CHAPTER II

Review of Literature
The study on post-harvest diseases of fruits and vegetables was initiated by Stevens (1915). He studied the diseases that occurred during the transportation of plant produce. Howkins (1917) worked out the methods of handling potato and on the incidence of potato leak disease. Shear (1918) stressed the importance of market pathology.

In the present investigation the studies concerning various aspects have been reviewed separately under following categories,

1. Market diseases of fruits and vegetables
2. Aeromycoflora study
3. Economic losses of post-harvest diseases in fruits and vegetables
4. Biological control of market diseases through plant extracts

1. Market diseases of fruits and vegetables

Dastur (1916) while working on banana rot, recommended the removal of infected fruits. Dey and Nigam (1933) noticed a large number of apple rot due to Aspergillus niger and recommended wrapping of fruits in tissue paper before packing to preserve them. Kheswalla (1936) carried out investigations on fruit diseases and described the symptoms of blue mold of apple caused by Penicillium expansum and, pink rot of apple caused by Trichothecium roseum. They recommended for the control of disease by careful handling of fruits to avoid bruises or injury to the skin. Mehta (1939) studied the effect of temperature and pH on the growth of Rhizopus arrhizus, which causes apple rot. Singh (1941) tested the pathogenicity of Penicillium expansum Link.
Rose (1943) studied market diseases of fruits and vegetables, citrus and other subtropical fruits. Wiast and Brately (1948) studied spoilage of fresh fruits and vegetables in rail shipments unloaded at New York city. Rose (1950) studied market diseases of fruits and vegetables viz., peaches, plums, cherries and other stone fruits.

Grewal (1954) carried out investigations and studied in detail the effect of temperature, humidity, light and age of fruit significance on the incidence of disease. Friedman (1960) studied market diseases of fruits and vegetables in orchards. Srivastava (1964) studied about fungal diseases of papaya fruits.

Thakur and Chenulu (1965) conducted systematic survey to determine the nature and extent of losses due to fungal diseases of a few commercially important fruits like apples, banana and mango and vegetables like potato and tomato in Delhi markets. Tandon et al (1974) studied post harvest disease of fruits and vegetables in Lucknow.

Link and Gardner (1919) and Link and Bailey (1926) reported black mold rot on onion caused by several species of *Fusarium cepa*, *Fusarium bulbigenum*, *Fusarium moniliforme*, *Fusarium oxysporum* and *Fusarium vasinfectum*. Machacek (1929), Venkataraman and Delvi (1951), Larbeer and Stone (1965), Hiremath and Govindu (1975) and Zohri (1994) reported *Fusarium* rot on onion caused by *Fusarium oxysporum*.

Rao and Hiremath (1966) and Hiremath and Govindu (1975) noticed that black mold rot of onion in storage was caused by *Aspergillus niger*. Link and Gardner (1919) and Zohri (1994) reported blue mold rot of onion was caused by *Penicillium sp.* and also were successful in isolating *Penicillium chrysogenum* from onion samples.

Walker et al (1925) and Hiremath and Govindu (1975) reported black mold rot on garlic caused by *Aspergillus niger*. Mathur and Sankhla (1966) reported dry rot of garlic caused by *Fusarium sp.*, *Macrophomia phoseloi* and *Penicillium sp.*

Link and Gardner (1919) noticed brown spot on cauliflower head caused by *Alternaria sp.* Walker (1953) observed a brown discoloration of the cauliflowers due to *Alternaria brassicicola*. Rao (1964) reported brown spot of cauliflower heads were due to *Alternaria brassicae* and Rhizopus soft rot of cauliflowers due to *Rhizopus nigricans*. Tandon and Varma (1964) observed *Fusarium sp.* causing the rotting of flowers. Hiremath and Govindu (1975) revealed that the waxy rot of cauliflowers was associated with *Geotrichum candidum* and brown rot of cauliflower heads due to *Alternaria tenuis* infection.

Link and Gardner (1919) noticed black leaf spot of cabbage infected by *Alternaria brassicae*. Rao (1964) and Hiremath & Govindu (1975), while
working with market diseases of vegetables reported *Alternaria brassicola* and soft rot caused by *Rhizopus nigricans*. Androsova (1964), and Leifert (1993) reported gray mold rot of cabbage due to *Botrytis cinerea*.

Link and Gardner (1919) studied in detail the market diseases of vegetables and reported *Alternaria sp.* on chilli. Subramanian (1954) noticed chilli rot caused by *Alternaria solani*. *Colletotrichum capsici* causing fruit rot of chillies was studied intensively by various workers, Rao (1964); Ratnam and Neema (1967); Hiremath and Govindu (1975); Sultan (1992) and Hodosy. Szurkene (1967) while studying *Colletotrichum* diseases of tomato and chilli, identified causal agent as *Colletotrichum akramentarum*. Hiremath and Govindu (1975) studied both fruit spot of chili and Fusarium rot and reported causal agents as *Curvularia lunata* and *Fusarium oxysporum*. Usha Bhole et al (2000) reported that seed borne fungi in chilli in Madhya Pradesh and their significance. They reported 16 fungi from 36 seed samples and identified the *Colletotrichum dematium* and *Alternaria alternata* cause severe seed rot and seedling decay.

Hiremath and Govindu (1975) surveyed market diseases of vegetables in Bangalore and found association of *Colletotrichum capsici* causing anthracnose and *Fusarium roseum* causing tip end rot of cluster bean. A leaf spot caused by *Alternaria brassicae* was recorded by Luttrell (1951) in Georgia. Yenjerappa (1989) noticed Alternaria spot on pods of cluster bean caused by *Alternaria cyamopsidis*.

Meier et al. (1922) found black rot of carrot was due to *Alternaria radicina* and *Drechslera sp.* under storage conditions. Hiremath and Govindu (1975) observed rotting of carrot due to *Fusarium oxysporum*. However, Maziano et al (1993) recorded association of *Fusarium solani* and *Fusarium*
avenaceum in causing rotting of carrots. Wright et al. (1964) identified a market disorder of pre-packed and bulk carrots due to Geotrichum candidum. Lauritzeen (1932) reported Rhizopus soft rot of carrot caused by Rhizopus sp. Hiremath and Govindu (1975) also noticed soft rot of carrots caused by Rhizopus nigricans.

Rao (1964) reported brown rot of ridge gourd caused by Fusarium oxysporum. Hiremath and Govindu (1975) observed brown rot, soft rot and Fusarium rot incited by Curvularia lunata, Rhizopus nigricans and Fusarium semitectum respectively.

Link and Gardner (1919) observed species of Alternaria causing black mold rot. Brown (1926) noticed stem end & center rot of tomato fruits infected by Alternaria sp. Rao (1964) observed the storage rot due to Alternaria solani in addition to Alternaria tenuis. Black mold rot of fruits was also reported by Thakur and Chenulu (1965), and Hiremath and Govindu (1973) observed heavy damage of fruits by Alternaria solani both in storage and market. Tandon and Kakkar (1965) studied the species of Curvularia causing tomato fruit rot during storage and identified the species Curvularia lunata and Curvularia geniculata. Fusarium rot of tomato was studied by Hiremath and Govindu (1973) reported Fusarium oxysporum and Fusarium roseum were being the casual pathogen.

Butler (1959), Rao (1964) and Hiremath and Govindu (1973) studied the waxy rot of tomato infected by Geotrichum candidum. While Okoli and Erinle (1989) made studies on both waxy rot and fruits rot caused by Geotrichum candidum and Macrophomina phaseoli respectively.

Chary and Reddy (1980) reported Nigrospora oxyzae and Stemphylium sp. on post-harvest fruits. Ratnam and Neema (1967), while studying the
market diseases of vegetables reported soft rot of tomato was caused by *Rhizopus arrhizus*. On the other hand, Hiremath and Govindu (1973) reported the soft rot caused by *Rhizopus nigricans*.

Rao (1964) noticed Fusarium rot of bitter gourd caused by *Fusarium oxysporum*. Tandon and Varma (1964) reported *Fusarium sp.* on the host. Hiremath and Govindu (1973) observed both Fusarium rot and black rot incited by *Fusarium oxysporum* and *Rhizopus nigricans*.

Thakur and Chenulu (1965) surveyed storage and market diseases of certain fruits and vegetables in Delhi market and reported *Aspergillus niger* as a minor disease causing pathogen of stored potato tubers. Kasai (1920) reported Fusarium rot of potato caused by *Fusarium trichothecioides* and Hiremath and Govindu (1973) reported *Fusarium coeruleum* and *Fusarium sambacinum*.

Harrison and Downie (1960) reported *Fusarium solani*, *Fusarium culmorum* and *Fusarium avenaceum* on potato. Janke and Zoth (1987) observed severe infection of potato by *Phoma sp.* Among them *Phoma exigua* var. *foveta* and *Phoma exigua* var. *exigua* were more infective, while *Phoma eupyrema* was less infective.

The phytophthora rot on potato tuber caused by *Phytophthora infestans* (Pushkarnath, 1960); water rot of potato by *Pythium ultimum* (Sampson and Fountain, 1961), *Phytophthora parasitica* on potato tubers (Rao, 1964), and cottony leak on potato tubers caused by *Phytophthora aphanidermatum* (Thakur and Chenulu, 1965) have been reported from various markets.

2. Aeromycoflora Study

Anton von Leeuwenhook was the first to observe microscopically and describe the microorganisms in the 17\textsuperscript{th} century. Later Micheli (1729) initiated the studies on Aerobiology. Pouchet (1860) and Pasteur's (1861) pioneering experiments have established the existence of "Microbial life" in the atmosphere and demonstrated the existence of air spora by using simple air sampling technique. This finding led them to establish the theory of "Germ Plasm of Disease".

Cunningham (1873) studied air spora over Calcutta jails in India and reported about air borne fungal spores. This research aspect involving microbial life in the upper air is referred as "Aero biology", while, Gregory (1973) designated the term "Air spora" to study microbial population in the atmosphere and stated mainly pollen grains, fungal spores and bacteria.

In recent years, Aeromycoflora survey has emerged as an important scientific pursuit and developed as a discipline of research. Gradually turned into routine aeromycoflora survey, to find out the air borne particles on pathology, allergy and bio-pollution.

Gregory (1973) coordinated much of the available information on Aerobiology and provided a synthesized picture of all aspects of this wide field of study in his book "Microbiology of the Atmosphere". Various workers have enumerated atmospheric composition of fungal spores, by employing different sampling techniques.

In India, Cunningham (1873) from Calcutta was the first person to undertake studies on the air spora. The credit of initiating a systematic research work on the air spora goes to Mehta (1952). The culture plate
technique was extensively used to study the composition of atmospheric fungal forms. Rajan et al. (1952) studied atmospheric fungal flora at Kanpur, and exposed Potato-Dextrose Agar plates for 5 minutes at 4 ft. and 8 ft. height and isolated 38 species of fungi. Kalra and Dumbrey (1957) from Poona isolated Aspergillus, Penicillium and Geotrichum from exposure plate method. Sandhu (1964) from Delhi identified a total of 14 fungal types by exposing Sabouraud's agar medium for 5 minutes. Among isolated colonies Alternaria, Cladosporium, Fusarium, Helminthosporium and Aspergillus were the dominant genera, identified 16 Aspergillus species of which the most frequent type was Aspergillus versicolor. Barat and Das (1966) compared the fungal population of air in urban and rural localities in West Bengal by exposing malt agar plates for one year and recorded the presence of Cladosporium, Aspergillus, Penicillium, Alternaria and Curvularia sp. in abundance. The maximum number of colonies were isolated during November and minimum in February. Mukherjee et al. (1969) and Agarwal & Shivpuri (1970) also gave an account of airborne fungi of Delhi. Using Martin's Rose Bengal Streptomycin medium, they reported 112 forms, out of which Cladosporium (24 %), Aspergillus (17.8 %), Curvularia (9.3 %) and Fusarium (6.4 %) and other types. Mishre and Srivastava (1970) compared the air spora over lake and adjacent fields of Gorakhpur using different media. Fusarium, Aspergillus flavus, Helminthosporium and Curvularia sp. were some of the genera recorded from all exposures. They discussed the general behaviour of air spora and noted Aspergillus fumigatus, Aspergillus nidulans, Aspergillus versicolor as summer types, Mucor, Fusarium, Curvularia sp. as rainy season types and Cladosporium, Alternaria sp. as winter types.

Rati and Ramalingam (1979) reported 35 species of Aspergillus from Mysore atmosphere. Bhati and Gaur (1979) recorded Thielaviopsis
bascola as the major specific type in Modinagar among 47 types isolated on Rose Bengal Streptomycin medium. Septonema and Spondycladium were the other specific types noted from that region.

Patil and Vyawahare (1981) from Ganesh kind, Poona used more than one media to assess the composition of air borne fungi. The average number of colonies per plate was highest (20.09%) for lactose yeast agar followed by Rose Bengal Streptomycin Agar (16.30%) and Sabouraud’s agar medium (10.87%) and reported 24 fungal types.

D’Silva and Freitus (1981) reported 30 genera, among these Aspergillus, Penicillium and Cladosporium accounted 50-75% of the total spore load. Khan and Sullia (1980) and Jayaprakash Narayana (1982) have studied airspora of Bangalore market. They found species of Aspergillus, Penicillium, Phoma and Trichoderma and airborne pathogenic forms. Whereas, Vittal and Ponnuswamy (1982) isolated 23 fungal genera on Potato Dextrose Agar and Sabouraud’s media. Cladosporium, Curvularia, Alternaria and Aspergillus were the most prevalent types isolated on all these media.

Agashe et al., (1983) conducted aeromycoflora of Bangalore and reported 37 fungal spore types. Among these Cladosporium and Alternaria were found to be the most dominate spore type and they correlated their incidence with meteorological data.

Kumar (1984) has discussed seasonal variation, frequency and circadian pattern of airborne fungi isolated from Dehra Dun city and reported 142 fungal types. Based on the seasonal abundance, summer types, winter types, and rainy forms were recognized. Rao (1986) from Andhra Pradesh studied the airspora of Nagarjunanagar and recorded Cladosporium, Fusarium,
Aspergillus, Alternaria and Neurospora sp. in abundance. It revealed 24 fungal spore types. Out of which Alternaria, Drechslera and Uredospores are dominant. Sarma and Sarma (1993) have studied incidence of air borne fungal spores in Guwahati by exposure slide and culture petriplate method and revealed 40 different types of spores. Out of these Cladosporium, Curvularia, Aspergillus occupied dominant place in aeromycoflora survey.

Agashe and Sudha (1994) conducted studies on seasonal periodicity of air borne fungal spores in Bangalore city and reported 55 fungal types. The dominant spores were Cladosporium, Alternaria, Penicillium, Nigrospora sp. etc., from non market area. Shashi Bala Avasthi and Shripad N.Agashe (1994) conducted survey of atmospheric pollen and fungal spores at two different sites in Bangalore. They reported fifty-one types of fungal spores during 1985-87.

Nanda et.al. (1997) conducted a study on airborne micro fungi in the bakers of Berhampur city, Orissa, by gravity petridish method and reported that Aspergillus, Cladosporium, Candida sp. was found to be abundant. Rafiyuddin et al. (1997) conducted indoor mycoflora of bakery by using culture plate technique, which revealed the incidence of Aspergillus flavus, Aspergillus niger, Aspergillus fumigatus and Penicillium sp. as mycotoxin producing fungal genera in indoor air.

Subrata Raha and Kashinath Bhattacharya (1997) conducted aeromycoflora of two residential area of west Bengal and reported 17 major spore types. The Cladosporium was recorded highest concentration during winter months and Cladosporium, Nigrospora, Curvularia, Drechslera and Aspergillus sp. were recorded throughout the year.
3. Economic losses of post-harvest diseases in fruits and vegetables

Economic losses caused by post harvest diseases are more severe than is often realized because fruits and vegetables increase manifold in unit value, while transporting from the field to the consumer. Dharam vir (1965) studied post harvest loss of tomato and Mango during transit and storage. He observed Alternaria rot of tomato caused by Alternaria tennis and Diplodia rot of mango caused by Diplodia natalensis.

Mehta (1975), carried out a survey in India, and reported that 20 to 30 per cent loss was due to post harvest decay of fruits and vegetables. Sharma and Sohi (1975) reported a heavy loss of tomato fruits due to infection of Phytophthora nicotianae infection which led to buck-eye rot in markets of Bangalore, Ooty, and Himachal Pradesh. Sharma and Sohi (1975) estimated a loss of 3 million rupees in tomato itself due to buck-eye rot infected by Phytophthora parasitica.

Tharaju. et al. (1989) noticed 22 to 25 % loss of tomato due to buck-eye rot in Haryana markets. Okoli and Erinle (1989) noticed 50% loss of tomato fruits due to infection of several fungi namely Geotrichum candidum, Curvularia lunata, Macrophomine phaseolina and Colletotrichum capsici. Potty (1990) reported post-harvest diseases loss of nearly 20 to 25 % of total produce of fruits and vegetables valued roughly Rs.6750 crores. Bottcher and Pohle (1991) noticed severe decay of garlic bulbs due to two fungal infections i.e., Penicillium and Botrytis sp. and recorded a loss of 75 % in storage and 12% in markets. Similarly, Kumar and Kotur (1991) estimated a loss of 11 to 13% cauliflower heads from infection of Xanthomonas compestris.
4. Biological control of market diseases through plant extracts

Little attention has been given to the biological control of post-harvest diseases of fruits and vegetables. Successful bio control of post-harvest diseases has been reported on several fruits and vegetables.

Pusey et al. (1984, 1988) reported the use of *Bacillus subtilis* for post-harvest control of peach brown rot with commercial fruit waxes, dicloran and cold storage conditions. Singh and Deverall (1984) reported *Bacillus subtilis* as a control agent against fungal pathogens of citrus fruit.

Janisiewicz (1987, 1988 &1990) described the general principles and steps in developing biological control for post-harvest diseases of fruit, using bio control of blue mold (*Penicillium expansum*) and gray mold (*Botrytis cinerea*) on apples and pears.

Dubey and Kishore (1988) found that essential oils from leaves of *Melaleuca leucadendron*, *Ocimum canum* and *Citrus medica* were able to protect several stored commodities from biodegradation by *Aspergillus flavus*. Purnima and Saxena (1990) tried the latex of *Euphorbia hirta* for the control of fruit rot of tomato.


Falik and Grinberg (1992) used volatile oil extract from the roots of *Hiba arberutae* (*Tujopsis dolabrata*) for the control of post harvest decay of *Capsicum annum* caused by *Alternaria alternata* at different concentrations.
Manickam and Rajappan (1996) used extracts of *Cocos nucifera, Sorghum vulgaris, Prosopis chilensis* and *Croton sparsiflorus* to prevent local lesion formation by tomato spotted wilt virus in cowpea.

Singh et al (1997) reported volatile constituents of many higher plants proved effective fungi toxicant against an array of fungi causing human and plant diseases. They reported that essential oil of *Cinnamomum* and *Cassia* bark has significant fungitoxic properties and they also recommended for in vivo trials in order to explore the possibility of their use as aerosol chemotherapeutant.

Wilson (1997) evaluated that plant extracts and essential oils from *Allium, Capsicum, Cymbopogon martini, Thymus zygis, Cinnamomum zeylanicum* and *Eugenia caryophyllata* showed most effective antifungal activity against *Botrytis cinerea*. Dubey (1998) reported plant extracts and oil cakes of *Moringa oleifera* and *Sesamum indicum* inhibited maximum mycelial growth of *Rhizoctonia solani*.

Ranjana sarma et al (1999) tested the efficacy of aqueous weed extracts of *Diplazium esculentum, Ageratum hoastonianum, Cassia tora, Solanum nigrum and Polygonum plebeium* on *Rhizoctonia solani*. All the weed extracts at 50% concentration inhibit the mycelial growth of the pathogen.

Sindhan et al (1999) reported the use of extracts of Onion bulb, Mint and Datura leaves on *Curvularia lunata, Macrophomina phaseolina* which showed complete check of mycelial growth and they also used leaf extracts of *Azadirachta indica, Mentha arvensis, Ocimum sanctum, Eucalyptus globuluns, Bougainvillea spectabellis*, rhizome and bulb of *Zingiber officinale, Allium*
sativum to control mycelial growth and sporulation in *Rhizoctonia solani* and *Rhizoctonia bataticola*.


Susanta Kumar Ghosh et al. (2000) reported solvent extracts of *Alpinia mutica*, *Cephalandra indica*, *Croton bonplandianum*, *Curcuma ameda*, *Holarrhena antidysenterica*, *Moringa oleifera* and *Zingiber spectabile* were found to contain antimicrobial properties.

Thirumala Rao et al. (2000) reported extracts of neem cake inhibited mycelial growth and spore germination of *Aspergillus niger* in soil. Janki Kandhari and Singh (2000) reported that the complete mycelial inhibition of *Rhizoctonia solani* was observed at 100 ppm concentration of *Syzygium aromaticum* with nonyl alcohol. A chemical constituent of *Jasminium officinale* with Citral phenyl ethyl propionate showed 83.3 to 88.3% antifungal effect. Benzene and Acetone extracts of *Tagetes tenifolia*, hexane and acetone extracts of *Tagetes erecta* also showed complete inhibition of mycelia at higher concentration (1000 ppm).

Singh and Navi (2000) reported 12% garlic extract with prophylactin spray showed 98 to 100% control under green house conditions on *Claviceps sorghii*. Jitendra Singh and Majumdar (2001) reported water, ethanol and acetone
extract of leaves of Datura and Tulsi. The Rhizome of Ginger and Turmeric, Garlic and Onion showed control over Alternaria fruit rot of pomegranate.

Prakasam et al. (2002) effectively managed post-harvest fungal diseases of carrot using *Azadirachta indica*, *Ocimum sanctum*, *Bougainvillea spectabilis*, *Catharanthus roseus*, *Eucalyptus globulus*, *Nerium odorum*, *Parthenium hysterophorus*, *Prosopis juliflora* and *Vitex negundo* extracts against *Cladosporium oxysporum*, *Fusarium oxysporum* and *Geotrichum candidum*.

Thiribhuvanamala et al (2002) reported that early blight of tomato caused by *Alternaria solani* was effectively controlled by using plant extracts of *Prosopis juliflora* and *Cocos nucifera*. It effectively controlled mycelial growth and spore germination.