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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Abstract

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 recorded 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 CG₁₁ recorded maximum (62.50) DSI at 9 months after inoculation followed by CG₇ and CG₈ which accounted 56.25 DSI and were on par with each other, which were found to be virulent compared to other isolates.

Keywords

Coconut, Ganoderma wilt, Virulence, Disease Severity Index, Soil type

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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.
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, Maharashtra, 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 nil 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 taluks 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 CG1, CG2, CG3, CG4, CG5, CG6, CG7, CG8, CG9, CG10, CG11, CG12, CG13, CG14, CG15, CG16, CG17, CG18, CG19, CG20, CG21, CG22, CG23 and CG24. 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 [CG1, CG3, CG4, CG7, CG8, CG11, CG13, CG14 and CG19] 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 bare well water and rainfed conditions. Similarly, gardens under flood irrigation recorded maximum (17.78 %) incidence compared to gardens under drip, basin/sprinkler 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
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, Seychelles, 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 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 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, Maharashtra, 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) in comparison to the maximum recorded 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 cm³) 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) Hiriyr         | 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) Tarkere         | 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          | Karekodi hally, Arsikere Tq. Hassan Dist. | CG1                                              |
| 2       | Root Samples        | Haranahally, Arsikere Tq. Hassan Dist. | CG2                                              |
| 3       | Sporocarps          | Vittalapura, Arsikere Tq. Hassan Dist. | CG3                                              |
| 4       | Sporocarps          | Nagenakoppalu, CR Pattana Tq. Hassan Dist. | CG4                                              |
| 5       | Root Sample         | Badarahally, Channarayapattna Tq. Hassan Dist. | CG5                                              |
| 6       | Root Samples        | Belagrali, Tiptur Tq. Tumkur Dist. | CG6                                              |
| 7       | Sporocarps          | Hindiskere, Tiptur Tq. Tumkur Dist. | CG7                                              |
| 8       | Sporocarps          | Thimmanahali, C.N.Halli Tq. Tumkur Dist. | CG8                                              |
| 9       | Sporocarps          | Anesidri, Hiriyur Tq. Tumkur Dist. | CG9                                              |
| 10      | Root Sample         | Dharmapura(H), Hiriyur Tq. Chitradurga Dist. | CG10                                             |
| 11      | Root Samples        | Venglapura, Hosdurga Tq. Chitradurga Dist. | CG11                                             |
| 12      | Sporocarps          | Shettihalli, Hosdurga Tq. Chitradurga Dist. | CG12                                             |
| 13      | Root Samples        | Thirumalapura Holalkere Tq. Chitradurga Dist. | CG13                                             |
| 14      | Sporocarps          | Thalakatta, Hosdurga Tq. Chitradurga Dist. | CG14                                             |
| 15      | Sporocarps          | Vaderahalli, Holalkere Tq. Chitradurga Dist. | CG15                                             |
| 16      | Root Sample         | Doddanaramangala, Tumkur Tq. Tumkur Dist. | CG16                                             |
| 17      | Root Samples        | Kodipalya, Tumkur Tq. Tumkur Dist | CG17                                             |
| 18      | Sporocarps          | Shettikere, C.N.Halli Tq. Tumkur Dist. | CG18                                             |
| 19      | Sporocarps          | Hullekere, Turvekere Tq. Tumkur Dist. | CG19                                             |
| 20      | Sporocarps          | Thyagaturu, Gubbi Tq. Tumkur Dist. | CG20                                             |
| 21      | Sporocarps          | Upparanahally, Hassan Tq. Hassan Dist. | CG21                                             |
| 22      | Root Samples        | Bhuvanahally, Hassan Tq. Hassan Dist. | CG22                                             |
| 23      | Sporocarps          | Bandarikatte, Beluru Tq. Hassan Dist. | CG23                                             |
| 24      | Root Samples        | Narasipura, Beluru Tq. Hassan Dist. | CG24                                             |
**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 hallly     | 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/Brinjal/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                                        | +                |
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/Brinjal/Chilli/Beans/gourds)  

v) Coconut + Fodder crops (Maize/Sorgum/Co-3)  
vii) Coconut + Betel vine  

4. Chikamagalore  
i) Coconut alone  





 iv) Coconut + Vegetables/Leafy vegetables (Tomato/Brinjal/Chilli/Beans/gourds/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       | CG₁      | 0 (0.45)                                                     | 0 (0.45) | 12.50 (15.23) | 31.25 (30.12) |
| 2       | CG₃      | 0 (0.45)                                                     | 0 (0.45) | 12.50 (11.58) | 25.00 (26.36) |
| 3       | CG₄      | 0 (0.45)                                                     | 6.25 (7.84) | 25.00 (26.36) | 50.00 (45.00) |
| 4       | CG₇      | 0 (0.45)                                                     | 6.25 (7.84) | 31.25 (33.75) | 56.25 (48.75) |
| 5       | CG₅      | 0 (0.45)                                                     | 0 (0.45) | 37.50 (37.50) | 56.25 (48.75) |
| 6       | CG₁₁     | 0 (0.45)                                                     | 12.50 (15.23) | 37.50 (37.50) | 62.50 (52.50) |
| 7       | CG₁₃     | 0 (0.45)                                                     | 0 (0.45) | 12.50 (15.23) | 37.50 (37.50) |
| 8       | CG₁₄     | 0 (0.45)                                                     | 6.25 (7.84) | 12.50 (15.23) | 31.25 (33.75) |
| 9       | CG₁₉     | 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

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

Cross section of infected seedlings

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

Note: \( T_1 = \text{CG}_1, T_2 = \text{CG}_2, T_3 = \text{CG}_3, T_4 = \text{CG}_4, T_5 = \text{CG}_5, T_6 = \text{CG}_6, T_7 = \text{CG}_7, T_8 = \text{CG}_8, T_9 = \text{CG}_9, T_{10} = \text{Control} \)
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 AG22 and AG4 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 various 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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