PART I

CAUSES AND EFFECTS

1

INTRODUCTION

Nature has blessed mankind and other living organisms by providing a wide range of plant products for our consumption. However, human beings, in their desire to domesticate plants to satisfy their need for food, feed, fiber, timber, and other plant products, have selected plants with high yield potential. Unfortunately, most of the plant species and crop cultivars with high yield potential became increasingly susceptible to diseases and pests that can cause severe epidemics and food famines. Diseases caused by microbial pathogens – fungi, bacteria, and viruses – account for substantial losses of grains, fruits, and vegetables at both pre- and postharvest stages of crop production. Stakman and Harrar (1957) emphasized that "the responsibilities of the plant pathologists do not end with the harvest of satisfactory yields of plant products and that harvesting marks the termination of one phase of plant protection and the beginning of another". This statement clearly indicates that the second phase of plant protection – of seeds, fruits, vegetables, and other economic plant parts, from the time of harvest until they reach the consumer – is equally important. Postharvest pathology, earlier termed "market pathology", deals with the science of, and practices for, the protection of harvested produce during harvesting, packing, transporting, processing, storing, and distribution.

Several studies have shown that losses occurring between harvesting and ultimate utilization of agricultural/ horticultural products by the consumer are substantial, though there is no precise estimate. The harvested produce may be classified as: (i) durables, consisting of cereal grains, oilseeds, and grain

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legumes; and (ii) perishables, comprising succulent storage organs such as fleshy fruits, vegetables, rhizomes, and tubers. The harvested commodities are essentially dormant plant organs with physiological functions quite different from tissues of the mother plant. As the ripening/senescence process sets in, the susceptibility of the stored products to decay caused by microbial pathogens increases progressively. Furthermore, storage is an abnormal state for living plants or plant organs and it requires crowding of high volumes of plant produce in intimate contact in the limited available space. These unnatural conditions are likely to predispose them to different kinds of diseases which may be due to physiologic or pathogenic causes. The discussion in this book is confined to diseases caused by microbial pathogens.

1.1 IMPORTANCE OF POSTHARVEST DISEASES

The postharvest diseases that cause spoilage of both durable and perishable commodities are widespread. Greater losses occur in developing countries due to nonavailability of proper storage and transportation facilities and improper handling methods, resulting in greater levels of injuries or wounds during harvesting and transit. Durable commodities are generally stored in a dry state with moisture level below 12%, whereas perishable products have higher moisture levels (about 50% or more) at the time of storage. The harvested produce might have been infected by pathogens prior to harvest under field conditions or they may get infected during transit and storage. It is estimated that, in the tropics, about 25% of all perishable food crops harvested are lost between harvest and consumption. Losses in durable commodities, such as cereals, oilseeds, and pulses, may be about 10% on a worldwide basis (Waller, 2002). The losses may be both quantitative and qualitative. Some of the assessments of losses in different commodities are presented in Table 1.1. Under conditions favoring pathogens, loss caused by postharvest diseases may be greater than the economic gains achieved by improvements in primary production. Studies on postharvest diseases are primarily directed at preventing economic loss from spoilage of harvested commodities during transit and storage, and at eliminating the adverse effects of mycotoxins produced by fungal pathogens contaminating both durables and perishables. The mycotoxins are known to be carcinogenic, causing several serious ailments in humans and animals (Narayanasamy, 2005). There is an imperative need to gather information on the microbial pathogens involved in various postharvest diseases, conditions favoring disease development, and methods of developing effective systems of disease management.

1.2 THE STUDY OF POSTHARVEST DISEASES

The rapid detection and identification of pathogens is the basic requirement for the study of various aspects of the diseases and to develop effective systems

TABLE 1.1 Assessment of Losses Caused by Postharvest Diseases

Crop/Country	Pathogens	Loss (%)	Reference
Apple/England	*Gloeosporium* spp. *Monilinia fructigena*	0.3–21.03	Preece, 1967
Apple/France	*Gloesporium* spp. *Botrytis cinerea* *M. fructigena* *Penicillium* spp.	7.58–22.6	Bondoux, 1967
Mango/India	*Colletotrichum gloeosporioides*	29	Sohi et al., 1973
Strawberry/USA	*Botrytis cinerea*	10–15	Legard et al., 2000
Kiwifruit/USA, New Zealand	*Botrytis cinerea*	20–30	Michailides and Elmer, 2000
Avocado/ New Zealand	*Botrydiplodia theobromae*	23	Ledger et al., 1993
	Colletotrichum gloeosporioides	28	

of management. The pathogen population has to be quantified by employing specific and sensitive techniques that will provide results rapidly (Chapter 2). The environmental factors that may influence the development, survival, and overwintering of microbial pathogens causing postharvest diseases have to be studied to explore the possibility of controlling them during storage (Chapter 3). When the conditions are favorable for the development of microbial pathogens, the phenomenon of pathogenesis is initiated and the characteristic symptoms are induced. The names of postharvest diseases are commonly based on the chief symptoms induced in the produce (Chapter 4). The influence of cultivation practices (Chapter 5), handling, and storage conditions have to be assessed carefully in order to avoid or minimize the incidence of postharvest diseases. The storage conditions markedly influence the development of microorganisms causing diseases and producing mycotoxins capable of inducing mycotoxicoses in humans and animals, if the contaminated foods and feeds are consumed (Chapter 6).

1.3 DEVELOPMENT OF DISEASE MANAGEMENT STRATEGIES

Depending on the virulence (pathogenic potential) of the microorganisms, level of susceptibility/ resistance of the crop cultivar and the environment to which both the host and pathogen are exposed, a combination of short-term and long-term strategies to contain the postharvest diseases have to be developed. Some strategies are preventive in nature and they may be effective only if they are adopted prior to infection by microbial pathogens. Exclusion of microbial pathogens at all stages after harvest is necessary to prevent access

to the harvested produce. The effects of different physical agents, such as ultraviolet-C (UV-C), different forms of heat, and modification of storage atmosphere, are discussed in Chapter 7. Production of crop cultivars resistant to postharvest pathogens may be the most desirable strategy. However, the nonavailability of dependable sources of resistance to diseases and the long period of time required for incorporating disease resistance genes into susceptible cultivars limit the wider application of this approach (Chapter 8).

The increasing concern of the public regarding health hazards and environmental pollution following indiscriminate use of agrochemicals have necessitated the intensive search for alternative strategies for the control of postharvest pathogens. A wide range of fungi and bacteria occurring in the natural environments in which the agricultural and horticultural crops are grown has been screened and selected microorganisms have been employed for the control of the postharvest pathogens. These biocontrol agents are particularly suited for the control of postharvest diseases, since the area of treatment is limited and the conditions in which the commodities have to be treated can be controlled. The effectiveness of the biocontrol agents in providing protection against the pathogens, the specific requirements of the biocontrol agents and the methods of improving their efficiency are highlighted in Chapter 9. Developments in molecular biology and genetic engineering have opened up new vistas for the development of cultivars with resistance to diseases by incorporating genes from wild relatives, microbes, and even animals. In addition, the levels of resistance of susceptible cultivars can be enhanced by employing physical and chemical elicitors of disease resistance (Chapter 10).

Among the disease management strategies, application of various chemicals has been widely practiced with varying degrees of success. However, their use has to be minimized or avoided, because of two important drawbacks – namely development of resistance to chemicals in several microbial pathogens and the levels of residues of chemicals persisting in the harvested produce leading to health hazards in humans and animals. These factors were the primary considerations for the restricted use of chemicals approved specifically for use against certain diseases of fruits and vegetables (Chapter 11). Most of the strategies that have been tested could provide satisfactory control only under particular set of conditions. Hence, it is considered that safe postharvest treatments should be integrated to enhance the level of control of postharvest diseases. The possibility of integrating physical, biological and chemical methods to effectively control postharvest pathogens and to provide pathogen-free and chemical-free products for the consumer is discussed in Chapter 12.

As the management of postharvest diseases has to commence from the field where from the produce is harvested and extend during the storage and transit, the cooperation of the producer and trader is essential. The cultivation practices and plant protection measures should be carefully monitored so that pathogen inoculum reaching the produce is minimized, if not eliminated entirely. The nature, amount, and time of nutrient application should be prop-

erly determined to avoid enhancement of host plant and produce susceptibility to microbial pathogens, both in the field and in storage. Furthermore, the use of fungicides in the field should be regulated to prevent the development of resistance to chemicals that are to be applied later, prior to storage. For example no preharvest application of dicarboximide was permitted in New Zealand because of the widespread emergence of dicarboximide resistance in *Botrytis cinerea* that causes gray mold disease of kiwifruit (Michailides and Elmer, 2000). Hence, the realization of the possible occurrence of fungicide-resistant strains of fungal pathogens and the importance of adopting effective corrective measures can be expected to pave the way for effective management of postharvest diseases. Further, another dimension to disease management has arisen, as the preference of consumers for minimally-processed fruits and vegetables is steadily increasing. Outbreaks of human illness seem to have originated from food-borne pathogens such as *Escherichia coli* and *Salmonella* present in fresh-cut fruits and vegetables (Chapter 6). The need to take appropriate measures is emphasized to enhance the level of food safety (Chapter 12).

This book aims to provide comprehensive information to understand the potential of the different kinds of postharvest microbial pathogens that cause serious losses in a wide range of harvested produce, when conditions conducive for their development exist. The options that can be exercised at different stages are discussed in detail, with an emphasis on the coordination of efforts and cooperation of all agencies involved in the production, transport and storage. The teachers, researchers, and graduate students in the Departments of Plant Pathology, Microbiology, Food Technology and Environmental Sciences, Commercial Production Centers, and Plant Quarantine and Certification agencies will find the information presented in this book helpful in their efforts to contain the postharvest diseases. The protocols described in different chapters will assist in the development of research investigations for monitoring disease incidence followed by the application of effective management systems.

SUMMARY

The importance of postharvest microbial pathogens – fungi, bacteria, and viruses – with potential to inflict substantial quantitative and qualitative losses of harvested produce has been recognized. The factors favoring the development of postharvest diseases and various strategies available for the management of these diseases are outlined.

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