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Foot rot (*Phytophthora nicotianae*) in Cactus Pear (*Opuntia* spp.) Genotypes under Arid Conditions

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Abstract: Foot rot caused by *Phytophthora nicotianae* has been observed as a major disease in the establishment of cactus pear (*Opunita* spp.) under arid conditions. Foot rot incidence was prevalent in 23.5% of the germplasm collections during the months of August and November. The fungal pathogen could infect the cladodes through infected planting materials as well as through soil. Soil drenching with 0.1% metalxyl plus mancozeb (Ridomil) and dipping of cut ends of cactus pads in fungicide at the time of planting were found effective in control of the foot rot.

Key words: Cactus pear, foot rot management.

Cactus pear (*Opuntia* spp.) has horticultural value for its tender pads (cladodes) as vegetable and fruits for human consumption besides its fodder value for animals. It has several medicinal and industrial applications (Singh and Felker, 1998). It is already popular in many countries. In India it has been introduced, but is still not grown commercially. Obviously, information on diseases has not been studied in detail. A large number of cactus genotypes from exotic and indigenous collections have been maintained at CIAH, Bikaner. Frequent drying of cactus genotypes were observed in our germplasm repository. Hence, the investigations on the nature of foot rot and its management are presented in this paper.

Materials and Methods

The present study was undertaken in CIAH farm at Bikaner during the year 1996-1997. Cactus pear germplasm (52 accessions) was planted through vegetative cuttings, i.e., cladodes (single cladode/pit) during the month of September and October 1996 at 3 x 1 m spacing with 3 plants in each replicate in a randomized block design. The soil was sandy having pH 8.5.

Foot rot incidence was constantly monitored during the year 1996 and 1997. Disease percentage was worked out on the basis of number of infected cladodes in each accession and then accessions were rated as resistant (0-5%), moderately resistant (6-10%), moderately susceptible (11-20%), susceptible (21-30%) and highly susceptible (30%). The infected cladodes were collected from the field and observed under microscope using cotton blue-lactophenol stain.

Soil rhizosphere samples were also collected along with the infected cladodes. The diseased portion of the cladode and adhering soil were separated and collected on sterile filter paper. Infected tissues were cut into small pieces (4-5 mm) and kept over filter paper to absorb the mucilage exudates from cut ends. The tissues were surface sterilized using 0.1% mercuric chloride and repeatedly washed in sterile

deionized water and placed on oat meal agar medium in sterile petri plates (90 mm). Plates were incubated at 25±2°C with 16 h light and 8 h dark. In another set of isolation, rhizosphere soil along with root bits was mixed in 10 ml of sterile deionized water and from the suspension 100 µl was spread over the solid medium. Plates were monitored daily, and one week after the inoculation, pure culture was maintained in the same medium. Pathogenicity of the fungus was tested in healthy clone 1287 and finally the pathogen was identified based on the description given by Webster (1979) and Hawksworth *et al.* (1996).

In order to manage this disease two systemic fungicides, i.e., carbendazim (Bavistin, 0.1%) and metalaxyl plus mancozeb (Ridomil, 0.1%) were tested. These fungicides were applied as soil drench (1 liter/cladode) at the time of planting. The cut ends of planting materials of cactus (cladodes) were also dipped in fungicide solution for 15 minutes before planting. Subsequently soil drenching was continued at fortnightly intervals during the endemic period (November to February). Similar treatments were given in a pot culture plantation for multiplication of accession, and foot rot incidence as recorded.

Results and Discussion

Cumulative incidence (23.5%) of the foot rot was assessed in 12 of the 52 accessions. Among the susceptible genotypes 50% were fodder types while the remaining were fruiting and vegetable types. In general, most of the fruiting and vegetable types (*Opuntia ficus indica*) were found to be resistant. *Opuntia hyptiacantha* (78%), *O. robusta* cv. *Robusta* (55.6%) and *O. megacantha* (56%) recorded more severe infection (Table 1).

The resistance and susceptible reactions of the genotypes need to be further investigated on the basis of differential interaction among the genotypes. Use of resistant varieties can obviously be the only practical method of control. The polygenic resistance sources identified in the genotypes may provide the most, simple and effective means to avoid foot rot infection in the field. Further studies are in progress to determine the characteristic differences for the susceptibility in fodder types and the resistance in the vegetable and fruiting types.

Symptomatology of foot rot

Since the main source of infection was from the soil, identification of the disease at early stage of the plant growth, i.e., before appearance of apparent symptoms, was difficult. In advanced stages, a prominent infection line up to 5-10 mm length above ground level was clearly seen. The underground portion of such cladodes along with soil was partially rotten leaving only the epidermal cells or outermost silvery layer intact. All the feeder roots turned brown and merged with soil. Longitudinal sections of the infected cladode revealed internally disintegrated tissues without the manifestation of external symptoms. Exudation of brown liquid having foul smell was common in severely infected cladodes and subsequently such cladodeds fell on the soil surface. Internal tissues were reddish brown interfaced with hyaline mycelium bearing sporangiospores and sporangia. Enhanced turgidity and arrest of new growth

Table 1. Reactions of catcus pear genotypes against foot rot

Opuntia species	Type	Foot rot (%)	Reaction
Opuntia sp.	Fruit	0	R
O. ficus indica	Fodder	33.3	HS
O. ficus indica (Ac. No. 1271)	Fruit	22.0	S
O. ficus indica (Ac. No. 1300)	Fruit	11.0	Ms
O. ficus indica (Ac. No. 1315-1324)	Fruit	0	R
O. ficus indica (Ac. No. 1326)	Fodder	0	R
O. ficus indica (Local)	Unknown	0	R
Nopalea sp.	Vegetable	0	R
O. ficus indica	Fodder	0	R
O. robusta cv. chico	Fodder	0	R
O. robusta cv. omnerery	Fodder	55.6	HS
O. robusta cv. robusta	Fodder	40	HS
O. ficus indica	Unknown	0	R
O. robusta	Unknown	0	R
O. undulata	Unknown	0	R
Nopalea cochenillifera	Fodder/vegetable	20	S
O. inermis	Fodder/vegetable	30	S
O. streptacantha	Unknown	0	R
O. streptacantha	Fruit	0	R
O. hpyticacantha	Fodder	78	HS
O. megacantha	Fodder	44.5	HS
O. megacantha	Fodder	56	HS
O. streptacantha	Unknown	0	R
O. megacantha	Unknown	0	R
O. megacantha	Fruit	0	R
O. fusicaulis	Fruit	0	R

were the characteristic symptoms in extensively infected cladodes. The underground portion of such cladode remained, with only fibrous tissues in soil. These observations are in agreement with those reported by Granata (1995).

The Pathogen and disease development

The pathogen grew rapidly on oat meal agar medium and formed regular colonies. Microscopic observations and characterization of the pathogen revealed involvement of *Phytophthora nicotianae* (Waterhouse, 1965). Direct mounting of mycelial mat from the infected tissues showed mycelium bearing sporagiophores and plenty of sporangia. Sporangia were ovoid, opiriform with two apexes. Similar characters of the pathogen were reported by Caciola and Magnano (1998). Production of chlamydospores was common in infected tissues and old cultures on artificial medium. Rhizosphere soil samples were also found to contain chalamydospores and mycelial

Table 2. Per cent foot rot control in cactus pear (Ac. No. 1287)

Treatment/Fungicides	Basvistin (Carbendazim)		Ridomil (Metalaxyl + mancozeb)	
	Pot culture	Field	Pot culture	Field
Drenching	51.50	44.75	58.25	54.00
Dipping	54.50	39.00	65.00	39.50
Drenching + Dipping	75.00	73.50	85.00	83.25
CD (P = 0.05)	6.70	9.97	9.70	10.91

Values are means of 4 replicates.

fragments. The sporangia germinated readily at 25.2°C under a moist chamber of Petri dishes. It was very difficult to identify the sexual stage of the pathogen. However, in very few samples aerial mycelium in the crown region of the infected cladodes formed antheridia and oogonia.

Tsao (1969) and Tsao and Bericker (1964; 1968) extensively studied *Phytophthora parasitica* in soil and found this pathogen to be primarily soil-borne. The fungus normally produces sporangia and zoospores which are responsible for the repeated infection (Waterhouse, 1963; Cacciola and Monganaw, 1998). They further reported that the pathogen could infect fallen fruit causing brown rot. In our studies, though fruits were not infected, soil borne nature of the pathogen and resting chlamydospores in infected tissues were observed. Since the climatic conditions in arid region are a highly fluctuating, the pathogen may over-winter and over-summer as dormant structures in soil and cladode tissues. Excessive humidity (75%) coupled with 28 to 35°C temperature favor sporangial germination. The active zoospores produce germ tube even at 35°C. Though temperature and soil moisture conditions are the predisposing factors for infection, production of oospores, and chlamydospores as resting spores can occur during adverse conditions. Kaung (1966) also found that the *Phytophthora* could survive in fruiting stage as dormant mycelium in the leftover portion of diseased plants. Similar results were observed presently in infected tissues. These dormant structures may contribute to the primary source of inoculum of foot rot disease. The view of Kaung (1966) was further confirmed from our laboratory investigations that the partially infected cladode could retain the viability of the foot rot pathogen for 7 months when infected cladodes were preserved in desiccator. Since the foot rot has been found for the first time in arid conditions, the possibility of survival and dissemination of this pathogen to alternate or collateral hosts is remote. However survival of the pathogen in a companion perennial crop (castor) cannot be ruled out. Singh (1968) reported the *Phytophthora* can be observed anytime during the growth of castor. In our farm castor has been planted along the periphery of germplasm blocks of ber, pomegranate aonla and cactus pear. Occurrence of seedling blight of castor was very common wherever the plants were grown. Therefore the foot rot pathogen could easily survive in this crop and subsequently infected cactus pear.

Chemical control

Soil drenching and dipping the cut ends of the cladodes in fungicide before planting effectively minimized the disease upto 85%. Among the two fungicides tested (metalaxyl

+ mancozeb 0.1% and carbendazim 0.1%), metalaxyl was found to be the best (Table 2). The effectiveness of this fungicide might be because of its selective action against Oomyces fungi (*P. nictianae*) than the broad spectrum action of other systemic fungicide (carbendazim). In another study, we have found that treatment of sugarcane seedling flats with metalaxyl 0.1% (Ridomyl) was more effective than captan and carbendazim against *Phythium graminicola*, the casual agent of seedling rot. Bhatt and Patel (1989) concluded that soil treatment with 100 ppm Ridomil + Mancozeb is most effective for the control of *Phytopthora parasitical* var. *nicotianae* on tobacco. Agrios (1977) also considered metalaxyl as the best systemic fungicide against Oomycetes. It is widely used in soil and seed treatments for the control of *Phytophthora* diseases. Besides its effectiveness, it is water soluble and is readily translocated from root to aerial parts of most plants. It can be summarized from the present investigation that foot rot is a major disease in the maintenance of cactus pear and this particular disease can be successfully controlled by metalaxyl plus mancozeb application as soil drenching at fortnight intervals during epidemic periods.

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