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Diseases of Peace lily [*Spathiphyllum* sp.] caused by fungi, bacteria and viruses: A review

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Abstract
Spathiphyllum is an important ornamental houseplant genera. They are known for their attractive flowers as well as for their ability to remove indoor air toxins. These plants are commonly attacked by different biotic agents leading to various diseases as recorded from different parts of the world including India. Relevant comprehensive compilations based on several research and literature findings of those diseases are made to present the significant importance of each and every disease in respect of various viewpoints such as geographical distribution of the disease, symptoms and its causal pathogen, epidemiology and management.

Keywords: ornamental diseases, Peace lily, *Spathiphyllum* sp., houseplant diseases.

Introduction
Spathiphyllum, commonly known as Spath or Peace lilies is an economically important ornamental plant, grown throughout the world including India. It is a genus of about 40 species of monocotyledonous flowering plants in the family Araceae, native to tropical regions of the Americas and southeastern Asia. It is a striking indoor plant with elegant dark green leaves that are often more than a foot long and huge fragrant white flowers, called spaches, on an off-white stalk or stem called a spadix. They thrive in the shade in temperatures below 55 °F and remove harmful toxins like acetone, ammonia, benzene, ethyl acetate, formaldehyde, methyl alcohol, trichloroethylene and xylene. Thus are rated as a top performer in NASA's clean air study. The peace lily flowers have strong symbolic significance. Besides the ornamental value, other important characteristics of this plant emphasize separate significance in agri-horticultural economic enterprises due to demand in International and Domestic markets.
It has been reported from different parts of the world including India that *Spathiphyllum* sp. is attacked by fungal, bacterial and viral diseases which reduce the economic value of the plant and make them less marketable by reducing their aesthetic value. Researches on various aspects of those diseases are also being conducted worldwide and considerable volume of research findings has been accumulated. Information on those aspects have been collected, compiled and presented below.

Table 1: Disease spectrum of *Spathiphylllum*

Disease	Causal organism
Fungal Diseases	
Root and petiole rot	*Cylindrocladium spathiphylli*
Grey mould	*Botrytis cinerea*
Alternaria leaf spot	*Alternaria alternate*
Myrothecium disease	*Myrothecium roridum*
Phytophthora blight	*Phytophthora parasitica* [*Phytophthora nicotianae var. parasitica*].
Bacterial leaf rot	*Pectobacterium carotovorum* sub sp. *carotovorum*.
Viral diseases	Impatiens necrotic spot virus (INVS) Tomato spotted wilt virus(TSWV)

Fungal diseases
Root and petiole rot
Distribution: The root and petiole rot of potted *Spathiphyllum* plants caused by *Cylindrocladium* spathiphylli was first reported from Italy by Carrai *et al.* (1990) [3]. Subsequently, the disease was reported from Hawaii and Florida, USA (Uchida *et al.*, 1992) [18], China (Jiang *et al.*, 1997) [11], Taiwan (Chen *et al*., 1998) [5] Africa (Schoch *et al.,* 1999) [16],

Japan (Horiuchi *et al.,* 2000) [9] and from Distrito Federal of Brazil (Reis *et al.*, 2004) [15].

Histo-Pathological Study

The changes of root system and petiole tissue at different time after inoculation exhibited that at 12 h after inoculation (HAI), the pathogen entered the hypoderm via wounds or intercellular spaces through hyphae. At 24 h, the protoplasm in some epidermal cells became browning and separated from cell wall. At 48 HAI, the diseased area of hypodermal parenchyma cell expanded deeply inward and the cell walls were browning. At 72 HAI, the pathogen invaded vascular tissues and the discoloration and destruction of phloem and xylem occurred. From the root cross section, tissues at 72 HAI, the pathogen entered the outer and middle hypoderm parenchyma cells through hyphae and clumping and blackening of disintegrated cell walls were observed. (Horiuchi *et al.,* 2000) [9]

Symptom, Causal organism and Pathogenicity study

The first report of the disease in Distrito Federal, Brazil was reported by *Reis et al.* (2004) [15]. Since 2003, potted plants of *Spathiphyllum wallisii* grown in a commercial greenhouse showed leaf yellowing and wilting due to collar and root rot, which later killed most of the diseased plants. The isolated pathogen was identified as *Cylindrocladium spathiphylli*. Morphological studies conducted at Hawaii and Florida by Uchida *et al*. (1992) [18] revealed that conidia of *C. spathiphylli* were occasionally biseptate or rarely triseptate in a predominantly uniseptate spore population. Vesicle shapes were generally capitate but also ellipsoid to spathulate.

In Africa, this organism was isolated from commercially cultivated *Spathiphyllum* plants and Koch's postulates were proven by Schoch *et al.* (1999) [16]. They collected the sequencing data along with the morphological characters for comparing the isolate to known cultures of *C. spathiphylli*. In Taiwan the first report of *Cylindrocladium*, the causal organism of root and petiole rot of *Spathiphyllum* spp., was done by Chen *et al.* (1998) [5] along with its identification, isolation and confirmation of pathogenicity. The fungus was believed to have spread to mainland China from Taiwan with seedlings imported (Jiang *et al.,* 1997) [11]. Since 1998, root and petiole rot pathogen of *Spathiphyllum* sp. was found to associate with plants grown under commercial glasshouses in Gifu city, Japan (Horiuchi *et al.,* 2000) [9].

Studies on pathogenic characteristics of *C. spathiphylli* were done by Wu *et al.* (2004) [20] in China. Pure cultures of five pathogen isolates from *Spathiphyllum* genotypes, namely *S. palls, S. lynise, Spathiphyllum* sp. cv. Sensation, *Spathiphyllum* sp. cv. Golden and *S. clevelandii* were obtained and used for cross inoculation. The results showed that cross infections by the five isolates occurred on all plants and natural symptom of brown rot appeared. Based on the morphological and pathogenic characteristics of the cultures, all five isolates were identified as being one species, *Cylindrocladium spathiphylli*.

Epidemiology

The study on biological characteristics demonstrated that the temperatures between 20 - 26 ^{0}C were suitable for the growth of pathogen, temperatures of above 34 ^{0}C or below 15 ^{0}C were not favourable for growth, the relative humidity of 90% or above was favourable for spore germination. The pathogen grew slowly on the medium containing Fe, Mg and K, but grew well under pH 5 - 9. (Wu *et al.*, 2004) [20]

Management

Norman *et al.* (1999) [14] screened twenty two *Spathiphyllum* cultivars for resistance to *Cylindrocladium* root rot (CRR). Four isolates of the fungus *Cylindrocladium spathiphylli* were selected from two different locations each in Florida and Hawaii. Spores of isolates were applied as a soil drench in replicated experiments using a randomized complete block design. The most severe symptoms were those produced by *C. spathiphylli* isolates from Hawaii. None of the *Spathiphyllum* cultivars tested were highly resistant to CRR, although resistance among the cultivars was observed. The cultivars Chris and Textura were the most promising cultivars, having fairly uniform resistance to the four isolates of *C. spathiphylli*. The cultivars Cupido, Daniel, Frederik, Jetty and Vanessa were moderately resistant when combined data from all tests were analyzed.

Fish hydrolyzed (HP), poultry manure (CF), shrimp skin (CC), cattle manure (EB), sewage sludge (LE) and castor bean press cake (TM) were evaluated for their effect of aqueous extracts with and without autoclaving, on mycelial growth and conidial germination of *Cylindrocladium spathiphylli*. The effect of mixtures of residues with potting mixes and their volatile compounds were also evaluated on the mycelial growth of the pathogen. To evaluate the effect of HP in the suppressiveness to *Cylindrocladium spathiphylli,* HP was added in potting mix artificially infested, at concentrations of 0, 10, 20, 30, 40 and 50% of the volume of water required to reach the water retention capacity of the potting mix. The mixtures were incubated for 10 days and transferred to pots containing one plug of *Spathiphyllum var* Opal per pot. In the *in vitro* experiments, aqueous extracts and mixtures containing HP showed the highest suppressiveness against the pathogen. In the *Spathiphyllum* growing, the suppressiveness occurred at concentrations higher than 20% of fish hydrolyzed. (Visconti *et al.,* 2010) [19].

Horiuchi *et al.* (2000) [9] tested ten fungicides against the pathogen and amongst them benomyl and triflumizole could control the disease effectively.

Grey mould disease

The occurrence of grey mould disease on *Spathiphyllum* sp. was noted during 1989-94 from Tokyo Metropolis, Japan, by Takeuchi *et al.* (1995) [17]. Later the causal fungus was isolated and identified as *Botrytis cinerea.*

***Myrothecium* disease**

Myrothecium roridum is an important fungal disease during the hardening of *in vitro* culture plants. Jamart (1997) [10] tested the effect of fungaflor (5 - 20 ml/plant) and daconil (5 - 20 ml/plant) on growth rate of pathogen on *Spathiphyllum* (cv. Euro 92). Daconil resulted in decreased growth rates in *Spathiphyllum* and was accepted as effective chemical control.

In Brazil, some fungicides were tested *in vitro* against an isolate of *M. roridum* and the mycelial growth was recorded after seven days. Fungicides with quaternary ammonium, tebuconazole and copper were highly effective in inhibiting the mycelial growth of *M. roridum* (Duval *et al.,* 2010) [7]

***Alternaria* leaf spot**

Since 1997, brown necrotic spots surrounded by chlorotic areas were observed on *Spathiphyllum* near Buenos Aires,

Argentina. The causal organism was isolated and identified as *A. alternata* and its pathogenicity was confirmed. This was the first report of *Alternaria* leaf spot of S*pathiphyllum* in Argentina by Cheheid *et al.* (2000) [4]

***Phytophthora* blight**

Distribution: The occurrence of root and crown rot of *Spathiphyllum wallisii* caused by *Phytophthora parasitica* was reported for the first time in the State of Sao Paulo, Brazil by Fischer *et al.* (2004) [8], from Taiwan by Ann (2000) [2] and from China by Chen (1999) [6].

Symptom and Pathogeniciy study

Phytophthora parasitica [Phytophthora nicotianae var. *parasitica]* was detected from the diseased tissues of peace lily (*Spathiphyllum kochii*) since 1992 in Taiwan. The pathogen caused severe leaf blight, root rot and death of the whole ornamental plant in many fields. A total of 19 A1 and 8 A2 isolates *of P. nicotianae* var. *parasitica* were obtained from 7 fields distributing in Taipei, Nantow, Changhua, Chiayi and Tainan. After stored for 3 - 8 years, 8 of 16 A1 isolates changed to A2 type and 2 to A1A2 type. However, none of A2 isolates changed. Disease symptoms similar to appearing in the fields were reproduced when plantlets of peace lily were inoculated with a zoospore suspension of *P. nicotianae* var. *parasitica* in pathogenicity tests. Three-month-old plantlets of peace lily showed high susceptibility to the pathogen and more than 80% inoculated plantings were killed within one month. *P. nicotianae* var. *parasitica* was reisolated from all artificially infected tissues. The peace lily isolates of *P. nicotianae* var. *parasitica* were pathogenic to three of the four members of aroids, including *Anthurium andreanum, Epiprenmum aureum*, *Philodendron scandens* subsp. *oxycardium*, which was recorded as hosts of the pathogen in Taiwan and vice versa. The pathogen did not cause disease symptoms on *Dieffenbachia amoena*. *Phytophthora* disease of peace lily was reported for the first time in Taiwan (Ann, 2000) [2]

Phytophthora isolates were obtained from 9 species of diseased floral plants (*Rosa chinensis, Rhododendron* spp., *Cattleya bowringiana*, *Dianthus caryophyllus*, *Calceolaria crenatiflora, Catharanthus roseus, Euphorbia pulcherrima, Lilium* sp. and *Spathiphyllum pallas)* collected in the Guangzhou region of China by Chen (1999) [6]. On the basis of the sexual and asexual characteristics of their single-spore cultures combined with their cardinal temperatures and the electrophoresis patterns of their proteins, it was identified as *P. nicotianae* as the causal organism on *Spathiphyllum pallas*.

Bacterial diseases of *Spathiphyllum*

Bacterial leaf rot

Symptom: A bacterial leaf rot disease of peace lily (*Spathiphyllum wallisii* Regel) caused by *Pectobacterium carotovorum* sub sp. *carotovorum* was observed in Argentina since May of 2008. Plants first showed water-soaked areas starting from the leaf tips. Infected tissue became irregular, brown, dark-to-black lesions on leaves ~12 - 14 mm in diameter surrounded by yellowish haloes. Disease incidence was found to approach 30%. (Alippi *et al.,* 2009) [1]

Causal organism

Abundant bacterial streaming was observed from lesions when examined at 100X. Bacteria isolated from lesions formed white-to-cream, glistening and convex colonies on yeast dextrose calcium carbonate agar. Three bacterial strains isolated from different symptomatic plants were selected for comparative analysis with *Pectobacterium carotovorum* subsp. *carotovorum* type strain ATCC 15713. All were facultatively anaerobic, gram-negative rods, pectolytic on crystal violet pectate agar, non-fluorescent on King's B medium, and elicited a hypersensitive response in tobacco plants. All strains were oxidase and arginine dihydrolase negative, fermented glucose, did not hydrolyze starch, did not produce lecithinase, indole or the blue pigment indigoidine, reduced nitrates, hydrolyzed gelatin and esculin, able to rot onion slices, caused soft rot of potato tubers, resistant to erythromycin, and grew at 37°C. Acid was produced from cellobiose, d-glucose, d-melibiose, d-mannitol, d-mannose, l-rhamnose, d-sucrose, and l-arabinose but not from inositol and d-sorbitol. Bacteria utilized N-acetyl-glucosamine and citrate but not tartrate, benzoate, or propionate. Their identity was confirmed by 16S rRNA gene sequencing of strain F402Pcc (GenBank Accession No. FJ717337) showing a 99% homology with that of strain ATCC 3326 (FJ 5958691) (Alippi *et al.,* 2009) [1].

Pathogenicity study

It was verified on *S. wallisii, Dieffenbachia picta, Aglaonema commutatum* and *Anthurium andraeanum* within the Araceae family by spraying two plants per strain tested with bacterial suspensions (10^8 CFU/ml) in sterile distilled water with and without wounding the leaves with sterile needles. Controls were sprayed with sterile distilled water. After 48 h in a humidity chamber, inoculated plants and controls were maintained at 25 ± 3°C in a greenhouse. Water-soaked areas developed from 24 - 48 h after inoculation and became necrotic within 4 - 5 days. Lesions expanded to resemble natural infection in *S. wallisii* within 20 days, while in the rest of the hosts tested, lesions were smaller and remained brown surrounded by yellowish haloes. All strains were reisolated from each host tested. The original and all reisolated strains were compared by enterobacterial repetitive intergeneric consensus-PCR confirming that DNA fingerprints of the reisolated strains were identical to those of the original strains. No lesions were observed on controls. The pathogen was identified as *P. carotovorum* subsp. *carotovorum* based on biochemical, physiological, pathogenicity tests and 16S rRNA sequencing. This was the first report of this pathogen on *S. wallisii* in Argentina although it was been reported as causing tomato pith necrosis and soft rot of vegetables after harvest (Alippi *et al.,* 2009) [1].

Viral diseases

Impatiens necrotic spot virus

Symptom: During September 1999, several *Spathiphyllum* sp. plants grown in a greenhouse in Tuscany, Central and Southern Bohemia, Italy and showed leaf symptoms in the form of concentric chlorotic ringspots, line patterns and irregular chlorotic blotches. These symptoms developed into localized necrosis. Determination of thrips in sites of INSV infection revealed that *Frankliniella occidentalis* was present. (Mertelik *et al.*, 2002) [13]

INSV was identified by enzyme-linked immunosorbent assay (ELISA) using polyclonal antibodies to INSV from Loewe Biochemica, Germany and from Bioreba, Switzerland. Sap from the infected plant species was used for mechanical inoculations of indicator plants. *Nicotiana benthamiana* developed characteristic symptoms of INSV infection; *Datura*

stramonium and *Solanum stramonifolium* reacted with local lesions, systemic mosaic and leaf deformation. The sap extracts of these infected indicator plants gave strong positive reactions in ELISA. Leaf homogenates of indicator plants were analysed by transmission electron microscopy. Spherical enveloped virus particles typical of a Tospovirus were detected. It was the first report of *Spathiphyllum* sp. infection by impatiens necrotic spot virus from Italy (Mertelik *et al*., 2002) [13].

Tomato spotted wilt virus and Impatiens necrotic spot virus

In July 2000, concentric necrotic rings and patterns were observed on greenhouse-grown pepper (*Capsicum annuum cv. Blondi*). Symptoms were present only on lower leaves. Typical tospovirus particles were observed, by electron microscopy, in leaf-dip preparations of symptomatic leaves. DAS-ELISA and nucleotide sequence analysis confirmed the presence of both tomato spotted wilt virus (TSWV) and Impatiens necrotic spot virus (INSV). In mechanical inoculation tests, both viruses were able to infect (either as single or mixed infections) a range of plant species, *i.e.* pepper, tomato, chrysanthemum, calla lily (*Zantedeschia*), cyclamen and *Spathiphyllum*. This was claimed to be the first report of TSWV and INSV in ornamental and vegetable plants in Slovenia. (Mavric and Ravnikar, 2001)

The above stated diseases damage the potted plants of *Spathiphyllum* sp. leading to considerable loss of their aesthetic as well as economic value and from the literature it is as well evident that no detailed work has been carried out on *Spathiphyllum* diseases in India, thus it opens a whole new area to be exploited.

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