its spoilage during storage. Shanmugam *et al.* (2002) identified ambient storage temperature detrimental to the pathogen, and studied survival of *R. solanacearum* in ginger-rhizomes at different temperatures. Rhizomes stored at 15°C and above were completely rotten. Even storage at 4°C could not completely eliminate bacteria.

Control measures : Management of wilt in hilly areas of Darjeeling was achieved with antibiotic terramycin (500 ppm) given as a seed protectant. Streptocycline and chloramphenicol at 500 ppm were effective (Ray *et al.* 2004).

Soft-rot, c.o. *Erwinia* sp.

The disease was reported from Queensland, Australia (Pegg *et al.* 1974). An unspecified rot was also reported from Kasaragod, Kerala (Anon. 1974).

Storage studies

Storage rots affect availability of healthy seed-rhizomes to farmers. Different fungi are found associated, affecting rhizome health during storage. Pre-storage rhizome treatment with Topsin-M (0.2%) for 60 minutes reduced storage-rot incidence, loss in rhizome weight, and increased rhizome recovery from storage pits.

TURMERIC (*Curcuma longa* L.)

Turmeric is an important constituent of condiments and spices. It is used in wool and silk industries, and is also a component of ayurvedic medicines. Storage of turmeric is a problem.

FUNGAL DISEASES

Rhizome-rot, c.o. *Pythium* spp.

The disease was first reported from Sri Lanka. Since then, it has been recorded from several parts of the world. In India, the disease was reported from Andhra Pradesh and Tamil Nadu (Rama Krishnan and Sowmini 1954). In Asom also the disease was reported on turmeric cultivars obtained from Andhra Pradesh (Rathaiah 1982). The fungus was identified as *P. myriotylum* Drechsl.

The study has shown that in addition to *P. aphanidermatum*, which is the common pathogen, other species like *P. graminicolum* and *P. myriotylum* also cause infection. Rhizome-rot is also reported to be caused by *Fusarium solani* (Dohroo 1988).

Symptoms : The disease is first recognized by dehydration and yellowing of lower-most leaves; similar to ginger. Irregularly dry patches develop on the leaf blade that gradually wilts. The base of the pseudostem becomes water-soaked and readily breaks away from the rhizome when pulled out. Toppling of affected tillers also occurs. In certain cases, youngest unfolded leaf rots, starting from the base. Such plants remain stunted and die slowly. At harvest, affected rhizome is left as a shell with fibrous tissues inside. Contaminated seed-rhizomes serve as the primary inoculum for turmeric rhizome-rot in the main field.

Control measures : Use of resistant cultivars. Cultivars Mydukur, Tekurpet and Duggirala are highly susceptible and Ca 69 and Shillong are resistant in Asom. The rhizome-rot resistant cultivars are also immune or tolerant to leaf-spot caused by *Taphrina maculans*.

Dipping seed-rhizomes in Ridomil (0.2%) along with soil drenching with Ridomil at the first appearance of symptoms considerably reduced rhizome-rot. Significant increase in yield was also reported. Treatment of rhizomes with Mancozeb 0.25% after harvest and before planting was reported to be effective against rhizome-rot caused by *P.graminicolum*.

Biological control. Reddy *et al.* (2002) established suppressive role of antagonistic microorganisms like *T. harzianum*, *Gliocladium* spp. against *F. solani* through *in-vitro* studies by dual-culture method and by VAM pot culture experiments. Among them, *T. harzianum* was most effective. VAM-treated plants also showed reduced disease incidence. Organic amendments were reported effective in managing rhizome-rot caused by *Fusarium* sp. Vermi compost @ 0.4 tonne/ha, followed by spraying with Carbendazim 0.1% was reported minimizing disease incidence and maximizing yield (Uma Devi 2008).

**Cottony white-or pink-rot, c.o. *Fusarium moniliforme* Sheldon
F. solani (Mart.) Sacc.**

Cottony white-or pink-rot is common in Himachal Pradesh during early summer (Dohroo 1985) and on the freshly harvested produce in the markets of West Bengal (Dasgupta and Mandal 1989).

Symptoms : The rot starts from the stem-end of the rhizomes or on the wounded areas. The infected tissues become slightly pale and softened. This region is covered by sparse to dense white or pink mycelial growth, depending on the presence of *F. moniliforme* or *F. solani* with a characteristic smell.

Control measures : Biocontrol measures mentioned under rhizome-rot (c.o. *Pythium* spp.) are applicable here also.

***Sclerotium*-rot, c.o. *Sclerotium rolfsii* Sacc.**

Sclerotium-rot of turmeric is regarded as a serious problem in Guntur district of Andhra Pradesh.

Symptoms : Rhizomes get partly dried and shrunken and become light weighed compared to normal ones. When cut open, a characteristic cavity with profuse mycelial growth can be noticed. Sclerotia with profuse mycelia are noticed abundantly on the surface of the affected rhizomes.

Control measures : Treatment of seed-rhizomes soon after harvest with fungicides, Ceresan wet (0.25-0.5%) or Aretan (0.5%) or Mercuric chloride (0.1%), was found promising (Reddy and Rao 1973).

Storage-rot/*Aspergillus*-rot, c.o. *Aspergillus* spp.

Turmeric is generally stored in heaps, where temperature ranges from 30 to 32°C. This is in contrast to open atmosphere temperature (25-38°C). With the advancement of rains, rotting occurs. Up to 70% rotting was reported due to several *Aspergillus* species (Sharma and Roy 1984). The most important one was *A. flavus*. Maximum rotting occurs at 35°C and no rotting was observed at 15°C. Similarly rotting is maximum at high humidity. *A. flavus* grows best at 35°C. This results in shrivelling and cracking of rhizomes and fungus enters through this. Turmeric rhizomes should be dried to a moisture limit of 7%.

The other fungi associated with storage-rots include the following.

Cladosporium cladosporioides (Fres) de Vries

Cephalosporium acremonium

Sharma and Roy, 1984 a, 1986.

Dreschlera tetramera

Fusarium culmorum, *F. nivale*, *F. oxysporum*

Macrophomina phaseolina (Tassi.) Goid.

Together these fungi caused 100% infection and showed decay (22-25%) of rhizome tissues after 21 days of inoculation. They are the most virulent ones and could penetrate and establish infection through intact host tissues. Other fungi isolated could spoil only 7-15% of tissues. Temperature of 28-32°C coupled with 60% RH provide most conducive environment for maximum fungal spoilage.

Macrophomina phaseolina and *Cladosporium cladosporioides* were the most virulent and widespread fungal pathogens. Temperature of 28-32°C coupled with 60% RH or more provided the most conducive environment for the maximum spoilage of rhizome tissues by both the pathogens (Sharma and Roy 1986).

Kumar and Roy (1990) observed maximum post-harvest rotting in September and minimum during May in Delhi markets. The fungi associated included the following. *Aspergillus flavus* Link. ex Fries; *A. niger* Van Tieghm; *Cladosporium cladosporioides*; *Drechslera* (*Leptosphaeria*) *rostrata*; *Fusarium moniliforme* (*Giberella fujikuroi*); *F. oxysporum*; *Macrophomina phaseolina*; *Pythium aphanidermatum*; *Rhizoctonia solani* (*Corticium rolfsii*).

The post-harvest pathogens associated with turmeric decay as recorded from the markets and storage godown of Odisha (Naik *et al.* 2004) included the following: *Aspergillus flavus*, *A. niger*; *Fusarium moniliforme*, *F. solani*; *Rhizopus* spp.

The conidial germination of these fungi was maximum within the 25-30°C with 100% relative humidity. Fungicides, Sixer (0.3%), Carbendazim and Mancozeb, were effective in reducing storage rots.

Koul and Sumbali (2008) observed *Aspergillus flavus* on dried ginger and turmeric. Analysis revealed presence of aflatoxin B₁ and B₂ in varied concentrations.

Control measures : The rhizomes for seed-purpose should be dried properly under shade and should be treated with Mancozeb (0.25%) after harvest and before planting. Ginger and turmeric for medicinal purposes should be dried to a moisture level of 7% and should be kept in air-tight containers. The dried rhizomes can be kept under cold storage (0-22°C and 60-70% RH) or irradiated with 6 Krad of gamma rays.



Part – C
MANAGEMENT OF POST-HARVEST
DISEASES OF TROPICAL ROOT /
TUBER CROPS

CHAPTER 27

Tropical Root/Tuber Crops

TAPIOCA/CASSAVA (*Manihot esculenta* Crantz.)

Cassava / tapioca is considered an important tuber-crop in the tropics. It is rich in carbohydrate and low in saturated fat, cholesterol and sodium. The trends in terms of area and production are observed high for cassava compared to other root crops due to its high demand as food, feed, and as a source of ethanol. It has attained the status of a commercial crop, especially in Tamil Nadu and Karnataka.

Storage rots are common problems in cassava. Certain cultivars are more susceptible to root-rots than others (Lozano and Terry 1976). The roots cannot be kept fresh for more than 3-4 days after harvest unless proper precautionary measures are taken care of. Two types of deteriorations, physiological and pathological, are generally noticed (Booth 1973; Anon. 1974, 1975).

Storage rots exhibit a rapid post-harvest physiological deterioration (PPD), and this occurs within 24-72 hours after harvest. PPD is an enzymatically mediated oxidative process with parallels to plant wound and defense response; in which reactive oxygen species (ROS) together with enzyme systems and compounds that modulate them play the central role (Beeching *et al.* 2006). It involves changes in gene expression, protein synthesis and accumulation of secondary metabolites. Research on the generation of transgenic cassava with improved nutritional traits and longer storage potential is on-going (Owiti *et al.* 2006).

The primary deterioration commences immediately after harvest and becomes visible in less than 48 hours. At this stage, tubers develop bluish vascular streaks, which are mainly due to biochemical and physical changes. This deterioration is closely followed by microbial deterioration. Among microorganisms, *Penicillium*, *Aspergillus*, *Rhizopus*, *Bacillus* species and yeasts are the dominating ones (Amla and Sankar 1975).

During storage, Maini and Balagopalan (1978) observed reduction in starch, hydrocyanic acid and drymatter and increase in total sugars. Dehydration resulted in cracks on the rind, followed by invasion of microorganisms. Biochemical nature of the primary deterioration is not fully understood even though a close association between polyphenol oxidation catalysed by polyphenol oxidase and vascular streak formation was reported

(Padmaja *et al.* 1980, 1980a). This finding was also supported by Plumbley *et al.* (1981). Secondary deterioration is caused by release of several enzymes by pathogens (Balagopalan *et al.* 1980). Enzymes are cellulase, amylase, pectin esterase (PE), polygalacturonase (PG) and polygalacturonate transeliminase (PGTE). These enzymes cleave polysaccharides of tubers and thus make available free sugars. These sugars may further support growth and multiplication of microorganisms (Padmaja *et al.* 1982). Maximum degrading enzyme activities were detected on the fourth and sixth days of storage.

Balagopalan and Padmaja (1985) also studied changes in cassava-tubers after storage for eight weeks. Tubers were stored in soil pits as well as in sand pits. Reduction in dry matter, starch, HCN and an increase in sugar content were recorded in tubers stored in soil pits as well as in sand pits.

Rapid perishability of harvested cassava-tubers is a serious factor limiting its utilization potential. Techniques to store cassava-tubers in the fresh state are essential for increasing its food and feed use as well as for expanding industrial uses of cassava-tubers.

Fresh cassava-tubers dipped for one minute in 2.2% aqueous emulsion of a fungicidal wax (petroleum wax), drained and dried could be stored at room temperature for 16 days with a wastage of 10% (Subrahmanyam and Mathur 1956; Subramanyan *et al.* 1958).

Insecticides and fungicides like methyl bromide, formalin, hypochlorites were also suggested for storing tubers. However, none of these extended the shelf-life beyond five days.

Cold storage is reported to be effective. Majumdar *et al.* (1956) stored tapioca-tubers for about 6½ months at a temperature of 32-35°F and RH 85-90%.

Madhavan Pillai and Sreemulanathan (1969) observed that under controlled conditions of relative humidity, tubers could be preserved up to 2-3 months. Earthenware pots having saturated humidity can be used as storage containers. Effect in storage of preservation media like sand, soil, moist saw dust was also well studied (Madhavan Pillai *et al.* 1970; Balagopalan and Padmaja, 1985). Tubers free from damage were stored in pits containing sand, soil and sawdust in various proportions. Tubers were interlayered with moist preservation medium. This helped in increasing shelf-life by a month without affecting cooking quality. Biochemical changes monitored during storage indicated only slight decrease in starch content and moderate increase in sugar content.

Small quantities of tubers can be preserved for several days by using simple techniques such as reburial, or coating with mud or placing them under water. Burying tubers in trenches or covering them with soil or a mixture of straw and soil gave good results (Ingram and Humphries 1972). Booth (1975) was able to store tubers up to three months in field clamps similar to those used for storing potatoes in Europe. It was reported that cassava could be

stored in boxes with moist saw-dust at room temperature. Cassava roots like many other root and tuber crops could be cured at temperature from 25 to 40°C (Lozana and Terry 1976). Storage studies carried out by Raja *et al.* (1978) showed that cassava-tubers showed better resistance to spoilage when stored at suitable environments — high and constant RH (<86%) and temperature not more than 27-28°C. Restricted aeration in the storage system also helped retain freshness of tubers. Under such conditions, tubers can be stored for a limited period even without any chemical preservatives.

Sreemulanathan *et al.* (1980) studied efficacy of wooden chambers and vacuum desiccators as storage containers. They found that weight loss could be reduced in wooden chambers and vacuum desiccators.

The possibility of using cassava-leaves as an interlaying material for large-scale storage of tubers was investigated by Aiyer *et al.* (1980). Storage with fresh leaves of cassava for 2-3 days is a local practice in Thiruvanthapuram. Clamp storage method was studied in which leaves were used as interlaying material and damage of tubers was assessed in comparison with control. It was found that after 28 days of storage, almost 68% of tubers remained undamaged.

Efficacy of dipping cassava tubers in Mertec (Thiabendazole) solution, followed by packing in polythene bags was studied (Anon. 1985). These tubers retained their freshness up to two weeks. Balagopalan and Padamaja (1985) developed a storage system to prolong shelf-life of cassava-tubers. Moist laterite soil, river sand and saw dust were used as the medium for preservation of tubers. Tubers free from damage with intact neck portion were used. Pits of 61 cm × 61 cm × 61 cm dimensions and packed with a layer of moist medium (35-45% moisture) were used. The selected tubers were spread in pits with alternate layers of moist medium. The moist medium prevented cassava-tubers from dehydration, controlled aeration and slowed down various enzymatic activities in the tubers, which ultimately prevented deterioration. The study helped prolong shelf-life of tubers by a month without affecting their cooking quality. Tubers kept for a week did not show changes in nutritional properties, like moisture, acidity, protein, lipid, carbohydrate, total sugars, ash and calorific value (Sahore *et al.* 2007).

The effect of pre-packing materials like plastics bags and film wraps was also studied well (Oudit 1976). Prasad and Neelakantan (1985) provided ventilation by punching holes on the surface, tied with twine threads and stored at room temperature. Quality parameters like colour, vascular streaking, appearance, odour, shelf-life and organoleptic qualities were evaluated. Pre-packing in polythene bags gave an acceptable shelf-life up to 120 hours depending upon the varieties. Vascular streaking and weight loss were also minimized (Data *et al.* 2002). Packing in polyethylene bags with 16 holes (2mm dia/hole) was reported to increase shelf-life of roots up to 10-14 days. For prolonged storage, dipping undamaged roots in Thiabendazole (0.4%) for

5 minutes is also recommended. Crate is also observed as a better transport container than straw-sacks.

Cassava-tubers are commonly stored in the form of dry chips. Tubers are either sliced and dried or parboiled and then dried in the sun. This is practised by farmers in Kerala. But these chips stored in gunny bags are often spoiled by fungi, bacteria and insects (Balagopalan *et al.* 1974; Balagopalan and Nair, 1976; Balagopalan and Padmaja, 1985). The predominant fungi were *Rhizopus*, *Penicillium*, *Aspergillus*, *Fusarium* and yeasts (Thankappan 1994). Insect damage is also considerable. Nature and extent of damage caused by insect-pests, *Aracerus fasciculatus*, *Sitophilus oryzae* and *Tribolium, castaneum*, on stored cassava-chips was also studied (Ramla Beevi *et al.* 1980).

Tapioca chips dipped in 0.5% sodium hypochlorite (NAOCI) for 2-3 minutes, washed with freshwater and dried at 70°C were found to have shelf-life up to 90 days as compared to 25 days shelf-life of untreated chips. Bacterial load also reduced considerably in treated chips (Nair *et al.* 1976).

Effect of storage period on the moisture content and insect infestation in dried cassava-chips and cassava-flour stored in different packaging systems was also studied in Thiruvananthapuram (Anon.1986); moisture content increased in both the cases. Polythene-lined jute bags were found superior to other packing materials for storage of cassava-chips and flour.

Drying systems for tuber chips (artificial dryers) are also available. But fuel cost is high. This can be overcome if combined or complemented with solar heat/and or heat from agricultural waste. Such a system has been developed at the Central Tuber Crops Research Institute, Thiruvananthapuram. The system consists of a double cylinder vertical drying chamber, an agricultural waste burner, a cyclone separator and a blonder. These components are accommodated in a shed; the roof of which is used as a flat-plate solar collector. Provisions are made in the system to draw heated air either from the solar collector or from the burner or from both at regulated proportions. The system can dry 2m³ of cassava or other tuber-chips in one batch (Kurup and Nanda 1994).

FUNGAL DISEASES

***Rhizopus*-rot, c.o. *Rhizopus* spp.**

The occurrence of *Rhizopus* sp. and *Bacillus* sp. in cassava causing root discolouration and increased acidity was reported from the Central Food Technological Research Institute, Mysore (Majumdar 1957).

Due to microbial infection, tubers become soft, discoloured and develop undesirable odour (Booth, 1976). In advanced cases, root surface gets covered with white cottony growth of the fungus and its black sporangia heads. Balagopalan *et al.* (1980) reported secondary deterioration due to *R.oryzae*. Philip (1981) also recorded *R. arrhizus* and *Mucor hiemalis*.

As control measures, avoid wounds and bruises on the tubers. Injured tubers should not be kept for more than 12 hours under ambient conditions.

***Botryodiplodia*-rot, c.o. *Botryodiplodia theobromae* Pat.**

The disease is very common in tropical countries. The fungus is a wound pathogen. Mechanical injuries accelerate infection.

Symptoms : Infected tubers may appear healthy externally; skin may be wrinkled. Blackish white growth of the fungus is visible on the cut ends. Internal tissues become soft and brown. Infection continues and finally root becomes mummified (Figs 27.1, 27.2). Numerous pycnidia may be observed on the surface. The fungus survives on crop debris, especially as pycnidia on stem-cuttings used for planting (Philip 1998).

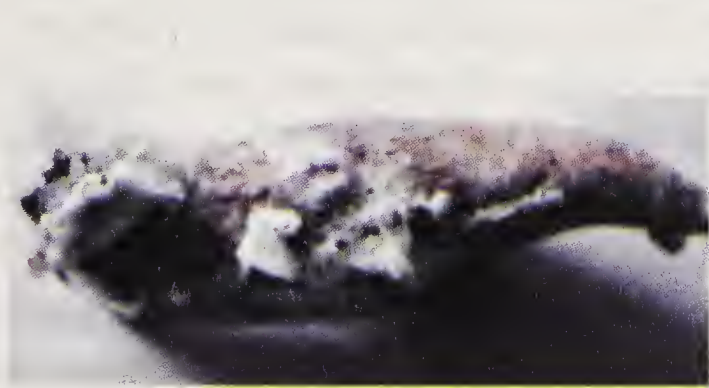


Fig. 27.1. *Botryodiplodia*-rot (advanced stage) on tapioca

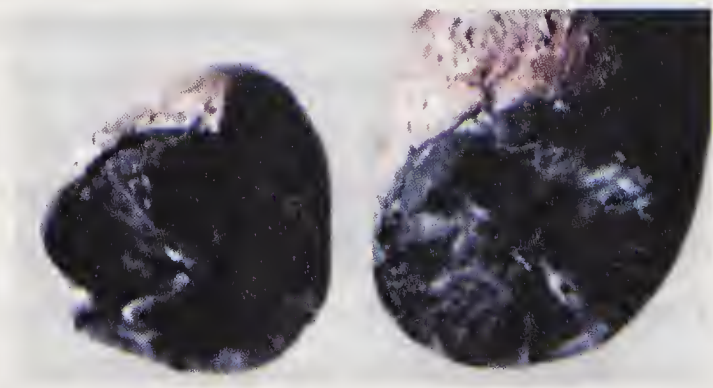


Fig. 27.2. *Botryodiplodia*-rot (Cross section) on tapioca

Set-rot due to *Diplodia natalensis* (= *B. theobromae*) was also reported.

Control measures : Wounds and bruises on tubers should be avoided. Use of healthy planting material is the best means to control the disease occurring on stem-cuttings/sets. Dipping cuttings in any of the fungicidal solutions (Benlate 0.1%, Bavistin 0.1%, Vitavax 0.1% or Thiram 0.2%) for 15 minutes, followed by drying in the shade and then planting in the field (Sivaprakasam *et.al.* 1976) are effective in checking disease in the field.

Dry-rot, c.o. *Fusarium solani* (Mart.) Sacc.

Dry-rot of cassava-tuber was reported from Tamil Nadu (Sivaprakasam *et al.* 1977; Johnson *et al.* 2000).

The infected tubers are usually hard, and colour of the pulp instead of being white varies from brown to reddish-brown and dark-brown. Streaks are seen inside the tubers. Diseased tubers are unfit for consumption. Dry-rot is the characteristic. But under humid conditions, white mould growth with soft-rot symptoms are also recorded. The fungus survives in the soil, and infection occurs through mechanical injuries. *F. dimerum* was reported to be associated predominantly (Jayashree *et.al.* 2002).

As a control measure avoid wounds and bruises on the tubers. Injured tubers should not be kept for more than 12 hours under ambient conditions.

Phytophthora-rot, c.o. *Phytophthora drechsleri* }
P. erythroseptica } from Africa
P. cryptogea }
P. palmivora Jayashree *et al.* (2002) from India

Along with *Phytophthora* several other fungi were also observed.

Tuber-rot caused by *Phytophthora* is an important disease and causes severe losses to farmers. The rot is noticed at the time of maturity (Oliveros *et al.* 1974; Snowdon 1991; Johnson and Palaniswami 1999; Johnson *et al.* 2000).

The disease was recorded from Namakkal taluks around Salem in Tamil nadu. Its incidence was high and caused 48.5% tuber yield loss.

Symptoms : Dark, round to irregular water-soaked lesions appear on mature tubers. Rotting continues during storage. White mycelial mat of the pathogen develops around the lesions. The lesions enlarge in size and cause internal browning. Oozing of internal fluid and shirvelling of the tubers are also noticed. Infected tubers emit a characteristic smell, and rot continues for 5-7 days (Jeeva *et al.* 2008).

Control measures : Application of neemcake @ 250 kg/ha and incorporation of a native strain of *Trichoderma* (10^6 /ml) multiplied on sorghum-grains when applied to soil controlled effectively the disease (Jeeva *et al.* 2008).

Biocontrol of the disease with a fluorescent *Pseudomonas* (Pf) isolated from urdbean was also reported. Its efficiency was tested against the pathogen in *in-vitro*. Application of bacterial cultures to soil significantly reduced disease incidence. Carbendazim application appeared less effective in contrast to Pf treatment in reducing disease incidence and in increasing tuber yield (Jayashree *et al.* 2002).

OTHER DISEASES

Tuber-rots caused by different fungi are as follows.

| | |
|------------------------------|------------------------------|
| <i>Aspergillus niger</i> | Kanaujia, 1979, Philip, 1981 |
| <i>A. flavus</i> | |
| <i>Corticium rolfsii</i> | |
| <i>Trichoderma harzianum</i> | Snowdon, 1991 |
| <i>Pythium</i> spp. | |
| <i>Pythium myriotylum</i> | |
| <i>Rhizoctonia solani</i> | Jayashree <i>et al.</i> 2002 |
| <i>Sclerotium rolfsii</i> | |

BACTERIAL DISEASES

Bacterial soft-rot, c.o. *Xanthomonas campestris* pv. *manihotis*

Lozano (1987) reported biocontrol of root-rot pathogens like *X.campestris*, *Pythium* spp. and *Diplodia natalensis* with bacterial antagonists, *Pseudomonas putida* and *P.fluorescens*.

Bacterial soft-rot caused by *Erwinia carotovora*, was also reported. Philip (1981) reported *Bacillus subtilis* and *Enterobacter aerogens* on deteriorated tubers. The disease is of minor importance.

Sequence of occurrence of microflora

Among the microorganisms, *R. arrhizus* and *M. hiemalis* occurred as initial colonizers, followed by *Aspergillus* spp. and *Fusarium* sp. *B. theobromae* appeared at the terminal stage of rotting and by the seventh day it completely enveloped tubers with its luxuriant mycelial growth. Bacteria are also observed at the final stages. Ultimately tubers become soft, discoloured and turn brownish with an unpleasant odour (Philip 1981).

SWEET-POTATO (*Ipomoea batatas* (L.) Lam.)

India is the largest sweet-potato producing country in the South-Asia. The crop is grown throughout the country as a secondary food crop. It is subjected to several forms of post-harvest losses like physical damage, weight loss, pathological decay, sprouting and weevil infestation.

Sweet-potato is harvested by digging out tubers. This results in bruises and damages. Damaged tubers show symptoms of rotting during storage. The affected tubers can be recognized easily by water-soaked appearance and mushy decay with a mild alcoholic odour (Anon. 1982). The tubers are cured by spreading in the sun for about seven days and storing in well-ventilated rooms (Nanda 1984). Weevil-infested sweet-potatoes should be discarded from storage.

Sweet-potato tubers stored under ambient conditions without any prior curing sprout. The crop is subjected to physical damage, weight loss, pathological decay, sprouting and weevil infestation (Ray and Balagopalan 1997).

Farmers store tubers up to four to five months. The common method of storage in Odisha is to dig a pit or heap graded tubers. The heap is then covered with paddy-straw and plastered with mud or cow-dung slurry (Anon. 1989). The tribal farmers of southern Odisha store tubers by adopting a clamp method of storage up to six months during comparatively cooler periods of November to March. In this method, tubers are heaped in a corner of their hut, near the wall, covered with a layer of paddy-straw, followed by plastering with soil-cowdung mixture. The huts are usually dark and cool inside even during the day time.

Storage studies conducted at the International Potato Centre, New Delhi, showed that weight loss of roots stored for 30 days could be reduced from 25.73 to 7.94% by storing them in sand. After 90 days, weight loss was 16% (Dayal *et al.* 1990). Mukhopadhyaya *et al.* (1991) studied storage of tubers with locally available materials like sawdust, red earth, earthen pot, wood ash, white sand, local earth and waste carbon-paper for 90 days and observed local earth as the most economical medium for storage. But marketable tuber recovery was more with waste carbon-paper.

Storage of sweet-potato tubers without deterioration is usually difficult because of heavy infestation by weevil *Cylas formicarius* Fab. Harvested tubers may contain any of the weevil stages. Tubers heaped on the floor of a godown and completely covered up to 5-cm depth with dried earth or wood-ash were observed to be free of weevil infestation on dehydration for two months (Rajamma 1984).

Sprouting is not observed under chilling and cold storage. Under chilling (storage temp. 10-15. 5°C, RH 80-85%) in the pre-cooling chamber of the cold store, sweet-potato tubers could be maintained in good condition for a storage period of 45 days with a marginal increase in total sugars. Under cold storage, internal necrosis and tuber decay were observed within 15 days of storage (Anon. 1983).

Curing and storage practices are difficult under Indian conditions. Storing sweet-potato in beds of sand or soil is suitable for restricting rotting and weevil infestation (Ray *et al.* 1994). Curing induces suberization of exposed parenchyma cells, and this helps in the development of a wound-periderm. Storage of tubers at approximately 90% RH and temperature of 26-30°C is ideal for curing and wound healing.

Hydro-warming or dipping tubers in hot-water maintained at 40-45°C for 5-10 minutes showed promise (Ray *et al.* 1994).

Pre-harvest foliar spray of malic hydrazide and cycocel resulted in suppression of sprouting in tubers. Tubers stored under evaporative cool chamber were of longer shelf-life (Shedge 2009).

FUNGAL DISEASES

***Rhizopus-rot*, c.o. *Rhizopus* spp.**

The disease has been reported from several countries including India (Ramsey *et al.* 1959; Coursey and Booth 1972; Rao 1966; Sinha and Prasad 1986; Dasgupta and Mandal 1989).

Rhizopus-rot is the most common and important storage disease of sweet-potato. *Rhizopus nigricans* and *R. stolonifer* are commonly found associated. The host range studies indicated that potato, tomato, dioscorea and apple are also infected by this pathogen.

Symptoms : The infected tubers quickly turn soft and moist at both ends. Symptoms develop only after fleshy roots are harvested or occasionally in the field following flooding. The tubers develop wet- or dry-rot depending on the humidity. When skin ruptures, a straw-coloured liquid drips out. And when the skin is intact affected tubers lose moisture and become shrivelled and mummified. On the surface of the affected tubers, thick tufts of superficial mycelia and black fruiting structures of the pathogen are seen. Maximum infection occurs during harvest.

Addy *et al.* (1987) studied metabolic aspects and observed significant increase in protein, OD phenols and total phenols after eight days of infection. They noticed that the DNA content of the tubers remained constant for two days and then showed a declining trend. The possible role of pectolytic and cellulolytic enzymes in roots colonized by *R. stolonifer* was recorded by Srivastava *et al.* (1959). Proteolytic enzymes role in pathogenesis was also well documented (Balasubramoniam 1972). Ray and Balagopalan (1997) observed phenol accumulation by *R. oryzae* in storage. Infected tubers exhibited five times more phenol accumulation than uninfected tubers, and this suggests that the fungus contributes partly to phenol pool of infected tubers.

Control measures : Among the 50 varieties tested by Thankappan (1994), 10 lines showed resistance to *Rhizopus*-rot. Careful handling of tubers during harvest and transport so as to avoid wounding and proper curing of roots before storage essential. Storehouses are to be thoroughly cleaned and walls and floor washed with 2.5% solution of copper sulphate. The temperature and the relative humidity are to be maintained at 26.5-30°C and 90%. This condition should be maintained for 10-14 days during which rapid healing of wounds occur. This should be followed by storage at 13°C and RH 85-95%.

As a chemical treatment, 2, 6, dichloro-4-nitroaniline has been approved for use on sweet-potatoes in the USA with 10 ppm tolerance. When it was applied at 3-4 ppm, the chemical was highly effective in preventing soft-rot development (Martin 1967).

Java black-rot, c.o. *Botryodiplodia theobromae* Pat.

Of all the storage-rots of sweet-potato in India, Java black-rot is the most significant one.

Symptoms : Infected tissues are at first yellowish brown and fairly firm and later become dark-black. After 6-8 weeks, affected roots show dark patches externally. Numerous pycnidia develop internally. The tissues turn yellow and later become coal-black. Finally roots shrivel, become brittle and mummified (Ray *et al.* 1994 ; Ray and Misra 1995).

The isolates from the infected tubers differed slightly in their physiological and cultural characters. Infections occurred at harvest and during subsequent handling and transportation. Like all post-harvest pathogens, the inoculum of *B. theobromae* is present in air and soil. Wounding predisposes tissues to infection. Maximum decay (98.8%) of stored sweet-potatoes occur at 30°C; decrease in storage temperature means less decay. The fungus grows best between 28 and 30°C.

Control measures : Post-harvest losses can be substantially reduced by storing tubers below 25°C. High relative humidity favours rotting, and it was appreciably high up to 85% RH but decreased gradually below 70 %. Storage below 70% RH is reported to be effective. Phenol accumulation in tubers was also recorded (Ray and Balagopalan, 1997).

Since tubers are mostly used as a food commodity, application of fungicides should be mostly avoided. Alternately, hydro-warming i.e. dipping tubers in water at 40-45°C for 5-10 minutes has been recorded as effective in controlling rots (Ray and Balagopalan 1997).

Black-rot, c.o. *Ceratocystis fimbriata* Ell. & Halst.

The pathogen is an ascomycetous fungus. It was previously known by synonyms *Ceratostomella fimbriatum* (Ell.& Halst.) Elliot, *Ophiostoma fimbriatum* (Ell. & Halst.), *Sphaeronema fimbriatum* (Ell. & Halst.) Sacc. and *Endoconidiophora fimbriata* (Ell. & Halst.) Davidson

Historically, black-rot is recorded as one of the significant diseases of sweet-potato. Black-rot is the common name used for the decay of fleshy roots, and is also applied to symptoms that occur on the sprouts and vines in the field. The disease can cause severe losses in storage, or in plant beds in the field.

Symptoms : Fleshy storage roots infected by black-rot pathogen develop firm black-rot. Externally symptoms appear grey to black when dry, and dark-greenish black when moistened. The periderm remains intact on the over-decayed cortical tissues. Lesions enlarge but do not usually extend below vascular ring, unless they are invaded by secondary organisms. The lesions are usually centred on wounds, lenticels or lateral roots. When infected tubers are used as seed material, symptoms develop on the emerging plants. Below ground portions of the sprouts may rot or may have numerous cankers, The cankers are also dark black and sunken. Secondary symptoms may vary depending upon the severity of the infection and may include stunting, wilting, yellowing, drooping of leaves and in some cases death of sprouts. The symptoms are similar to those produced by *Fusarium* stem canker (Clark and Moyer 1988). Black-rot can develop over a range of environments, and optimum temperature for development is 23-27°C.

Control measures : Sanitation, rotation and careful sorting of tubers before storage are essential for containing the rot. Washing tubers in 1 % solution of Borax is effective in controlling infection. After sun-drying for an hour, the roots are placed in aerated containers and stored in properly ventilated rooms. Seed treatment with Thiabendazole (0.1%) was recommended in the USA. Proper curing at 30-35°C and at 85-90% RH for 5-10 days immediately after harvest reduced incidence of infection (Clark and Moyer 1988).

Another black-rot, c.o. *Cochliobolus lunatus* (*Curvularia lunata*), was reported by Ray and Balagopalan (1997) from Thiruvananthapuram. When fresh tubers are inoculated with the mycelium of *C.lunatus*, tubers become swollen and spongy within 8-10 days and flesh turns brown, and finally black. Usually this disease is confused with black-rot caused by *Ceratocystis fimbriata*.

***Fusarium*-rot, c.o. *Fusarium* spp.**

Fusarium-rot is common in areas where sweet-potatoes are stored for longer period. The disease was reported by Harter and Weimer (1919), Martin

and Persoon (1951), Moyer *et al.* (1982) and Clark and Moyer (1988). The incidence is more in temperate climate. The causal agents are *F. oxysporum* and *F. solani* (Clark, 1992); *F. pallidoroseum* was also reported (Ray and Balagopalan, 1997).

Symptoms : The rot is noticed on fleshy storage roots. Occasionally this occurs prior to harvest on roots that have been mechanically injured by growth-cracks or by feeding of nematodes, insects or rodents. Surface rot lesions are circular, light to dark-brown, firm and dry. They usually do not extend into root beyond the vascular ring. When infected roots are stored for extended periods, tissues within and around the lesions dry and become shrunken. The root eventually becomes hard and mummified.

Fusarium spp. that cause disease of sweet-potato can persist in the soil for several years, primarily as chlamydospores. Strains of *F. oxysporum* and *F. solani* that cause surface-rot and root-rot enter roots only through wounds formed during harvesting, and during storage, root-rot develops. But the disease does not spread to other roots in storage unless new wounds occur on the infected roots. *F. oxysporum* does not spread from infected mother roots to sprouts, but *F. solani* can spread in this manner and can cause stem canker.

Control measures : Hydro-warming of the tubers *as detailed under the Java black-rot is applicable here also.*

Charcoal-rot, c.o. *Macrophomina phaseoli* (Maubl.) Ashby

The disease is common in the USA and other parts of the world (Dhingra and Sinclair 1978). In India, it was reported from Maharashtra (Patel *et al.* 1949 in Bilgrami *et al.* 1979) and from West Bengal (Mandal and Dasgupta 1980).

The fungus was once thought to be sterile and was named *Sclerotium bataticola* Taub. (Syn. *Rhizoctonia bataticola*). It produces pycnidia as well as sclerotia, and is now recognized as *Macrophomina phaseoli*. The fungus is soil-borne and survives as sclerotia.

Symptoms : They develop from cut- end. Symptoms begin as reddish brown, firm moist-rot, initially restricted to the cortex of the storage root from the cut end. As the decay progresses, pathogen crosses vascular cambium, and pith rots progressively. Two distinct zones become apparent. Ultimately the affected tissues become charcoal-black, hard and mummified. The disease is favoured by relatively high temperature with an optimum of 29-31°C. It is common in storage houses, where crates are closer to heaters (Clark and Moyer 1988).

Control measures : Hydro-warming of tubers as detailed under Java black rot is applicable here also.

Dry-rot, c.o. *Phomopsis batatae*

Diaporthe phaseolorum var. *batatis* (Harter & Field)

The disease may cause serious damage in storage. The rot usually begins at the stem-end of the root and later involves the whole root. The diseased

roots are shrunken and shrivelled. Their surface is covered with numerous mounds, and under these fructifications of the fungus are seen in a coal-black stroma. The internal tissues decay and become coal-black.

Circular-spot, c.o. *Sclerotium rolfsii* Sacc.

Circular-spots/ lesions occur only on the fleshy storage roots. The extent of lesion development varies considerably among genotypes. But on commercially grown varieties, they usually range from 1 to 2 cm in diameter. The lesion surface is brown with a margin that may be slightly darker than the rest. The tissues within the lesion are yellowish-brown to brown, soft and mushy. The root becomes leathery in texture as the lesions dry. Generally lesions are shallow, 1-5-mm deep and do not usually extend beyond vascular cambium. Circular lesions do not crack at harvest, but may crack as they dry in storage (Martin 1953; Aycock 1966).

Scurf, c.o. *Monilochaetes infuscans* Ell. & Halst.ex Harter

The disease earlier known as 'soil stain' is very common in the USA, many islands of the Pacific and Japan. It becomes serious with the use of infected planting materials. The disease is of minor importance.

Symptoms : They are restricted to underground portions of the plant. Dark brown to black spots develop on the fleshy storage roots. The spots slowly enlarge and may coalesce until entire root surface is affected and discoloured. The symptoms are restricted to periderm and do not directly affect cortex. Severely affected tubers may develop small cracks. Scurf lesions continue to enlarge when sweet-potatoes are in storage, and new lesions may develop only at higher relative humidities (Harter 1916; Daines 1955; Clark and Watson 1983).

A combination of sanitation procedures and fungicide application (Thiabendazole 0.1%) is recommended as control measure (Martin 1972).

Black mould-rot, c.o. *Aspergillus niger* Van Tieghm.

Infection starts around wounded areas and appears as small water-soaked dull areas with a white mycelial growth, followed by profuse black sporulation of the fungus. The infection advances in irregular patches. Generally disease develops at a temperature of above 35°C (Dasgupta and Mandal 1989). Ray and Misra (1995) had also isolated *A. terreus*, *A. flavus* and *A. fumigatus* from sweet-potato tubers.

Green mould-rot, c.o. *Penicillium digitatum* Sacc.

Blue mould-rot due to *Penicillium* sp. was reported by Coursey and Booth (1972) from Solomon Islands, and by *P. digitatum* was reported from Karnataka (Ravichandran and Sullia 1983).

Symptoms : Initially water-soaked discolourations appear. Spots develop on the root surface, followed by abundant growth of the fungal mycelium, which later turns green due to the colour of the spore mass.

Brown soft-rot, c.o. *Rhizoctonia solani* Kühn

Ravichandran and Sullia (1983) described the disease from Karnataka. Initially pale-brown spots appear on the root surface. The affected roots shrivel. Eventually entire surface gets covered with fungal growth. Sclerotia are also noticed. Contact with infected roots should be avoided.

Slimy brown-patch, c.o. *Myrothecium roridum* (Tode ex Fr.)

The disease was reported from Karnataka (Ravichandran and Sullia 1983). The symptoms initiate as brown patches with a grey coating. Later root gets covered by a large number of dark sporodochia with slimy spore mass. The disease is of minor importance.

Shiny black-rot, c.o. *Arthrrium phaeospermum* Corda and Ellis

The disease was reported from Karnataka (Ravichandran and Sullia 1983). The symptoms appear as black circular spots along with the shiny black spore masses over the spots. The disease is of minor importance.

Sunken brown-spot, c.o. *Stemphylium botryosum* Wallr.

Ravichandran and Sullia (1983) first reported the disease from Karnataka. The dark-brown spots appear and that are covered by greyish mycelium. In advanced stages, roots decay and on applying a gentle pressure, conidia ooze out. The internal contents turn grey and granular.

Hydro-warming as detailed *under Java black-rot is applicable here also.*

Waxy-rot, c.o. *Geotrichum candidum* Link.

The disease is of minor importance and occurs on injured or physiologically weakened tubers. The characteristic symptom is watery, slow and shallow partial rot of tubers with a white powdery wax-like growth (Mandal and Dasgupta, 1980).

Control measures as detailed *under tomato of Solanaceous crops are applicable here also.*

Violet root-rot, c.o. *Helicobasidium mompa* Tanaka

The disease develops only in the field. Decay of fibrous roots progresses from tip and may eventually destroy entire root system. Storage roots usually decay from the distal-end towards the proximal end. The entire root usually rots but remains are held together by a thick mantle of hyphae over its surface. This coarse network is at first white but gradually turns pink to brown, and eventually develops characteristic violet colour. The disease is common in China, Korea and Japan. The disease has not been reported from India.

***Phymatotrichum* root-rot, c.o. *Phymatotrichum omnivorum* Shear**

The disease is also known as cottony root-rot or Texas root-rot. The symptoms appear as circular spots in the field. The decay is firm and dry,

and is initially associated to root surface. It often progresses from one end of the root; the interior of the root is not affected until rot is quite advanced. The outside of the root may be dark-brown to black at first but as decay proceeds, distinctive mycelia appear as white protuberances with brown to buff strands. By the time infected sweet-potatoes are dug, entire root below the ground system may be severely decomposed and fleshy storage roots may become hard, dry, buff to brown and mummified (Clark and Moyer 1988). The disease has not been reported from India.

Foot-rot, c.o. *Plendomus desturens* Harter

This is of minor importance. The pathogen grows down the stem into the storage root and causes slow decay (Martin 1972).

The disease is not reported from India.

OTHER STORAGE DISEASES AND CAUSAL ORGANISMS

| | | |
|------------------------|--|---------------------------|
| Grey mould-rot | <i>Botrytis</i> spp. | |
| Mucor-rot | <i>Mucor</i> spp. | Snowdon, 1991 |
| Watery soft-rot | <i>Sclerotinia minor</i> <i>S. sclerotiorum</i> | |
| Trichoderma-rot | <i>Trichoderma koningii</i> | Ray and Balagopalan, 1997 |

PROKARYOTES AND BACTERIAL DISEASES

Soil-rot/ *Streptomyces-pox*/ground-rot/scab, c.o. *Streptomyces ipomoea* (Person & W.J. Martin) Waksman

Soil-rot is common in sweet-potato-growing areas of United States and Japan. The disease may lower roots market value but does not appear to develop further in storage.

Symptoms : The most common symptom is the 'scab' type of lesions on the storage roots. These lesions are circular to irregular in outline and are usually less than 5-mm deep. They are composed of dark-brown to black necrotic corky areas with frequent cracks radiating from the centre. The lesions vary in diameter.

Bacterial stem-and root-rot/bacterial soft-rot,

c.o. *Erwinia chrysanthemi* Burkh Holder, M C Fadden & Dimmock.

The bacterium is readily differentiated from other soft-rotting *Erwinia* by its pattern of carbohydrate utilization, sensitivity to erythromycin, production of gas from glucose, higher optimum temperature for growth, etc.

Economic losses due to bacterial stem-and root-rot were reported for the first time from Georgia, USA, in 1974. Storage roots often have a dark-black margin and appear to be restricted. Some storage roots appear healthy from outside but are decayed internally. Black streaks may appear in the vascular

tissue of storage roots. Mother roots often decay totally in plant beds (Martin and Dukes 1977; Schaad and Brenner 1977). Infections may remain latent below 27°C. But symptoms may develop quickly with the advent of higher temperature (30°C or higher).

Aroids and Yams

COLOCASIA (Arum/Aroids/Cocoyam) (*Colocasia esculenta* (L.) Schott)
(*Xanthosoma sagittifolium* (L.) Schott.)

Tubers of colocasia and *Xanthosoma* rank only after yams and cassava as staple food. These tubers provide easily digestible starch and contain protein, vit. C, thiamine, riboflavin and niacin (Coursey 1968).

The corms and roots are frequently affected by fungal pathogens both in the field and in the storage, resulting in heavy losses.

FUNGAL DISEASES

Corm-rot, c.o. *Phytophthora colocasiae* Raciborski
P. nicotianae B.de Haan

The disease is commonly found in wetlands and in poorly drained soils. The disease was reported on stored corms from British Solomon islands (Jackson and Gollifer 1975).

Symptoms : The damage may be confined to few corms or may be widespread resulting in 100 % loss depending upon the weather. Corms may become slimy or water-soaked and their skin may slip off easily. Intermittent rain, cloudy weather and temperature of 22-28°C are ideal for rapid spread of the disease.

Control measures : Use of healthy planting material, harvesting crop at the right time, removal of crop debris and strict field sanitation have been recorded as control measures. Storage in soil, kept in well-drained pits, remained free of infection up to four weeks.

Use of resistant cultivars was promising. Cultivars, Kadma local, Nadia local and Muktakeshi were reported to be immune from Ranchi and JCC 24 and JCC 25 were resistant varieties from Asom (Kumar and Dubey 1996; Alam *et al.* 1996).

Spraying Metalaxyl (0.3%) in the field at 2-3-week interval proved effective in controlling the disease. Metalaxyl mixed with Mancozeb (0.2%) or Zineb (0.2%) is also effective.

Integration of dipping corms for a hour in a fungicidal solution of Carbendazim (0.1%) + Mancozeb (0.2%) before sowing with three foliar sprays with Ridomil MZ(0.25%), starting with the disease appearance, contained the disease (Sharma *et al.* 2004).

Essential oils of *Nepeta hindostana* and *Ocimum canum* possess antifungal properties against corm-rot (Chouhan *et al.* 1994).

Internal soft-rot, c.o. *Pythium* spp.

Soft-rot due to *Pythium* spp. is common. *P. ultimum* and *P. splendens* were recorded from Puerto Rico and Solomon Islands (Alvarez and Cartaz, 1971; Jackson and Gollifer, 1975). Isolations revealed *P. splendens* and *P. myriotylum* in abundance along with other fungi. Infection resulted in complete decay.

Control measures : To reduce losses, leave petiole bases of cormels and roots that delay infection.

Colocasia tubers treatment with Captan (0.2%) or Thiram (0.2%) or copper oxychloride (COC) at 0.5% is effective. Soil treatment with the same chemicals is also promising.

Watery soft-rot, c.o. *Rhizopus stolonifer* (Ehrenb.) Vuill.

The disease is generally reported to be of minor importance. Burton (1970) reported the fungus to cause severe losses in corms along with other fungi. Dasgupta and Mandal (1989) recorded the disease after rains on physiologically impaired or injured tubers as water-soaked spots, which gradually increased, and were covered by a stringy extra matrical mycelial mass giving bad odour. The rot rarely involves inner tissues, which turn watery and soft.

Avoid wounds and bruises on the harvested produce. Removal of dirt and soil particles, followed by air-drying /curing and storing in cool dry atmosphere at 50% RH is effective.

Root and corm-rot, c.o. *Sclerotium rolfsii* Sacc.

Rhizoctonia sp.

Harter as early as 1916 reported the disease; it is of worldwide importance. It was recorded from Nigeria (Bailey 1966), Chicago (Burton 1970), Solomon Islands (Gollifer and Booth 1973; Jackson and Gollifer 1975). In India, Satya Prasad and Rao (1979) recorded the disease from Hyderabad. Rotted corms of taro produced radiating mycelia with abundant sclerotia on rotted corms. This fungus also attacked onion-bulbs, ginger, brinjal, soybean and chilli-fruits (Rama Rao and Usha Raja 1977; Roy 1977).

The diseased plant may also exhibit symptoms like chlorosis and collapse of petioles at the collar region. In severe cases, corms and root underneath are also affected. This leads to wilting of the whole plant.

Inhibitory effects of some host constituents on *Sclerotium*-rot were also reported (Nwufo and Fajola 1981; Arinze 1997). Phenol oxidase as well as peroxidase activities and plant growth inhibitory substances were observed to be significantly higher in the peripheral zone of rot compared to other areas in all the varieties infested by *S. rolfsii*.

Losses could be minimized by proper selection of tubers, removal of dirt and soil particles, followed by air-drying / curing and storing in cool dry atmosphere at 50% relative humidity. Immersion of seed-tubers in seed-dressing chemicals like plant-wax, Agrosan GN or Ceresan wet at 50 ppm

for 30 minutes was reported to be effective in controlling the disease (Goyal *et al.* 1974).

Black-rot/spongy black-rot,

c.o. *Botryodiplodia theobromae* Pat.

The disease was reported as the most important one from the South-East Nigeria. D'Souza and Moniz (1968) observed the disease on *Colocasia antiquorum* Schott from Maharashtra. The affected tubers become spongy or dry and powdery depending upon the storage conditions. This fungus may invade undamaged tubers also under high relative humidity.

Losses could be minimized by proper selection of tubers, removal of dust and soil particles, followed by air-drying/curing and storing in cool dry atmosphere at 50% RH. Storage under dry and low temperature conditions reduces incidence of corm-rot.

Dry-rot, c.o. *Fusarium* spp.

The disease was reported from several parts of the world. *F. solani* was recorded as early as 1916 by Harter. The disease is common in Egypt (Michali *et al.* 1969), Solomon Islands (Gollifer and Booth 1975; Jackson and Gollifer 1975) and Nigeria (Ogundana 1975; Nwifo and Fajola 1981). In India, dry-rot of *C. antiquorum* due to *F. caerulinum* was reported from Uttar Pradesh, Rajasthan and Madhya Pradesh (Sharma and Upadhyay 1977) and from Bhubaneswar (Mishra and Rath 1986).

Rotting becomes a major problem towards the end of the storage period. The rot starts as small lesions and is confined to the sides of the corm around points, from where cormels have been detached. The affected area develops a brown discolouration. *Aspergillus niger* also produces a dry-rot with a characteristic purple brown colour. *F. solani* is more important in Nigeria (Nwifo and Fajola, 1981). Sharma and Upadhyay (1977) observed dried and shrunken corms, brownish black in colour with deposition of white powdery growth. Corms become light, and browning of the tissues progresses in all directions. Complete rotting and drying is observed within 60 days. Rotten tubers emit a musty odour. Ogundana (1975) also reported *F. moniliforme* from *X. sagittifolium*.

A soft-rot (c.o., *Cylindrocarpon lichenicola* = *Fusarium lichenicola*) was also reported from Hyderabad (Usharani and Rama Rao 1981). The rot spreads gradually in stored tubers and finally whole corm transforms into a mass.

Losses can be minimized by using intact tubers for storage, removal of roots and soil from the corm, cleaning in water, followed by a disinfectant solution, air-drying / curing and storing in cool, airy rooms with about 50% relative humidity (Thankappan 1994). Seed treatment with Manocozeb (0.2%) is also found effective in controlling storage rots.

ELEPHANT-FOOT YAM (*Amorphophallus campanulatus* Blume ex Decne)

It is a cheap source of carbohydrate, and is rich in minerals and vitamins (vit. A and vit. B). Calcium oxalate present in the corm causes irritation to tongue. This is high in wild types and less in cultivated varieties. The yam is high in fibre and omega-3 fatty acid, and has a low glycemic index value. Hence, the yam is good for people suffering from diabetics.

Post-harvest rotting of elephant-foot yam is commonly encountered by cultivators. The yams need to be stored properly during off-season for using them as seed material for the next planting season.

Storage of elephant-foot yam corms is a problem to farmers due to their loss in weight and rotting when stored in heaps for the next season planting. Weight loss, sprouting and spoilage are reported in yams and sweet-potato tubers (Coursey and Walker 1960; Passam 1977; Balagopalan and Padmaja 1985; Picha 1986). About 50-60% moisture loss during the first four months of storage was reported in room temperature, and corms stored in white-sand recorded only 30-32% moisture loss (Anon. 1990). Sprouting and rotting of seed-corms in storage reduce seed quality to a great extent. Das *et al.* (1995) evaluated different low-cost storage methods and observed that relatively high temperature prevailed under covered area. Weight loss enhanced with advancement of storage period irrespective of the storage media and was much more in uncovered lot. But the loss could be reduced by keeping a water-tray below the stored seed-corms. The moisture loss and sprouting of seed-corm were reduced by storing seed-corms under dry soil and dry ash. Mondal *et al.* (2004) observed similar results from West Bengal. The comparative efficacy is recorded as soil > sawdust > sand. Seed-corms treated during storage with Captafol (0.2%) gave highest results, followed by treatments with Bavistin (0.1%) and Blitox (0.5%).

FUNGAL DISEASES

Soft corm-rot, c.o. *Sclerotium rolfsii* Sacc./ *Rhizoctonia solani* Kühn

Coursey and Booth (1972) reported disease from Solomon Islands. In India, the disease was recorded from Maharashtra (Uppal *et al.* 1925 (cited Vasudeva, 1960), West Bengal (Roy 1949; Mandal and Dasgupta 1981), Rajasthan (Tyagi and Sharma, 1977) and from Tamil Nadu (Siva Prakasam and Kandaswami 1982).

Symptoms : No external symptoms are noticed. The affected area becomes soft after 5-7 days, and white mycelial growth becomes visible on the outer corm skin (Fig. 27.3). Sclerotia are also noticed in abundance. They are white at first but gradually become brown and later dark-brown. The disease causes extensive decay during rainy season, and is favoured by high relative humidity and temperature around 30°C.

Mandal and Das Gupta (1980) recorded dirty grey-rot due to *Rhizoctonia solani* (*Thanatephorus cucumeris*) as a major disease on harvested yams during late rainy season in West Bengal. The infected corms showed rotting in the form of a shallow cone. Water-soaked areas appear, which gradually enlarge and attain diameter of about 5-10 cm. The natural flesh colour of the corm is transformed into ivory black. Similar symptoms were also noticed by Philip

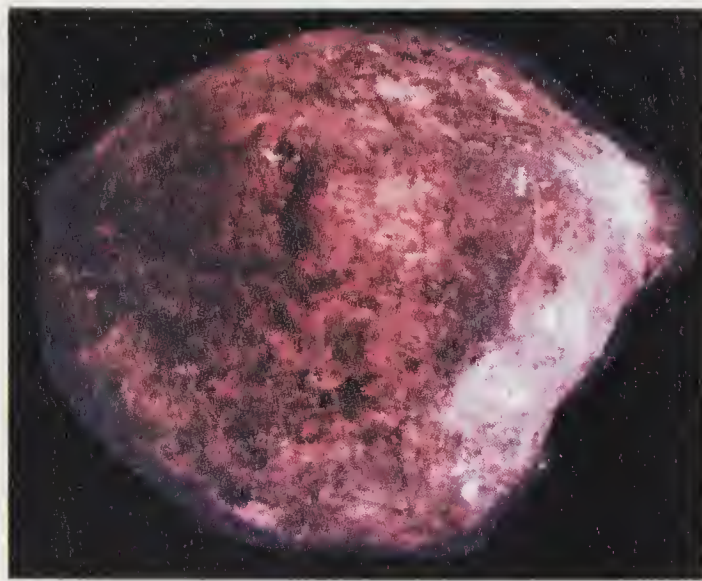


Fig. 27.3. *Rhizoctonia*-rot on elephant-foot yam

(1998) on yams harvested from Idukki district in Kerala, which were transported to Thiruvananthapuram markets during the *onam* festival season; 50-75% rotting was recorded in certain cases. The pathogen is carried from field through wounds and causes severe damage during storage.

Other important pathogens causing soft-rot of elephant-foot yam tubers include *Phytophthora colocasiae*, *Botryodiplodia theobromae*, *Fusarium* sp. and *Rhizopus* sp.

Bacterial-rot caused by *Erwinia carotovora* was also reported to cause serious damage to yam-tubers. Storage at higher temperature with poor aeration helps in building-up of inoculum. Tuber-rot caused by nematode-fungal-bacterial complex was also reported (Misra *et al.* 2006).

Control measures: Biological control. Treatment of yam-setts with Ampalaya (*Momordica charantia*) crude ethanolic/acetonic extracts, followed by regular spraying with the same extracts up to 6 months after planting protected the crop against yam anthracnose. The degree of protection was better than that of Benlate in Philippines (Palomar *et.al.* 2004).

Tyagi and Sharma (1977) observed disease control in the field with *Trichoderma harzianum* combined with fungicidal application.

Effect of *T.harzianum* on plant growth and intensity of collar-rot was also recorded from Asom. Soil application of *T.harzianum* (10^9 conidia/ml) increased plant height, canopy size, lowered disease incidence, and yielded more. Corms treated with Captan (0.2%), followed by two soil applications of *T.harzianum*, as well as corms cut and dipped overnight in conidial suspension of *T.harzianum*, dried in shade and then used for planting showed promise (Gogoi *et al.* 2004).

Trichoderma-based management of collar-rot and tuber-rot was reported from Varanasi and Uttar Pradesh. Treatment of planting material with fresh cowdung slurry mixed with *Trichoderma* formulation (10^6 spores/ml) @ 5g/kg along with neemcake @ 250 g/ pit at the time of planting and application

of *Trichoderma* enriched cowdung compost in soil @ 4 tonnes/ha were found best package for effective management (Misra *et al.* 2006).

Fungi on Yam Chips

The following fungi are recorded on yam-chips in storage from Nigeria (Amusa and Moor 2001):

- Penicillium oxalicum* Lind.
- Rhizopus stolonifer* (Ehrenb.) Vuill.
- Fusarium oxysporum* Schlect.
- Botryodiplodia theobromae* Pat.
- Aspergillus niger* Van Tieghm.
- A. flavus* Link. ex Fries
- Drechslera* sp.

DIOSCOREA/GREATER YAM (*Dioscorea alata* L.)

The genus *Dioscorea* includes several edible and wild varieties; of which *D. alata* (greater yam) and *D. esculenta* (lesser yam) are very popular in India. The crop is harvested once in a year and usually stored in traditional ways. It is rich in starch and other nutrients. The crop is extensively cultivated in Africa.

The yams of the genus *D. prazeri* Prain and Burkill are the main source of 'Diosgenin', a steroidal sapogenin. It is an important starting material for synthesis of cortisones, sex hormones and oral contraceptives (Sharma and Chatterjee, 1982).

Biochemical changes in yam-tubers during storage were recorded by Sundaresan *et al.* (1990). Three species — *D. alata*, *D. esculenta* and *D. rotundata*— were stored under ambient conditions and monitored periodically. The following observations were made:

- Starch content was found reduced;
- Total free sugars remained constant;
- Total polyphenols did not show any variation in *D. rotundata*. But in the other two species, the level increased by 13%;
- Moisture loss was rapid. In *D. rotundata*, a decrease of 23% was recorded while in *D. alata* and *D. esculenta*, net decrease within 4 months was 10% and 6%, respectively.

Avoiding mechanical injuries is the most important factor to be remembered in the storage of yams. The point of entry for the rot organisms is through wounds or due to senescence of sound tubers, resulting in autolytic breakdown, followed by decay. Yam-tubers remain without any change in nutritional properties (moisture, acidity, protein, lipid, carbohydrate, total sugars, ash and calorific value) up to four weeks and thereafter show alterations (Sahore *et al.* 2007).

A widely used traditional method of yam storage in S. Africa is the use of outdoor yam-barns. The barn consists of a framework of vertical poles 3-m

high and 50-cm apart, held together by horizontal poles. The tubers are tied individually in a horizontal position to vertical poles (On Wuema 1978). Storage of tubers individually in horizontal position in open-sided bamboo or wooden shelves is also followed in Nigeria (Ikediobi 1985).

James (1990) in his studies on the storage for seed purpose observed weight loss in the open barn higher than the covered barn storage in pits. Mud plastered ventilated covers and mud-plastered heaps showed 87-100% sprouting. Sand heap and dry soil heap were also tried. Among the different storage practices, placing on racks in the covered barns was found promising.

Regulated air movement around the tubers resulted in low moisture loss. Moisture loss was enhanced at medium and at high fan speed because of the evaporation effect of the moving air (Osi Mozie 1996).

Tubers exposed to 12.5 krads of gamma radiations could be stored for eight months without sprouting. But, exposure to doses above 5 krades caused damage to internal tissues (Adesuyil 1976).

FUNGAL DISEASES

Brown dry-rot/wet-rot, c.o. *Botryodiplodia theobromae* Pat.

The disease is of common occurrence and has been reported from several countries like Brazil, Ghana, Ivory Coast, Nigeria, Fiji etc (Okafor 1966; Coursey 1967; Ogunda *et al.* 1970; Okigbo and Ikedugwu 2000). Prasad and Bhatnagar (1970) reported rot under storage conditions with a loss of 10-29% from Rajasthan.

Symptoms : Rotten tubers turn grey internally and get dried up. The tissues turn fibrous and becomes light in weight. The bark remains intact, covering internal rotten portion. In the initial stages, the inner tissues become crispy, light grey and develop cracking. Infected tubers generally fail to sprout. Under high humidity, wet-rot sets in and turns tubers into watery mass. Together with *Macrophomina phaseoli* and *Hendersonia tortuloidia*, *B. theobromae* caused rotting in stored *D. alata*, *D. coyenensis* and *D. rotundata* in Nigeria (Okafor 1966).

Control measures : Dipping cut ends of tubers in fungicides like Benomyl (Benlate 1,000 ppm, 2,000 ppm) and Bavistin (1,000 ppm, 2,000 ppm) controlled rot during storage (Bammi *et al.* 1972; Sarma 1984).

Tuber-rot, c.o *Fusarium solani* (Mart.) Sacc.

The disease was reported from Darjeeling on *D. prazeri*. High incidence of tuber-rot with graded severity was noticed from different plantations in Darjeeling hills. *F. oxysporum*, *F. chlamydosporum* and *F. solani* were recorded. Wounds, bruises, insect damage etc are the pre-disposing factors. The symptoms appear as dirty light-brown to dark-brown discolourations at the entry point. The tissues sooner become soft and emit offensive smell. The skin

turns dark-brown, wrinkled and get covered with a crust of conidiophores bearing micro and macro conidia (Sharma and Chatterjee 1980,1982).

Fusarium sp. was also reported by Nwachukwu (2003) on *D. rotunda*. The rotting extent increased with storage time. Extensive rotting occurred in combination with *Aspergillus* sp. and *Penicillium* sp.

Application of Dithane M-45(0.2%) to stored tubers inhibited mould growth.

Rhizopus-rot, c.o. *Rhizopus oryzae* Went & Prinsen Geerligs

Reni (2002) reported the disease. The wounds created by nematodes on the tubers surface act as an entry point through which fungal infection occurs. The fungus also causes decay of yams in storage. *R. stolonifer* was also recorded to affect stored tubers of *D. prazeri*.

Control measures detailed under Botryodiplodia-rot are applicable in this case also.

Hard brown dry-rot, c.o. *Penicillium sclerotigenum*

The disease was reported from China, Nigeria, United Kingdom etc (Yamamoto *et al.* 1955; Okafor, 1966; Coursey, 1967; Ogundana *et al.* 1970, 1971). Agarwal and Gupta (1973, 1977) reported the disease from Uttar Pradesh on *D. alata*. It is a wound parasite and infection occurs at 25°C and at 80% relative humidity.

Penicillium oxalicum was also reported to cause dry-rot on several species of yams — *D. alata*, *D. cyanensis*, *D. dumetorum*, *D. esculenta* and *D. rotundata*. *Penicillium* sp. was also reported. The extent of rot increased with storage time. Combination of *Aspergillus* and *Penicillium* caused extensive decay (Nwachukwu 2003).

Symptoms : Infected tubers show complete drying of tissues. Slight shrinkage and darkening of the affected parts is the initial symptom. The rot progresses rapidly and occupies interior areas. With further advancement, skin gets wrinkled. Underlying tissues become dry and develop cavities lined with white fungal mycelia. Blue-green sporulating masses in colonies are noticed on the upper surface. Tubers become hard and light in weight. Philip (1998) also observed disease on the vertically cut tubers. Irregular or star-like colonies, dark-green in colour, are noticed in abundance.

Control measures : Cut tubers for seed-purpose should be treated with Mancozeb (0.2%) before storage.

***Aspergillus*-rot**

It is considered as an important post-harvest rot of *Dioscorea* during transport and marketing (Maheswari *et al.* 1983). *A. flavus* and *A. fumigatus* were also reported.

Cut-tubers for seed-purpose should be treated with Mancozeb (0.2%) before storage.

OTHER ASSOCIATED FUNGI

Ogundana *et al.* (1970, 1971) from Africa reported *Botryodiplodia theobromae*, *Fusarium moniliforme*, *F. poae*, *F. solani*, *F. coeruleum*, *Mucor circinelloides*, *Rhizopus stolonifer*, *Penicillium sclerotigenum* and *Trichoderma viride* from stored yams.

Several other fungi, *Alternaria alternata*, *A. solani*, *Helminthosporium* sp., *Verticillium* sp., *Cephalosporium indicum*, *Curvularia pallescens* and *C. lunata*, were recorded on stored yams (Sharma and Chatterjee 1980; Okigbo and Ikedugwu 2000).

Ray *et al.* (2000) observed following microorganisms from Odisha—*Aspergillus awamori*, *A. versicolor*, *B. theobromae*, *F. solani*, *P. decumbens*, and *P. purpurogenum*. These fungi caused primary dry-rot, while bacteria *Serratia* sp. and *Erwinia* sp. caused primary and secondary soft-rots.

POST-HARVEST MANAGEMENT

Chemical protection

Dipping cut ends of the tubers in fungicides Benomyl (1,000 ppm, 2,000 ppm) and Bavistin (1,000 ppm, 2,000 ppm) were effective in controlling rot during storage (Bammi *et al.* 1972; Sarma 1984).

Biological control

Okigbo and Ikediugwu (2001) controlled storage rots of *Dioscorea* successfully in Nigeria with *Trichoderma viride*. Conidial suspensions were sprayed on yams (white yam, *D. rotundata*) that were kept for six months; *T. viride* successfully displaced all naturally occurring mycoflora on the surface of yam-tubers. The fungi included *Rhizopus* sp., *Aspergillus niger*, *Fusarium solani* and *Neurospores* sp. Most of these fungi were opportunistic pathogens, waiting for any wound to penetrate tuber (Ogundana *et al.* 1970).

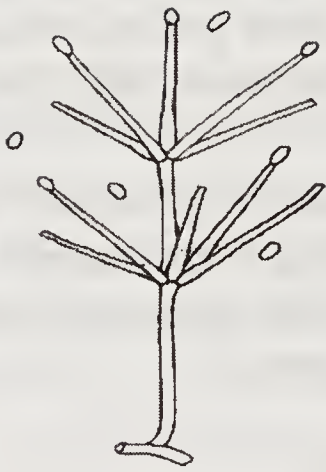
T. viride produces antibiotic substances that causes lysis of fungi (Padmodaya and Reddy 1996; Calistru *et al.* 1997). Alternately, *T. viride* may also colonize micro-sites faster than naturally occurring fungi (Gohi and Vala 1996). Okigbo (1995) and Calistru *et al.* (1997) reported complete inhibition of spore germination by *T. viride*.

Antifungal microorganisms isolated from cowdung effectively inhibited growth of several fungi *in vitro* as well as on fresh yam-tubers (Swain *et al.* 2006). Treatment of yams-tubers and foliar spray at 15, 30, 45, 60 days after planting with 5% 'Panchagavya' (fermented mixture of cowdung and urine, milk, buttermilk and ghee) kept plants free of any disease and increased tuber yield (Nayak *et al.* 2006). This is also mentioned in the ancient book 'Vrikshayurveda'.

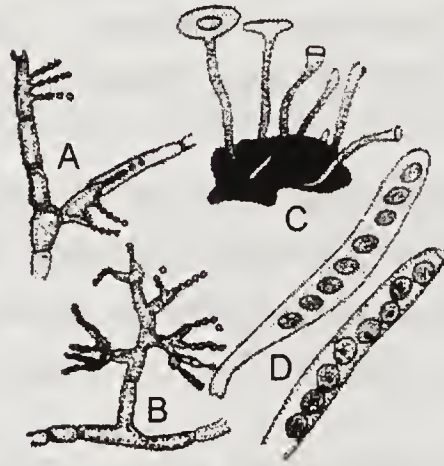


Appendix 1

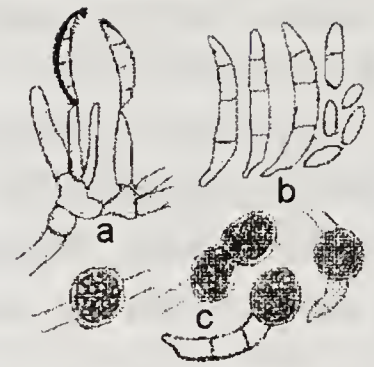
Fungal Spores



Verticillium



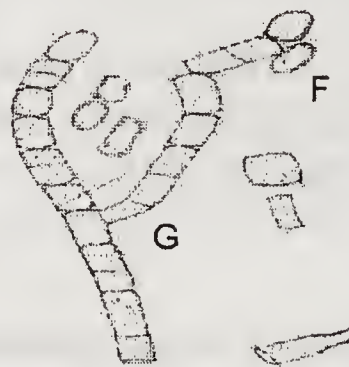
Sclerotinia sclerotiorum



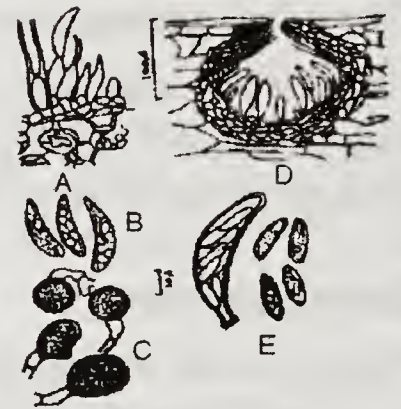
Fusarium



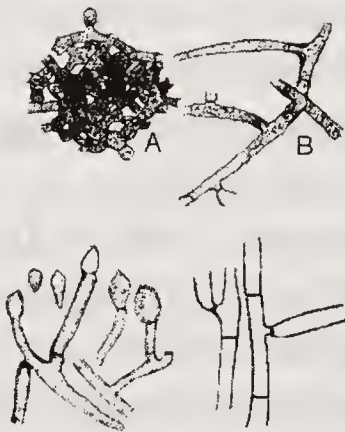
Curvularia



Geotrichum candidum



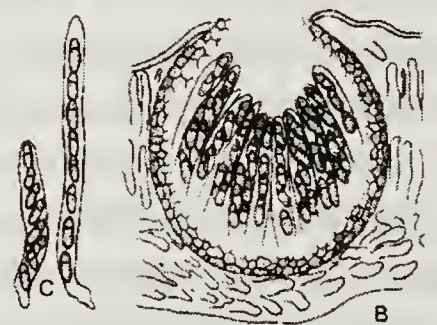
Glomerella cingulata



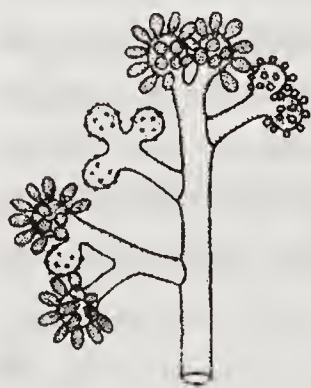
Thanatephorus (Rhizoctonia)



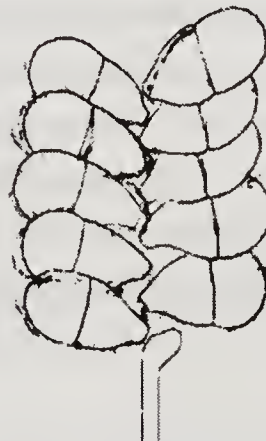
Pilocaea pomi



Venturia inaequalis



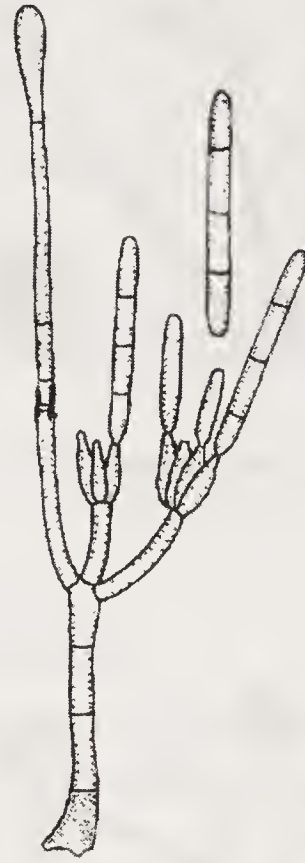
Botrytis



Trichothecium



Alternaria



Cylichrocladium



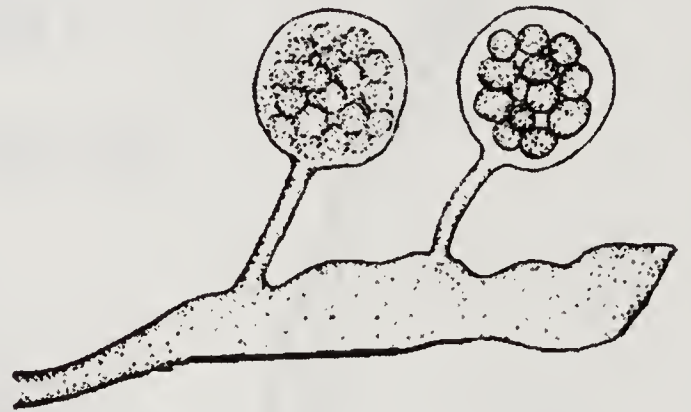
Corynespora



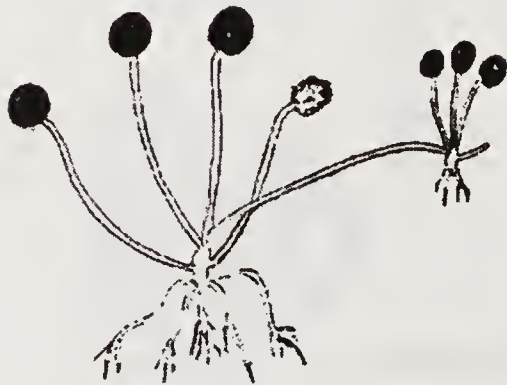
Helminthosporium



Phytophthora



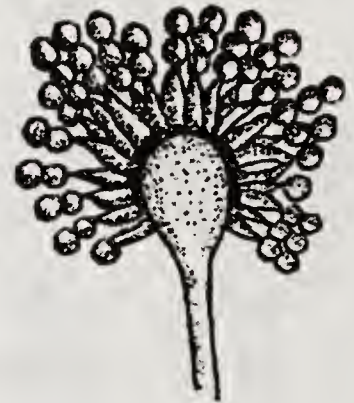
Pythium



Rhizopus



Penicillium



Aspergillus



Pestalotia



Colletotrichum

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Subject Index

- Acacia nilotica* 36
Alternaria blight 195
Alternaria leaf-spot 149
Alternaria spp. 7
Alternaria-rot 86, 96, 127, 136, 180, 230
Alternaria-rot/core-rot/black-rot 34
Alternate technologies 57
ammonia-releasing fumigants 245
Anamorph 3, 179, 214
Ananas comosus 98
Angular leaf-spot of beans 205
antagonistic microflora 233
Anthracnose 18, 35, 59, 73, 83, 107, 118, 123, 126, 132, 137, 138, 142, 194, 198, 202
Anthracnose (Bird's eye-rot) 55
Anthracnose/ripe-rot/fruit-rot 152
Antibiotic substances 299
antibiotics, use of 81
Apple (*Malus domestica*) 1
Apple-scab 3
Apple-scald 12
Apricot 17
Aroids and yams 291
Artocarpus heterophyllus 67
Ascochyta pod-spot 204
Ascochyta-rot 86
Ash-grey spots 221
Aspergillus 37, 89
Aspergillus fruit-rot 106
Aspergillus niger 10
Aspergillus niger, metabolites of 243
Aspergillus-rot 64, 96, 101, 113, 129, 184, 272, 298
Aspire 50
Aubergine 143

Bacillus subtilis 168
Bacterial black-spot 77
Bacterial blight 196
Bacterial blight/fuscous blight 209
Bacterial diseases 17, 28, 40, 77, 90, 108, 150, 173, 196, 201, 209, 215, 222, 223, 229, 239, 252, 270, 282
Bacterial epiphytes 251
Bacterial fruit-rot 189
bacterial leaf-spot 164
Bacterial soft-rot 150, 173, 188, 240, 252, 282
Bacterial stalk-rot 253
Bacterial wilt 270
Bacterial-blight 212, 239
Bacterial-rot 78
Bacterial-rotting 163
Bacterial-spot 189, 223, 230
Banana (*Musa* spp.) 18
Banana black-rot 27
banana fruit-rot 22
Bark extract 36
Basal-rot 98, 99
Bean mosaic virus 210
Beet root/sugarbeet 232
Benzyl alcohol, use of 57
Beta vulgaris 232
Biochemical changes 152
Biocontrol 73
biocontrol agent 168, 194
biocontrol antagonists 155
Biocontrol with antagonistic fungi 75
bio-ingredients 154
Biological control 5, 34, 35, 43, 50, 52, 53, 66, 84, 86, 112, 145, 262, 295, 299
Biological control in field 155
Biological control measures 237
Biological control methods 103
Bittergourd 131
Bitter-pit 13
Bitter-rot 6, 54, 96
Black curd-rot 217
Black curd-rot/dark leaf-spot/*Alternaria*-rot 224
Black grain-rot 107

- Black mould-rot 10, 25, 75, 109, 126, 207, 212, 242, 288
 Black soft-rot 76
 Black-blotch 76
 Black-leg 173, 221, 236
 Black-mould 50
 Black-rot 54, 64, 68, 77, 206, 215, 222, 239, 269, 286, 293
 Black-rot/bacterial-rot 229
 Black-spot 23, 108
 blight 245
 Blossom-end-rot 132
 Blue mould-rot 50, 94, 95
Botryodiplodia fruit-rot 87
Botryodiplodia-rot 24
Botryodiplodia theobromae 21
Botryodiplodia-rot 27, 53, 60, 83, 95, 124, 139, 159
Botrytis cinerea 26
Botrytis end-rot 26
Botrytis-rot 187
Botrytis-rot/soft-rot 172
 Bottlegourd 138
 Brinjal 143
 Brown discolouration 52
 Brown dry-rot/wet-rot 297, 298
 Brown pedicel-end-rot 109
 Brown soft-rot 289
 Brown spongy-rot 149
 Brown-head 220
 Brown-rot 5, 24, 47, 53, 68, 92, 96, 105, 121, 160, 203
 Brown-rot/bacterial-wilt/ring disease 175
 Brown-rot/*Phytophthora*-rot 38
 Buck eye-rot 177
 Bulb crops 242
 Bulb-decay 254
 Bulb-rot 251
 bunch-rot of grapes 55

 CA storage 58
 Cabbage 217
 Calyx-blotch and stem-end-rot 113
Candida oleophila 21
Carica papaya 83
 Carrot 236
 Cauliflower 224
 cellulolytic enzymes 174
Ceratocystis paradoxa 21, 160
Cercospora leaf-spot 235
Chaetosphaeropsis truncata 28
 Chalmydospores 98
 Charcoal-rot 125, 128, 137, 141, 171, 246, 287
 Chayote/Chow-chow 131
 Chemical control 74
 Chemical methods 181
 Chemical protection 81, 299
 Chemicals, use of 33, 42
 Chilli 151
 Chilling disorder 104
 chlorine dip 227
Choanephora-rot 120, 124, 127, 159, 227
 Cigar-end rot 22
 citral 164
 Citrinin 4
 citronellal 164
Citrus 32
 Citrus canker 40
Citrus greasy-spot 39
Cladosporium fruit-rot 107
Cladosporium-rot 128, 161, 186, 227
Cladosporium-rot (Green ball-rot) 53
Cladosporium-rot/gummosis/scab 121
 Clusterbean 211
 coconut soap 9
 Cold storage 15, 278
 Cole crops 217
Coleophoma fruit-spot 107
 Collar-rot 193, 216
Colletotrichum 83
Colletotrichum fruit-rot 74, 261
Colletotrichum gloeosporioides 45
Colletotrichum musae 21
 Colocasia 291
 Common Beans /Rajmash/Frenchbean 202
 Common scab 176
 Conidial stage 222
 controlled atmosphere 30

- Controlled atmosphere storage 16
Cool chamber technology 176
Cool chambers 29
Cool-chamber technology 190
Core-rot 7
Corky lesion 258
Corm-rot 291
Corynespora fruit-rot 89, 133
Cottony white-rot 125, 133, 193, 234, 237
Cottony-leak 124, 138, 140, 148, 182, 199, 259
Cottony-leak/fruit-rot 117
Cottony-leak/*Pythium*-rot 131
Cowpea 197
Cowpea mild mottle virus 202
Cowpea mosaic virus 201
Creepy white rhizome-rot 268
Creepy white-rot/*Sclerotium*-wilt 171
Creepy-rot 141
Crown-rot 20
cucumber mosaic virus 201
Cucurbita pepo 123
cultivars for resistance 243
cultivars, resistant 271
cultivars, rhizome-rot resistant 271
Cunninghamella fruit-rot 124
Curd-rot 218
Curd-smudge 227
Curing, artificial 247
Curvularia fruit-rot 28, 147
Curvularia lunata 28, 161, 200
Curvularia-rot 53, 142
Cylindrocarpon-rot 97
Cylindrocladium-rot 185
- Damping-off 160, 182, 206, 225
Damping-off and seedling diseases 234
depressed spots 179
Diaporthe pod-blight 207
Didymella black fruit-rot 134
Dioscorea/Greater Yam 296
Diplodia stem-end-rot 71
Diplodia-rot 149
Dirty grey-rot 140
disease syndrome 218
Diseases and their causal organisms 11, 94, 113, 123, 130, 139, 141, 150, 162, 173, 188, 196, 199, 222, 240
Diseases management 56
Distal-end rot 258
Dolichos-bean 214
Dothiorella-rot 27
Downy mildew 195, 228, 250
Drechslera fruit-rot 108
Drumstick/Moringa Fruit 258
Dry fruit-rot 101, 159, 161, 198
Dry root-rot/*Rhizoctonia* root-rot 233
Dry surface-rot 45
Dry-rot 165, 259, 265, 269, 281, 287, 293
Dry-rot/Brown-rot 111
- early-maturing varieties 196
Elephant-foot Yam 294
Embellisia allii 256
Endomyces reessii 240
Endo-polygalacturonase 33
Etiological studies 266
eugenol 164
Evaporative cool chamber 44
Eye-end rot 172
- faresol 164
finger-rot 24
Fly- speck and sooty-blotch 9
Foliar-blight 257
Foxtail-bean 213
Fragaria chilensis 111
Fruit canker 61
Fruit- rot 107
Fruitlet core-rot 100
Fruit-rot 28, 39, 45, 47, 63, 70, 88, 140, 142, 144, 147, 158, 161
Fruit-rot /cottony-leak 130
fruit-rot, management of 154
Fruit-rot/cottony-leak 127, 132
Fruit-rots and causal organisms 78
Fruit-spot 108, 186
fruit-wrapper 33
Fumigation 57

- Fungal Diseases 3, 17, 18, 32, 45, 48, 59, 67, 69, 71, 83, 92, 95, 105, 109, 111, 117, 123, 126, 130, 131, 132, 135, 138, 140, 142, 143, 152, 165, 177, 192, 198, 202, 211, 214, 215, 224, 230, 232, 236, 239, 240, 242, 257, 264, 271, 280, 284, 291, 294
 Fungi associated with rotting 56
 Fungi on Yam Chips 296
 Fungicide impregnated paper-liners 190
 fungicides application, preharvest 56
 fungicides, seed treatment with 262
 fungicides, systemic 42
 Fungicides, systemic, use of 33
 fungicides, use of 35, 81, 86
Fusarium dry-rot 166
Fusarium moniliforme 146
Fusarium oxysporum 146
Fusarium spp. 38
Fusarium tip-rot 23
Fusarium-blight 260
Fusarium-rot 87, 129, 130, 131, 135, 146, 178, 203, 214, 241, 286
Fusarium-rot /cottony-rot 138
 Fuscos-blight 215
 Fuzzy yellowish-rot 133

 Gangerine 170
 Garden-pea 192
 Garlic 254
 Garlic-bulb canker 256
Geotrichum candidum 37
Geotrichum-rot 270
 Ginger 264
 Ginger-yellows 268
 Girdling of stem 221
Gliocladium virens 145
Gloeodes pomigena 9
Glomerella cingulata 6, 35
 Goa-bean 213
 Gooseberry/Aonla 45
 Grape 48
 Greater yam 296
 Green mould-rot 25, 64, 109, 171, 288
Greenaria fuligena 54
 Grey blight-rot 259
 Grey mould-rot 48, 111, 219
 Grey mould-rot/dry-eye rot/Botrytis-rot 11
 Grey white-rot 133
 grey-mould 5
 grey-mould species 246
 Grey-mould/neck-rot 246
 Grey-rot 270
 Guava 59

 Halo-blight 209
 Head-rot 220
Helminthosporium fruit-rot 26
 homeopathic drugs, use of 43
 host range 266
 Hot-water rinsing and brushing 190
 Hot-water treatment 19, 80, 218
 hot-water, use of 33, 41, 62
 Hydro-cooling 190
 Indian Bean 214
 insect repellent 254
 Internal bulb-rot 255
 Internal dry-rot 269
 Internal soft-rot 292
 Irregular target-spot 186
 Isatin 105
 Ivory-gourd 142

 Jackfruit 67
 Java black-rot 285
 Johnston-spot 22
 Jonathan-spot 15

 Knol-khol/Kohl-rabi 230
 Koval 142

 Lady's finger 259
 Late-blight 167, 169
 Leaf extracts 251
 Leaf-blight 257
 Leaf-spot 204, 217, 241
 Lenticel spots 15
 Light leaf-spot 228
 linseed oil 4
 Litchi 69

- Litchi chinensis* 69
 Low-temperature storage 29

Macrophoma allahabadensis 63
Macrophoma-rot 142
Macrophomina root-rot 235
Macrophomina-rot 211
Malus pimula 3, 17
Mangifera indica 71
 Mango 71
 mango bacterial canker 77
Manilkara zapota 109
Marssonina coronariae 10
Marssonina-blotch 10
 Melting decay of grapes 56
 microflora , sequence of occurrence of
 283
Microthyriella rubi 9
 Minor diseases and their causal
 organisms 39, 65
 modified atmospheric packaging 21
 molecular variabilities 180
Monilinia fructigena 5, 105
 Mouldy brown-rot 46
Mucor-rot 95, 159, 260
 Muskmelon 130
 mycotoxins 4
Myrothecium-rot 128, 134, 185, 198,
 208

 necrosis 245
 neem-based biopesticide 194
Nepeta hindostana 291
 nerol 164
 nest rot 48
Neurospora crassa 88
Nigrospora-rot 228
 Non-parasitic storage disorders 12

 Onion 242
 Onion, curing of 244
 Onion-smudge 248
 organoleptic qualities 279
 organomercurials 193

 packing houses 41

 Papaya 83
 para amino benzoic acid 59
 patulin 4, 135
 Pea mosaic 197
 Peach 92
 Pear 95
 pelleting 154
 Pelleting with fungicides 234
Penicillium expansum 4, 95
Penicillium fruit-rot 106
Penicillium spp. 32
Penicillium-rot 32, 101, 251
Periconia-rot 161
Peronospora pisi 195
Pestalotia-rot 61
Phoma leaf-spot 236
 Phoma-rot 160, 179, 207, 214
Phomopsis fruit-rot 54, 88, 106, 145
Phomopsis-blight 143
Phomopsis-rot 129, 172
Phyllanthus emblica 45
Phymatotrichum root-rot 289
Phytophthora finger-rot 27
Phytophthora fruit-rot 6, 63, 67, 110,
 136
Phytophthora infestans 167
Phytophthora nicotianae var. *parasitica*
 27
Phytophthora spp. 6
Phytophthora-rot 84, 120, 126, 127,
 131
 Pimple-rot 54, 110
 Pineapple 98
 Pink disease 102
 Pink mould-rot 26, 187
 Pink-rot 88, 168, 216
 Pitting disease 22
 plant extract, use of 43
 Plant products, use of 156
 plastic-film packing 81
 Plum 105
 Plum-rot 105
 Pod-blemish 207
 Pod-rot 199, 214
 Pod-rot/white-rot 194
 Pod-spot 261

- polyethylene-lined CFB boxes 44
 polymeric films 91
 polythene packing 42
 Pomegranate 106
 Post-harvest curing 33
 Post-harvest diseases management 28, 41, 70, 79, 90, 94, 190, 252
 Post-harvest management 17, 57, 104, 110, 113, 299
 post-harvest pathogens 273
 post-harvest rotting 273
 Post-harvest treatments 52
 post-infection treatments 245
 Potato 165
 Powdery-mildew 94, 222, 228
 Pre-harvest application of fungicides 52, 56
 Pre-harvest protection 19
 Pre-harvest treatment 40, 41, 49, 218, 221
 Prokaryotes and bacterial diseases 290
 promelain 98
 protoplasmic poison 243
Prunus armeniaca 17
Prunus domestica 105
Prunus persica 92
Pseudomonas syringae 5
Psidium guajava 59
 Pumpkin 123
Punica granatum 106
 Purple-blotch 245
 pycnidial encrustations 36
 pycnidial spots 143
 pycniospores 144
Pyrus communis 95
Pythium aphanidermatum 225
Pythium fruit-rot 136
Pythium-rot/damping-off 220

 radiation, use of 33, 75
 Radish 240
 Red-rot 265, 269
 rhizobacterial formulation 251
Rhizoctonia disease/collar-rot 204
Rhizoctonia fruit-rot 183
Rhizoctonia root-rot 238

Rhizoctonia solani 68
Rhizoctonia-rot 227
Rhizopus arrhizus 8
Rhizopus fruit-rot 85, 235
Rhizopus soft-rot 181
Rhizopus stolonifer 25, 51
Rhizopus-rot 17, 25, 67, 93, 95, 102, 107, 112, 127, 135, 252, 280, 284, 298
Rhizopus-rot/shrivelled bulb-rot 255
Rhizopus-rot/soft-rot 147
 Ridge-gourd 140
 Ring-rot 149, 185
 Ring-spot 219, 228
 Ripe fruit-rot 112
 Root and corm-rot 292
 Root crops 232
 root extracts, use of 156
 Root-scab 239
 Rust 236

 Sapota 109
 Scanty cottony white-rot /*Fusarium*-rot 122
Sclerotinia fruit-rot 11, 26, 139
Sclerotinia sclerotiorum 11, 139
Sclerotinia stalk-rot/white-rot 226
Sclerotinia-rot 122
Sclerotium rolfsii 141
Sclerotium root-rot/creepy white-rot 232
Sclerotium-rot 185, 272
 Scurf 288
Sechium edule 131
 Seed microflora 123, 189, 210
 Seed mycoflora 135, 151, 164, 197, 213, 215, 228, 236, 241, 254
 seed-borne 192
 Seed-borne infection 147
 seed-borne inoculum 193
 seed-borne pathogens 149
 Seed-borne viral diseases 210
 Seed-crop production 226
 Seedling-blight 138, 232, 241
 Seed-potatoes 176
 Seed-rot 160, 208, 261

- Seed-rot/damping-off 211
 seeds, pelleting of 154
 Set-rot 281
 Shiny black-rot 289
 skin-spot 170
 Slimy brown-patch 289
 Slow pedicel end-rot 69
 Smut 248, 256
 Snakegourd and pointed-gourd 135
 Soft corm-rot 294
 Soft curd-rot 225
 Soft watery-rot 132
 Soft-rot 47, 51, 76, 102, 119, 120, 140,
 157, 168, 194, 207, 230, 264, 265,
 270
 soft-rot management 268
 soft-rot of stored onions 249
 Soft-rot/ *Mucor*-rot 182
 Soft-rot/ stalk-rot 223
 Soft-rot/*Rhizopus*-rot, 64
 Soft-rot/*Sclerotium* fruit-rot 125
 Soft-rot/wet-rot/*Rhizopus*-rot 159
 Soft-rots 110
 Soft-scald 13
 Soil solarization 226
 soil sterilization by steam 190
 Soil-rot 120, 183
Solanum melongena 143
 Sooty mould 27
 Sooty-mould 77
 sorbitol 105
 Sour-rot 37, 130, 137, 141, 183, 238
 Speckle/ black- spot/ black-tip 22
 Sponge-gourd 141
 Spongy-rot/soil-rot 125
Sporotrichum aureum 37
Sporotrichum-rot 37
 Squirter disease 23
 Stalk end-rot 60
 Stem-and fruit-rot 161
 Stem-end-rot 36, 99
Stemphylium-blight 251
 sterilization of seed-tubers 175
 Storage diseases and causal organisms
 290
 Storage studies of red chillies 163
 Storage-rot 77, 251, 272
 Strawberry 111
 Styler-end rot 62
 Sulphur dioxide fumigation 49
 Sunken brown-spot 289
 sunken spots 143
 Sweet-potato 283
 Sword-bean 215
 systemic fungicides 42

 Tapioca/cassava 277
 Target-rot/early blight 169
 Target-spot 217
 Teliomorph 143, 172
Thanatephorus cucumeris 120
Thielaviopsis paradoxa 27
 Tomato 176
 toxic secondary metabolites 7
Trichoderma harzianum 11
Trichoderma viride 39
Trichoderma, effects of 267
Trichoderma-rot 39
Trichothecium roseum 8
 Tropical Root/Tuber Crops 277
 tuber chips, drying system for 280
 Tuber-rot 173, 297
 Tuber-rot/internal black-rot 173
 Tuber-rots 282
 Turmeric 271

 Use of biphenyl impregnated fruit-
 wrapper 33
 Use of chemicals 33
 Use of fungicides and chemicals 19
 Use of systemic fungicides 33
 Use of wrappers, wax-coating 15

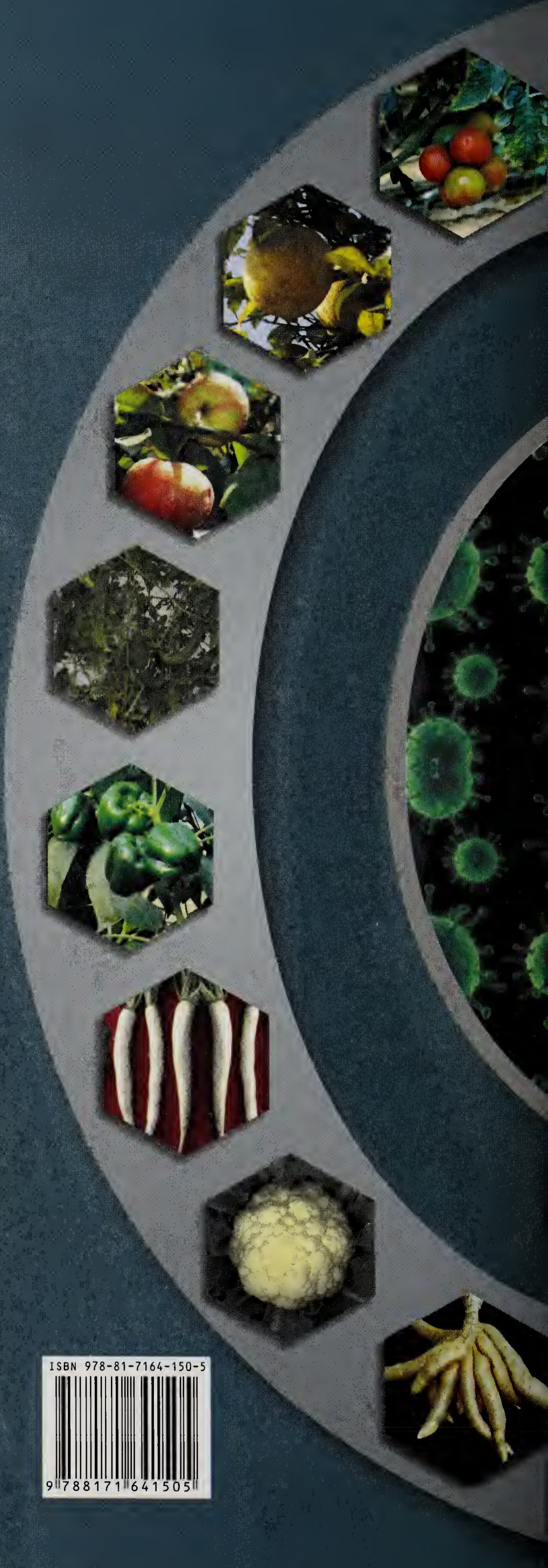
 Vacuum packing 30, 44
 Vapour, application of 57
 Varietal resistance 144
 varieties, resistant 266
Venturia inaequalis 3
 Violet root-rot 289
 Virus Diseases 197, 201, 210
Vitis vinifera 48
 water soaked lesions 186

- Water-core 14
water-soaked areas 179
water-soaked lesions 147, 148
Watery soft-rot 26, 118, 221, 236, 292
Watery wound-rot/leak 169
watery-rot/soft-rot 85
Wax coating 74
wax emulsion 82
Wax-coating 29, 42
Waxy-rot 240, 289
Web-blight 214
Wet-rot 148
Whiskers-rot/soft-rot 8
White mould /*Sclerotinia*-rot/soft-rot 205
White soft-rot/basal-rot 244
White-rot 249, 256
White-rust 241
Winged-bean 213
wrapper, use of 81
Wrinkled-rot 46

Xanthomonas campestris 40

yams 291
Yeast-rotting 56
Yeasty-rots 103

Zonations 192



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