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# Review on ber (*Ziziphus mauritiana* Lamk) diseases and their management

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**Abstract**

Ber ( *Ziziphus mauritiana* Lamk) is an ancient and poor man fruit crop grown in semiarid and arid regions of India and other few countries. Ber fruits from commercial varieties like Gola, Umran, Seb, Mundia, Chomu local are considered as supplementary source of nutrition to the poor people of arid region. However, the yield and quality of ber fruits are adversely affected by various abiotic and biotic factors. Out of different biotic factors, fruit fly infestation and powdery mildew incidence pose much problems in attaining economic yield and consumers preference of these commercial varieties. Being an under utilized fruit crop, much attention has not been given on documentation of the production constraints mainly the biotic factors. Unless there is a comprehensive information available about the symptoms, life cycle and epidemiology of particular disease, suitable management practices can not be worked out. In this review, all possible efforts have been critically evaluated and only the relevant information from different sources, the working experience and publications available with the authors are presented. Emphasis was given on almost all the diseases based on the economical significance of particular disease in ber growing areas of the country preferably Western parts of Gujarat and Rajasthan. Disease like powdery mildew, fruit rots and post harvest diseases are elaborated with suitable literatures and management practices including some of the resistant varieties. This review could be more useful to formulate integrated management strategies for managing ber diseases at present and in future.

**Key words :** *Ber, diseases, fungicides, pathogens, symptoms and resistant varieties*

## Introduction

Ber (*Ziziphus mauritiana* Lamk) is a major fruit crop cultivated all over the water deficit areas of arid and semiarid regions of the Indian subcontinent. Ber orchards are relatively free from diseases wherein the dry and hot weather conditions coupled with very less relative humidity prevails. However some diseases like powdery mildew and leaf spots in humid region, fruit rots in arid conditions and post harvest diseases in all locations are economically important and concern with yield and quality. Complete loss of ber fruits due to havoc nature of ber powdery mildew being experienced in semi arid and humid regions every year. Successful management practices depend upon the proper diagnosis and distinction of symptomotlogy of different diseases in ber. However, there is no comprehensive information about major diseases and their management and therefore, this review will be immensely useful for the researchers, extension personals and ber growers.

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## 1. Powdery Mildew

Powdery mildew is a major disease concern with low productivity and quality of ber fruits. Being an obligate parasite, recurrent incidence results in heavy loss on susceptible cultivars grown in humid region every year. Ber powdery mildew caused by *Oidium erysiphoides* f.sp. *ziziphi* was first reported from Allahabad (Mitter and Tandan, 1930). Kumar *et al.* (1978) noted the occurrence of powdery mildew of ber (*Ziziphus* spp.) in Indian arid zone. However, complete life cycle of this major disease is yet to be investigated.

**Symptoms:** Initial symptoms appear on tender or young fruits at pea stage. White specks may occur on any parts of immature fruits at this stage. In severe incidence, floral parts, whole fruits; pedicel, tender branches and leaves would appear with powdery mass of conidia of the fungus. Severe dropping of such fruits can be seen under the tree canopy. The spots change into light to dark brown discolourations. Both upper and under surfaces of tender leaves are also affected and the colonized area are slightly raised and rough in appearance causing shrink and defoliation. Stunted growth of new branches, less fruit

setting and mummified fruits are the later symptoms of same tree already infected in severe form. Under severe incidence, whole tree would appear with very less number of fruit setting and malformed fruits. The matured fruits appear with brown rusty patches over the surface and such fruits are tasteless resulting complete loss on yield and quality. Ber orchards are devastated completely when the powdery mildew is in severe form at flowering and fruit setting stages.

**Epidemiology:** The cloudy, humid and moderate temperature coupled with few rainy days favour powdery mildew occurrence in moderate to severe form in ber orchards. Disease intensity may vary in different cultivars grown under various environmental conditions. In North India, infections appear from October and reached peak by December. Maximum severity of 100% could occur at maximum temperature of 21.9°C, 88% morning relative humidity, 59% evening relative humidity and 9.6hrs sunshine per day. In Southern states, disease intensity increase steadily from 38th meteorological week having 45.3% disease intensity and reached maximum of 90.7% disease intensity by 50th meteorological week. In Western parts of Gujarat, it appears in the month of September and persists up to January. Maximum temperature of 23.9 to 32.6°C, minimum temperature of 3.8 to 18.4°C coupled with morning relative humidity of 67-83% and evening relative humidity of 17-59% were found favourable for the disease development (Anonymous, 2002b).

**Pathogen:** According to Mitter and Tandan, (1930), the casual organism of ber powdery mildew has been reported to be *Oidium erysiphoides* f.sp. *ziziphi*. Other literatures reveal involvement of *Microspherea alphiditoides* f.sp.*ziziphi*. These belong to Ascomycotina, order Plectoycetes. The conidiophores are simple, erect measuring 75.8-139.8 x 12.6 ìm in size. Conida are cylindrical, one celled and hyaline measuring 25.2- 37.8 x 16.8-21ìm. Recently, CIAH, Bikaner has studied the basic aspects of this pathogen by collecting different isolates of powdery mildew from various locations of the country. Variability on morphogenesis of conidia and conidiophores was observed in all isolates (Anonymous, 2002a). Investigations on the molecular basis on ber powdery mildew resistance revealed that the phenolics, oxidative enzymes and calcium ion content could be considered as biochemical markers in demarcation of ber cultivars with regard to powdery mildew resistance (Nallathambi and Umamaheswari, 2002).

**Perpetuation:** Powdery mildew pathogen can survive in the absence of vulnerable growth stages of ber plants and subsequently infect under favourable conditions. However, limited works were carried on this particular aspect resulting different opinions about survival of this pathogen. It can survive on bud woods of the host plants during the non-flowering period. Prakash and Jhoooty (1987) reported that the pathogen can survive as normal and active mycelium on the leaves of ber plants growing under shade. Pathogen may also over winter or over summer and survive in the form of dormant mycelia in bark tissues. Laboratory studies revealed the persistence of dormant mycelia even in 6 months old leaves and fruits of susceptible cultivars like Gola, Umran and Seb (Anonymous, 2002). This pathogen may also survive on some of the collateral hosts viz., *Acanthospermum hispidum*, Haldi grass, *Xanthium xanthocarpum*, *Agrotum*, *Phyllanthus miuri*, *Tridax procumbus* and *Cenchrus biflorus* (Anonymous, 2002b).

## Management practices

**Cultural practices:** Successful management is easily achieved through integrated methods and maximum inoculum could be destroyed by cultural practices. During off season, wild species of ber viz., *Z.nummularia* and *Z.routantifolia* have been found to harbor the pathogen. Therefore, orchards must be free from such wild species. Some of the collateral hosts viz., *Acanthospermum hispidum*, Haldi grass, *Xanthium xanthocarpum*, *Agrotum*, *Phyllanthus miuri*, *Tridax procumbus* and *Cenchrus biflorus* have to be removed from ber orchards. Summer plouging of orchard help in desiccation of soil borne cleistothecia of pathogen. Regular monitoring of orchards is required particularly after flowering and fruit setting. As soon as white powdery specks appear on immature fruits at pea stage, such fruits should be removed and destroyed.

**Resistant varieties:** Plantation of resistant cultivars is an appropriate method for reducing intensity of this disease for a reasonable period of time. Jayarajan and Cheema (1972) reported some of the ber cultivars (Chhuhara, Safeda selected, Nazuk, Glory, Sanur-2, ZG-2, ZG-3 and Chinese), resistant to powdery mildew. Subsequently, these varieties also broke down their resistance and at present all the commercial varieties are susceptible. Kapoor *et al.* (1975) have tested 37 varieties and found that Sanaur 1 to 4, Bahadurgarthi, Noki and Chinese were tolerant. Genotype viz., Desi Alwar, Dharkhi, Desi, Sukhwani, Gulli, Villaiti and Seedless have also showed filed tolerance. Lodha *et al.* (1984) have screened 66 cultivars and of which 31 showed no symptoms of *Oidium erysiphoides* f.sp.*ziziphi* and 20 were moderately resistant under arid conditions. Some of the resistant tyeps (Chinese, Jogia and Vikas ) identified by AICRP on Arid Zone Fruits may have potential genes of resistance for varietal improvement either through hybridization or by other means of breeding programmes.

**Chemical control:** The control efficacy of various fungicides for the management of ber powdery mildew has been worked out by many workers. Kapoor *et al.* (1975) have reported that out of 9 fungicides, the best was benlate giving 92.1% control followed by afugan, both at 0.07%.

Spraying of 0.2% karathane and morestan (quinomethionate) @ 0.07% could result up to 97 per cent control of this disease (Gupta *et al.*, 1978). Subsequently, Singh and Sindhu (1985) found the best control of this disease could be achieved by 2 sprays of bavistin at a 25 days intervals starting fruits at pea stage, followed by karathane (0.1% dinocap) at 10-15 days.. Karathane at 0.1% was the most effective fungicide tested against *Oidium* sp on ber (Yadav and Singh, 1985). Commonly available fungicides have been tested for their efficacy and concluded that the acaricide i.e., karathane (Dinocap) is one of the best fungicides for the management of this disease. It can be recommended that spraying of 0.1% karathane immediately after pruning, will control the existing inoculums from the previous crop. Later on the spray schedule should be started at 15 days intervals from the time of full foliage to fruit maturity stage if, the areas under endemic location and expecting high intensity otherwise, number of sprays should be reduced to one or two based on the necessity at fruit setting stage.

**Biological control:** The biocontrol method of powdery mildew management is very limited in most of the crop plants. In many cases, hyperparasites like *Ampelomyces quisqualis* has been exploited in other horticultural crops. Hofstein *et al.* (1996) have developed new product known as 'AQ10' for the management of powdery mildews with suggestions that it could be included as preventive control agent. However, CIAH, Bikaner has initiated work on exploitation of native isolates of both bacterial and fungal antagonists. The field experiments on management of powdery mildew were carried out under powdery mildew endemic location. The native isolates of *Trichoderma* (CIAH-240) and *Pseudomonas fluorescens* (CIAH-196) along with 50% less than recommended dose of fungicide (karathane) were sprayed at monthly intervals on susceptible cultivars (Gola and Umran). The overall results depicted that the maximum (90.66) per cent disease control has been achieved by spraying 5% culture filtrate of *Trichoderma* (CIAH-240) followed by conidial suspension of *Trichoderma* (5 and 10%) spray resulting 82.19 and 83.2% respectively. In case of cv.Gola. per cent control efficacy of 95.81 could be achieved by combined application of *P.fluorescens* and 0.05% karathane. Bacterial antagonist alone was moderately effective as compared to combination with fungicides (Nallathmbi *et al.*, 2003) Therefore, these bioagnets will have grate importance as an alternative component in formulation of integrated management strategies against powdery mildew.

**Fruit Rots :** Fruit rots of ber are not a major problem in other parts of the Country. However, in western parts particularly in arid regions of Rajasthan, it is and major disease and economically important as compared to powdery mildew. Nallathambi (2001) studied in details about different kinds of rots due to various fungal pathogens in this region. Different types of fruit rots were recorded in almost all the major varieties of ber. The cumulative analysis of data form two years survey in different locations of arid region revealed that the fruit rot infection index was up to 22.5% with an estimated total yield loss up to 31%. Therefore, the fruit rots can cause major loss of ber fruits in coming years unless suitable management practices are followed.

## 2. Alternaria Rot

**Symptoms:** Disease incidence can be seen in immature as well as young and matured fruits. In Gola variety, *Alternaria* infection initiates from pedicel end and subsequently in bottom portion of fruits. Ripened fruits are relatively free from infection. Severe infection on maturing fruits resulted in dark brown blotch and ultimately whole fruit got rotted. Such fruits ultimately fall down resulting severe losses. Some fruits with complete rotting contained concentric rings having plenty of spores of the pathogen. In advanced stage of infection, fruits skin is found to be rough, shrivelled with distorted tissues. Fruits infected at pea and maturing stage also fall down from branches. At times, all the young fruits also fall down by severe infection and ber plants appear with moderate bearing of fruits. When infected fruits at maturity stage cut open, brown pulp in contrast to whitish green in healthy fruits could be seen easily. Seed development in such fruits is arrested or seeds are malformed.

Symptomatology on fruits of Umran variety is slightly different. Pathogen starts infection from pedicel end resulting in dark brown lesion lacking distinct margin on fruits and in some cases, infection can be seen in pedicel also. Dark brown lesions in batches can be observed on entire fruit surface and it is a characteristic symptom in this particular variety. Maturing fruits are mostly affected than young fruits and fruit dropping will be high in such plants. However, some of the fruits do not fall and remain on the branches in dry conditions. Internal symptoms show dark brown tissues with necrosis. Epidermal cells of fruit skin are found disrupted, light to dark brown and rough. However, pulp colour is not changed as much as in case of Gola variety. In premature fruits, seed is affected while in matured fruits under severe infection, seeds turn grey to brown or black as compare to healthy fruits. In case of cv. Seb, young fruits (pea stage) are mostly affected by Alternaria fruit rot. Fruits under maturity and ripening stages are less susceptible. Dropping of fruits is relatively less even under severe infection. Brown lesions from pedicel end enlarged rapidly and covered the whole fruits. Seed necrosis within light brown pulp tissues the internal symptoms. Fruits of Chomu local under maturity and ripening stage are mostly free from Alternaria infection. However, young berries are completely rotten and dropping

could be seen under the trees. Dark browning and shrivelled skin are the main symptoms due to this pathogen. Such fruits are hard to open. Internal symptoms can be seen as distortion of seed having pathogen growth on its surface. Pulp tissues are fibrous and interlocked with dark brown mycelium of the fungus.

**Pathogen:** Pathogenic fungi responsible for this disease has been identified as *Alternaria alternata* (Fr.) (Perfect state : *Pleospora infectoria*). This pathogen expressed variation in its growth characters. Mycelia were olive green in the initial growth and later on turned to blackish green. Brown mycelia with frequent concentric rings and dark brown mycelia lacking concentric rings can be observed. *A. alternata* is widely present in almost all host plant either as parasite or saprophyte on dead organic matter and therefore, it can easily survive during over winter and summer season. In addition, the dormant mycelia can be observed at inter and intracellular spaces of infected dead tissue and these can serve as primary inoculum for fresh infection under favourable conditions.

### 3. Black Rot or Aureobasidim Rot

Nallathambi *et al.* (2001) have studied in detail about disease for the first time in ber fruits (var. Gola). External symptoms of this disease are different from other fruit rots. Black lesions from pedicel region progressed rapidly on entire fruit. Infact, it is the only fruit rot showing black lesions on fruits and hence, this disease was named as black rot of ber berries. Infected fruits are not easily detachable from branches since pedicel of such fruits appears green and healthy. The casual organism of black rot has been identified as *Aureobasidium pullutans* (de Bary) G. Arnaud. (*Dematium pullulans*, *Pullularia pullulans* (de Bary)-Berkhout Microscopic observation can show dark grey to black, thick walls and frequent septation in mycelium. Conidia have borne on dark brown structures called denticles directly from the hyphae. Primary conidia are dark brown, thick wall with cylinderical shape. In 15 days old culture, budding from the primaries exhibits formation of secondary conidia by budding from the primaries. Secondary conidia are smaller (7-10 x 3-4.5 µm) than primary conidia, not adhering to each other, hyaline or light brown with smooth walls.

### 4. Cladosporium Rot

It is caused by *Cladosporium oxysporum* and found to occur in all the major varieties grown in the arid zone of Rajasthan. Infection appears predominantly on young and maturing fruits of Gola and Umran. Light brown lesions or blotches of browning on fruits surface are observed. Greenish mycelium of the pathogen can be also seen on fruit surface. Mycelial colonies of this pathogen are constricted and slow in growth on PDA medium. Initially colonies are olive green, slightly wringled or dark green and conidiophores are long, light brown, sparsely and irregularly branched.

### 5. Colletotrichum Rot

This disease is caused by *Colletotrichum gloeosporioides* on young and maturing fruits. Initial symptoms appear as water soaked, light brown lesions on fruit surface. Young berries also exhibit such symptoms. Whereas infection in ripening fruits is characterised with depressed, reddish brown lesions. Advanced infection show mass of acervuli on fruit surface. In Umran variety, reddish brown spots enlarged and coalesced forming bigger lesions. However, dropping of fruits is not severe as in case of Alternaria fruit rot. The pathogen *Colletotrichum gloeosporioides* (Penz.) sacc., Teleomorph *Glomerella cingulata* (Stomenason) Spould. and Schrenk. was found in association with fruit rot. Mycelial growth was grey on PDA medium. Acervuli production in the initial stage of mycelial growth is not common but plenty of conidia and setae are produced in 15 days old culture. Ber fruit rot symptoms of *Alternaria* and *Colletotrichum* are easily distinguishable in irrespective of varieties they infect, e.g. *A. alternata* produces browning with clear margin or brown batches in Kaitha variety while *Colletotrichum gloeosporioides* express water soaked lesions in Mirchia variety. Both pathogens also coexisted in same variety producing their characteristic symptoms.

### 6. Epicoccum Rot

Nallathambi *et al.* (2002) recorded for the first time under field conditions. During surveys undertaken in arid region of Rajasthan, this fruit rot was encountered in cv.Gola. Infection on maturing fruits appeared as a brown strips progressing downwards in one side of fruit where yellowing on other side. In severe infection, depression of fruit surface as well as hardening and malformation of such fruits can be observed. In some fruits with severe infection, small pinhead like growth of the pathogen having clusters of dark conidia were found. Internal symptoms showed fibrous nature of pulp tissues with necrotic seeds. Pathogen of this fruit rot has been identified as *Epicoccum nigrum* Link. It is a hyphomycetes fungus, commonly appears as saprophyte or secondary invader. However it has been found to cause fruit rot on ber fruits. The pathogen produced numerous large sized, spherical, irregularly septate conidia, borne on rapidly growing mycelium. Conidia appear in clusters, black, borne solitarily on short conidiophores, measuring 15-25 µm diameters with rough walls obscuring many septa.

### 7. Phytophthora Rot

Jee Hyeong Jin *et al.* (1990) have studied in details about the fruit rot due to *Phytophthora citricola* on *Zizyphus sativa* fruit. Symptoms consisted of brownish to reddish rot on fruits resulting in early drop or mummification. The causal fungus isolated from infected fruits and adjacent leaf stalks was identified as *P. citricola*. The fungus was highly pathogenic to *Z. sativa* and other fruit crops like apple, pear, orange, persimmon and aubergine and relatively weak to citron, tomato, capsicum and cucumber. Phytophthora rot will be severe and major problem if, rain occurs during the harvesting period. Pathogen can also infect at storage and causes losses during transit and in the market (Lin,1984).

### 8. Trichothecium Rot

This disease can be observed in later stages of fruit development, which are maturing and ripening during the months of January and February (Nallathambi, 2001). Fruits at ripening stage are more susceptible than young and maturing stages. Initially, reddish sunken spots on fruit surfaces were seen and in advanced stage of infection, few spots coalesce and cover a larger area. Dropping of fruits was not common in orchards. In some fruits, pathogen also colonized on surface. *Trichothecium roseum* (Pers.) Link is associated with this fruit rot. Mycelial colonies of this pathogen on PDA medium are orange pink with powdery mass of conidia. Microscopic observations revealed the profuse branching of mycelium, which are hyaline and septate. Conidiophores are long, erect, simple or aseptate, unbranched, hyaline and swollen at apex bearing conidia at the tips successively, each formed as a blown out cell below the previous, sometimes adhering loosely in chain. Conidia are hyaline, almost ellipsoidal to puriform with a single septa with the size of 16-20 x 8-10 µm. Conidia are having thin and smooth wall.

## Management practices

**Cultural practices:** Management of fruit rots is essentially required to get better yield and quality fruits of ber. In ber, *A. alternata* causes a major proportion of loss. This particular pathogen has many alternate hosts and it can survive as saprophyte in any kind of organic matter. Therefore, removal and destruction of infected fruits and other host plants in ber orchards can reduce the inoculum level. The use of fungicides is imperative to save not only the crops from avoidable losses but also for increasing productivity and ensuring stability and security because they play an integral role crops for better yields. Fungicidal sprays at fortnight intervals (0.2% mancozeb or copper oxychloride or chlorothalonil) can minimize the level of incidence if, the fruit rot incidence is more. Since *A. alternata* is also causes leaf and fruit spot disease in pomegranate, all the precaution measures followed in ber orchards have to be adopted in case of pomegranate orchards also so that the fruit rot incidence of ber can be minimized indirectly by arresting the inoculum from pomegranate plants to ber.

**Chemical control:** Evaluation of some of the non-systemic fungicides at different concentrations against *A. alternata* resulted that out of 7 fungicides including a biofungicide. dinocap (Karathane) inhibited the growth of the pathogen 100% at all concentrations. Mancozeb and copper oxychloride are also significantly effective to check the growth. However, captan showed moderate efficacy upto 250 ppm and higher concentrations (500 and 1000 ppm) of this fungicide resulted 72.28% and 82.75% inhibition respectively. Wettable sulphur and alcidine are not effective to the test pathogen. Systemic fungicides act systemically in plant after application either in soil or as foliar sprays. Propiconazole and tridemorph completely inhibited the mycelial growth of test pathogen followed by triademefon with an inhibition range of 72.52 to 98.63% at 50 to 1000 ppm active ingredients. The least efficacy was expressed by carbendazim (3.5 to 15%) followed by metalaxyl+ mancozeb and thiophenate methyl (Nallathambi and Thakore, 2003)

**Biological control:** It is gaining importance for management of crop diseases (Backer and Cook, 1974). Diseases caused by *Alternaria* species have also been successfully managed by biocontrol agents like *Trichoderma harzianum* and *Bacillus* sp (Mercer and Papadopolous, 1990) and Fluorescent pseudomonads (Silva *et al.*, 1998; Prasad and Kulshresthra, 1999). Native isolates of *Trichoderma* were evaluated for *in vitro* inhibition of *A. alternata*. (Nallathambi and Thakore, 2002a). Out of 16 isolates, 9 isolates could check more than 50% growth of pathogen. Native isolate CIAH-240 was significantly superior than rest of the isolates. Isolates viz., CIAH-142, CIAH-150, CIAH-161, CIAH-165a, CIAH-259 and SBI-33 showed less than 50% check ((Nallathambi and Thakore,2002b). Least inhibition (26.41%) was expressed by CIAH-150. Different native isolates of *Trichoderma* inhibited the pathogen by different mechanisms. The superior isolate CIAH-240 was mycoparasitic as well as secreted toxic metabolites. Weakening, lysis and distorted mycelium of pathogen results in response to *Trichoderma* colonization. Isolates CIAH-142 and 165a can be used as mycoparasitic while rest of isolates are merely competitive. Out of 14 native isolates of *P.fluorescens* tested, CIAH-196 inhibited the maximum mycelial growth. Interestingly, sporulation of test pathogen was suppressed by some of the native isolates (Nallathambi and Thakore, 2002b). However, practical applications have to be evaluated.

**Management of Alternaria rot at post harvest stage**

Generally post harvest infection due to microbial organisms results into severe losses particularly in fruits due to high perishability. Fruits are enriched with high carbohydrates which are ready-made food with other nutrients thereby utilization is easy for fungal colonization. In order to find some post harvest treatments for combating *A. alternata* infection which was found to spoil fruits in transit and storage (Nallathambi and Thakore, 2004) have screened to select an effective bioagents under laboratory conditions using biocontrol agents, fungicides and combination of these two methods to reduce the infection. Bacterial antagonists are also useful for post harvest treatments for the control of fruits diseases (Pusey and Wilson, 1984). Nallathambi (2001) has identified some of the effective isolates of *P. fluorescens* under *in vivo*. All native isolates of *P. fluorescens* were effective with more than 60% control efficiency after 7 days of treatment. In addition, physical properties like texture and colour of ber fruits were better in bacteria treated fruits. Isolates of bioagents i.e. CIAH-240 (*Trichoderma*) and CIAH-196 (*P. fluorescens*) are better than rest of the biocontrol agents tested and therefore, these two effective isolates have been taken for further experiments. Fungicides treatment showed that dinocap and copper oxychloride at 50 ppm are effective and resulted in more than 50% control. Whereas, at 100 ppm concentration, except mancozeb, wettable sulphur and dinocap were found to control more than 60%. Copper oxychloride has given 67.7% control. Dinocap also expressed some scorching effect on treated fruits and smell of treated fruits was also bad. Some of the systemic fungicides except carbendazim have resulted more than 50% control at both concentrations tested. Moreover, propiconazole and tridemorph can injure the fruits resulting in scorching or necrotic spots on fruits just after treatment.

Integration of more than one component can result better efficacy on management of post harvest pathogens. Effective fungicides as well as bioagents were combined for the control of fruit rot of ber so that maximum loss is reduced with minimum use of fungicides. Effective isolate of *Trichoderma* (CIAH-240) and *P. fluorescens* (CIAH-196) were chosen for combined treatment with fungicides. Mixing of *Trichoderma* certainly improved the efficiency of the treatment, as there was marked increase in disease control. More than 70% efficiency can be realized when thiophenate methyl, mancozeb and alcidine at 50 ppm whereas more than 80% PEDC was obtained when 100 ppm of thiophenate methyl, chlorothalonil, mancozeb and alcidine were mixed with *Trichoderma* isolate (CIAH-240).

In other case, per cent control efficiency was more than 60% when *P. fluorescens* isolate (CIAH-196) was mixed with thiophenate methyl, captan and alcidine at 50 ppm. Similarly mixing of *P. fluorescens* with thiophenate methyl, captan, and alcidine cay be effective to control the Alternaria rot of ber. Fungicides solution mixed in *Trichoderma* (isolate, CIAH-240) solution first, then with bacterial cells suspension and then pathogen inoculated fruits were treated in this mixture. Lower concentration of fungicides (50 ppm a.i.) mancozeb + metalaxyl, triademefon, thiophenate methyl, captan, chlorothalonil, copper oxychloride, mancozeb and alcidine gave more than 50% PEDC. Nevertheless, mancozeb, thiophanate methyl and alcidine were significantly controlled the disease at 50 ppm with both the bioagents. In order to ascertain the actual resistance level, some of the genotypes were evaluated under laboratory conditions using its toxin. Genotypes viz., Chhuhara, Bagwadi, Khura B. Bawandi, Reshmi and Ponda showed immune response to fruit rot pathogen.

## 9. Black leaf spot

**Symptoms :** Gupta *et al.* (1977) have reported this disease for the first time from Haryana. It is common in Southern and Northern parts of the Country. Cloudy weather with moderate temperature during October-November is favourable conditions for the development of this disease. Black spots, which are sooty, tuft like circular to irregular black spots develop on leaf surface. During advanced stage, the lower surface of leaves also covered in larger area and corresponding upper surfaces show brown discolouration. Microscopic examination indicated that hyphae penetrated the lower epidermal cells, disintegrated them together with the spongy parenchyma and rapidly colonized between the palisade and spongy parenchyma cells to penetrate the upper epidermis causing necrosis and browning.

**Pathogen:** This disease is caused by *Isariopsis indica* var.*zizyphi*. The fungus as primary inoculum survives in plant debris and soil for subsequent infection. Plenty of spores produced from each spots serve as secondary spread through wind. An isolate of *I. indica* var. *zizyphi* from *Ziziphus mauritiana* grew and sporulated best at 20°C. which was the most prevalent temperature during January, when the disease was most severe under natural conditions. The fungus can survive up to 6 months on infected leaves after dropping on the ground or sticking to crotches of branches and cracks in the bark.

## Management:

**Cultural practices:** The infected leaves and twigs are to be removed and destroyed as soon appearance of disease is seen. Ber orchards should be maintained free of weeds and ber plants should be properly pruned with optimum canopy density so that humidity may not develop and the available inoculum will not proliferate for fresh infection. However, this pathogen also infects other plants like mulberry trees used as wind brakes around the plantations and the common weeds *Cynodon dactylon* and *Bidens pilosa* (Verma *et al.*, 1984). Therefore, such plants have to

be avoided in the vicinity of ber orchards in addition to destruction of all weed hosts.

**Resistant varieties:** Gupta *et al.* (1980) reported that out of 56 *Ziziphus mauritiana* varieties screened for resistance to *Isariopsis* (*Phaeoisariopsis*) *indica* var. *ziziphi* in the field at Hissar. Some of them were resistant varieties viz., ZG-3, Seo Bahadurgarhia and Safeda Rohtak. Cheema and Dhilon (1981) studied the resistance level of different cultivars and reported that none of the 36 of *Ziziphus mautitiana* was resistant to this disease. Some of the cultivars like ZG-3, Safeda Rohtak, Mundia-Murthera, Sua, Sanour-1, Padami, Jhajjar selection; Seo-Bahadurgarhia and Jhajjar special were reported to be resistant.

**Chemical control:** Other than cultural practices like removal and destruction of infected leaves, some of the contact fungicides have been found to be effective in control of this disease. Different fungicides have been evaluated to manage the disease. However, spraying of bavistin or difolatan (0.2%) was found effective. It was also reported that this disease was successfully controlled by 4 sprays of carbendazim, copper oxychloride or Bordeaux mixture applied fortnightly from the first week in November and containing a suitable adjuvant (Verma and Cheema, 1983). Of 6 fungicides applied as sprays, 0.1% Bavistin was effective in reducing the disease incidence followed by 0.2% Dithane M-45 mancozeb (Sekhar, *et al.*, 1989). Rawal and Saxena (1989) have concluded that *Isariopsis indica* var. *zizyphi* was effectively controlled with treatment of 0.1% Bavistin (carbendazim) followed by Daconil (chlorothalonil) at 0.2% under field trials. A mycoparasite called *Hansfordia pulvinata* (Berk et.Curt) Hughes was growing on diseased spots in nature can also control disease without further damage to the host (Gupta and Madaan, 1979).

## 10. Alternaria leaf spot

Alternaria leaf spot in ber is commonly noticed in ber orchards. Except in few locations where the environmental conditions are highly conducive for disease development, there will not be much loss in orchards. The disease is characterized by the formation of small, irregular brown spots on upper surface of leaves. Corresponding lower side appears with dark brown to black spots. Under humid conditions, black patches comprising plenty of conida can be seen and which serve as air borne inoculum. As in case of other plants, under severe conditions many spots coalesce to form big patches and later such leaves defoliate from branches. Different authors have reported various species of *Alternaria* species.

This disease development is favoured between 20 to 30°C with an optimum temperature at 25°C. Plant debris serves as potential source of primary infection. High relative humidity coupled with frequent rainy days appears to be more important than temperature in disease development. Madaan and Chand (1986) confirmed that the pathogen survives over the summer in debris of *Ziziphus mauritiana*, providing primary infection and perpetuation in soil and plant debris to provide recurrent infection. In order to manage this disease, plantation of resistant cultivars is recommended. Bahadugarhia, Govindgarh special, Gola-Gurbaon, popular Gola, Seo, ZG-3, Safeda Rohtak, Jhajjar special and Mirchia were reported to be resistant to this particular leaf spot (Jayarajan and Cheema, 1972). However, the disease can be effectively managed by weekly spray of either one of the fungicides like Difolatan, Dithane-Z-78 or 0.2% mancozeb.

## 11. Red Rust

The algae *Cephaleuros virescens* Kunze causes red rust in ber. However, leaf rust of *Zizyphus mauritiana* caused by *Phakopsora zizyphi-vulgaris* has been reported from Haryana, When it occurs, at first some light green spots appear on the over blade of the leaves, then some yellow powder will appear, that is the summer spores of the pathogen (Quan and Quan, 2002). Gjaerum (1973) has reported *Uromyces anthyllidis* and *Ziziphi vulgaris* on *Ziziphus mauritiana*. Jujube rust disease (*Phakopsora ziziphi - vulgaris* (P. Hean.) Diet.) is an important disease for jujube trees. It usually attacks the leaves and often makes the leaves to fall by 30-40%, so the production will be much reduced. The spots are of 2-5mm diameter. They occur on the upper surface of the leaves as first greenish gray and later they turn into purplish black with central tuft of blight orange. Severely infected twigs are stunted growth and leaves wither from them. Symptoms are severe on old leaves and uncared trees.

This disease can be managed through integrated approaches. Plantation of resistant varieties would be the permanent and effective method of managing this disease. Of 58 cultivars screened under field conditions having natural infection, 7 were resistant against this disease. Fungicidal spray is required when there is moderate to severe incidence. However, prophylatic spray is advisable for checking initiation of incidence. The best control of leaf spot on Z.*mauritiana* was given by 0.1% carbendazim followed by 0.1% thiophanate-methyl (Gupta *et al.*,1989). Spraying Bordeaux mixture, lime sulfur, triadimefon (as amiral) or carboxin effectively managed the *Ziziphus* rust of ber in some locations.

## 12. Stem Blight

Stem blight of ber has been reported for the first time in ber under arid conditions (Nallathambi and Umamaheswari, 2001). This disease was observed after pruning. Almost 80% of the genotypes in the National germplasm repository were infected and failed to sprout. Initially, black lesions appeared from cut ends of the stem

and progressed downwards. In severe infection half portion of the stems were observed with black lesions. Complete drying of the whole tree was noticed when the blighting progressed below the soil level. When the bark was split open, pinhead like pycnidia interlocked in mycelia mat of the pathogen could be seen. The saprophytic fungus *Torula herbarum* has been identified as casual organism of this disease. This pathogen could survive for long time in the infected stems in the form of dormant mycelium and pycnidia. In order to manage this disease, infected stems or the part the stems, which is not sprouting for long time, have to be removed from the tree and injured portions may be pasted with Bordeaux paste. Pasting and soil drenching of copper fungicide (Bordeaux mixture) are effective in suppression of the disease.

## 13. Amellophorella Leaf Spot

It is considered as minor disease in ber except some places in central and Southern parts of the India have reported that this leaf spot is serous problem. This disease appears during the months of January and February. Formation of small, irregular, pale or dark grey spots on the leaves are the symptoms. In advanced stage of infection, such spots get enlarge result drying of leaves. This disease is caused by *Amellophorella zoenoplia* and it can be easily managed by spraying 0.2% Difolatan or Dithane M-45 when there is severe infection.

## 14. Cercospora Leaf Spot

It appears during the months of January and February. This disease is caused by *Cercospora jujubae* Choudury( *Cladosporium ziziphi* Karst). Small, round, gray spots with red margin on both sides of the leaves are the symptoms of this leaf spot. Severely infected leaf areas dries up and fall off showing shot hole symptoms. It is also known as shot hole disease. Some time this particular disease can also produce sooty mould growth having dark brown blotches on the under surface of the leaves. Though it is not a major disease, the contact fungicides like 0.2% mancozeb or copper oxychloride or zineb can control it.

## 15. Post Harvest Diseases of Ber

Ber fruits are having short period of shelf life and therefore, many fungal pathogens at their saprophytic stage can easily infect few days after the harvest or in other words, after complete ripening of the fruits. The per cent infection of fruit rot due to post harvest pathogens may vary from 5-12 per cent irrespective of the varieties. After 5-7 days of harvest, ber fruits are adversely affected by different saprophytic fungus. Kainsa *et al.* (1978) have studied the surface mycoflora of freshly harvested ber fruits. Inoculating the fruits by pinprick injury and placing them in sterile desiccators for 10 days at room temperatures and studied the relative efficiency of different microorganisms among the surface microflora. In India, post harvest rots of ber is mostly confined with deuteromycetus fungi, whereas, in other countries even lower fungi also cause fruit rots. Gray mold disease on *Z.jujuba* and *Z.marutiana* caused by *Botrytis cinerea* has been reported from Taiwan (Hsieh and Tsai, 1978). Wadia *et al.* (1980) reported three post harvest pathogens viz., *Alternaria alternata, Fusarium decemcellulare* (*Calonectria rigidiuscula*) and *Cladosporium cladosporioides* on *Z.mauritiana* fruits from India. The consolidated reports from different research centers of AICRP revealed the involvement of fungus viz.,*Aspergillus terrens, A. flavus, A. niger, Alternaria alternata, Colletotrichum gloesporioides, Penicillium spp., Phoma spp., Rhizopus stolanifer and Cladosporiun oxysporum.* Sumbali and Mehrotra (1982) have studied the post harvest fungal diseases of ber fruits caused by *Trichothecium roseum, Glomerella cingulata, Cladosporium oxysporum, Alternaria alternata, Geotrichum* sp, *Phoma herbarum* and *Fusarium equiseti.* Maadan and Dasgupta (1983) have surveyed of markets in West Bengal and reported *Aspergillus aculeatus* on *Z.jujuba.* Ullasa and Rawal (1986) have described the post harvest decay caused by *Phytophthora nicotianae, Sclerotium rolfisii* and *Botryodiplodia theobromae* in ber fruits. In several markets of Rajasthan, some new post harvest diseases were observed and the fungi including *Cladosporium tenuissimum, Fusarium pallidoroseum, Pythium aphanedermatum, Phoma nebulosa and Rhizoctonia solani,* which have not been reported as post harvest pathogens of this host (Sharma *et al.*, 1978). A number of fungi causing rotting with an average incidence ranged from 2 to 15.3% of ber fruits have been identified from a regular survey of Chomu, Jaipur and Jobner areas of Rajasthan, wherein the ber cultivation is abundant. The most frequently occurring fungi were *A.alternata, Cladosporium oxysporum, Rhizoctonia solani, Fusarium solani, F.pallidoroseum, Pestalotiopsis palmarum, Phoma hisorensis, Rhizophus stolonifer, Colletotrichum* sp and *Aspergillus* sp (Jat *et al.*, 1997). The most frequently isolated pathogens were *A. flavus, A.niger, Emericella nidulans, A.alternata, Cladosporium oxysporum, Curvularia lunata* (*Cochliobolus lunatus*), *Fusarium sporotrichioides and Penicillium chrysogenum.* The relationship exists between preharvest fungal populations and postharvest fruit rot of *Z. mauritiana.* Among the mycoflora on the surface of jujube (*Ziziphus mauritiana*) fruits, *Aspergillus flavus* was consistently recorded during the entire period of fruit development.

## Management

In order to avoid the fruit loss due to these fungal pathogens, ber fruits have to be harvested in right time without injuries on the fruits. Harvested fruits should be

marketed as quickly as possible. Since the ber fruits are directly consumed, it is not advisable to go for chemical treatments for the control above mentioned fungal infection. However, the physical and biological treatments can preserve the fruits somewhat free from the fungal species. Singh and Gupta (1983) evaluated four types of packaging and 2 cushioning materials for their effect on microbial decay during storage of Umran and Kaithli cultivars of ber (*Ziziphus mauritiana*) at room temperature. Gunny bags and wooden boxes were better at reducing spoilage than packing made of bamboo basket or cardboard. Paper cuttings were the best cushioning material for reduction of decay losses due to *Ulocladium chartarum, Phoma hissarensis* and *Botryodiplodia theobromae*. Lal *et al.* (1981) have recommended as fruit dips at 500ppm of Bavistin (carbendazim) and 1000 ppm of Difolatan (captafol) and performed best. Nallathambi *et al.*, (1999) reported that the post harvest infection of ber fruits can be minimized when the fruits treated with calcium nitrate are stored at low temperature (below 10°C). The symptoms of *Colletotrichum gloeosporioides* (*Glomerella cingulata*), *Botryodiplodia theobromae, Rhizopus stolonifer, Phomopsis nastume*, and *Pestalotiopsis palmarum* were described. In order to reduce the incidence of such diseases and improve fruit quality, the correct harvesting period is essential.

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