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Virulence Analysis and Influence of Soil Type and Agronomic Practices with Respect to Incidence of *Ganoderma* Wilt of Coconut in Southern Karnataka, India

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A B S T R A C T

Ganoderma wilt of coconut, caused by *Ganoderma* spp. is one of the most important constraints limiting coconut production and productivity in Southern Karnataka. The incidence of *Ganoderma* wilt of coconut during the year 2015-16 ranged from 0 to 47 per cent in southern dry tracts of Karnataka among 356 gardens surveyed. Tumkur recorded maximum incidence (16.75 %) followed by Chitradurga (14.86 %) and Hassan (11.12 %) among four districts surveyed. *Ganoderma* wilt was noticed in mono crop as well as mixed crop of coconut and incidence of disease was more with coconut and arecanut intercropping compared to sole crop. However, the percentage of incidence with particular cropping system varied greatly from garden to garden. Among the different soil types, maximum incidence (14.28 %) was observed in sandy soils followed by red soils (13.52 %). Canal water irrigated gardens accounted maximum (19.20 %) incidence. Similarly, gardens under flood irrigation recorded maximum (17.78 %) incidence. The gardens under regular cultivation recoded maximum incidence compared to un cultivated gardens. The disease incidence with respect to age of the palms revealed that maximum (14.92 %) incidence was noticed in age group of 30-50 years followed by 15-30 years of age. Virulence of 9 *Ganoderma* isolates of coconut tested under pot culture revealed that isolate CG_{11} recorded maximum (62.50) DSI at 9 months after inoculation followed by CG_7 and CG_8 which accounted 56.25 DSI and were on par with each other, which were found to be virulent compared to other isolates.

Introduction

Coconut (*Cocos nucifera* L.) belonging to family Arecaceae are important commercial crop of India providing livelihood to a substantial number of farm families. Coconut, the versatile palm popularly known as 'King of Palms', 'Tree of Heaven', 'Tree of life', 'Tree of Abundance', as well as 'God's gift to mankind', is grown in more than 93 countries within an area of 12.8 million hectares and production of 10.9 m MT (copra equivalent) in 2001. The total area and the production in Asian Pacific Coconut Committee (APCC) countries are estimated at 11.4 mha and 9.2 m MT, which is 90 and 84 per cent of world area

and production (Rethinam and Taufikkurahman 2002). In India coconut palms are grown in an area of 1.94 million hectares with a production of 14811.4 million nuts and a productivity of 7608 nuts/ha. annually.

Coconut palms are normally affected by various biotic and abiotic stresses resulting in drastic reduction in yields. Among the various biotic stress that affect coconut and arecanut production in India, Basal Stem Rot (BSR) or *Ganoderma* wilt caused by *Ganoderma applanatum* Pers and *G. lucidum* Leys. Karst. is a major constraint in coconut and arecanut production, especially in dry tracts of Southern Karnataka. The disease is reported from various places all over the tropical world *viz*., India, Srilanka, West Indies, Seycheles, Guam etc.

Though the disease was first recorded by Dr. Butler in the beginning of 20th century and later by Venkatanarayan (1936) from Karnataka, a severe outbreak occurred in 1652 in Thanjavur district of Tamil Nadu, and hence named as Thanjavur wilt. The disease is also reported from Andhra Pradesh (Basal stem rot), Kerala , Maharastra, Gujarath and Orissa (Bhaskaran,1994;Wilson *et al.,* 1987). The disease incidence was maximum (62.5%) in coconut palms cultivated in sandy soils and red soils while it was negligible (1.21%) and nill in black soils, paddy bunds or fish pond bunds (Srinivasalu *et al.,* 2003).

Naik *et al.,* (2000) reported that the disease severity ranged from 17.16 to 76.92 per cent in Arsikere Taluk of Hassan in Karnataka. However, not much study has been done relating to etiology and incidence of *Ganoderma* wilt 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 and cropping systems followed by farmers in disease hotspot areas of Karnataka and to establish the pathogenicity of *Ganoderma*. Further, assessment of disease incidence and severity with respect to different agronomic practices followed by farmers in disease hotspot areas of Karnataka, will be useful to take/design further remedial measures to combat the disease, thereby coconut and arecanut production will be enhanced.

Therefore, investigations on *Ganoderma* wilt of coconut and arecanut with respect to pathogen variability and disease management were under taken with the following objectives. Hence, present study was under taken to elucidate the disease incidence with respect to different agronomic practices followed by farmers in disease hotspot areas of Karnataka.

Materials and Methods

Survey for the incidence *Ganoderma* wilt of coconut

In southern Karnataka, major coconut growing districts, taluks and villages were selected for survey (Table 1). Based on stratified random sampling technique in each garden 100 palms uniformly were observed and number of palms infested with basal stem rot (*Ganoderma* wilt) and other major diseases were recorded and expressed as Disease Incidence (%).

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

During the course of survey, different agronomic practices followed by the farmers for cultivation of coconut and arecanut and soil type, method of irrigation etc were recorded and correlated with disease incidence. In addition, farmers practices

(ITK) for management of BSR coconut and other related information were also documented (Fig. 1).

Collection of diseased root samples/stem bit and sporocarps of coconut

The major coconut growing districts and talukas were selected and numbers of gardens/villages are selected based on stratified sampling technique. Different parts of the coconut palms such as diseased root bits/stem bits affected by *Ganoderma* wilt showing typical symptoms and sporocarps were collected from infected palms from different places of southern Karnataka (Table 2). The samples were labeled and packed in polythene bags for the purpose of isolation of the causal organism.

Isolation and designation of the causal organism isolates

Infected roots/ stem bits collected from infected palms were washed thoroughly with sterile water and cut into small bits/pieces and were surface sterilized in 0.1 per cent mercuric chloride for 30 seconds and washed three times serially in sterile distilled water 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 8 to 10 days of incubation period, slight mycelial growth was observed and that was transferred into Potato Dextrose Agar (PDA) medium. The inoculated plates were incubated at room temperature (28 °C ± 2 °C) for 3-5 days to facilitate growth of the fungus. Later, the bit of fungal growth was transferred to PDA slants. The pure culture of the fungus was obtained by following hyphal tip culture technique under aseptic conditions. The isolated *Ganoderma* isolates of coconut were designated as CG_1, CG_2, CG_3, CG_4, CG_5, CG_6, CG_7, CG_8, CG_9, CG_{10}, CG_{11}, CG_{12}, CG_{13}, CG_{14}, CG_{15}, CG_{16}, CG_{17}, CG_{18}, CG_{19}, CG_{20}, CG_{21}, CG_{22}, CG_{23} and CG_{24}. The cultures so obtained were stored in refrigerator at 4°C for further studies and they were cultured periodically once in month.

Pathogenicity of *Ganoderma* isolates

A pot culture experiment was laid out at Agriculture Research Station, Konehally, Tiptur to test virulence of *Ganoderma* isolates on coconut seedlings through soil inoculation during the year 2015-16. Nine *Ganoderma* isolates of coconut [CG_1, CG3, CG_4, CG_7, CG_8, CG_{11} , CG_{13} , CG_{14} and CG_{19}] were mass multiplied separately on sorghum grains in poly bags and were used for soil inoculation by mixing with 200 g/pot with the potting mixture at the time of planting. A control was maintained without inoculating *Ganoderma* isolates. All the treatments were replicated four times and arranged in a randomized block design. The seedlings used for virulence experiment were Tiptur tall and were 6-8 months old.

Disease severity index (DSI)

The plants were scored for disease class on a scale of 0 to 4 (Table 3). After recording the disease class for each control and treatment, the Disease Severity Index (DSI) was calculated using a modified method of Abdullah *et al.*, (2003) and Ilias (2000).

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

$$\text{Disease Severity Index (DSI)} = \frac{\Sigma (A \times B) \times 100}{\Sigma B \times 4}$$

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

Results and Discussion

Survey for the incidence of *Ganoderma* wilt of coconut

Among four districts surveyed, Tumkur recorded maximum incidence of *Ganoderma* wilt (16.75 %) followed by Chitradurga and Hassan which accounted 14.86 and 11.12 per cent incidence respectively. Chikanayakanahally Taluk of Tumkur district accounted maximum (29.95 %) incidence followed by Tiptur and Arsikere by accounting 25.05 and 21.10 per cent respectively. However, the minimum (3.89) per cent incidence was observed in Kadur Tq. of Chikamagalore district (Table 4).

The garden wise incidence of *Ganoderma* wilt ranged from 0 to 47.00 per cent in four districts surveyed wherein, maximum incidence was recorded in Shetikere (47.00 %) followed by Thimanahally village (38.00 %) of Chikanayakanahally Tq. of Tumkur district and Haranahally (31.00%) village of Arsikere Tq. of Hassan Dist among 356 villages/ gardens surveyed.

The *Ganoderma* wilt incidence with respect major soil type and agronomic practices were recorded that, maximum incidence (14.28 %) was observed in sandy soils followed red soils (13.52 %). As well, the canal water-irrigated gardens accounted maximum (19.20 %) incidence compared to gardens under bore well water and rainfed conditions. Similarly, gardens under flood irrigation recorded maximum (17.78 %) incidence compared to gardens under drip, basin/sprikler methods of irrigation. The gardens under regular cultivation recoded maximum incidence compared to un cultivated gardens (Table 5). The disease incidence with respect to age of the palms revealed that maximum (14.92%) incidence was noticed in age group of 30-50 years followed by 15-30 years of age.

Incidence of *Ganoderma* wilt with respect agronomic practices

The survey results indicated that 10 to 40 years old palms were normally affected by *Ganoderma* wilt disease. Though the disease incidence was observed both in irrigated and rainfed coconut gardens, more incidence was observed where there was regular inter cultivation. Srinivasulu *et al.,* (2003) reported that the incidence was observed maximum (up to 62.50 %) in coconut gardens raised in sandy and red soils in coastal district of Andhra Pradesh, while negligible (1.21 %) and 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 spread of the disease was completely checked by water stagnation.

Ganoderma wilt of coconut with respect to cropping system/pattern

Various types of coconut based cropping pattern/systems and sole crop of coconut and arecanut were observed during course of investigation. Incidence of *Ganoderma* wilt (BSR) disease with respect to different cropping pattern/systems were observed and the results revealed that BSR disease incidence was noticed in all most 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 compared to sole crop.

However, the percentage of incidence with particular cropping pattern/system varies greatly from garden to garden. Further, to confirm the influence of various cropping pattern/system on incidence and severity of disease may require long range systematic study. The most common symptoms observed

during course of investigation are yellowing of outer whorl 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 common ITK practices practiced by the farmers for the management of basal stem rot/stem bleeding disease are 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 at above the bleeding patch (thinking that bleeding patch should not go up), burning the bleeding patch with fire and planting rasa kalli (*Cactus* sp.) at base of the plant, putting nails on trunk etc were observed

Isolation and designation of the causal organism 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 48.27 and 32.25 per cent, respectively in coconut. Similarly, in case of arecanut out of fifty two samples subjected for isolation, *Ganoderma* was isolated from 21 samples.

The percentage of isolates obtained from sporophore and diseased root bits was 52.94 and 46.42 per cent, respectively (Table 7) and were designated as described under material and methods.

The *Ganoderma* was not isolated from diseased stem bits/ bark either in coconut or areacnut. The isolated pathogens were identified as *Ganoderma* sp. based on colony morphology and mycelia characteristics. 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.

Pathogenicity of *Ganoderma* isolates

Virulence of nine *Ganoderma* isolates of coconut on coconut seedlings was tested in pot culture through soil of sorghum based inoculum. The disease severity index (DSI) values were found non-significant at three and five months after inoculation (MAI) and are found significant at 7 and 9 MAI. Among nine *Ganoderma* isolates tested CG_{11} recorded maximum (62.50) DSI at 9 months after inoculation followed by CG_7 and CG_8 which accounted 56.25 DSI and are on par with each other and are found to be virulent compare to other isolates (Table 8).

Isolate CG_3 and CG_{19} recorded minimum (25) DSI. The leaves of infected plants showed yellowing, browning of leaves starting from outer whorl of leaf and it was followed by chloratic symptoms of leaf and wilting of plants/seedlings were observed in isolate CG_7, CG_8 and CG_{11}. The white fungal mass on basal part of the plants was also observed. The cross-section of an infected plant stem showed a necrotic lesion at the vascular region (Fig. 3).

The results clearly revealed that, the virulence of isolates varied greatly from isolate to isolate and isolate G_{11} (CN) was found most virulent among 9 isolates tested. The causal organism was re-isolated from the infected seedlings and was compared with the original culture. Thus, the pathogenicity of *Ganoderma* isolates to coconut seedlings (Tiptur tall) was established through soil inoculation technique.

Incidence of *Ganoderma* wilt

Incidence of *Ganoderma* wilt of coconut was observed in all districts surveyed in dry tracts of Karnataka and was becoming major problem limiting production and productivity of palms. The disease has been reported from

various places all over the tropical world *viz*., India, Sri Lanka, West Indies, Seycheles, Guam, etc. Though the disease was first recorded by Dr. Butler in the beginning of 20th Century, and later by Venkatanarayan (1936) from Karnataka, a severe outbreak occurred in 1952 in Thanjavur district of Tamil Nadu. Till $1960_{s,}$ 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 in Thanjavur district, the incidence was as high as 31 per cent (Bhaskaran *et al.,* 1984). Apart from Tamil Nadu, the disease is reported from Andhra Pradesh (Srinivasalu *et al.,* 2003), Karnataka (Govindu *et al.,* 1983 and Palanna *et al.,* 2009), and Kerala, Maharastra, Gujarath and Orissa (Bhaskaran *et al.,* 1994; Wilson *et al.,* 1987). *Ganoderma* sp. has a wide host range attacking variety of palms and several forest, avenue and fruit trees (Govindu *et al.,* 1983; Bhaskaran *et al.,* 1994).

The fungus usually attacks old or weak palms growing under unfavorable conditions. The pathogen is a soil dweller inhabiting dead as well as living plant material in the soil, enters through the wounds and disease spread mainly through soil. Basal stem rot disease incidence ranged from 6.06 to 36.15 per cent in Arsikere Taluk of Karnataka (Naik *et al.,* 2000)

Incidence of *Ganoderma* wilt with respect agronomic practices

The disease incidence noticed in all most all soil type and cropping systems. The garden to garden incidence varied with different agronomic practices.The present findings were in accordance with the findings of Garett (1944) and Stover (1953) who stated that most of root infecting fungi *viz Fusarium* spp. and *Ganoderma lucidum* were aerobes favored by light soils and low soil moisture. When method of irrigation and water source is considered, BSR disease incidence was noticed in all types/methods of irrigation and water sources. Maximum incidence was noticed in gardens with flood irrigation by canal water. Bhaskaran *et al.,* (1978) stated that irrigation alone was infective in reducing the intensity of disease. The disease was more severe during summer months which might be due to the lack of soils moisture during these months (Vijayan and Natarajan *et al.,* 1997 and Ramaswami *et al.,* 1997). When, cultivated and uncultivated gardens is considered more BSR incidence was noticed in cultivated gardens compare to uncultivated gardens. It may be due to the fact that, during cultivation spread of soil/inoculum form infected palm to healthy palms and root damage may helped the pathogen to cause the disease.

Canal irrigated gardens accounted maximum the incidence of foot rot caused by *Ganoderma* spp. (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 (Palanna *et al.,* 2018)

Pathogenicity of *Ganoderma* isolates

All isolates tested in our study excreted different degrees of virulence. Artificial infection of plants/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 isolates of

coconut and 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. Information related to different level of virulence among *Ganoderma* isolates of coconut and arecanut collected from various locations in dry tracts of southern Karnataka will be useful for future researchers.

Idris *et al.,* (2004) employed root inoculation method where primary roots of oil palm seedlings in polybag were exposed and inserted into test tubes containing various *Ganoderma* spp. isolates grown in POPW medium (mixture of paddy, oil palm wood sawdust, supplemented with sucrose, ammonium sulphate, calcium sulphate, and bacto peptone). Of a total of 344 isolates tested, 304 isolates were found pathogenic and 40 isolates were nonpathogenic.

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 or 432 cm^3) pre-inoculated with *Ganoderma boninense*. Most of the literatures reported that the signs or symptoms for diseased seedlings only manifested approximately 3-4 months after treatments for 4 to 6-month-old seedlings (Breton *et al.,* 2006, Nur Ain Izzati and Abdullah, 2008, Rees *et al.,* 2007).

Table.1 List of major coconut and arecanut growing areas selected for survey in southern Karnataka

Sl. No.	Name of District	Name of Taluk	Number of Villages	Number gardens covered	Total Number of Palms observed
1	Chitradurga	i) Hosdurga	198	17	1700
		ii) Holalkere	166	14	1400
		iii)Hiriyur	164	14	1400
		Sub total	**528**	**45**	**4500**
2	Hassan	i) Arsikere	340	30	3000
		ii) Chanarayapatana	375	33	3300
		iii) Beluru	384	33	3300
		iv) Hassan	391	34	3400
		Sub total	**1490**	**130**	**13000**
3	Tumkur	i) Tiptur	231	20	2000
		ii) Chikanayakanahally	234	21	2100
		iii) Tumkur	373	33	3300
		iv) Turuvekere	243	21	2100
		v) Gubbi	346	30	3000
		Sub Total	**1427**	**125**	**12500**
4	Chikkamagalore	i) Kadur	314	28	2800
		ii) Tarikere	250	22	2200
		iii)Narashimarajapura	59	6	600
		Sub Total	**623**	**56**	**5600**
		Grand Total	**4071**	**356**	**35600**

Table.2 Identity and designation of *Ganoderma* isolates of coconut and their source of collection

Sl. No.	Source of isolation	Place of collection	Identity and designation of *Ganoderma* isolates
Coconut			
1	Sporocarps	Karekodihally, ArsikereTq. Hassan Dist.	CG_1
2	Root Samples	Haranahally, ArsikereTq. Hassan Dist.	CG_2
3	Sporocarps	Vittalapura, ArsikereTq. Hassan Dist.	CG_3
4	Sporocarps	Nagenakoppalu, CR Pattana Tq. Hassan Dist.	CG_4
5	Root Sample	Badarahally, Channarayapattana Tq. Hassan Dist.	CG_5
6	Root Samples	Belagralli, Tiptur Tq. Tumkur Dist.	CG_6
7	Sporocarps	Hindiskere, Tiptur Tq. Tumkur Dist.	CG_7
8	Sporocarps	Thimmanahali, C.N.Halli Tq. Tumkur Dist.	CG_8
9	Sporocarps	Anesidri, Hiriyur Tq. Tumkur Dist.	CG_9
10	Root Sample	Dharmapura(H), Hiriyur Tq. Chitradurga Dist.	CG_{10}
11	Root Samples	Venglapura, Hosdurga Tq. Chitradurga Dist.	CG_{11}
12	Sporocarps	Shettihalli, HosdurgaTq. Chitradurga Dist.	CG_{12}
13	Root Samples	Thirumalapura Holalkere Tq. Chitradurga Dist.	CG_{13}
14	Sporocarps	Thalakatta, HosdurgaTq. Chitradurga Dist.	CG_{14}
15	Sporocarps	Vaderahalli, Holalkere Tq. Chitradurga Dist.	CG_{15}
16	Root Sample	Doddanaramangala, Tumkur Tq. Tumkur Dist.	CG_{16}
17	Root Samples	Kodipalya, Tumkur Tq. Tumkur Dist	CG_{17}
18	Sporocarps	Shettikere, C.N.Halli Tq. Tumkur Dist.	CG_{18}
19	Sporocarps	Hullekere, Turvekere Tq. Tumkur Dist.	CG_{19}
20	Sporocarps	Thyagaturu, Gubbi Tq. Tumkur Dist.	CG_{20}
21	Sporocarps	Upparanahally, HassanTq. Hassan Dist.	CG_{21}
22	Root Samples	Bhuvanahally,HassanTq. Hassan Dist.	CG_{22}
23	Sporocarps	Bandarikatte,BeluruTq. Hassan Dist.	CG_{23}
24	Root Samples	Narasipura, BeluruTq. Hassan Dist.	CG_{24}

Table.3 Disease scale for *Ganoderma* wilt 0-4 (Abdullah *et al.*, 2003; Ilias 2000)

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

Table.4 Incidence of *Ganoderma* wilt coconut in southern Karnataka

Sl. No.	District	Taluk	No Gardens Observed	Number of palms observed	Disease incidence (%)
1	Chitradurga	i) Hosdurga	17	1700	17.58
		ii) Holalkere	14	1400	20.35
		iii)Hiriyur	14	1400	6.07
		Sub total	**45**	**4500**	**14.86**
2	Hassan	i) Arsikere	30	3000	21.10
		ii) C R Patna	33	3300	6.34
		iii) Beluru	33	3300	7.81
		iv) Hassan	34	3400	10.17
		Sub total	**130**	**13000**	**11.12**
3	Tumkur	i) Tiptur	20	2000	25.05
		ii) C N hally	21	2100	29.95
		iii) Tumkur	33	3300	9.52
		iv) Turuvekere	21	2100	14.67
		v) Gubbi	30	3000	11.40
		Sub Total	**125**	**12500**	**16.75**
4	Chickkamagalore	i) Kadur	28	2800	3.89
		ii) Tarikere	22	2200	3.90
		iii) NR Pura	06	600	8.34
		Sub Total	**56**	**5600**	**4.37**

* Number of palms observed

Table.5 Incidence of *Ganoderma* wilt of coconut and arecanut with respect to soil types and different agronomic practices in southern Karnataka

Sl. No.	Particulars	Disease Incidence (%)
1	**Soil type**	
	a) Red soil	13.52
	b) Black soil	8.18
	c) Sandy soil	14.28
2	**Water source**	
	a) Bore well	13.96
	b) Canal	19.20
	c) Rainfed	4.53
3	**Method of irrigation**	
	a) Drip	6.65
	b) Flood irrigation	17.78
	c) Basin method /Sprinkler	10.62
	d) Rainfed	5.08
4	**Cultivation**	
	a) Cultivated	15.23
	b) Un cultivated	4.34
5	**Age of the palms (Years)**	
	a) > 15	6.76
	b)15-30	14.27
	c) 30-50	14.92
	d) < 50	9.66

Table.6 Effect of different cropping pattern/system on Incidence of *Ganoderma* wilt disease of coconut in southern Karnataka

Sl. No.	District	Cropping pattern observed during survey	Incidence of BSR
1	Chitradurga	i) Coconut alone	+
		ii) Arecanut alone	+
		iii) Coconut + Horticulture crops (Arecanut/Banana)	+
		iv) Coconut + Vegetables (Tomato/Brinjol/Chilli)	+
		v) Coconut + Pulses (Cowpea/Greengram)	+
		vi) Coconut + Fodder crops (Maize/Sorgum/Co-3)	+
2	Hassan	i) Coconut alone	+
		ii) Arecanut alone	+
		iii) Coconut + Arecanut	+ +
		iv) Coconut + Vegetables	+

		(Tomato/Brinjol/Chilli)	
		v) Coconut + Pulses/Green manure (Cowpea/Green gram)	+
		vi) Coconut + Fodder crops (Maize/Sorgum/Co-3)	+
		vii) Coconut + Flower crops (Marigold/Chrysanthimum)	+
		viii) Coconut + Spice crops (Turmeric/Zinger)	+
3	Tumkur	i) Coconut alone	+
		ii) Arecanut alone	+
		iii) Coconut + Arecanut	+++
		iv) Coconut + Vegetables/Leafy vegetables (Tomato/Brinjol/Chilli/Beans/gouards)	+
		v) Coconut + Fodder crops (Maize/Sorgum/Co-3)	+
		vi) Coconut + Flower crops (Marigold/Chrysanthimum)	+
		vii) Coconut + Betel vine	+
4.	Chikamagalore	i) Coconut alone	+
		ii) Arecanut alone	+
		iii) Coconut + Arecanut	++
		iv) Coconut + Vegetables/Leafy vegetables (Tomato/Brinjol/Chilli/Beans/gaurds/ cucumber)	+
		v) Coconut + Fodder crops (Maize/Sorgum/Co-3)	+
		vi) Coconut + Flower crops (Marigold/Chrysanthimum)	+
		vii) Coconut + Betel vine	+

Note**:** + *Ganoderma* wilt incidence noticed

Table.7 *Ganoderma* isolates isolated from coconut

Sl. No.	Type of sample	Number of sample	*Ganoderma* obtained	% isolates obtained
I COCONUT				
1	Sporophore	29	14	48.27
2	Root samples	31	10	32.25
3	Disease Stem Bits/Bark	10	00	0.00
	Total	**70**	**24**	**--**

Table.8 Virulence of *Ganoderma* isolates of coconut to coconut seedlings

Sl. No.	Isolates	Disease Severity Index (DSI) Months after inoculation (MAI)*			
		3	5	7	9
1	CG_1	0 (0.45)	0 (0.45)	12.50 (15.23)	31.25 (30.12)
2	CG_3	0 (0.45)	0 (0.45)	12.50 (11.58)	25.00 (26.36)
3	CG_4	0 (0.45)	6.25 (7.84)	25.00 (26.36)	50.00 (45.00)
4	CG_7	0 (0.45)	6.25 (7.84)	31.25 (33.75)	56.25 (48.75)
5	CG_8	0 (0.45)	0 (0.45)	37.50 (37.50)	56.25 (48.75)
6	CG_{11}	0 (0.45)	12.50 (15.23)	37.50 (37.50)	62.50 (52.50)
7	CG_{13}	0 (0.45)	0 (0.45)	12.50 (15.23)	37.50 (37.50)
8	CG_{14}	0 (0.45)	6.25 (7.84)	12.50 (15.23)	31.25 (33.75)
9	CG_{19}	0 (0.45)	0 (0.45)	6.25 (15.23)	25.00 (26.36)
10	Control	0 (0.45)	0 (0.45)	0 (0.45)	0 (0.45)
SEm ±		-	-	**204.64**	**187.86**
CD (p=0.05)		**NS**	**NS**	**20.759**	**19.885**
CV (%)		-	-	**68.755**	**39.218**

Note: Fig. in parenthesis are arc sine transformed values * Mean of four replications

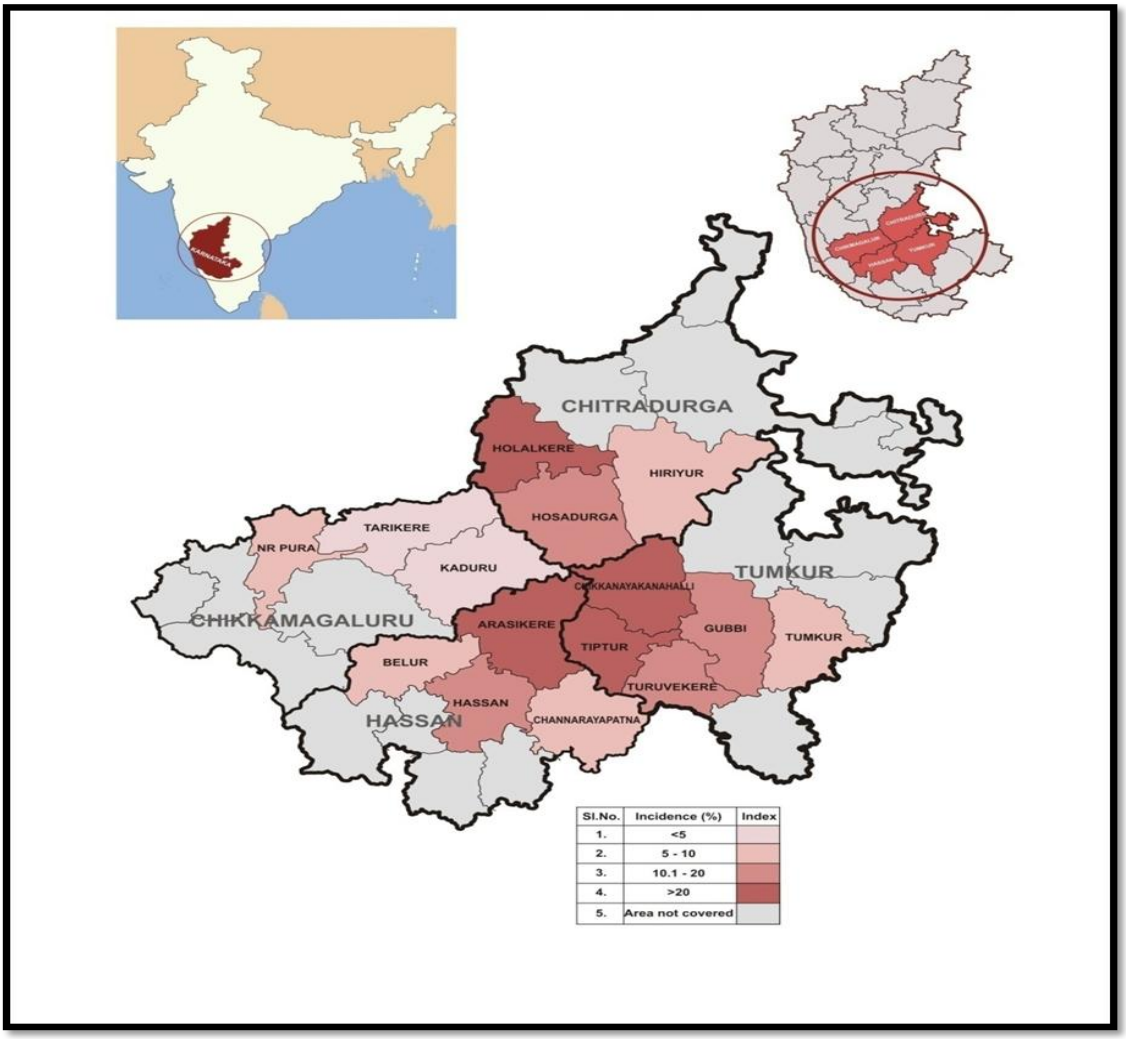
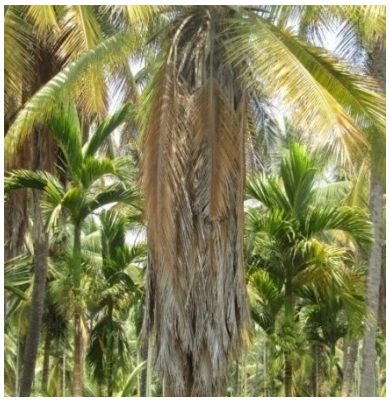


Fig.1 Disease hot spots map of *Ganoderma* wilt of coconut in southern Karnataka


Yellowing and reduction in crown size

Drooping of leaves around the crown and skirt formation



Stem Bleeding



Sporocarps at the infected tree base


A field view of affected coconut garden

Fig.2 Symptoms of *Ganoderma* wilt in coconut

Gaint culture of *Ganoderma* multiplication on sorghum grains

An experimental view of virulence of Coconut *Ganoderma* isolates

T_1 T_2 T_3 T_4 T_5 T_6 T_7 T_8 T_9 T_{10}

Seedlings showing infection by different isolates of Coconut (*Ganoderma* isolate)

T_4 T_5 T_6 T_7 T_{10} **T_5 T_6 T_{10}**

Cross section of infected seedlings

Fig.3 Virulence of *Ganoderma* isolates of coconut on coconut seedlings (Tiptur tall)

Note: $T_1 = CG_1$, $T_2 = CG_3$, $T_3 = CG_4$, $T_4 = CG_7$, $T_5 = CG_8$, $T_6 = CG_{11}$, $T_7 = CG_{13}$, $T_8 = CG_{14}$, $T_9 = CG_{19}$, T_{10} = Control

However, in this study, the appearance initial infection symptom was noted in few isolates 3-4 months after inoculation. This also could be due to difference in aggressiveness of different isolates used in the study.

Similar results were also reported by Kok *et al.,* 2013, reported that, there was no significant difference in mean disease severity index (DSI) among the 14 different treatments at 8 weeks after artificial inoculation in oil palms. Variations in the degree of virulence for 12 different *G. boninense* isolates tested in this study ranged from highly virulence to least virulence. Virulence of 10 *Ganoderma* isolates of arecanut tested under pot culture revealed that isolate AG9, recorded maximum disease severity index (75 DSI) nine months after inoculation followed by AG_{22} and AG_4 which accounted 68.8 DSI each (Palanna *et al.,* 2018).

All *Ganoderma* isolates collected from various locations in southern dry tracts of Karnataka were found to demonstrate different degree of virulence ranging from highly pathogenic to least pathogenic. Therefore, it is crucial to incorporate more than one isolate into any researchers on screening for *Ganoderma* resistance or tolerance planting materials, searching for potential biological control agents, and studying bitrophic or tri-trophic interactions, such as pathogen-host or beneficial microbial agent, pathogen and host plant relationships.

The present study revealed incidence *Ganoderma* wilt of coconut, caused by *Ganoderma* spp. 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. The disease incidence of ranged from 0 to 47 per cent in southern dry tracts of Karnataka among 356 gardens surveyed. *Ganoderma* wilt was more with coconut and arecanut intercropping compared to sole crop and other cropping systems. However, the percentage of incidence with particular cropping system varied greatly from garden to garden. *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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