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Fungal diseases of Betel vine (*Piper betle* L.) in India and their management : An overview

ATREYEE BANERJEE[1] AND RAJYASRI GHOSH[2*]

[1]Research Centre, Ramakrishna Mission Swami Vivekananda's Ancestral House and Cultural Centre.105 Vivekananda Road, Kolkata 700006

[2]Department of Botany, Scottish Church College.1&3, Urquhart square. Kolkata 700006

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Betel vine (*Piper betle* L.) ,commonly known as Pan, is one of the major cash crops in India. It is also referred to as green gold of India. Following the traditional practice, betel leaves are chewed directly by the people of different states of India and it is also indispensable in various religious , social and cultural aspects of human life. Besides this, Betel vine has nutritive and therapeutic value by virtue of its phytochemical constituents. The present review mainly discusses the major diseases of Betel vine such as Foot rot, Collar rot, Root rot, Leaf spot and Powdery mildew caused by fungal pathogens. The environmental conditions inside Pan Baroj are favourable for the growth of fungal pathogens, thus resulting to the incidence of fungal diseases of betel vine. Among the above mentioned diseases, Foot rot caused by *Phytophthora parasitica* and Collar rot caused by *Sclerotium rolfsii* are the two most deadly diseases of betel vine which cause significant reduction in yield (upto 90-100%) every year consequencing huge economic loss. Although chemical fungicide treatment was found to be the most effective method for disease management, but considering their toxic effect on human health and ecosystem , the use of biocontrol agents is a better alternative for disease control. Recently Integrated disease management strategy is found to be effective in controlling fungal diseases of betel vine.

Keywords: Betel vine, biocontrol agent, disease management, fungal pathogen, green gold

INTRODUCTION

Betel vine (*Piper betle* L.) , commonly known as Pan, is a cash crop in India and often referred to as green gold of India. India is the largest producer of betel leaves in the World (Kumar *et al* ,2023). Betel leaves are directly consumed by more than 20 million people in India on a regular basis (Pandey *et al* , 2018). If other countries of the World are taken into account, then the number of total consumers may reach up to more than 2 billions (Biswas *et al.*2022). Betel vine is a perennial, evergreen, aromatic plant of creeping habit. It belongs to the dicot family piperaceae , growing in tropical and subtropical agroclimatic conditions. Although the plants are dioecious in nature ,but the male plants are mostly cultivated for commercial purpose (Guha, 2006).

Betel leaf plays an important role in India since ancient time for aroma, refreshing taste and medicinal properties. Betel leaf can act as a natural tonic and mouth freshener to prevent oral malodor .The use of betel leaf in India dates back to 400 BC. According to the ancient literature viz. Ayurveda, Charaka, Sushruta Samhitas and Kashyapa Bhojanakalpa, the practice of chewing betel quid had been a common practice between 75 AD and 300 AD .Towards the 13th century, European traveller Marco Polo recorded betel chewing among the kings and the upper class individuals in India (Toprani and Patel , 2013). Betel leaves were also in use in other countries since ancient time like China, West Indies and Latin America as it is referred in their traditional and folk medicines. Betel leaves have immense economical, medicinal, nutritional benefits as well as socio-cultural, religious values in India since ancient time. Betel leaves and areca nuts are indispensable in any Hindu religious or social ceremony (Biswas *et al.* 2022).

*Correspondence: rgbotn @scottishchurch.ac.in

The primary Centre of origin of this plant is considered to be Central and Eastern Peninsular Malaysia and is distributed to East Africa and tropical countries of Asia. Among the hundred varieties of betel vine cultiversfound across the globe, 40 varieties are found only in India and of which 30 are recorded from West Bengal and Bangladesh (Biswas *et al.*2022).The major betel vine growing states of India are Madhya Pradesh ,Karnataka, Odisha, Tamil Nadu, West Bengal, Andhra Pradesh, Assam, Uttar Pradesh, Bihar, Gujrat and Rajasthan. Madhya Pradesh is thehighest producer of betel leaf, whereas West Bengal is the third highest betel leaf growing state (Kumar, *et al.* 2023). Some of the major varieties are Bangla, Meetha, Sanchi, Kapoori, Kashi, Banarasi Tellaku, Maghai, Kariyale, Desavari, Desi Bangla,Kallipatti, Godi Bangla, Pachakodi, Vellaikodi, Ghanagete, Simurali, Bhavna, Ramtek Bangla, Kali Bangla etc (Jain, *et al.* 2022).These varieties are mainly categorized on the basis of their distinct color, refreshing aroma,bitter and peppery taste and diverse shape as well as size (Madhumita, *et al.* 2019).Betel vine has many names in different languages like Pan,Tambool, Vakshapatra, Sompatra, Tamalapaku, Voojan-galata, Saptaseera, Nagaballi etc in different parts of India (Guha , 2006**).**

As far as our national economy is concerned, almost 20 million people in India thrive directly or indirectly on cultivation, processing, transp-ortation, trading and commerce ofbetelvine leaves (Kumar *et al.* 2023). West Bengal produces about 1,39,18,300 mote betel leaves (1 mote = 10,000 betel leaves) per year as per Department of Food Processing Industries and Horticulture, Govt. of West Bengal (Nandi *et al.* 2022). Betel leaf cultivation is the source of monetary income throughout the year to the farming families whereas the major crops like rice, wheat, pulses can deliver income only once or twice a year. As per the report of Directorate General of Commercial Intelligence & Statistics (DGCIS), Govt. of India, India had exported betel leaves up to 6517.369 tons and grossed foreign currency to the extent of rupees 459.729227 million in the year of 2021-2022(Kumar *et al.*2023; Nandi *et al.* 2022).

CULTIVATION

In India Betel vine is cultivated in black, friable, clay loamy soil containing huge amount of organic matters with pH5-7. But in Bengal the best varieties are grown in light loamy and slightly reddish coloured soil. For the luxuriant vine growth, annual rainfall of more than 150cm is necessary. Temperature range should be within 10-25^{0}C. Adequate relative humidity and presence of soil moisture are other two imperative factors. The native habitat of betel vine is humid tropical forest conditions with high percentage of relative humidity.

The cultivation technique can be broadly classified under two categories namely under natural condition and under controlled condition. The open system of cultivation (natural condition) is practiced in regions where conditions like of high humidity and moderate sunshine are seen all through the year. Betel vine is a climber which requires support from other trees like areca nut, coconut and generally it attains a height of 10-15meters with profuse branching at the top with plenty of foliages.

In controlled situation or closed system , betel vines are being cultivated under artificially made erect, covered structures known as 'Boroj'. Boroj is basically an erect structure made up of local materials such as wooden or bamboo poles, coconut leaves ,jute sticks, paddy straws and a variety of grasses as thatching material .The top of the Boroj is covered by locally available grasses to reduce the amount of light incidence on the plant as well as on the soil surface. The vines are planted close to each other for retention of moisture that can create a favourable microclimate for vine growth. The modification of plant habitat inside the Boroj results in suppression of linear growth and promotion of profuse branching. This type of controlled cultivation is genuinely practiced in subtropical regions where relative humidity is low and maximum temperature in summer is 40°C and in winter below 10^{0}C. Height of the Boroj varies from 2-3 meters or little more depending on the season and growth of the vines. Proper shade and irrigation are crucial for successful vine cultivation (Pradhan *et al* ,2013). Hot dry winds can cause

harm to the plants. Betel vine is generally propagated by stem cuttings rather than by germinating seeds. The cuttings are planted during the onset of the monsoon, in the months of May to June. Certain soil amendments such as cow dung, rotten farmyard manure, mustard oil cakes, neem cakes ,dry leaves, wood ash help in vigorous vine growth. After one year of planting, the leaves get ready for plucking (Biswas *et al.* 2022).

PHYTOCHEMICAL CONSTITUENTS

The phytochemical studies of betel leaf illustrate that it contains a wide variety of biologically active compounds. Betel leaves contain water (85-90%), proteins, carbohydrates, minerals, fat, fibre (2.3%), essential oils (0.08%), tannin, alkaloid (arakene), Vitamin A,C,B1,B2,B3, minerals such as calcium, iron, iodine and potassium (Afridi *et al.* 2021). The concentrations of biologically active compounds, thoroughly depend on the geographical location, soil, humidity, agricultural practices, rainfall, season and type of plant cultivar. The specific pungent aroma of betel leaf is due to the presence of essential oils, mainly consisting of phenols (Biswas *et al.* 2022). Younger leaves have been reported to yield more essential oil (Bhalerao *et al.* 2013). .Presence of various important phytochemicals viz. phenol, flavonoid, tannin, ethanol, ethyl acetate, acetone, and dichloromethane are detected in betel vine leaves (Biswas *et al.* 2022). Apart from these, chavibetol (53.1%) ,chavibetol acetate (15.5%), α-pinene (0.21%), β-pinene (0.21%), alimonene, safrol, 1,8-cineole, allypyrocatechol diacetate, campene, chavibetol methyl ester, eugenol, methyl eugenol, hydroxycatechol and steroids are also being analysed in betel leaves. (Bhalerao *et al.* 2013; Biswas *et al.* 2022). Diastase and catalase enzymes activities are also detected in the leaflet (Sahu *et al.* 2022).

MEDICINAL PROPERTIES

Various phytochemicals present in the betel vines help in curing and treating many medical conditions, including bad breath , gum swelling abscess, conjunctivitis, constipation, hysteria, itching, mastitis, leucorrhoea, otorrhoea, ringworm, rheumatism, abrasions and injuries (Pradhan *et al.* 2013). Betel leaf extract has a curative effect on toxoplasmosis, which is an infection caused by unicellular parasite *Toxoplasma gondii*. Betel leaves are also used as Ethnomedicine. Leaf paste is used in treatment of filariasis and consumption of betel leaf with black pepper reduces obesity. The leaves are used for curing eczema, rheumatism, piles, arthritis, cough and cold. The leaves possess cooling and analgesic properties and they also show antifungal activities (Afridi *et al.* 2021).

FUNGAL DISEASES OF BETEL VINE

Betel vines are generally cultivated by vegetative propagation under partially shaded and humid conditions inside the Boroj. The microclimate of boroj not only helps in betel vine growth but also aggravates the growth of other unwanted pathogens. Betel leaf growers face a huge loss in the field due to such devastating diseases.

Among the microbial phytopathogens, fungi are the most important harmful pathogens causing huge economic loss by decreasing yield significantly in the field and also during post-harvest storage and transportation. It is observed that in most of the cases fungal pathogens infect the betel leaves due to its delicate, fleshy and soft nature. The root system gets affected by the pathogen attack resulting in root rot and finally death of the vine. The aerial parts of betel vine are also attacked by fungal pathogens causing leaf spots, anthracnose, leaf rot, foot rots and powdery mildews (Hedawoo and Makode, 2019). Low temperature, high humidity and diffused light conditions that prevail inside the Boroj not only favour the vine growth , but are also suitable for the growth of the fungal pathogens (Garain, *et al.* 2020). The favorable environmental condition for rapid progression of these fungal diseases is the rainy season of India(July–September), when temperature ranges from 26-30^{0}C and relative humidity varies from 81-95%. Foot rot, leaf rot, collar rot, anthracnose and powdery mildews are the important diseases of betel vine. Foot rot caused by *Phytophthora parasitica* and Collar rot caused by *Sclerotium rolfsii* are considered to be two most devastating diseases of betel vine causing huge loss in yield every year. The extent of loss varies from 5%-90% in foot rot and 17-

100% in case of collar rot (Garain *et al*. 2020 ; Sahu *et al*. 2022). Foot rot disease incidence is initially observed during monsoon in the month of July (Chandra and Sagar, 2004). The disease is most severe during the months of September to February due to high atmospheric humidity and cool night temperature (23^0C or less) (Kumar *et al.* 2023). In case of Collar rot first disease occurrence is observed from March to June. However second incidence occurs during middle of October and lasts upto November (Garain *et al*. 2020).

DISEASE MANAGEMENT

Cultural practice

The cultivation of betel leaf is generally carried out inside the Boroj. The temperature, high humidity and diffused light inside the Boroj are ideal conditions for growth of pathogens. So proper maintenance of Boroj is essential for lowering the disease occurrence. It is necessary that the Boroj should be built in such a way that the central cultivated area should be raised from the boundary, so that irrigation water or rain water does not stand in the soil and is drained off quickly. Besides ,Boroj should be covered by polythene tent during rainy season to prevent the rain water falling on the plants (Maity *et al*. 2019).The soil borne diseases are mainly spread through irrigation water and the pathogens survive in infected plant debris (Das *et al.* 2000). So uprooting the infected plants, cleaning of plant debris and burning them are necessary procedures to be followed to reduce the diseases caused by soil borne pathogens (Maity *et al*. 2019).

Chemical Control

Foot rot of betel vine can be controlled by application of Bordeaux mixture (Dasgupta *et.al.* 2008). It has been reported that treatment of cuttings with Streptomycin solution and spraying Bordeaux mixture (1%) thrice a month could completely check the disease. Fosetyl A L and Bordeaux mixture could also effectively control *Phytophthora* leaf rot (Mohanty and Dasgupta 2008). Maity *et al.* (2019) also reported that dipping of cuttings in Bordeaux mixture or 0.15% Ridomil solution and spraying of leaves with Bordeaux mixture (0.5%) in rainy season can control foot rot. Kumar *et.al*. (2023) suggested that soaking of seedlings in 500ppm of Streptocycline and Bordeaux mixture (0.05%) can control the disease. Maity *et al.*(2019) recommended the treatment of soil with lime water or dilute bleaching powder or neem turmeric solution after uprooting the infected plant parts.Another most common disease of Betel vine is collar rot. Parvin *et al.* (2020) reported that after removal of diseased vine and roots , soil should be treated with the neem cake , mustard cake or farmyard manure and then the soil can be drenched with 0.1% Carbendazim for management of the collar rot disease.To control Powdery mildews, it is essential to remove diseased leaves from the plant and after that spraying 0.2% wettable Sulfur or dust Sulfur (25kg /ha) is essential (Chhetri *et.al.,* 2021). Similarly Anthracnose disease of betel vine can be controlled by spraying 0.2% Ziram or 0.5% Bordeaux mixture after plucking the diseased leaves from the infected plant (Kumar *et al.* 2016).

Biological Control

Since betel leaf is directly consumed by human beings by chewing without any processing , it is essential to reduce the toxic hazards which can be caused by the chemical fungicides (Sengupta *et al.* 2011). Thus ecofriendly biological control methods can be implemented to control fungal diseases of betel vine. Dipping of cuttings in *Trichoderma viridae* cell suspension can effectively reduce foot rot of betel vine. D'Souza *et al.* (2001) also reported the use of *Trichoderma. harzianum* in controlling the foot rot. Sengupta *et al* (2011) recommended two applications of bioagent *T. harzianum* inoculated in 500 kg oil cake/ha at quarterly intervals during pre and post monsoon can effectively reduce the incidence of foot rot. Although the fungicide Bordeaux mixture was proved to be most effective in controlling the disease (Roy *et al.* 2002; Dasgupta *et al.*2003), but considering the health issues and cost : benefit ratio, the use of biocontrol agents can be considered as a better alternative in disease management. Similarly Singh *et al.* (2003) in field trial demonstrated that two strains of plant growth promoting rhizobacteria (PGPR), *Pseudomonas*

Fig.1: (A) Cultivation of Betel vine inside the Boroj and (B-E) Fungal Diseases. *Phytophthora* sp causing Foot rot (B) and Leaf rot (C); *Colletotrichum capsici* causing Anthracnose (D); *Diaporthe tulliensis* causing Leaf spot disease. (Source: AINP on Medicinal Aromatic Plants and Betel vine, BCKV; Shabong and Kayang , 2023)

Table 1: List of Common Fungal Diseases of Betel Vine

Name of the Disease	Causal Organism	Symptoms	Reference
Leaf rot/ Foot rot disease	*Phytophthora* spp. (*P. parasitica , P. nicotinae var.parasitica , P. palmivora, P. capsica).*	i)Initially symptoms appear as water soaked lesions on leaf lamina. ii)Infected spots increase in size rapidly to cover the whole leaf blade, which ultimately rots. iii)Diseased leaves turn brown to dark brown in colour. iv)The lower portion of stem adjacent to soil becomes soft , yellow and gets completely rotten. v)Finally the plant wilts, accompanied by yellowing of leaves and drooping of vines. vi)Diseased plants die within 2-3 days.	Chandra and Sagar (2004) Sahu *et al.* (2022) Kumar *et al* . (2023)
Stem rot or collar rot	*Sclerotium rolfsii*	i)Plants of all stages are susceptible to infection. ii)The infection arises in the collar region. iii)White cottony mycelium is seen on the stem and root. iv)Infected tissues start rotting. v)Defoliation and wilting occur before drying up.	Garain *et al* . (2020) Kumar *et al.* (2023)
Root rot disease	*Rhizoctonia bataticola*	i)Initially symptoms appear at the base of the shoot. ii) Reddish-brown lesions appear on the older roots. iii) Gradually the roots show red colouration and split into small portions iv)Leaves turn pale at the primary stage of infection and finally become discoloured vi) Death of the plants takes place ultimately.	Maity *et al.* (2019)
Anthracnose leaf spot	*Colletotrichum capsici*	i)Black or brown spots of different shape and size occur on the leaves. ii)Many spots coalesce to form large spots.	Maity *et.al.,* 2019. Kumar *et al* . (2023)

		iii)Yellow halo is found encircling the spots. The spots appear on the margins of the leaves. iv)The affected leaves turn pale yellow and dry	
Powdery mildew	*Oidium piperis*	i)Initially white to light brown patches appear on the surface of leaves. ii) These patches enlarge, covering the leaf surface with characteristic white and black powdery dusty coatings on the upper and lower surface of leaves. iii)Defoliation and yellowing of leaves occur in severe infection.	Chandra and Sagar (2004) Patra and Pradhan (2018) Kumar *et al* (2023)
Wilting disease	*Fusarium semitectum*	i)Initial symptoms appear as rolling of tip of the leaves. ii)Infection spread on the stem within few days. iii) Whole plants wilt and die.	Hedawoo and Makode (2019)
Leaf spot	*Diaporthe tulliensis*	i)Leaf spots are irregular in shape and size, light to dark brown in colour . ii) The spots are surrounded by chlorotic yellow halo. iii)Gradually the whole leaf withers and droops down.	Shabong and Kayang (2023)

fluorescens NBR1-N and NBR1-N6 can increase the yield and a consortium of these two strains can control collar rot of betel vine. Tanjila *et al.* (2022) evaluated the antifungal activity of medicinal plants extracts and biocontrol agents against collar rot pathogen *S. rolfsii in vitro.* The highest percentage of inhibition was observed using aqueous ,ethanolic and acetone leaf extracts of *Datura metel* and *Lawsonia inermis*. Among six biocontrol agents tested, *T. harzianum* showed maximum percentage of inhibition of radial growth of *S.rolfsii in vitro*. Results showed that the botanical extracts and bioagents have the significant potential to be used in the field to control pathogens in place of chemical pesticides.

Integrated Pest Management

In recent years Integrated Pest Management (IPM) strategies are found to be employed for effective management of plant diseases. Rahman *et.al.* (2019) recommended soil drenching with either Provax 200 (0.25%) or Score 250 EC(0.05%) or garlic clove (1:1 W/V, 15% conc.) in combination of soil amendment with *T. harzianum* (5g culture in barley grain) or vermicompost (30g/plant) for controlling foot or root rot caused by *S.rolfsii,* upto100% with simultaneously increase in yield upto 82.78% than untreated control plants. Ruth *et al* (2021) carried out a field study of Integrated management of foot rot of betel vine during 2016-2017 and 2017-2018 at Chinavorumpadu village of Andhra Pradesh. The experiment was set up in Randomized block design with eight combinations of treatment being replicated thrice. Minimum incidence of foot rot, leaf rot and leaf fall was noted during November, December, January, February and March when the soil was treated with consortium of PGPR

capsules @ 5 capsules/ha along with execution of proper sanitation, raised bed and drip irrigation method during cultivation. All the other combination of applications using *T.harzianum* ,Fosetyl AL (0.2%), Potassium Phosphonate (0.3%) , *Bacillus subtilis*, Bordeaux mixture (1%) were also found to be effective in disease control when compared to control.

CONCLUSION

Betel vine which is referred to as the green gold of India is associated with the indian culture, religious, social and traditional rituals and is also significantly related to the agro-economics of the country. A large number of Indian population survive on cultivation, processing, transportation, trading and commerce of betel leaves. So it is extremely important to maintain the gross production for sustainance of economic potential of this crop. Fungal diseases cause major damage to this crop resulting in significant loss in yield every year. Apart from cultural practices which include proper maintenance of Boroj condition and cultivation space, it is also essential to use the chemical fungicides as soil application or as spraying to control the fungal pathogens. Since betel leaves are consumed directly by chewing after harvest, it is also necessary to reconsider the uses of fungicides to avoid toxic health hazards. Thus to reduce the use of chemical fungicides, there are reports of application of biocontrol agents such as *T. harzianum*, *T. viridae* and *P. fluorescence* in the field for disease management. Recently Integrated disease management strategy combining both the implementation of biological and chemical control has been reported to be most effective method of disease control. Although highest leaf yield was recorded in case of chemical fungicide treatment but in terms of cost : benefit ratio, biological control method was found to be more superior. Thus to avoid the toxic health hazards and for maintenance of the ecological balance, more innovative and ecofriendly approach should be adopted using biocontrol antagonists for controlling betel vine diseases caused by fungal phytopathogens.

DECLARATIONS

Conflict of interest: Authors declare no conflict of interest.

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