# SUSTAINABLE BIOLOGICAL MANAGEMENT OF IMPORTANT TEMPERATE FRUIT DISEASES FOR QUALITY FRUIT PRODUCTION

**Abstract**

Sustainable biological management of important temperate fruit diseases involves utilizing ecological and biological principles to control or mitigate the impact of diseases on fruit crops. This approach focuses on minimizing the use of synthetic chemicals and promoting practices that are environmentally friendly, economically viable, and socially responsible. This chapter explores innovative strategies for the sustainable biological management of key temperate fruit diseases, aiming to enhance fruit quality while minimizing environmental impact. Focusing on ecological principles, the chapter discusses practices such as crop rotation, the use of resistant varieties, biological control, companion planting, and organic amendments. The chapter includes the various plant diseases and their sustainable management through various biological practices. It emphasizes the importance of maintaining a balanced ecosystem through proper irrigation, sanitation, and cultural practices. Integrated Pest Management (IPM) approaches and the role of education, research, and innovation are highlighted to empower growers in adopting environmentally friendly and economically viable methods. By providing a comprehensive overview of sustainable biological management practices, this chapter aims to contribute to the promotion of resilient and ecologically sound fruit production systems.

**Keywords:** Sustainable biological, synthetic chemicals, environmentally friendly,

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## I. INTRODUCTION

The potential for increasing the area as well as the production of fruits that grow in low temperature areas particularly apples is enormous, thanks to the agro climatic conditions in hilly states. These fruits are subject to a number of diseases brought on by fungi, bacteria, and viruses that have a significant impact on how they are produced. Farmers suffer significant losses as a result of these diseases. In the fruit production system, producers use chemical control strategies to reduce losses brought on by diseases. The use of chemical fungicides on fruit crops poses risks to the environment and human health. Moreover they are very costly and the local marginal farmers cannot afford them. The emergence of pathogen populations that are resistant to pesticides has also stoked interest in developing an integrated disease control system. Incorporating biological control into conventional disease management programs of temperate fruit production systems would be helpful for the economy of our country, also it may reduce the ill effects caused by the chemicals. The production of temperate fruits, a perennial crop, presents distinct potential and challenges for the employment of biological control methods, particularly during the plant establishing process (Anwar et al. 2008). There will be numerous chances in the nursery setting to apply microbial inoculants such biocontrol agents or mycorrhizal fungi. When an orchard is first established, there is an additional window of opportunity for the introduction of biocontrol agents.

## II. SOIL-BORNE DISEASES

1. **Replant Problem:** Fruit tree cultivation is undergoing a rapid change as growers switch from low density, strong tree orchards to high density, dwarfing rootstock orchards. Growers are forced to set up new plantations on the location of the previous orchard because there isn't much area available to plant new orchards. Due to this, growers are now quite concerned about the replanting issue. Replant difficulty or replant disease is the term used to describe the issue with planting fruit trees in old nursery or orchard areas. Abiotic and biotic variables that affect replanting can result in stunted growth and late fruit yield. Replant disease is one of the elements of the replant problem that is brought on by biotic causes. Replanting issues are a complicated disease affecting temperate fruit crops. It is brought on by both biotic and abiotic elements. Replanting issues are caused by abiotic variables such as phytotoxins, nutritional imbalance, poor soil structure, poor drainage draught stress or too much moisture. Numerous pathogens and plant parasitic nematodes have been reported to be related with replant disease among other biotic variables. Numerous researchers have discovered a number of fungi, bacteria, and nematode species that are linked to replant disease, including various species of *Fusarium* like *F. equiseti*, *F. oxysporum* etc Various species of *Rhizoctonia* and *Cylindrocladium*, *Rosellinia necatrix*, *Penicillium claviforme*, *P. janthinellum*, *Phytophthora* spp. Each region has its own unique causes for the replanting issue. Different control measures are used depending on the primary element contributing to the replanting issue. However, it is not a desirable strategy because temperature and moisture can affect how effective volatile fumigants are. Additionally, applying fumigants is challenging, costly, and dangerous. Furthermore, it is thought that soil fumigation disturbs the balance between pathogens and other organisms in the soil. In this regard, efforts have been made to create a biological remedy for the replanting issue. According to several studies, the following growth of apples in replanted soil benefits from the

application of rhizobacteria that promote plant growth and inhibit disease (Caesar and Burr, 1987; Utkhede and Li, 1989b; Janisiewicz and Covey, 1983). Apple seedling growth in replant soil was shown to be accelerated by the application of strain B8 of *E. Aerogenesalone* (Utkhede and Li, 1989a). Similar to formalin fumigation, soil drenching with the BACT-1, EBW, and B10 strains of *Bacillus subtilis* and the B8 strain of *E. aerogenes* promoted plant growth (Utkhede and Li, 1989b). Replanting problems have been resolved in greenhouse and nursery testing by inoculating the roots of immature apple plants with *Agrobacterium radiobacter* (Catska and Hudska, 1990). This biocontrol product decreased the number of phytotoxic micromycetes colonies, which are a factor in replant disease. *Pseudomonas putidastrain* 2 CB isolated from apple roots was found to increase growth of M-26 root stock in different apple replant soil while inhibiting growth of each component of the fungal complex identified to instigate replant disease (Mazzola et al., 2002). Two fluorescent *Pseudomonads* and an intestinal bacterium that might encourage apple growth in replant soils were discovered by Casear and Burr in 1987. *Cylindrocarpon destructans*, a fungal pathogen known to cause apple replant disease, was found to have less root infection as a result of these *Rhizobacteria* enhanced development (Jaffe et al., 1982; Mazzola, 1998). In British Columbia, Canada, it has also been discovered that the application of *Bacillus subtilis* and *Enterobacter aerogenes* is efficient in increasing apple plant growth even in field conditions (Utkhede and Smith, 1994). These findings suggest that these rhizobacteria species have the ability to biologically reduce replant disease. Phosphorus is a crucial mineral for new plant growth in replant soil, according to a number of studies. In particular for immobile ions like phosphate, mycorrhizae symbiosis can increase nutrient absorption (Mosse, 1973). AMF *Glomus fasciculatum* and *G. Macrocarpus* vaccination of apple seedlings reduced the number of phytotoxic micromycetes, which are the cause of replant disease, and enhanced plant biomass (Catska, 1994). In replant soil, two AMF, *Glomus intraradices* and *G. Mosseae*, markedly enhanced overall shoot length and the number of shoots per rootstock. In replant soil that was neither fertilised nor pasteurised, the seedlings injected with *G. Mosseae* shown higher growth (Utkhede et al., 1992). After sterilising the soil prior to planting and inoculating it with AMF, *Glomus epigaeum* considerably reduced the problem of apple and peach replanting. According to observations, autoclaved replant soil exhibited greater growth stimulation following AMF inoculation (Bingye and Shengrui, 1998).

2. **Root Rot:** As the illness progresses, all of the lateral roots are attacked, and the fibrous root structure is destroyed. The lateral roots turn dark brown and are covered in a greenish grey or white mycelial mat. On the affected areas, a whitish mycelial mat-like fungal growth can be seen during the monsoon season. Within two to three years of infection, the infected plants exhibit bronzing of the leaves and a steady decline before dying. Infected roots continue to harbour the infection as mycelium or sclerotia. New plant roots can become infected by the fungal mycelium that is present in the soil on detritus or by coming into touch with old, dead plant roots. In acidic soils with high water content, the illness is more severe. Root rot management requires careful management as the infection resides very deep. Reaching the point of infection with corrective therapy is quite challenging. It can be controlled by putting preventive and therapeutic strategies into practise that include cultural, biological, and chemical techniques as well as resistant root stocks. Investigations into the biocontrol of bacteria and fungi that are hostile to soil-borne diseases have been ongoing for many years. This technique has drawn a lot of

interest and seems to hold promise as a workable addition to or replacement for chemical control. Iekiet al. (1969) observed that various isolates of Trichoderma spp. inhibited R. Necatrix. According to Freeman et al. (1986), two *Trichoderma* species—*T. harzianum* and *T. Hamatum*—isolated from naturally rotting roots prevented the growth of the fungus *R. necatrix*. Along with soil solarization, the use of antagonistic *Trichoderma* spp. as a treatment for the illness has been investigated (Sztejnberget al., 1987). Studies on pot culture have also shown that antagonists such *T. harzianum*, *T. koningii*, and *T. viride* can reduce root rot (Sharma, 1993). In tests using pot culture, the fungi *T. harzianum* and *T. viride*, as well as the bacteria *Pseudomonas fluorescens* and Bacillus spp., all demonstrated efficacy in reducing root rot (Sharma, 2000). According to Gupta and Jindal (1989), other bacterial antagonists called *Enterobacter aerogenes* have been shown to shield the plants from *D. nectrix*. These antagonists became more effective against the virus and had a longer-lasting effect when they were applied repeatedly. Arbuscular mycorrhizal fungi (AMF) have also been utilised against soil-borne diseases in addition to antagonistic fungi and bacteria. When researching the interactions between AMF and the microorganisms that cause root rot, Bharat and Bhardwaj (2001) According to research on *D. necatrixon* apple seedlings grown in pots, seedlings that had previously been inoculated with a local AMF isolate of *Glomus spp*. had less severe root rot than seedlings that hadn't received the inoculation. Additionally, the mycorrhizal seedlings showed faster development.

3. **Crown Rot:** In every region of the world where apples are grown, crown rot, often called collar rot, is a common problem. A fungus called *Phytophthora cactorum* (Lebert-Cohn) Schroeter is the culprit. The disease frequently results in significant losses, including tree death. The collar region is where the illness first appears, and it primarily spreads to subsurface organs and the above-ground stem. Bark rots and becomes sticky at the soil level, causing a canked area. The foliage on the affected trees is chlorotic and has reddish veins and edges. It is known that the causative fungus can live in orchard soils as chlamydospores in plant matter or soil. The primary inoculum is produced by the fungus in the form of oospores. High soil moisture and a moderate temperature encourage the illness. There have been attempts to manage this illness utilising drugs, cultural practises, and host resistance. The use of biological treatments to control *P. cactrum*, however, has also been investigated by a number of researchers. *Trichoderma* spp. were tested against *Phytophthora* crown Rot of Apple by Roiger and Jeffer (1991), who discovered that *T. virens*, *T. koningii*, and *T. harzianum* were successful in containing the disease. *Trichoderma* species *T. longibrachiatum* and *T. viride* also demonstrated efficacy in preventing P. cactorum in apples (Kumar, 2002). A few bacterial antagonists have also been discovered to be successful in controlling the illness. *P. cactorum* is hostile to *Enterobacter aerogenes*, as demonstrated by Utkhede (1983). The infection of *P. Cactorumin* McIntosh apple seedlings was decreased when these antagonistic bacterial cells were applied as a soil drench. According to Janisiecki and Covey and Utkhede (1983, 1984), *Pseudomonas* spp. and *Bacillus subtilis* were also effective against *Phytophthora* crown rot. Gupta and Utkhede (1986) also noted the antifungal activity of *E. aerogenes* and *Bacillus* spp. against *P. cactorum*, and they treated apple plants with these antagonists to successfully treat crown rot infections in the field (Utkhede, 1987). Utkhede and Smith (1991) studied the effects of soil soaking apple trees with *E. aerogenes* for three years in British Columbia with good disease control. In addition to reducing *P. Cactorum* infection, apple trees treated with strain B8 of *E. aerogenes* for two

consecutive years also grew taller (Levesque et al., 1993). Additionally, it has been shown that apple trees are protected from infection by various soil-borne diseases by antibiotics produced by *E. aerogenes* (Marchi and Utkhede, 1994). In the McSpur apple on MM 106 rootstock, which is otherwise sensitive rootstock for crown rot, another species of antagonistic bacterium *Enterobacter*, *E. agglomerans*, has also been observed to minimise disease severity and enhance the trunk girth and fruit yield (Utkhede and Smith, 1997). This antagonist's lyophilized dry formulation of strain B8 worked well. According to Orlikowski and Schmidle (1985), the *P. cactorum* infection in apple seedlings can be successfully controlled by the use of the product Binab-1, which was made from the antagonist *Trichoderma viride*. In a six-year trial, the application of the bacterial antagonists *E. agglomerans* and *B. subtilis* as well as the arbuscular mycorrhizal fungus *Glomus intraradices* greatly decreased the infection of apple trees with *P. cactorum* and boosted fruit yield and tree trunk growth (Utkhede and Smith, 2000). This antagonist's use has also been tested in conjunction with the fungicide metalaxyl as a soil trunk drench once in the spring for seven years and twice a year for three years. *P. Cactorum* disease ratings were decreased by the combined application (Utkhede and Smith, 1993). The same mixture (each 1g/tree) also caused affected apple plants to grow their trunk diameter more quickly each year when sprayed only once per year (Levesque et al., 1993). In pot cultures, Kumar (2002) discovered that concurrently inoculating apple seedlings with *Bacillus subtilis* and pre-inoculating them with *Trichoderma longibrachiatum* effectively inhibited *P. cactorum* infection.

## III. FOLIAR AND FRUIT DISEASES

1. **Apple Scab:** The most significant apple disease is apple scab, which affects apples everywhere. Fruit quality is reduced as a result, which is its main effect. Infected fruit cannot be stored for as long because of size reduction, premature fruit drop, defoliation, and poor fruit bud growth for the following year. In India, Kashmir was where the illness was originally discovered in 1930 (Nath, 1935). In Kashmir, this disease devastated the apple harvest in 1973 when it first emerged as an outbreak. The illness was discovered in Himachal Pradesh in 1977 (Gupta, 1978), and it became widespread in 1983 (Gupta, 1989). The majority of the state's apple harvest was devastated by the illness. One of the top five plant diseases of national significance, according to the Indian government, is the illness. On leaves, petioles, blooms, fruits, and pedicels, the disease symptoms can be seen. Velvety brown to olive green lesions first show up on the lower surface of developing leaves before spreading to the other surfaces. Deformed leaves develop from the tissue around the lesion becoming thicker as the affected leaf ages. The name "scab" is used to describe to this sort of symptoms. The number of lesions can range from one to several, and sometimes the entire surfaces get covered with scab. Petioles and pedicels that are infected cause leaves and fruits to ripen prematurely. The virus ruined the majority of the state's apple crop. The ailment is one of the top five plant diseases of national importance in India, according to the government. The disease signs can be detected on pedicels, flowers, fruits, and leaves. Before spreading to the other surfaces, velvety brown to olive green lesions first appear on the lower surface of growing leaves. As the damaged leaf ages, the tissue around it thickens, which leads to deformed leaves. The term "scab" is used to characterise this particular set of symptoms. One to multiple lesions may be present, and occasionally the entire area will be covered in scabs. Infected petioles and pedicels accelerate the ripening of leaves and fruits. On Mills period or

Tables, the criteria of temperature and length of leaf wetness for scab infection are well stated. Scab prediction and warning have become possible based on meteorological information and the quantity of primary inoculum, which is advantageous for the monitored apple scab management campaign, particularly in Himachal Pradesh. In India, a protective fungicide spraying programme is being used to manage the illness. At the silver tip stage is when the first protective fungicide spray should be applied. In this approach, the necessity for 6-7 sprays of different fungicides during the growth season results in pollution and health risks. In order to combat apple scab biologically, work on resistance breeding was started. The work on biological control is mostly concentrated on controlling the pathogen's overwintering stage on leaf litter. *Microsphearopsis* spp., *Diplodia* spp., and *Trichoderma* spp. are antagonistic fungi that have been researched by Carisseet al. (2000) for their effects on ascospore generation in the wild, either as foliar postharvest sprays or as a ground treatment at 90% leaf fall. They discovered a notable decline in ascospore production. According to Carisse et al. (2007), the antagonistic fungus *Microsphaeropsis ochraceae* is a powerful bio-sanitation agent against apple scab because it destroys the *V. Inaequalis* fungus's resting structures and lowers the initial inoculum. In organic apple cultivation in Canada, the use of biocontrol agents for the management of apple scab has gained popularity (Carisse and Dewdney, 2002). An alternative to chemical control strategies is the use of antagonistic fungus to suppress the overwintering stage of the scab pathogen in fallen leaves (Bengtsonet al., 2001). Yeasts isolated from apple leaves have also been tested for their antagonistic action towards V. inaequalis (Fisset al. 2003). Under greenhouse tests, three strains—H10, H15, and H25—were discovered to lessen the severity of scab on apple seedlings. An application of 1.5 x 107 yeast cells per millilitre significantly reduced scab on a 9-year-old Golden Delicious apple tree. In their 2002 study, The antagonistic effects of 30 various fungus isolates against the apple cultivars granny smith, stark spur golden, and starkrimson were examined by Altinok and colleagues. The production of volatile antibiotics by a number of isolates, including *Cryptococcus spp*. (white yeast), *Sporobolomyces spp*. (pink yeast), *Alternaria spp*., *Epicoccum spp*., and *Popularia spp*., was found to be fully inhibitory of the formation of the scab pathogen's colony. There have also been evaluations of specific biofungicides against apple scab. Fruitine, a biofungicide formulation of the *Bacillus subtilis* strain BIMV 262 tested by Pleskatsevich and Berlinchick (2004) against scab, found a decrease in the disease. In Russia, it was discovered that the biofungicide formulations Dizofungin, Biostat, and Narciss of bacterial and fungal species caused resistance in apple plants to scab (Nadykta, 2004).

2. **Apple Powdery Mildew:** Apple powdery mildew is a serious foliar disease that affects all nations that produce apples. In Iova, USA, in 1871, apple saplings were the first to show symptoms of the illness (Bessey, 1877). The biotrophic fungus *Podosphaera leucotricha* (Ell. and Ev.) Salm is the culprit. Every stage of the development of apples can have substantial commercial implications, from stunting the growth of nursery stock to causing fruit rusting (Jones and Aldwinckle, 1990). The disease survives the winter in dormant apple buds, and infected buds may not produce new shoots during the next growing season. The primary source of inoculum is overwintering mycelium's conidia, and secondary pathogen propagation is sparked by inoculum that forms from infection of young leaves, flowers, and other plant parts. Although the perfect stage of the pathogen has been observed in nature (Bharat and Bhardwaj, 2000), it is not thought to play a significant part in the progression of the disease. All agents that have been documented to

provide biological control of powdery mildew are of the fungal variety. As biotrophs, powdery mildews normally do not require exogenous nutrients for germination and initial penetration, so controlling them by competing for nutrients is not a practical tactic. Antibiosis control is unlikely to be an effective disease control strategy, just as the pathogen's exposure on the leaf surface during spore germination is constrained. As a result, the use of mycoparasites for the management of powdery mildews has received the most attention. *Ampelomyces quisqualis* is one of them (Novitskaya and Puzanova, 1992). The fungus's method of biocontrol has been identified as hyper-parasitism because it can colonise powdery mildew's mycelium and form reproductive structures. This fungus is a naturally occurring hyper-parasite of the powdery mildew pathogen's sexual and asexual structures. Within the hyphae, conidiophores, and cleistothecia of powdery mildew, it parasitizes and forms pycnidia. Powdery mildew parasitized colonies have a drab look, are flattened off-white to grey in colour, and produce fewer spores (Falk et al., 1995). A. quisqualis has also been isolated by Vaidya and Thakur (2005) from afflicted apple plants and other rosaceae family plant species. For the purpose of treating powdery mildew disease, it demonstrated the naturally occurring occurrence of this hyper-parasite in the western Himalayan region. According to Meszka and Bielenin (2006), using plant extracts in conjunction with hyper-parasite treatments, particularly walnut extract, has been shown to lessen the initial infection of apple foliar diseases such powdery mildew. For the biological management of powdery mildew, the mycoparasite A. quisqualisisolate A-10 has been made available as a commercial product under the trade name AQ 10 TM (Grove and Boal, 1997). According to Smol-Yokova et al. (2004), another ampelomitsin formulation from the genus *Ampelomyces spp*. was able to prevent powdery mildew on temperate fruit to a 70–80% degree.

## IV. POSTHARVEST DISEASES

Stone fruits are significantly more perishable and vulnerable to postharvest illnesses than other temperate fruits. According to Steppe (1976), postharvest infections cause 10–50% losses to temperate fruit. Numerous fungi and bacteria can result in post-harvest spoiling, with *Alternaria*, *Aspergillus*, *Botyosphaeria*, *Botrytis*, *Colletotrichum*, *Monilinia*, *Mucor*, *Penicillium*, *Rhizopus*, and *Trichothecium* species being the main pathogens. The majority of the time, postharvest pathogens enter sensitive fruit tissues and spread infection through fruit surface wounds that are caused by handling and harvesting the fruit as well as by wounds on the fruit's surface. Some infections can also enter through lenticels or the sinus between the calyx and core cavity, or decay may start there (Spottset al., 1988). It is possible to limit postharvest illnesses by paying attention to fruit handling procedures in the field and during storage to prevent mechanical and physical harm, as well as by managing controlled air conditions. These techniques do not, however, guarantee that stored fruits are well protected. Fungicide use has thus been essential in the management of postharvest disease (Eckert and Ogawa, 1988). But in the present era of organic farming, fungicide use is being avoided because of potential or real risks to human health and the environment. The employment of biological methods for controlling postharvest diseases has attracted a lot of attention and even had some degree of success over the past 20 years since fruits can be sources of direct fungicide intake. The microbial community living on the fruit surface and in the phyllosphere has been the main source of biological agents for controlling postharvest diseases (Janisiewicz, 1987). The most often used agents for the biological management of postharvest illnesses of temperate fruits have been bacteria and yeasts or yeast-like organisms (Sharma and Kaul, 1999). For the management of postharvest diseases of apples, pears, and peaches, bacterial agents have been discovered in several investigations. Grey mould, blue mould, and mucor rot on pears as well as on apples were biologically controlled by a saprophytic strain of *Pseudomonas syringe* (Janisiewicz and Marchi, 1992; Jeffers and Wright, 1994). Currently, the *P. syringe* ESC-11 strain is approved for postharvest treatment to apples and sold under the trade name Bio-save 110. Blue mould and grey mould on Golden Delicious apples were biologically controlled by an isolate of *Burkholderia cepacia* (Jamisiewicz and Roitman, 1988). Fruit rot brought on by *Penicillium expansum*, *P. malicorticis*, and *Botrytis cineria* was lessened when *Bacillus subtilis* was administered to damaged apples (Leibinger et al., 1997). *Bacillus subtilis*, *Epicoccum nigrum*, and *Pseudomonas spp*. have been used to biologically reduce postharvest brown rot in stone fruits (Pusey and Wilson, 1984; Smilaricket al., 1993; Madrigal et al., 1994; Foschiet al., 1995). *B. subtilis* can also be added to wax, which is typically used to prevent brown rot in peaches (Pusey and colleagues, 1986). Yeast use has proved successful in biologically controlling fruit postharvest illnesses. Studies on apple yeast diversity for biological controls of postharvest decays have been conducted. It has been reported that the yeasts *Condidaguillier mondii*, *C. oleophila*, *Cryptococcus laurentii*, *Kloeckera apiculata*, and *Sporobolo mycesroseus* can control *Penicillium expansum*, *Botrytis cineria*, and *Mucor* spp. Commercialised as postharvest fungicide Aspire for control of Penicillium spp. and Botrytis spp. is the yeast *Candida oleophilastrain* 182. The application of strain combinations has been encouraged by the use of numerous agents, which when used in concert broaden the area of biocontrol activity. However, the biological control of postharvest diseases has been achieved by the use of individual isolates. According to Janisiewicz (1988), *Pseudomonas* spp. and *Acremonium* provided total control over *B. cineria* and *P. expansumon* apple. The control of blue mould obtained by treatment with the individual agents applied separately using a biomass equivalent to that of the mixture was superior to that obtained by treatment with the bacterial antagonist *P. syringe* and the yeast *S. roseus* applied in equal biomass (Janisiewicz and Bors, 1995). When it came to preventing decay brought on by *B. cineria*, *P. expansum*, and *P. malicorticis*, a combination of two *Aureobasidium pullulans* strains and an isolate of *Rhodotorula glutinis* performed better than any of the strains treated alone (Leibinger et al., 1997). Antibiosis competitive exclusion, host-induced resistance, the creation of hydrolytic enzymes, and the suppression of *B. cinerea* and *P. expansum* are some of the mechanisms identified to support biological management of postharvest illnesses, reportedly involves the manufacture of the antibiotic pyrrolnitrin by *Burkholderia cepacia* (Janisiewicze et al., 1991). Iturin peptides, an antifungal chemical generated by *Bacillus subtilis*, have a broad range of antifungal activity. This chemical was found to be the antagonistic bacterium's main route of action in inducing the brown rot of stone fruits caused by *Monilinia fructicola* (McKeenet al., 1986). Using carbon or nitrogen sources, competing for nutrients, and physically excluding pathogens are all thought to be potential mechanisms by which yeasts could manage postharvest illnesses of fruits (Roberts, 1990). According to Droby and Chalutz (1994), the application of yeasts to wounds on several fruits increased the synthesis of the chemical ethylene. It was suggested that because ethylene is known to play a part in the process of inducing resistance, inducing host resistance may contribute to the suppression of sickness brought on by yeast application.

Determining the viability of using bio-control agents in the fields before to harvest as a means of controlling postharvest diseases has attracted growing interest. The fact that postharvest viruses can infect fruit in the field before it is harvested or as a result of a wound caused during handling and harvesting but before the fruit is moved into dump tanks where bio-control chemicals have been sprayed is what sparked this interest. Based on the few research that have been done, biological management of fruit postharvest diseases in a preharvest context does seem to be an option. Bulls eye rot symptoms in storage were greatly lessened by applying *Trichoderma harzianum* to apples in the field. In order to control postharvest disease, Leibinger et al. (1997) administered antagonists to Golden Delicious apples in the field. The administration of a combination combining the antagonists Aurobasidium pullans and Rhodotorulaglutinis was just as successful as using chemical fungicides to treat these illnesses. According to these findings, the use of specific biocontrol agents that are a typical component of the native microflora of fruits may be helpful in preventing infections both in the field and later on during fruit storage.

## REFERENCES

[1] Agarwala, R. K. (1961) Problems of root rot of apple in Himachal Pradesh and Prospectus of its control with antibiotics. Himachal Hortic. 2, 171-178.
[2] Agarwala, R. K. and Sharma, V. C. (1966) White root rot disease of apple in Himachal Pradesh. *Indian Phytopath*. 19, 82-86.
[3] Ali A, Amina, F., Moncef, H. and Ali, B. (2004) Efficacy of non-pathogenic *Agrobacterium* strain K84 and K1026 against crown gall in Tunisia. *Phytopathol.Mediter.*43, 167-176.
[4] Anwar A., GN Bhat, KA Bhat(2008)Mycoparasitic behaviour of certain bioagents against sheath blight pathogen (*Rhizoctonia solani*) of rice.*Indian Journal of Mycology and Plant Pathology*,38(1):135-40.
[5] Al-Momani, F., Saadoun, I. and Malkawi, H. I. (1999) *Streptomyces* spp. from Jordon soils with *in vitro* inhibitory activity against *Agrobacterium tumefaciens* Ab. 136 pti 854.*African Plant Production* 5, 129-130.
[6] Altinok, H. H., Erkilik, A. and Canihos, Y. (2002) Antagonistic effect of volatile and non-volatile antibiotics produced by fungi isolated from apple phyllosphere on *Venturia inaequalis*(Cke). Wint. Bulletin-0ILB/SROP 25(10), 249-252.
[7] Bengtson, M., Green, H., Hockenhull, J. and Pedersen, H. L. (2001) Microbiological control of cherry leaf spot and apple scab. DJE Rapport Markbrug 49, 33-38.
[8] Bessy, C. W. (1877) On injurious fungi: The blight (*Erysiphe*): Iowa State College of Agriculture Bienn. Rep. pp 185-204.
[9] Bharat, N. K. and Bhardwaj, L. N. (2001) Interactions between VA-mycorrhizal fungi and *Dematophora necatrix*and their effect of health of apple seedlings.Indian J. Plant Pathol. 19, 47-51.
[10] Bharat, N. K. and Bhardwaj, L. N.(2000) Occurrence of perfect stage of powdery mildew of apple in North Western Himalaya. Plant Dis. Res. 15, 81-82.
[11] Bingye, X. and Shengrui, Y. (1998) Studies on replant problems of apple and peach.ActaHortic. 477, 83-88.
[12] Caesar, A. J and Burr, T. J. (1987) Growth promotion of apple seedling rootstocks by specific strains of rhizobacteria.Phytopathology 77, 1583-1588.
[13] Carisse, O. and Dewdbney, M. (2002) A review of non-fungicidal approaches for the control of apple scab. Phytoprotection 83, 1-29.
[14] Carisse, O., Holloway, G. and Leggett, M. (2007) Potential and limitations of *Microsphaeropsi sochraceae*, an agent for bio-sanitation of apple scab. Biological Control-a Global Perspective 2007, 234-240.
[15] Carisse, O., Philion, V., Rolland, D. and Bernier, J. (2000) Effect of fall application of fungal antagonists on spring ascospore production of apple scab pathogen, *Venturia inaequalis.* Phytopathology 90, 31-37.
[16] Catska, V. (1994) Interrelationship between vesicular-arbuscularmycorrhiza and rhizosphere microflora in apple replant disease. Biologia Plantarum 36, 99-104.
[17] Catska, V. and Hudska, G. (1990) The possibility of using biological preparations of *Agrobacterium radiobacter* for biological control of apple replant problem. Replant Newsletter 3, 3.
[18] Catska, V. and Taube-Baab, H. (1994) Biological control of replant problems.ActaHortic. 363, 115-119.
[19] Droby, S. and Chalutz, E. (1994) Mode of action of biocontrol agents of post harvestdiseases.**In:** Biocontrol of postharvest diseases Theory and Practice, Wilson, C.L.Q. and Wisniewski, M. E. (eds.) Boca Raton, F L: CRC Press, pp. 365-389.
[20] Eckert, J. W. and Ogawa, J. M. (1988) The chemical control of postharvest diseases: deciduous fruit, berries, vegetables and root/tuber crops. Annu. Rev. Phytopathol. 26, 433-469.

[21] Falk, S. P., Gadoury, D. M. and Pearson, R. C. (1995)Partial control of grape powdery mildew by the mycoparasite *Ampelomyces quisqualis.* Plant Dis. 79, 483-490.
[22] Fiss, M., Barckhausen, O., Gherbawy, Y., Kollar, A., Hamamoto, M. and Auling, G. (2003) Characterization of apiphytotic yeasts of apple as potential biocontrol agents against apple scabs.(*Venturia inaequalis*).Zeitsch.Pflanz.Krankh.Pflanzensch.110(6), 513-523.
[23] Foschi, S., Roberti, R., Bremelli, A. and Flori, P. (1995) Application of antagonistic fungi against *Monilinia lexa* agent of fruit rot of peach. Bull OILB/SROP. 18, 79-82.
[24] Freeman, S., Sztejnberg, A. and Chet, I. (1986) Evaluation of *Trichoderma* as a biocontrol agent for *Rosellinia necatrix*. Plant Soil 94, 163-170.
[25] Grove, G. G. and Boal, R. J. (1997) Apple powdery control trials using the mycroparasite *Ampelomyce squisqualis*(AQ 10).F & N Tests 52, 7.
[26] Gupta, A. K. and Khosla, K. (2007) Integration of soil solarization and potential native antagonist for the management of crown gall or cherry root stock colt. ScientiaHortic. 112, 51-57.
[27] Gupta, G. K. (1978) Present status of apple scab (*Venturia inaequalis*) in Himachal Pradesh and strategy for its control. Pesticides 12, 13-14.
[28] Gupta, G. K. (1989) Apple scab-economics and Technology. Pesticides 23, 33-39.
[29] Gupta, V. K. and Jindal, K. K. (1989) Management of white root rot of apple (*Rosellinia necatrix*) by biological and cultural methods. Proc. Int. Hortic.Cong. Italy 2, 3229.
[30] Gupta, V. K. and Utkhede, R. S. (1986) Factors affecting the production of antifungal compounds by *Enterobacter aerogenes genes* and *Bacillus subtilis*, antagonists of *Phytophthora cactorum.* J. Phytopathol. 117, 9-16.
[31] Ieki, H., Kubomura, Y. and Koi, S. (1969) Detection and vertical distribution of white root rot fungus in forest soils. Ann. Phytopathol. Soc. Japan 35, 76-81.
[32] Ito, S. I. and Nakamura, N. (1984) An outbreak of white root rot and its environmental conditions in the experimental arboretum. J. Japan For. Sci. 66, 262-267.
[33] Jaffee, B. A., Abawi, G. S. and Mai, W. F. (1982) Role of soil microflora and *Pratylenchus penetrans* in the apple replant disease. Phytopathology 72, 247-251.
[34] Jamisiewicz, W. J. and Covey, R. P. (1983) Biological control of collar rot caused by *Phytophthora cactorum*.Phytopathology 73, 822.
[35] Janisiewicz, W. J. (1987) Postharvest biological control of blue mold on apples. Phytopathology 77, 481-485.
[36] Janisiewicz, W. J. (1988) Biocontrol of postharvest disease of apples with antagonist mixtures. Phytopathology 78, 194-198.
[37] Janisiewicz, W. J. and Bors, B. (1995) Development of a microbial community of bacterial and yeast antagonists to control wound invading postharvest pathogens of fruit. Appl. Environ. Microbiol.61, 3261-3267.
[38] Janisiewicz, W. J. and Marchi, A. (1992) Control of storage rots on various pear cultivars with a saprophytic strain of *Pseudomonas syringe.* Plant Dis. 76, 55-560.
[39] Janisiewicz, W. J. and Roitman, J. (1988) Biological control of blue mold and gray mold on apple and pear with *Pseudomonas cepacia*. Phytopathology 78, 1697-1700.
[40] Janisiewicz, W. J., Peterson, D. L. and Bors, R. (1994) Control of storage decay of apples with *Sporobolomyces roseus*. Plant Dis. 78, 466-470.
[41] Janisiewicz, W. J., Yourman, L., Roitman, J. and Mahoney, N. (1991) Postharvest control of blue mold and gray mold of apple and pears by dip-treatment with pyrrolnitrin, a metabolite of *Pseudomonas cepacia*. Plant Dis. 75, 490-494.
[42] Janisiewicz, W. Z. and Covey, R. B. (1983b) Biological control of *Phytophthora cactorum* Z.Pflanz.Pflanzenschutz. 90, 140-145.
[43] Jeffers, S. N. and Wright, T. S. (1994) Comparison of four promising biological control agents for managing postharvest diseases of apples and pears. Phytopathology 84, 1082.
[44] Johnson, K. B. and Dileone, J. A. (1999) Effect of antibiosis on antagonist dose plant disease response relationships for biological control of tomato and cherry. Phytopathology 89, 974-980.
[45] Jones, A. L. and Aldwinckle, H. S. (1990) Compendium of apple and pear diseases. APS Press. St. Paul, Minnesota 101pp.
[46] Jones, D. A. and Kerr, A. (1989) *Agrobacterium radiobacter*strain K1026, a genetically engineered derivative of strain K-84, for biological control of crown gall. Plant Dis. 73, 15-18.
[47] Kerr, A. (1980) Biological control of crown gall through production of agrocin 84. Plant Dis. 64, 25-30.

 

[48] Kumar, B. (2002) Studies on collar rot of apple. Ph.D. Thesis, Dr. Y.S. Parmar UHF, Nauni, Solan H.P., India.
[49] Leibinger, W., Breuker, B., Hahn, M. and Mendgen, K. (1997) Control of postharvest pathogens and colonization of the apple surface by the antagonistic microorganisms in the field. Phytopathology 87, 1103-1110.
[50] Levesque, C. A., Holley, J. D. and Utkhede, R. S. (1993) Individual and combined effect of *Eaterobacteraero* genes and metalaxyl on apple tree growth and *Phytophthora* crown and root rot development. Soil Biol. Biochem. 25, 975-979.
[51] Madrigal, C., Pascual, S. and Melgarejo, P. (1994) Biological control of peach twig blight (*Monilinialaxa*) with *Epicoccum nigrum*.Plant Pathol.43, 554-561.
[52] Marchi, A. and Utkhede, R. S. (1994) Effect of *Enterobacter aerogenes* or rhizosphere microflora of apple trees. J. Phytopathol. 141, 127-132.
[53] Mazzola, M. (1998) Elucidation of the microbial complex having a causal role in the development of apple replant disease in Washington. Phytopathology 88, 930-938.
[54] Mazzola, M., Granastein, D. M. Elfving, D. C., Mullinix, K. and Gu, Y. H. (2002) Cultural management of microbial community structure to enhance growth of apple in replant soils. Phytopathology 92, 1363-1366.
[55] McKeen, C. D., Reilly, C. L. and Pusey, P. L. (1986) Production and partial characterization of antifungal substances antagonistic to *Monilinia fructicola* from *Bacillus subtilis*. Phytopathology 76, 136-139.
[56] McLaughlin, R. J., Wilson, C. L., Droby, S., Ben-Arie, R. and Chalutz, E. (1992) Biological control of postharvest diseases of grape, peach and apple with the yeasts *Kloeckera epiculata* and *Candida guilliermondii*. Plant Dis. 76, 470-473.
[57] Mohammad Mehdi, Ali Anwar(2009). Role of genetically engineered system of male sterility in hybrid production of vegetables.*Journal of Phytology* , 1(6): 448–460.
[58] Mercier, J. and Wilson, C. L. (1994) Colonization of apple wounds by naturally occurring and introduced *Candida oleophila* and their effect on infection by *Botrytis cineria* during storage. Biol. Control 4, 138-144.
[59] Meszka, B. and Biclenin, A. (2006) Non-chemical possibilities for control of apple fungal diseases.Phytopathologia Polonica 39, 63-70.
[60] Moore, L. W., and Warren, G. (1979) *Agrobacterium radiobacter*strain 84 and biological control of crown gall.Annu. Rev. Phytopathol 17, 163-179.
[61] Mosse, B. (1973) Advances in the study of vesicular- arbuscularmycorrhiza.Annu. Rev. Phytopathol. 11, 171-192.
[62] Nadykta, V. D. (2004) Prospects of biological plant protection from phytopathogenic organisms. Zashchita-i-KarantinRastenii 6, 26-28.
[63] Nath, P. (1935) Studies in the disease of apple in Northern India. II. A short note on apple scab due to *Fusicladium dendriticum* Fuckel. J. Indian Bot. Soc. 14, 121-124.
[64] Nemec, S. (1980) Effect of fungicides on endomycorrhizal development in sour orange. Can. J. Bot. 58, 522-526.
[65] Novitskaya, L. N. and Puzanova, L. A. (1992) Biological protection of fruit nursery from powdery mildew.Zashch Rust. (Mosc.).6, 25.
[66] Orlikowski L B and Schmidle A. 1985.On the biological control of *Phytophthora cactorum* with *Trichoderma viride*.Deutsch.Pflanzensch. 37, 78-79.
[67] Pleskatsevich, R. I. and Berlinchik, E. E. (2004) Evaluation of the efficiency of local paste like biofungicide fruitine against apple scab. *Zashchita rastenii* 28, 132-138.
[68] Pusey, P. L., Wilson, C. L., Hotchkiss, M. W. and Franklin, J. D. (1986) Compatibility of *Bacillus subtilis* for postharvest control of peach brown rot with commercial fruit waxes, dichloran and cold storage conditions. Plant Dis. 70, 587-590.
[69] Pussey, P. L. and Wilson, C. L. (1984) Postharvest biological control of stone fruit brown rot by *Bacillus subtilis*. Plant Disease 68, 753-756.
[70] Roberts, R. G. (1990) Postharvest biological control of gray mold of apple by *Cryptococcus laurentii*. Phytopathology 80, 526-530.
[71] Roiger, D. J. and Jeffer, S. N. (1991) Evaluation of *Trichoderma* spp. for biological control of *Phytophthora* crown rot of apple seedlings. Phytopathology 81, 910-917.
[72] ShahidAhamad, Ali Anwar, PK Sharma (2011).Plant Disease Management on Horticultural Crops.PP.1-399,Daya Publishing House, 1123/74, Deva Ram Park Tri Nagar, New Delhi - 110 035

[73] Sharma, M. (2000) Non chemical methods for the management of white root rot of apple, Ph.D. Thesis, Dr. Y.S. Parmar UHF, Nauni, Solan (HP), India.
[74] Sharma, R. C. and Kaul, J. L. (1999) Postharvest diseases of temperature fruits and their management.**In:** Diseases of Horticultural Crops Fruits, Verma, L. R. and Sharma, R. C. (eds.). Indus Pub.Co.New Delhi, 582-623pp.
[75] Sharma, S. K. (1993) Studies on management of white root rot of apple. Ph.D. Thesis, Dr. Y.S. Parmar UHF, Nauni, Solan (HP), India, 146p.
[76] Smilarick, J. L., Deris-Arrue, R., Bosch, J. R., Gonzalez, A. R., Herson, D. and Janisiewicz, W. J. (1993) Control of postharvest brown rot of nectarines and peaches by *Pseudomonas* Species. Crop Prot. 12, 313-320.
[77] Smol-Yakova, V. M., Podogornaya, M. E., Puzanova, L. A., Cherkezova, S. R. and Yakuba, G. V. (2004) Ecologization of production of stone fruits from diseases. Sadovodstovo-i-Vinogradorstvo 5, 5-8.
[78] Spotts, R. A., Holmes, J. R. and Washington, W. S. (1988) Factors effecting wet core rot of apples. Aus. Plant Pathol. 14, 53-57.
[79] Steppe, H. M. (1976) Postharvest losses of agricultural products.Rep W.P./225/76 Serial No. 240 UNDP, Tehran, Iran.
[80] Sun, Y., Wang, H., Wang, J. and Song, X. (2000) Pathogenic bacteria of apple crown gall and their biological control. Acta Phytopathol.Sinica 30, 332-336.
[81] Sztejnberg, A., Freeman, S., Chet, I. and Katan, J. (1987) Control of *Rosellinianecatrix*in soil and in apple orchard by solarization and *Trichoderma harzianum*. Plant Dis. 71, 365-369.
[82] Utkhede R S and Smith E M. (1991a) Biological and chemical treatment for control of *Phytophthora* crown and root rot caused by *Phytophthora cactorum* in high density apple orchard. *Can. J. Plant Pathol.***13**: 267-270.
[83] Utkhede, R S. and Smith, E. M. (1994) Development of biological control of apple replant disease. ActaHortic. 363, 129-133.
[84] Utkhede, R. S. (1984) Effect of bacterial antagonists on *Phytophthora cactorum* and apple crown rot. Phytopathol. Z. 109, 169-176.
[85] Utkhede, R. S. (1987) Chemical and biological control of crown and root rot of apple caused by *Phytophthora cactorum*. Can. J. Bot. 61, 3343-3348.
[86] Utkhede, R. S. (1996) Replant disease and soil sickness. In: Management of soil-borne diseases (Eds. Utkhede RS and Gupta VK), Kalyani Publishers Ludhiana pp. 21-39.
[87] Utkhede, R. S. and Li, T. S. C. (1989b) Evaluation of *Bacillus subtilis* for potential control of apple replant disease. J. Phytopathol. 126, 305-312.
[88] Utkhede, R. S. and Li, T.S.C. (1989). Chemical and biological treatments for control of apple replant disease in British Columbia. *Can. J. Plant Pathol.***11**: 143-147.
[89] Utkhede, R. S. and Smith, E. M. (1991b) Phytophthora and Pythium spp. associated with root rot of young apple trees and their control. Soil Biol. Biochem. 23, 1059-1063.
[90] Utkhede, R. S. and Smith, E. M. (1993) Long term effect of chemicals and biological treatment on crown rot and root rot of apple trees caused by *Phytophthora cactorum*. Soil Biol. Biochem. 25, 383-386.
[91] Utkhede, R. S. and Smith, E. M. (1997) Effectiveness of dry formulation of *Enterobacter aerogenes* for control of crown and root rot of apple trees. Can. J. Plant Pathol. 19, 397-401.
[92] Utkhede, R. S. and Smith, E. M. (2000) Impact of chemical, biological and cultural treatments on growth and yield of apple in replant disease soil. Aus. Plant Path. 29, 129-136.
[93] Utkhede, R. S., Li, T.S.C. and Smith, E. M. (1992) The effect of *Glomus mosseae* and *Enterobacter aerogenes* on apple seedlings grown in apple replant disease soil. J. Phytopathol. 135, 281-288.
[94] Vaidya, S. and Thakur, V. S. (2005) *Ampelomyces quisqualis* Ces.-a mycoparasite of apple powdery mildew in western Himalayas.IndianPhytopath. 58, 250-251.
[95] Wazir, F. K., Meladul, K., Qureshi, J. A., Barech, A. R. and Kakar, K. M. (2000) Effect of physical and biological control measures soil. Sarhad Journal Agriculture 16: 49-51.
[96] Zambryski, P. C. (1992) Chronicles from the *Agrobacterium* plant cell DNA transfer strong. Annu. Rev. Plant Mol. Biol. 43, 465-490.

 