



# Virulence analysis and influence of soil pattern and agronomic practices with respect to *Ganoderma* foot rot of arecanut in southern Karnataka

K.B. Palanna\*, T. Narendrappa, S. Basavaraj and K.R. Shreenivasa

University of Agricultural Sciences, GKV, Bengaluru-560065, Karnataka, India

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## Abstract

The foot rot of arecanut, caused by *Ganoderma*, is one of the most important constraint limiting arecanut production and productivity in South Karnataka. The incidence of foot rot of arecanut during the year 2014-15 ranged from 0 to 55 per cent in southern dry tracts of Karnataka. Among the four districts surveyed, Tumkur recorded the maximum disease incidence (19.3%) followed by Chitradurga (18.1%) and Hassan (4.3%). *Ganoderma* sporophore and infected root bits of arecanut were found ideal source for isolation, as they yielded 52.9 and 46.4 per cent of the isolates, respectively. Foot rot was noticed in mono crop as well as mixed crop of arecanut and coconut. Among the 15 taluks surveyed, Chikanayakanahally had the maximum incidence (34.0%) followed by Gubbi and Holalkere which accounted 28.8 and 27.2 per cent, respectively. The minimum per cent incidence (1.8%) was observed in Beluru taluk of Hassan district. Among the different soil types, maximum incidence (13.5%) was observed in sandy soils followed by red soils (8.9%). Canal irrigated gardens accounted maximum the incidence (12.7%) compared with bore-well irrigated gardens and those under rainfed conditions. Similarly, gardens under flood irrigation recorded 15.1 per cent of maximum incidence compared to gardens under drip, basin/sprinkler irrigation systems and gardens under regular cultivation recorded the maximum incidence compared to uncultivated gardens. Virulence of 10 *Ganoderma* isolates of arecanut tested under pot culture revealed that isolate AG<sub>1</sub>, recorded maximum disease severity index (75 DSI) nine months after inoculation followed by AG<sub>22</sub> and AG<sub>4</sub> which accounted 68.8 DSI each.

**Keywords:** Arecanut, disease severity index, foot rot, *Ganoderma*, pathogenicity

## Introduction

Arecanut is a tropical palm belonging to family Areaceae and grown all over South-East Asia. The nut (fruit) is popularly known as the betel nut or supari in India. The present production of arecanut in the world is about 127 thousand tonnes from an area of 925 thousand hectares. In India, arecanut is cultivated in an area of 4.5 lakh hectares with an annual production of 6.3 lakh tones and India ranks first in both area (49%) and production (50%). Karnataka state ranks first in India in terms of production followed by Kerala and Assam. Other major arecanut producing countries are Indonesia, China and Bangladesh (Ramappa, 2013).

Arecanut palms are affected by various biotic and abiotic stresses resulting in drastic reduction in yield. Among the various biotic stresses that affect arecanut production in India, foot rot (*Anabe roga* in Kannada) caused by *Ganoderma lucidum* is a major constraint, especially in dry tracts of southern Karnataka. Foot rot was reported by Coleman from Karnataka in 1911. This disease has also been reported from Kerala, Assam, West Bengal (Sharples, 1928), Nicobar Islands (Sangal *et al.*, 1961) and also from parts of Tamil Nadu. Several workers (Naik *et al.*, 2000; Palanna *et al.*, 2009, 2016) have reported *Ganoderma* wilt incidence in southern Karnataka on coconut. However, not much

\*Corresponding Author: kbpalanna@gmail.com

study has been done relating to etiology and incidence of foot rot of arecanut with respect to soil types and agronomic practices in southern dry tracts of Karnataka. Hence the present study was undertaken to elucidate the disease incidence with respect to soil types, agronomic practices followed by farmers in disease hotspot areas of Karnataka and to establish the pathogenicity of *Ganoderma*.

## Materials and methods

### Survey on the incidence foot rot of arecanut

In southern Karnataka, major arecanut growing districts, taluks and villages were selected for survey (Table 1). Based on stratified random sampling technique, in each garden, 100 palms were observed and number of palms infected with foot rot were recorded and expressed as disease incidence (%).

**Table 1. List of major arecanut growing areas selected for survey in Southern Karnataka**

District	Taluk	Number of villages	No. of gardens surveyed	No. of palms observed
Chitradurga	i) Hosdurga	198	17	1700
	ii) Holalkere	166	14	1400
	iii) Hiriya	164	14	1400
<b>Sub total</b>		<b>528</b>	<b>45</b>	
Hassan	i) Arsikere	340	30	3000
	ii) C.R. Patna	375	33	3000
	iii) Beluru	384	33	3300
	iv) Hassan	391	34	3400
<b>Sub total</b>		<b>1490</b>	<b>130</b>	
Tumkur	i) Tiptur	231	20	2000
	ii) C.N. Halli	234	21	2100
	iii) Tumkur	373	33	3300
	iv) Turuvekere	243	21	2100
	v) Gubbi	346	30	3000
<b>Sub Total</b>		<b>1427</b>	<b>125</b>	
Chickamagalore	i) Kadur	314	28	2800
	ii) Tarikere	250	22	2200
	iii) N.R. Pura	59	06	600
<b>Sub Total</b>		<b>623</b>	<b>56</b>	
<b>Grand Total</b>		<b>4071</b>	<b>4071</b>	<b>35600</b>

$$\text{Disease (\%)} = \frac{\text{No. of plants infected}}{\text{Total no. of plants observed}} \times 100$$

During the course of survey, different agronomic practices followed by the farmers for cultivation of arecanut and soil types, method of irrigation *etc.*

were recorded and correlated with disease incidence. In addition, practices of farmers for managing foot rot of arecanut and other related information were also documented.

### Collection of diseased root samples/stem bit and sporocarps of arecanut

Different parts of arecanut palms such as diseased root/stem bits affected by foot rot, showing typical symptoms and sporocarps, were collected from different locations of southern Karnataka (Table 1). The samples were labeled and packed in polythene bags for the purpose of isolation of the causal organism.

### Isolation, identification and designation of isolates

Infected roots/stem bits and sporocarps collected from infected palms were washed thoroughly with sterile water and cut into small pieces and surface sterilized with 0.1 per cent mercuric chloride for 30 seconds and washed to remove the traces of mercuric chloride. After surface sterilization, diseased specimens were kept in sterilized bags along with wet cotton under room temperature for about 8 to 10 days, after which mycelial growth observed were aseptically transferred on potato dextrose agar (PDA) medium. The inoculated plates were incubated at room temperature ( $28 \pm 2$  °C) for 3 to 5 days to facilitate growth of the pathogen. Later, the culture was transferred to PDA slants. Pure culture of the pathogen was obtained by following hyphal tip culture technique under aseptic conditions.

The *Ganoderma* isolates were identified based on colony morphology and mycelial characteristics. Further, the isolates were identified through amplification of internal transcribed spacer (ITS) region using universal primers ITS1 and ITS4 and designated as Arecanut *Ganoderma* (AG)<sub>1</sub> to (AG)<sub>22</sub> (Table 2). Subsequently, the pathogen was sub-cultured on PDA slants and maintained at  $28 \pm 2$  °C for 8 to 10 days and used for pathogenicity studies.

### Virulence of *Ganoderma* isolates

A pot culture experiment was laid out at Agriculture Research Station, Konehally, Tiptur to

**Table 2. Geographical origin and designation of *Ganoderma* isolates infecting arecanut**

Sl. No.	Source of isolation	Geographical origin	Isolate code/ designation
1.	Root sample	Mallenahally, Channarayapattana Taluk, Hassan District	AG <sub>1</sub>
2.	Root sample	Jodigatte, Channarayapattana Taluk, Hassan District	AG <sub>2</sub>
3.	Sporocarps	Shettikere, C.N.Halli Taluk, Tumkur District	AG <sub>3</sub>
4.	Sporocarps	Thimmanahalli, C.N.Halli Taluk, Tumkur District	AG <sub>4</sub>
5.	Root samples	Hosuru, Beluru Taluk, Hassan District	AG <sub>5</sub>
6.	Sporocarps	Bidarahally, Hassan Taluk, Hassan District	AG <sub>6</sub>
7.	Root samples	Adivala Hiriyur Taluk, Chitradurga District	AG <sub>7</sub>
8.	Root samples	Hosahally, Tiptur Taluk, Tumkur District	AG <sub>8</sub>
9.	Sporocarps	Kodipalya, Tumkur Taluk, Tumkur District	AG <sub>9</sub>
10.	Root samples	Vadavalughatta, Tiptur Taluk, Tumkur District	AG <sub>10</sub>
11.	Sporocarps	Thyagaturu, Gubbi Taluk, Tumkur District	AG <sub>11</sub>
12.	Sporocarps	Nagalapura, Gubbi Taluk, Tumkur District	AG <sub>12</sub>
13.	Root samples	Kalkodi, Gubbi Taluk, Tumkur District	AG <sub>13</sub>
14.	Root samples	Ammanagatta, Gubbi Taluk, Tumkur District	AG <sub>14</sub>
15.	Root samples	Doddenahalli, Turvekere Taluk, Tumkur District	AG <sub>15</sub>
16.	Sporocarps	Goppenahalli, Turvekere Taluk, Tumkur District	AG <sub>16</sub>
17.	Root samples	Doddanaramangala, Tumkur Taluk, Tumkur District	AG <sub>17</sub>
18.	Sporocarps	Madadakere (H), Hosdurga Taluk, Chitradurga District	AG <sub>18</sub>
19.	Sporocarps	Chiknaramangla, Tumkur Taluk, Chitradurga District	AG <sub>19</sub>
20.	Root samples	Doddakittadahalli, Hosdurga Taluk, Chitradurga District	AG <sub>20</sub>
21.	Root samples	Krishnagiri, Hiriyur Taluk, Chitradurga District	AG <sub>21</sub>
22.	Root samples	Malsandra, Tumkur Taluk, Chitradurga District	AG <sub>22</sub>

test virulence of *Ganoderma* isolates on arecanut seedlings through soil inoculation during the year 2014-15. Ten *Ganoderma* isolates (AG<sub>1</sub>, AG<sub>7</sub>, AG<sub>8</sub>, AG<sub>9</sub>, AG<sub>10</sub>, AG<sub>12</sub>, AG<sub>14</sub>, AG<sub>15</sub>, AG<sub>20</sub> and AG<sub>22</sub>) which were found to be fast growing under *in vitro*, conditions were mass multiplied separately on sorghum grains in poly bags and were used for soil inoculation at the rate of 100 g per pot with the potting mixture at the time of planting. A control was maintained without inoculating *Ganoderma* isolates. All the treatments were replicated thrice and arranged in a randomised block design (RBD). The seedlings used for virulence experiment were 5 to 6 months old Thirthahally local.

**Disease severity index (DSI).**

The plants were scored for disease severity on a scale of 0 to 4 (Table 3). After recording the disease severity for each control and treatment, the disease severity index (DSI) was calculated according to Ilias (2000) and Abdullah *et al.* (2003).

The DSI was calculated at monthly intervals based on the following formula:

$$DSI = \frac{\sum (A \times B) \times 100}{\sum B \times 4}$$

**Table 3. Disease scale to assess the foot rot of arecanut**

Disease class	Signs and symptoms of infection
0	Healthy plants with green leaves without appearance of fungal mycelium on any part of plants
1	Appearance of white fungal mass on any part of plants, with or without chlorotic leaves
2	Appearance of fungal mass/ mycelium on any part of plants with chlorotic leaves (1-3 leaves)
3	Appearance of fungal mass/ mycelium on any part of plants with chlorotic leaves (> 3 leaves)
4	Formation of well-developed basidioma and the plants dried/wilted

where, A – Disease class (0, 1, 2, 3 or 4) and B – Number of plants showing that disease class per treatment

**Results and discussion**

**Incidence of foot rot of arecanut with respect to soil types and agronomic practices in southern Karnataka**

Surveys were undertaken adopting the stratified random sampling technique in major arecanut growing districts of southern Karnataka

during 2014-15. Among the surveyed regions, Tumkur district recorded the maximum incidence (19.3%) followed by Chitradurga and Hassan districts, which were 18.1 and 4.3 per cent incidence, respectively (Table 4 and Fig. 1). Among the 15 taluks surveyed Chikanayakanahally accounted maximum incidence (34.0%) followed by Gubbi and

Holalkere accounting 28.8 and 27.2 per cent, respectively. The minimum per cent incidence (1.8) was observed in Beluru taluk of Hassan district. The incidence of foot rot ranged from 0 to 55 per cent in the 356 gardens surveyed in four districts with 55 per cent in Sarigehally village of Turuvekere taluk followed by Thyagatagere (38.0%) village of Gubbi taluk of Tumkur district.

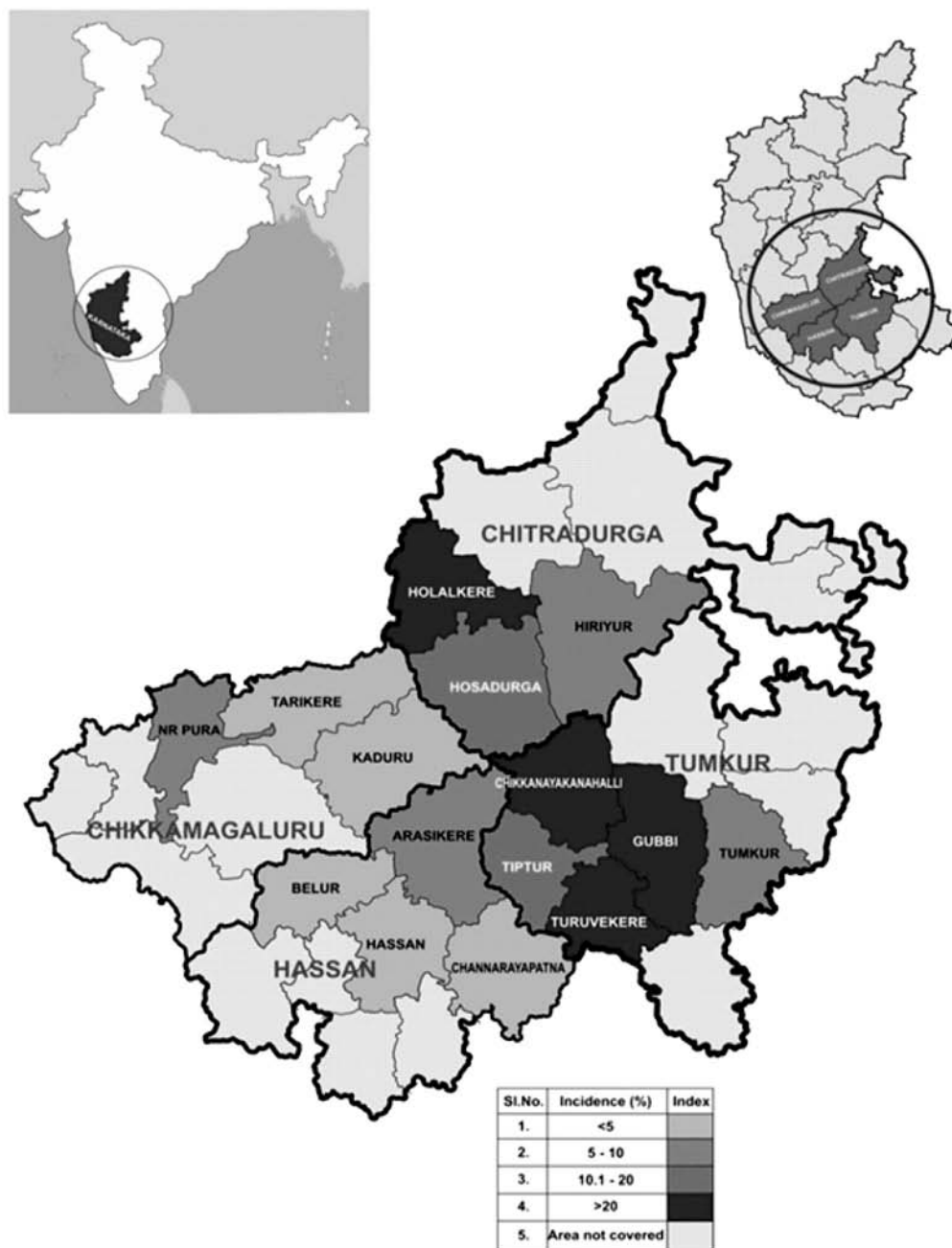


Fig. 1. Geographical map depicting hot spots of arecanut foot rot in southern Karnataka

**Table 4. Incidence of foot rot of arecanut in southern Karnataka**

District	Taluk	No. of gardens surveyed	No. of palms observed	Incidence (%)
Chitradurga	i) Hosdurga	17	1700	20.0
	ii) Holalkere	14	1400	27.2
	iii) Hiriyyur	14	1400	6.7
<b>Sub total</b>		<b>45</b>	<b>4500</b>	<b>18.1</b>
Hassan	i) Arsikere	30	3000	9.9
	ii) C.R. Patna	33	3000	2.8
	iii) Beluru	33	3300	1.8
	iv) Hassan	34	3400	3.2
<b>Sub total</b>		<b>130</b>	<b>13000</b>	<b>4.3</b>
Tumkur	i) Tiptur	20	2000	14.6
	ii) C.N. Halli	21	2100	34.0
	iii) Tumkur	33	3300	6.7
	iv) Turuvekere	21	2100	20.2
	v) Gubbi	30	3000	28.8
<b>Sub Total</b>		<b>125</b>	<b>12500</b>	<b>19.3</b>
ChickkamaGaluru	i) Kadur	28	2800	3.2
	ii) Tarikere	22	2200	3.5
	iii) N.R. Pura	06	600	8.0
<b>Sub Total</b>		<b>56</b>	<b>5600</b>	<b>3.8</b>

The foot rot incidence in arecanut with respect to major soil types and agronomic practices were considered: maximum incidence (13.5%) was observed in sandy soils followed by red soils (8.86%). With respect to source of water canal irrigated gardens accounted for maximum incidence (12.7%) compared to gardens with bore well water irrigation and rainfed conditions. Similarly, gardens under flood irrigation recorded maximum incidence (15.1%) compared to gardens under drip, basin/sprinkler irrigation systems. The gardens under regular cultivation recorded maximum incidence (11.5%) compared to uncultivated gardens (8.3%). When disease incidence with respect to age of the palms was considered, the maximum incidence (16.0%) was noticed in the age group of 15 to 30 years followed by 30 to 50 years (Table 5).

The survey results indicated that 10 to 40 years old palms were normally affected by foot rot disease. Though the disease incidence was observed both in irrigated and rainfed coconut gardens, higher incidence was observed where there was regular inter cultivation. Srinivasulu *et al.* (2003) reported that the disease incidence was maximum in coconut gardens raised in sandy and red soils in coastal

**Table 5. Incidence of foot rot of arecanut with respect to soil types and different agronomic practices in Southern Karnataka**

Particulars	Disease incidence (%)
<b>1. Soil type</b>	
a) Red soil	8.9
b) Black soil	8.1
c) Sandy soil	13.5
<b>2. Water source</b>	
a) Bore well	10.9
b) Canal	12.7
c) Rainfed	12.0
<b>3. Method of irrigation</b>	
a) Drip	4.8
b) Flood irrigation	15.1
c) Basin method /Sprinkler	9.9
d) Rainfed	9.7
<b>4. Cultivation</b>	
a) Cultivated	11.5
b) Un cultivated	8.2
<b>5. Age of the palms (Years)</b>	
a) > 15	3.6
b) 15-30	16.0
c) 30-50	12.4
d) < 50	7.5

districts of Andhra Pradesh, while negligible or no incidence was observed in black soils, paddy bunds or fish or prawn pond bunds. They also stated that number of rainy days and rainfall had a negative relationship with the spread of basal stem rot disease of coconut and the spread of the disease was completely prevented by water stagnation.

The disease has been reported on palms from various places all over the tropical world *viz.*, India, Sri Lanka, West Indies, Seychelles, Guam, *etc.* The disease was first recorded by Butler in the beginning of 20<sup>th</sup> Century, and later by Venkatanarayan (1936) from Karnataka. However, a severe outbreak occurred in 1952 in Thanjavur district of Tamil Nadu and till 1960s, the disease was confined to the coastal areas of Tamil Nadu. In 1978, the disease was noticed in all the districts of Tamil Nadu (Bhaskaran and Ramanathan, 1984). In severely affected gardens of Thanjavur district, the incidence was as high as 31 per cent (Bhaskaran *et al.*, 1984). Apart from Tamil Nadu, the disease was reported from Andhra Pradesh (Srinivasulu *et al.*, 2003), Karnataka (Govindu *et al.*, 1983) Kerala, Maharashtra, Gujarat and Orissa (Bhaskaran *et al.*, 1994; Wilson *et al.*, 1987). Basal stem rot disease incidence of coconut ranged from

6.1 to 36.2 per cent in Arsikere Taluk of Karnataka (Naik *et al.*, 2000). *Ganoderma* sp. has a wide host range attacking variety of palms and several fruit, forest and avenue trees (Naidu *et al.*, 1966; Govindu *et al.*, 1983; Bhaskaran *et al.*, 1994). The pathogen usually attacks old or weak palms growing under unfavourable conditions. The pathogen is a soil dweller, inhabiting dead as well as living plants material in the soil, enters through the wounds and which spread mainly through soil.

The present findings are in accordance with the findings of Garrett (1944) and Stover (1953) who stated that, most of root infecting fungi *viz.*, *Fusarium* spp. and *Ganoderma lucidum* are aerobes favoured by light soils and low soil moisture content. Rao and Rao (1966) reported that *Ganoderma* wilt incidence was low in heavy soils compared to light soils. When method of irrigation and water source was considered, foot rot incidence was noticed in all types/methods of irrigation and water sources. The maximum incidence was noticed in gardens with flood irrigation by canal water. Bhaskaran *et al.* (1978) stated that, irrigation alone was effective in reducing the intensity of disease. The disease was more severe during summer which might be due to the lack of soil moisture during these months (Vijayan and Natarajan *et al.*, 1972; Ramaswami *et al.*, 1997). When cultivated and uncultivated gardens were compared, higher foot rot incidence was noticed in cultivated gardens than uncultivated gardens. It may be due to the fact that during cultivation, root damage and spread of soil/inoculum from infected palm to healthy palms may help the pathogen to cause the disease.

#### **Incidence of foot rot of arecanut with respect to cropping system/pattern**

Various types of arecanut based cropping pattern/systems and sole crop of arecanut were observed during the course of investigation. The incidence of foot rot disease with respect to different cropping pattern/systems was observed and the results revealed that foot rot disease incidence were noticed in almost all the cropping patterns/systems and in sole crop of coconut and arecanut (Table 6). The incidence of disease was more with coconut and arecanut intercropping system compared to sole

crop. However, the percentage of incidence with particular cropping pattern/system differed from garden to garden in the four districts of Karnataka surveyed. Further, to confirm the influence of various cropping pattern/system on incidence and severity of disease, long term systematic studies are required.

The most common symptoms observed during the course of investigation were yellowing of outer whorl of the leaves, reduction in crown size, drooping of leaves, bleeding on trunk and formation of brackets on dead and severely affected palms (Fig. 2). Some of the common ITK practices practiced by the farmers for the management of foot rot/stem bleeding disease recorded were pasting red earth and lime on trunk of the palm, chiseling the bleeding patch and pasting of lime paste, pasting of tar on bleeding patch, chiseling around the trunk above the bleeding patch, burning the bleeding patch, planting *rasa kalli* (*Cactus* sp.) at base of the plant putting nails on trunk.

#### **Isolation, identification and designation of isolates**

*Ganoderma* sporophore and diseased root bits were found good source for aseptic isolation. The percentage of isolates obtained from sporophore and diseased root bits were 52.9 and 46.4 per cent, respectively. Out of 52 samples subjected to isolation, *Ganoderma* was isolated from 22 samples.

However, the pathogen could not be isolated from diseased stem/bark bits. The isolated pathogens were identified as *Ganoderma* sp. based on colony morphology and mycelial characteristics. Amplification of DNA of *Ganoderma* isolates with universal primers specific to fungus (ITS1 and ITS4) revealed a band of 650 bp in all isolates tested. Taxonomic correlation of the isolates proved that the isolates were related to *Ganoderma* sp. Bhaskaran *et al.* (1991) stated that, among various diseased samples subjected for isolation *G. lucidum* and *G. applanatum* were isolated only from diseased root pieces.

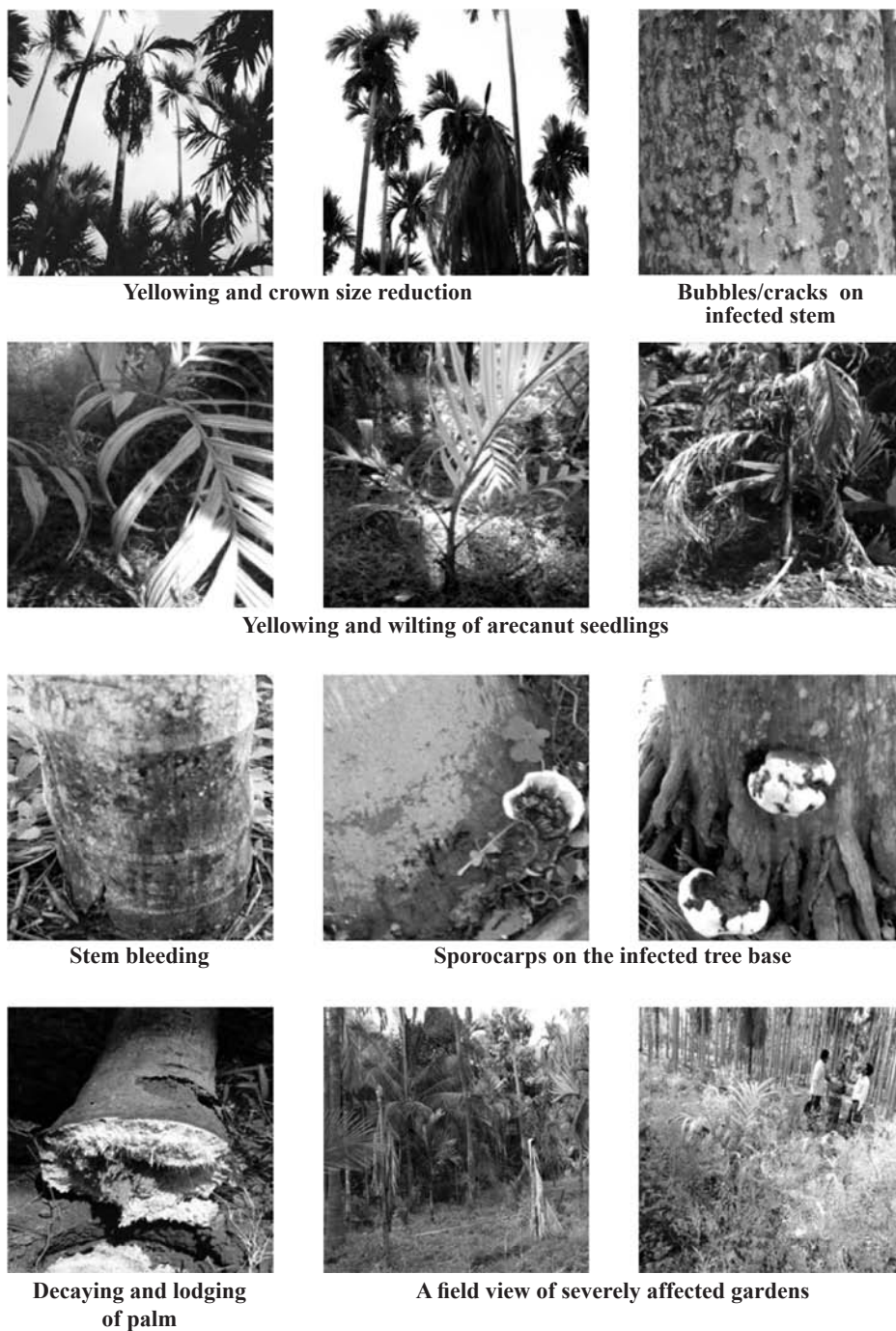
#### **Virulence of *Ganoderma* isolates of arecanut**

Among the 10 *Ganoderma* isolates tested, AG<sub>9</sub> recorded maximum (75) DSI at 9 months after inoculation followed by AG<sub>22</sub> which accounted 68.8 DSI and were on par with each other and were found

**Table 6. Effect of different cropping pattern/system on incidence of foot rot disease of arecanut in southern Karnataka**

Sl. No.	District	Cropping pattern/systems observed during survey	Incidence of foot rot
1.	Chitradurga	i) Arecanut alone	++
		ii) Arecanut + Coconut	+++
		iii) Arecanut + Vegetables (Tomato/Brinjal/Chilli)	+
		iv) Arecanut + Pulses/Green manure (Cowpea/Green gram)	++
		v) Arecanut + Fodder crops (Maize/Sorghum/Napier)	+
		vi) Arecanut + Banana	+
		vii) Arecanut + Coconut + Vegetables	+++
		viii) Arecanut + Coconut + Pulses	++
		ix) Arecanut + Coconut + Fodder crops	+++
		x) Arecanut + Coconut + Flower crops	+++
2.	Hassan	i) Arecanut alone	++
		ii) Arecanut + Coconut	+++
		iii) Arecanut + Vegetables (Tomato/Brinjal/Chilli)	+
		iv) Arecanut + Pulses/Green manure (Cowpea/Green gram)	++
		v) Arecanut + Fodder crops (Maize/Sorghum/Co-3)	++
		vi) Arecanut + Banana	++
		vii) Arecanut + Spices (Turmeric/Ginger)	++
		viii) Arecanut + Coconut + Vegetables	+
		ix) Arecanut + Coconut + Pulses	+++
		x) Arecanut + Coconut + Fodder crops	+++
		xi) Arecanut + Coconut + Flower crops	+++
		xii) Arecanut + Coconut + Spice crops	+++
3.	Tumkur	i) Arecanut alone	++
		ii) Arecanut + Coconut	+++
		iii) Arecanut + Vegetables (Tomato/Brinjal/Chilli/Beans)	++
		iv) Arecanut + Pulses/Green manure (Cowpea/Green gram)	++
		v) Arecanut + Fodder crops (Maize/Sorghum/Napier)	++
		vi) Arecanut + Banana	+
		vii) Arecanut + Flower crops (Marigold/ Chrysanthemum)	+
		viii) Arecanut + Coconut + Vegetables	++
		ix) Arecanut + Coconut + Pulses	+++
		x) Arecanut + Coconut + Fodder crops	+++
		xi) Arecanut + Coconut + Flower crops	+++
		xii) Arecanut + Coconut + Betel vine	+++
4.	Chikamagalore	i) Arecanut alone	++
		ii) Arecanut + Coconut	+++
		iii) Arecanut + Vegetables (Beans/Snake and ridge guards/Cucumber/ Tomato/Brinjal/Chilli)	++
		iv) Arecanut + Pulses/Green manure (Cowpea/Green gram)	+
		v) Arecanut + Fodder crops (Maize/Sorghum/Napier)	+
		vi) Arecanut + Banana	+
		vii) Arecanut + Flower crops (Marigold/ Chrysanthemum)	+
		viii) Arecanut + Betel vine	++
		ix) Arecanut + Coconut + Spices (Turmeric/Ginger)	++
		xi) Arecanut + Coconut + Vegetables	+++
		xii) Arecanut + Coconut + Pulses	+++
		xiii) Arecanut + Coconut + Fodder crops	+++
		xiv) Arecanut + Coconut + Flower crops	+++
		xv) Arecanut + Coconut + Spice crops	+++
		xvi) Arecanut + Coconut + Betel vine	+++

Foot rot incidence + : 0 to 10%; ++ : 11-15% +++ : >16%



**Fig. 2. Symptoms of foot rot disease of arecanut**

significantly virulent isolates. However, isolate AG<sub>20</sub> and AG<sub>15</sub> recorded minimum DSI of 18.8 and 25.0, respectively (Table 8 and Fig. 3).

The leaves of infected plants showed yellowing symptoms and wilting when inoculated with the isolates *viz.*, AG<sub>9</sub>, AG<sub>8</sub> and AG<sub>22</sub>. White fungal mass

on basal part of the plants was also observed. The cross-section of infected plant stem showed necrotic lesion on the vascular region. The virulence of isolates varied greatly from isolate to isolate. The pathogen was re-isolated from the infected seedlings and was compared with the original culture.

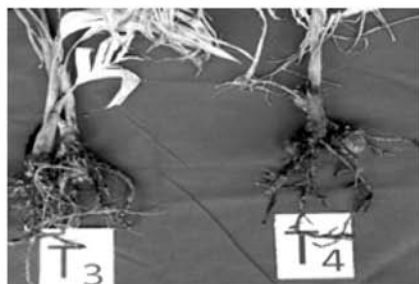
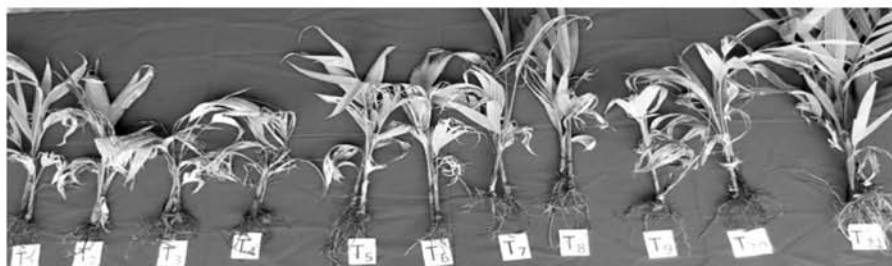
**Table 7.** *Ganoderma* isolates isolated from sporophore and infected samples of arecanut

Sl. No.	Type of sample	Number of samples	<i>Ganoderma</i> isolated	% isolates
1.	Sporophore	17	09	52.9
2.	Diseased root sample	28	13	46.4
3.	Diseased stem/bark bits	07	00	0.0
<b>Total</b>		<b>52</b>	<b>22</b>	<b>—</b>

Thus, the pathogenicity of *Ganoderma* isolates to arecanut seedlings was established through soil inoculation technique. Artificial infection of seedlings by contact with the inoculum block carrying *G. boninense* FA 5201 is an effective strategy for inducing the infection (Breton *et al.*, 2006). The present results revealed that there is variation in level of aggressiveness of different



An experimental view of virulence of arecanut *Ganoderma* isolates



Seedlings showing infection by different *Ganoderma* isolates



Cross section of infected seedlings

**Fig. 3.** Virulence of *Ganoderma* isolates on arecanut seedlings (T<sub>1</sub>: AG<sub>1</sub>, T<sub>2</sub>: AG<sub>7</sub>, T<sub>3</sub>: AG<sub>8</sub>, T<sub>4</sub>: AG<sub>9</sub>, T<sub>5</sub>: AG<sub>10</sub>, T<sub>6</sub>: AG<sub>12</sub>, T<sub>7</sub>: AG<sub>14</sub>, T<sub>8</sub>: AG<sub>15</sub>, T<sub>9</sub>: AG<sub>20</sub>, T<sub>10</sub>: AG<sub>22</sub>, T<sub>11</sub>: Control)

**Table 8: Virulence in terms of disease severity index (DSI) of *Ganoderma* isolates of on arecanut seedlings**

Isolates	Months after inoculation*			
	3	5	7	9
AG <sub>1</sub>	0 (0.45)	12.5 (15.23)	25.0 (26.36)	37.50 (37.50)
AG <sub>7</sub>	0 (0.45)	6.25 (7.84)	18.75 (22.62)	31.25 (33.75)
AG <sub>8</sub>	0 (0.45)	6.25 (7.84)	31.25 (18.97)	56.25 (48.75)
AG <sub>9</sub>	0 (0.45)	18.75 (22.62)	37.50 (37.50)	75.00 (63.64)
AG <sub>10</sub>	0 (0.45)	12.5 (15.23)	25.00 (26.36)	31.25 (59.88)
AG <sub>12</sub>	0 (0.45)	6.25 (7.84)	18.75 (22.62)	37.50 (37.50)
AG <sub>14</sub>	0 (0.45)	6.25 (7.84)	31.25 (33.75)	37.50 (37.50)
AG <sub>15</sub>	0 (0.45)	0 (0.45)	12.50 (15.23)	25.00 (26.36)
AG <sub>20</sub>	0 (0.45)	6.25 (7.84)	12.50 (15.23)	18.75 (22.62)
AG <sub>22</sub>	0 (0.45)	18.75 (18.97)	37.50 (37.50)	68.75 (59.88)
Control	0 (0.45)	0 (0.45)	0 (0.45)	0 (0.45)
SEm ±	-	-	205.49	154.52
CD (p=0.05)	NS	NS	20.69	17.94
CV (%)	-	-	61.45	31.96

**Note:** Figures in parenthesis are arc sine transformed values \* Mean of four replications

isolates of arecanut and were in accordance with findings of Breton *et al.* (2006) who reported that there were variations in the level of aggressiveness in seven *G. boninense* isolates collected from three different estates in Indonesia. The results related to different level of virulence among *Ganoderma* isolates of arecanut collected from various locations in dry tracts of Southern Karnataka will be useful for future researchers.

Root inoculation with primary roots of oil palm seedlings in polybags by exposing test tubes containing various *Ganoderma* isolates grown in POPW medium (mixture of paddy, oil palm wood sawdust, supplemented with sucrose, ammonium sulphate, calcium sulphate, and bacto peptone). Of the 344 isolates tested, 304 isolates were found pathogenic and 40 isolates were non pathogenic (Idris *et al.*, 2004). Khairudin *et al.*, (1991) reported 100 per cent success in infecting oil palm by wrapping bare roots of seedlings over rubber wood blocks (RWB) (6 x 6 x 12 cm) pre-inoculated with *G. boninense*.

Most of the literatures reported that, the signs or symptoms for diseased seedlings manifested approximately 3 to 4 months after treatments on 4 to 6 month old seedlings (Breton *et al.*, 2006; Nur Ain Izzati and Abdullah, 2008). However, in this study, the initial symptoms were noticed with few isolates 3 to 4 months after inoculation. This

could be due to difference in aggressiveness of the isolates employed in the study. Kok *et al.*, (2013) reported that, there was no significant difference in mean disease severity index among the 14 different treatments at 8 weeks after artificial inoculation in oil palm. Variations in the degree of virulence for 12 different *G. boninense* isolates tested in this study ranged from highly virulent to least virulent.

The present study revealed incidence of foot rot is emerging as a serious threat, which results in drastic reduction in production and productivity of the palms. Since the disease is soil-borne, infection takes place through roots and spread mainly through soil and water. Most of the farmers are not aware about cause, symptoms, nature of spread and its management. One of the major aspects to control this disease is to prevent spread of disease from infected palms to healthy ones. Hence, creating awareness among the farmers on various aspects of deadly disease is highly essential for the management and to prevent further spread of disease. *Ganoderma* isolates tested for their pathogenicity were found to demonstrate different degree of virulence ranging from highly pathogenic to least pathogenic. Therefore, it is essential to incorporate more than one isolate during screening for *Ganoderma* disease resistance or tolerance planting materials, searching for potential biological control agents, and studying various interactions, such as pathogen-host or beneficial microbial agent, pathogen and host plant relationships.

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