Advances in Horticulture Vol. 10 – Plantation and Spice Crops Part 2 (1994). Eds: *K.L. Chadha and P. Rethinam*

Ganoderma Wilt Disease of Coconut

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1. INTRODUCTION

Among the various fungal diseases affecting coconut palm (*Cocos nucifera L.*) in India, *Ganoderma* wilt is the most destructive one. In Tamil Nadu, this disease was first observed in Thanjavur district in 1952 and hence called Thanjavur wilt (Vijayan and Natarajan, 1972). In Karnataka, this disease is called Anabe Roga and in Andhra Pradesh, 'Ganoderma wilt'. During the past few years, a disease with similar symptoms has been observed in Maharashtra and Gujarat states also (Nambiar and Rethinam, 1986; Bhaskaran *et al.*, 1989). Wilson *et al.* (1987) reported the occurrence of a 'basal stem rot' disease of coconut in Kerala caused by *Ganoderma lucidum* (Leys) Karst. In Sri Lanka, a basal stem rot disease of coconut caused by G. *boninense Pat.* was reported by Peries (1974). In this chapter, the research work carried out on Ganoderma wilt of coconut in India is reviewed.

2. OCCURRENCE AND DISTRIBUTION

In India, *G. lucidum* was first recorded in coconut palm in Karnataka State in 1913 by Butler. In Tamil Nadu, it was first reported from Thanjavur district in 1952. Till 1965-66, the disease was confined to the coastal areas of Tamil Nadu and the incidence ranged from 3.3 to 10.8 per cent with the highest incidence (10.8%) in Thanjavur district followed by Kanyakumari (6.3%), Tiruchirappalli (4.0%), Ramanathapuram (4.0%), South Arcot (3.5%) and Chengalpattu (3.3%) districts. In 1978, the disease was noticed in all the districts of Tamil Nadu and the incidence ranged from 0.6 to 4.9 per cent (Bhaskaran and Ramanathan, 1984). Maximum incidence of the disease was in Thanjavur district with a mean of 4.9 per cent followed by Chengalpattu district with 4.5 per cent incidence. In Thanjavur district, the incidence was very high in Muthupet block with a mean of 8.4 per cent and, in some of the severely infected gardens, the incidence was as high as 31.4 per cent (Bhaskaran *et al.*, 1984a).

In Andhra Pradesh, the disease is mainly prevalent in lighter soils in the coastal districts than in heavy soils (Papa Rao and Govinda Rao, 1966; Satyanarayana *et al.*, 1985). In Karnataka, the disease is widely prevalent in the *maidan* tract especially in sandy soils of the southern region (Govindu Rao and Keshava Murthy, 1983).

3. SYMPTOMATOLOGY

3.1 Stem

Exudation of reddish brown viscous fluid from the basal portions of the stem is the first visible symptom of the disease in the affected palm (Fig. 1). The bleeding patches begin from the base and extend up to three metres upwards as the disease progresses. Internal rotting and discolouration in the stem can be seen up to the height of bleeding. In advanced stages, basal portion of the stem decays completely. Occasionally, some infected palms do not show bleeding symptoms. In some palms, the bark from the base of the stem peels off. This is very common in Karnataka State and in parts of Tamil Nadu adjoining Karnataka State. Sporophores of *G. lucidum* appear at the base of the trunk in some palms just above the soil level prior to wilting or just after the death of the palm (Vijayan *et al.*, 1973; Bhaskaran *et al.*, 1982, 1989; Rethinam, 1984; Bhaskaran, 1986) (Fig. 2).

Fig. 1 : *Ganoderma* wilt disease affected palm showing bleeding patches at the base of the stem.

Fig. 2 : Ganoderma wilt affected palm with Ganoderma fruit bodies.

3.2 Leaves

The leaflets exhibit wilting symptoms and outer one or two whorls of leaves turn yellow. Later, they exhibit light to moderate browning followed by drooping (Fig. 3). As the disease advances, the remaining leaves also droop down in quick succession and the spindle alone remains. Under prolonged infection, production of new leaves is delayed resulting in reduced number of leaves in the crown; the outer leaves fall off and subsequent leaves are reduced in size with a shortened spindle that does not unfold properly. In some cases, leaves break off near the base along the midrib. In certain cases, soft rot sets in the bud resulting in loss of turgidity and death of the cells due to breakdown of conducting elements. The affected bud emits a foul smell and in advanced stages, the crown is blown off leaving the decapitated stem (Vijayan and Natarajan, 1972; Bhaskaran *et al.*, 1982; Bhaskaran, 1986).

3.3 Flowers

As the disease progresses, normal development of flowers and bunches is arrested, leading to button shedding. In the early stages, there is no button shedding. As the leaves droop down, the subtended bunches also hang down. The nuts become barren. Where disease progress is slow, a few normal nuts are produced. Most of the palms bear profusely, just prior to and at the time of initiation of symptoms (Vijayan and Natarajan, 1972; Anon., 1976; Bhaskaran, 1986). In severely diseased palms, whole

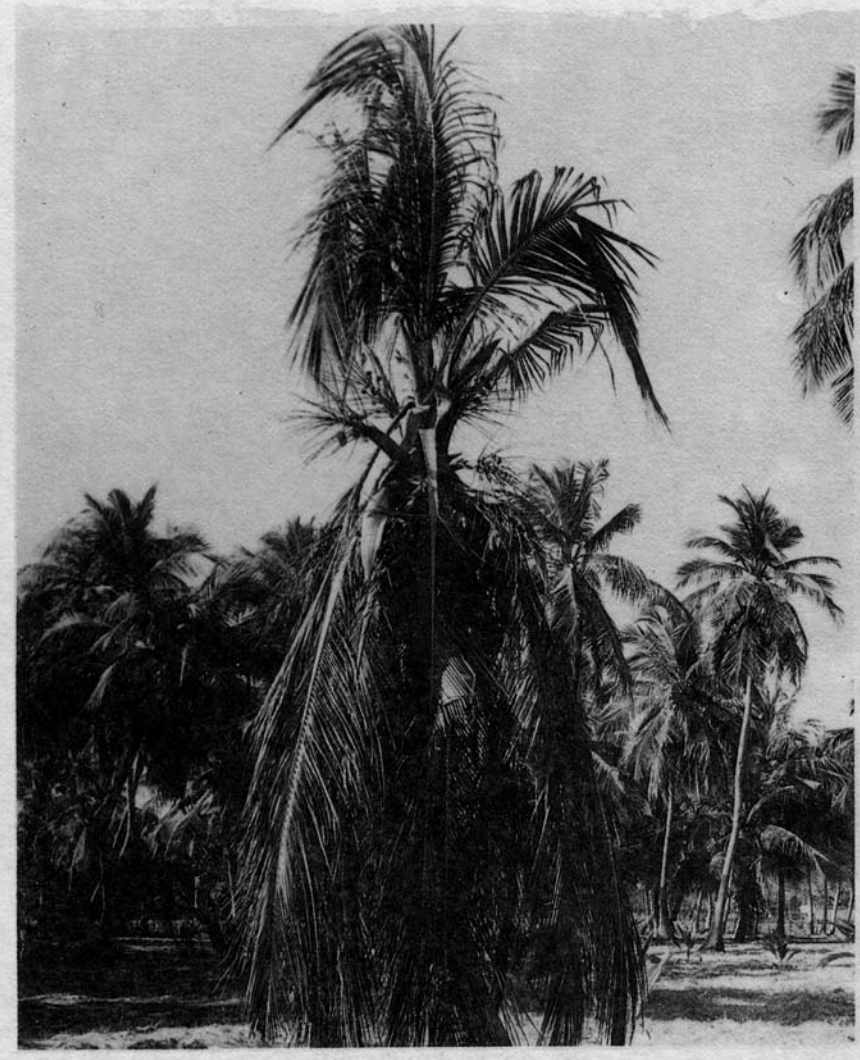

Fig. 3 : Advanced stage of the disease showing drooping of leaves.

nut weight, kernel weight, water content, copra weight and oil content decreased very much (Bhaskaran *et al.*, 1990a)

3.4 Roots

Decay and death of the fine roots is the first underground symptom of the disease which precedes the appearance of bleeding patches in the stem. Extensive rotting and discolouration of root system follows. In severely diseased palms, more than 70 per cent root rotting was observed. Root rot was more up to 60 cm depth (42 to 75% root

rot) than at deeper layers (17% root rot). Thus, with increase in depth from soil surface, extent of root rotting decreased. In the roots, cortical tissues disintegrate. The roots are watery with a distinct alcoholic smell, red below the hypodermis and brownish towards stele. New roots are rarely produced after the initiation of symptoms and the number of new roots produced is progressively reduced (Anon., 1976; Rethinam, 1984; Bhaskaran, 1986; Bhaskaran *et al.*, 1990a, 1990b).

4. STAGES OF DEVELOPMENT OF DISEASE

Five distinct stages can be recognized in the development of Thanjavur wilt.

4.1 Stage-I

Wilting of leaflets (which sometimes may not be very prominent), yellowing of the lowest leaf whorl, decay and death of fine roots.

4.2 Stage-II

Appearance of bleeding patches at the base of the stem near the ground level; the lesions gradually extend upwards; extensive root decay; cessation of new bunch production.

4.3 Stage-III

Bleeding patches extend in the stem; drooping of leaves in the outer whorl; heavy button shedding and nuts become barren.

4.4 Stage-IV

Stem decay traverses upwards; outer leaf whorl dries and drops off; other leaves also droop except the spindle leaf and surrounding two or three young leaves which remain erect and healthy.

4.5 Stage-V

All the leaves droop and fall off leaving the decapitated stem. Stem shrivels and dries up.

The time taken from the initial appearance of bleeding patches in the stem (Stage-II) to death of the palms (Stage-V) is from 6 to 54 months, the average being 24 months. In the middle or late stages of disease (Stages III, IV and V), sometimes the scolytid beetle *Xyleborus perforans* and the weevil (*Diocalandra stigmaticollis* are found infesting the stem in large numbers at the bleeding patches from which powdery mass is thrown out. The insects accelerate the death of the palm (Anon., 1976; Bhaskaran *et al.*, 1982; Rethinam 1984; Bhaskaran, 1986; Bhaskaran *et al.*, 1989).

5. ETIOLOGY

The exact cause of the disease is still an enigma. From diseased palms, *Ganoderma applanatum* (Pers.) Pat., *G. lucidum, Ceratostomella* sp., *Fusarium solani, Rhizoctonia* sp., *Schizophyllum commune* and *Trichoderma* sp. were isolated. But none of these fungi could produce symptoms of the disease on artificial inoculation.

Repeated attempts to isolate bacteria have met with failures only indicating possible non-involvement of bacteria in the disease (Bhaskaran *et al.*, 1990b). The root samples examined were free from parasitic nematodes while the soil samples yielded very low population of nematodes belonging to genera, viz., *Tylenchorhynchus, Dorylaimus, Ecphyadophora, Hoplolaimus; Longidorus, Rhadcitis* and *Monochus* (Anon., 1981a). Sivagami *et al.* (1987) reported the occurrence of *Meloidogyne* sp., *Rotylenchulus reniformis* and *Pratylenchus* sp. in coconut rhizosphere in Kanyakumari and Tirunelveli districts of Tamil Nadu. However, these are not related to disease incidence. The involvement of nematodes in this disease is thus highly doubtful.

Recently, isolation of pathogen(s) from diseased palms with profuse or less bleeding symptoms and with or without *Ganoderma* sporophore was attempted from different tissues. *G. applanatum* and *G. lucidum* were isolataed only from roots irrespective of the extent of bleeding symptom (Table 1) and not from above ground parts of the palm (Anon., 1987).

Table 1 : *Ganoderma* spp. isolated from coconut roots (Anon., 1987)

Sporophore observed	Bleeding in stem	Species isolated from roots
G. applanatum	Less	*G. applanatum*
G. applanatum	Profuse	*G. applanatum*
G. lucidum	Profuse	*G. lucidum*
Nil	Profuse	*G. lucidum*

Six months after inoculation with *G. lucidum*, root rotting up to 21 per cent was noticed. However, in the roots inoculated with *G. applanatum*, there was no root rotting, but the fungus colonised the surface of the roots to a distance of 8-10 cm on either side of the point of inoculation. From inoculated roots, *G. lucidum* was re-isolated both from cortical tissues and bark of the roots, while *G. applanatum* was re-isolataed only from the bark of the roots (Anon., 1989, 1990). Earlier, Venkatarayan (1936) reported the pathogenicity of *G. lucidum* in coconut by inoculating the fungus in the trunk region.

6. HOST RANGE

G. lucidum has got a wide host range attacking a variety of palms and several forest, avenue and fruit trees. According to Naidu *et al.* (1986), hosts belonging to 19 families, 36 genera and 48 species have been reported to be affected. Besides coconut,

it has been recorded to infect *Acacia catechu* Wild., *A. auriculaeformis A. Cunn., A. melanoxylon* R. Br., A. nilotica (L) Willd. ex Del., *Acrocarpus fraxinifolius Wt., Albizzia chinensis* (Osbeck) Merr., *A., lebbeck Benth., A., procera Benth., Aquillaria agallocha Roxb., Areca catechu L., Bosweilia serrata* Roxb., *Cassia fistula, L., C., javanica L., C. nodosa* Ham., *C., siamea* Lam., *Casuarina equisetifolia* Forst., Dalbergia latifolia Roxb., *D. sissoo* Roxb., *Delonix regia* (Boj. ex Hook) Raf., *Elaeis guineensis* Jacq., *Eucalyptus citriodora* Hook., *Fiscus* spp., *Hevea* spp., *Jacaranda acutifolia* Humb d Bonpl., *Lannea coromandelica* (Houtt.) Merr., L. *grandis Engl., Mangifera indica* L., *Pinus roxburghii* Sarg., *Pleiogynium cerasiferum* (F.V.M.). Parker, *Pongamia pinnata* (L.) Merr., *Populus euramericana* (Dode) Guinier, *Pterocarpus marsupium* Roxb., *Quercus semecarpifolia Smith, Shorea robusta* Gaertn., *Sterculia villosa* Roxb., *Tamarindus indica* L., *Terminalia alata* Hayne. ex Roths. Var. *nepalensiss* (Haines) Fern. W.A., *T. tomentosa* W.A., *Toona cibiata* Roem. and *Vitis vinifera* L. (Venkatarayan, 1936 : Bakshi *et al.*, 1972, 1976; Govindu *et al.*, 1983; Rajan, 1987; Adaskaveg and Gilbertson, 1987).

7. EPIDEMIOLOGY

7.1 Soil Conditions

The disease is generally observed in sandy or sandy loam soils in coastal areas in the east coast where coconut is grown under rainfed conditions and also in neglected plantations. Soil moisture stress experienced during summer months, water stagnation during rainy seasons, presence of old infected stumps in the garden and non-adoption of recommended cultural practices were found to favour the spread of the disease. Presence of hard pan formation in the sub-soil impedes root penetration, which in turn predisposes the coconut palms to infection (Anon., 1976; Ramasami *et al.*, 1977). In Andhra Pradesh, the disease incidence was low in heavy soils than in lighter soils (Papa Rao and Govinda Rao, 1966; Satyanarayana *et al.*, 1985). This was attributed to retention of more moisture by heavy soils, besides the presence of high population of antagonistic microflora.

7.2 Age of the Palm

Coconut trees in the age group of 10 to 30 years are generally more susceptible to the disease (43%) than younger trees (17%) (Vijayan and Natarajan, 1972). The hybrid VHC 1 was found to be affected up to 5 per cent at the age of 5 to 6 years in endemic areas.

7.3 Weather Factors

In the wilt endemic area of Thambikkottai of Thanjavur district, Tamil Nadu, it was found that the disease incidence was more between March and August. It was directly related with mean maximum soil temperature, but was not related with minimum temperature, rainfall and relative humidity (Ramasami *et al.*, 1977; Lewin *et al.*, 1973; Bhaskaran *et*

al., 1985). Further observations made at Veppankulam centre showed that the mean maximum soil temperature at 15 to 30 cm depths had profound effect on disease severity than that at 5 and 50 cm depths, though soil temperature at all depths studied had a positive correlation. Soil moisture at 5, 15 and 30 cm depths had a negative correlation with disease severity.

Observations made at Ambajipet, Andhra Pradesh showed that the disease spread was more when the range of difference in relative humidity was higher and rainfall lesser. The linear spread of the disease was more during December to May compared to the spread during June to November. The lesser linear spread of the disease during rainy season was attributed to the adverse effect of high soil moisture on the pathogen resulting from heavy rainfall (Ramapandu *et al.*, 1981).

8. MORPHOLOGICAL AND CULTURAL CHARACTERS OF THE PATHOGEN

8.1 Nomenclature

The fungus *G. lucidum* was first described under the name *Fomes lucidus* (Leys) Fr. (Butler, 1909). According to Butler and Bisby (1931), the synonyms with *G. lucidum* are *Fomes lucidus, Polyporus lucidus Fr., G. resinoceum* Boud., *Polystictus egregius Massee, G. amboinensis* (Lam.) Pat., F. *amboinensis* Lam., *P. amboinensis Ft. Van* Overeem (1925) cited the names synonyms of *G. lucidum* as *Ganoderma sessile* Murill, *G. mangiferae* Lev., *Polyporus fulvellus* Bres., *P. resinosus* Schraeder and *P. curtisii* (Bert.) Murrill.

8.2 Hyphal Character

Aerial mycelium hyaline, thin-walled, branched with frequent clamp connections, 1.4-2.9µ in diameter; chlamydospores formed abundantly which are slightly thick-walled, terminal or intercallary, ellipsoid, sometimes in chains, 8.8-11.8µ × 3.7-5.9µ in size; cuticular cells from crustose layer hyaline to light brown, round to irregular in shape and closely packed; staghorn hyphae with projection present in some isolates while absent in others; submerged mycelium thin walled, hyphae and chlamydospores as in aerial mycelium (Manjusri Sen, 1973; Govindu *et al.*, 1983).

8.3 Sporophore

The fruit body is perennial, stipitate, usually lateral, sometimes sessile, corky, becoming woody later, usually 10-12 × 10-12 × 3-4 cm, but may grow up to 30 cm or more; upper surface is shining, laccate crust, ox-blood in colour, smooth. The palisade hyphae is about 40µ long and is impregnated with a dark orange varnishing substance which they secrete. Hymenial surface is whitish or creamish, turning brown later, pores small, round, 90-250µ in diameter. Pore tubes are about 6-7 mm long, basidiospores are brown, thick-walled, minutely verrucose, truncate at one end and 8.3-10.0 × 5.8-6.7µ in size (Bose, 1930; Govindu *et al.*, 1983).

8.4 Growth in Culture

Nambiar and Radhakrishnan Nair (1973) reported that the best medium for growth of *G. lucidum* was Waksman's medium. Sporophore production was observed in saw dust medium (moist saw dust 300 g, 10 per cent malt extract plus 15 ml of biotin 5 ppm) two months after inoculation. Maximum growth of the fungus occurred at pH 5.5 in culture, though the fungus was observed to grow in a wider range of pH. Glucose was the best carbon source for the funugs, though it can utilize a very wide range of carbohydrates including several mono-, di-and polysaccharides. Peptone was the best nitrogen source for the *G. lucidum* (Nambiar and Radhakrishnan Nair, 1973).

8.5 Production of Enzymes

G. lucidum is known to secrete several enzymes in culture including diastase, laccase, protease, invertase, coagulase, endopolygalacturonase, rennetase and oxidase (Venkatarayan, 1936). Lalithakumari and Sirsi (1971) purified the enzyme endopolygalacturonase and partially purified and charactersied the enzyme laccase.

9. PHYSIOLOGY OF THE DISEASED PALMS

Nitrogen, phosphorus, potassium, calcium and magnesium decreased in the diseased leaf, stem, bole and root tissues compared to the corresponding healthy tissues (Anbalagan, 1979; Anbalagan *et al.*, 1987). Maximum decrease (52%) in total nitrogen was noticed in the bole region while decrease in phosphorus was pronounced in diseased root tissue (41%). Potassium content decreased by 39 per cent and calcium by 26 per cent in diseased stem tissue. There was an increase of 20 to 25 per cent in total phenols in diseased tissues and the increase in the *ortho* dihydroxy phenol content was much more pronounced (40 to 48%) than the total phenol itself. Total and reducing sugars increased in diseased tissues.

It was observed that tapping of diseased palms for 'neera' production caused a reduction in the sugar content in the leaves and an increase in level of total phenols. The quantity of 'neera' produced was only 8 l/palm/month in the case of diseased palm compared to 28 in healthy palm. The sugar content of neera was only 9 per cent in diseased palm as against 13 per cent in healthy palms (Vijayaraghavan *et al.*, 1986, 1987; Anbalagan *et al.*, 1987).

10. EARLY DETECTION OF THE DISEASE

Ganoderma wilt disease of coconut can be contained by management practices, if the disease is detected in the early stages. A few methods have been reported to be useful for early diagnosis of the diseases, though the methods need further refinement (Natarajan *et al.*, 1986; Vijayaraghavan *et al.*, 1987).

10.1 Chemical Methods

10.1.1 *Colorimetric Method*

In one of the colorimetric methods, 10 ml of saturated potassium hydroxide was added to 5 g of root or stem tissues and autoclaved for 30 minutes at 1.05 kg/cm^2. The solution was decanted and the tissues were treated with 5 ml of 95 per cent ethanol. One ml of the ethanol extract was made up to 10 ml with the same solvent and read in a spectrophotometer at 425 nm. The optical density of stem tissues increased with increase in disease intensity from 0.445 in healthy to 1.002 in severely diseased palms (Natarajan *et al.*, 1986).

10.1.2 *Iodine-Potassium Iodide Staining Technique*

In the iodine-potassium iodide staining technique, bark and root tissues from diseased and healthy palms were autoclaved separately with saturated KOH at 1.05 kg/cm^2 and washed repeatedly with 90 per cent ethanol and stained with iodine-potassium iodide solution (0.2 g iodine + 2 g potassium iodide in 100 ml of water). The stained tissues were examined under microscope. The healthy bark and root tissues stained yellow and the colour intensity increased with increase in disease severity (Anon., 1990).

10.1.3 *EDTA Method*

In the EDTA test, leaf or root tissues were extracted with 0.3 M EDTA solution. The optical density at 400 nm increased with increase in diseases severity (Natarajan *et al.*, 1986; Vijayaraghavan *et al.*, 1987). Further studies at Veppankulam Centre revealed that apparently healthy palms showed increased O.D. value than the healthy palms in EDTA test and these apparently healthy palms developed symptoms of the disease six months after exhibiting increased O.D. value. Hence, this method perhaps can be successfully employed for early detection of the disease. However, further refinement needs to be done by fixing critical O.D. values for symptom expression.

10.1.4 *Orthophenanthroline Reagent Method*

In the orthophenanthroline reagent test, O.D. values at 570 nm in root samples increased with increase in disease intensity (Table 2).

Table 2 : Optical density of root and leaf samples in orthophenanthroline test (Anon., 1990)

Samples	O.D. values at 570 nm	
	Leaf	Root
Healthy	0.109	0.168
Diseased-mild	0.115	0.254
Diseased-moderate	0.104	0.285
Diseased-severe	0.107	0.308

The iron content of the extracts was more in diseased tissues in both EDTA and orthophenanthroline tests than healthy roots. However, within the different disease categories, the iron content decreased with increase in disease severity in EDTA extracts (Table 3).

Table 3 : Relationship between disease intensity and iron content in EDTA and Orthophenanthroline extracts of *Ganoderma* affected palms (Anon., 1990)

Samples	Iron content (µg/g fresh weight)			
	EDTA		Orthophenanthroline	
	Leaf	Root	Leaf	Root
Healthy	19.8	22.2	22.1	13.7
Diseased-mild	22.7	52.2	21.6	18.8
Diseased-moderate	21.3	39.2	25.8	20.2
Diseased-severe	20.1	25.1	24.1	23.2

10.2 Transpiration Rate

Transpiration rate was significantly low in the diseased palms while the stomatal diffusive resistance was slightly higher than healthy palms. These parameters can also be employed as probable tools for early diagnosis (Vijayaraghavan *et al.*, 1987).

10.3 Indicator Plants

G. lucidum has got a very wide host range and some of the plant species are highly susceptible and are infected in the field much earlier than certain other species of host plants. For detecting the presence of *G. lucidum* inoculum in coconut gardens, various plant species were tested of which Subabul (*Leucaena leucocephala*) and *Glyricidia maculata* were very useful as indicator plants since these plants showed natural infection under field conditions at least six months earlier to infection on coconut palms (Anon., 1989b).

In the glasshouse, 80 per cent of the Subabul seedlings inoculated with *G. lucidum* culture established in sterilized coconut roots, showed drying of terminal shoot and leaves and rotting of fine roots one month after inoculation. This shows that Subabul may be useful as an indicator plant for *Ganoderma* disease under field conditions.

11. MANAGEMENT OF DISEASE

A series of field experiments were conducted on cultural, chemical and biological control of *Ganoderma* wilt of coconut at different centres of the All India Co-ordinated Research Project on Palms of the Indian Council of Agricultural Research, viz., at Veppankulam Centre of Tamil Nadu Agricultural University, Razole/Ambajipet Centres in Andhra Pradesh and Arsikere Centre in Karnataka. These experiments have given certain definite indications on the practices to be followed for managing the disease.

11.1 Management of Soil Moisture Regime

Irrigation alone cannot effectively contain the disease. Basin irrigation coupled with application of fertilizers increased the disease intensity. Irrigation combined with Bordeaux mixture drenching helped in checking the disease intensity considerably. Organic manure with irrigation also ameliorated the disease symptoms to certain extent. Irrigation along with farm yard manure plus burying coconut husk in circular trench around the palm plus Bordeaux mixture drenching was very effective in reducing the disease intensity (Bhaskaran *et al.*, 1978a). It was also observed that burying 500 coconut husks in circular trench around the diseased palms contained the disease (Vijayan and Natarajan, 1975; Bhaskaran *et al.*, 1984a).

11.2 Effect of Fertilizers

Observations made at Veppankulam Centre from 1977 to 1982 showed that plots treated with 350, 250 and 450 g N, P_2O_5 and K_2O respectively per palm per year had low disease index and high nut yield while higher doses of fertilizers increased the disease intensity (Bhaskaran *et al.*, 1978b; Bhaskaran and Ramanathan, 1983) (Table 4).

Table 4 : Effect of fertilizer on *Ganoderma* wilt of coconut (Bhaskaran and Ramanathan, 1983)

Treatments*	Disease index	Nut yield/palm/year**
$N_1P_1K_1$	4.20	72
$N_2P_1K_1$	29.65	55
$N_3P_1K_1$	99.60	21
$N_1P_2K_1$	50.04	43
$N_1P_3K_1$	67.43	60
$N_1P_1K_2$	58.63	59
$N_1P_1K_3$	127.73	37
$N_0P_0K_0$	2.58	48
C.D. (P=0.05)	32.05	22

*Nitrogen : 0.35(N_1), 0.70(N_2) and 1.05(N_3) kg/palm/year.
P_2O_5 : 0.25(P_1), 0.50(P_2) and 0.75(P_3) kg/palm/year.
K_2O : 0.45(K_1), 0.90(K_2) and 1.35 (K_3) kg/palm/year.
**Mean of four years of post-treatment yield.

11.3 Effect of Micronutrients

Manganese sulphate, when applied at the rate of 227 g/palm/year, reduced the intensity of the disease (disease index 2.8 in treated palms as against 33.0 in control). The disease intensity was maximum in palms that received molybdenum (Table 5) (Jaganathan and Ramasami, 1975; Anon., 1978a; Bhaskaran *et al.*, 1984a; Bhaskaran *et al.*, 1985). However, Sindha Mathar *et al.*, (1983) could not observe any direct effect on the disease by application of micronutrients in Kanyakumari District of Tamil Nadu.

Table 5 : Effect of micronutrients on disease intensity and yield of *Ganoderma* affected coconut palms (mean of five years) (Bhaskaran *et al.*, 1984a)

Treatments*	No. of palms wilted	Disease index	Yield/palm/year
Borax	0	16.9	46
Copper sulphate	1	16.7	56
Manganese sulphate	0	2.8	86
Zinc sulphate	2	41.5	59
Ferrous sulphate	2	18.7	33
Ammonium molybdate	1	50.4	56
Control	1	33.0	46

*227 g per palm/year except ammonium molybdate (10 g/palm/year).

11.4 Effect of Organic Manures

Application of 50 kg farm yard manure or green leaves or 300 kg tank silt or 5 kg neem cake every year was reported to be beneficial in arresting the progress of the disease (Vijayan and Natarajan, 1975). Application of neem cake alone and in combinatioin with drenching 1 per cent Bordeaux mixture thrice at quarterly intervals was the most effective in reducing the intensity of the disease giving 12.30 and 11.42 disease index, respectively compared to 117.72 in control palms (Bhaskaran and Ramanathan, 1983). Field trials carried out for five years on the effect of 100 kg tank silt + 50 kg green leaves + 1 per cent Bordeaux mixture soil drenching helped in bringing down the disease index in these plots (15.0) compared to control (75.2) (Anon., 1981b).

11.5 Effect of Fungicides and Chemicals

The fungicidal trials conducted between 1965 and 1969 at Veppankulam Centre (Tamil Nadu) revealed that drenching with 40 l of 1 per cent Bordeaux mixture was effective when compared to copper oxychloride + BHC + coal application. Studies conducted from 1969 to 1973 indicated that the application of Bordeaux mixture during October-January was effective in reducing the intensity of the disease (Anon., 1978b, 1978c). The field trial conducted with systemic fungicides and antibiotics from 1972 to 1976 indicated that Aureofungin-sol (0.2%) was very effective in reducing the intensity of the disease (Anon., 1978a, b). Drenching with 10 l of 0.1 per cent benomyl per palm after exposing the roots also gave good disease control (Kolandaisamy and Arjunan, 1977). Drenching the soil with 40 l of 1 per cent Bordeaux mixture and stem injection of Aureofungin-sol 2 g plus l g copper sulphate in 100 ml of water thrice at quarterly intervals significantly reduced the disease intensity and increased the yield of nuts (Bhaskaran and Ramanathan, 1982; Bhaskaran *et al.*, 1984b) (Table 6). However, the treatment should be repeated once in three years (Ramadoss and Bhaskaran, 1987).

Anbalagan and Shanmugam (1984) reported that tridemorph at 500 ppm inhibited the growth of *G. lucidum in-vitro*. Sindha Mathar and Balasubramaniam (1987) reported

Table 6 : Efficacy of fungicides on disease intensity and yield of wilt affected palms (Bhaskaran and Ramanathan, 1982)

Treatments	Disease index	Nut yield/ palm/year
Aureofungin-sol 20 g in 20 litres of water (AF)	59.94	35
Benomyl "	70.52	58
Carbendazim "	95.65	23
Carboxin "	98.48	43
FM spray 600 ml in 30 litres of water	66.89	36
Bordeaux mixture (1%) 40 litres (BM)	40.64	31
Aureofungin sol stem injection plus Bordeaux mixture drenching	16.91	80
Control	89.09	49

*Mean yield for four years of post-treatment period.

that soil drenching with 0.1 per cent IBP, carboxin, tridemorph or 0.05 per cent carbendazim in combination with neem cake at 5 kg/palm reduced the disease intensity significantly. Field trial conducted at Palghat (Kerala) by Central Plantation Crops Research Institute, Kasaragod showed that in tridemorph (Calixin) and Aureofungin-sol treated palms (Table 7), the disease was less (Anon., 1989a). Similar results were obtained at Veppankulam Centre also, where treatments like tridemorph root feeding (thrice at quarterly interval) in combination with neem cake application and aureofungin-sol root feeding plus neem cake with and without Bordeaux mixture drenching helped in reducing disease index and increasing yield of treated palms (Table 8). A similar observation was made in Andhra Pradesh also (Anon., 1990).

At Arsikere, Karnataka, it was found that Aureofungin-sol (2 g) + 1 per cent Bordeaux mixture (40 litres) + neem cake (5 kg) checked further spread of the disease in the palms (Anon., 1985). At Razole, Andhra Pradesh, the treatment mildothane (10 g in 5 l of water), Aureofungin-sol 1.5 g + copper sulphate 1 g in 5 litres of water (AF), carboxin stem injection 500 mg in 5 ml of water (CAR) and AF + CAR reduced the

Table 7 : Management of Thanjavur wilt disease at Palghat (Anon., 1989a)

Garden No.	No. of palms	Average yield (No. of nuts) 1986	1987	1988
1	20 A	14	36	58
	5 C	7	15	49
2	5 A	47	59	51
3	4 A	46	60	64
	3 C	—	65	65
4	7 A	17	28	47
	7 C	—	9	52

A = Aureofungin-sol treated; C = Calixin treated.

Table 8 : Efficacy of fungicides and neem cake in the management of *Ganoderma* wilt of coconut (Anon., 1990)

Treatments	Disease index	Nut yield/palm (1989)
Neem cake 5 kg/palm (NC)	30.35	81
NC + Carbendazim 2 g/100 ml as root feeding	77.66	48
NC + Carboxin 2 g/100 ml as root feeding	95.87	64
NC + Aureofungin-sol 2 g + 1 g copper sulphate in 100 ml as root feeding (NC+AF)	8.01	117
NC + Tridemorph 2 ml/100 ml as root feeding	16.32	106
NC + AF + Bordeaux mixture 1% 40 litres as soil drenching	10.36	127
Control	62.58	57
C.D. (P=0.05)	11.12	10

linear spread of the disease significantly when compared to control (Satyanarayana *et al.*, 1985).

Since the association of the scolytid beetle *Xyleborus perforans* was also noticed in some wilt affected palms, a field trial using dieldrex, heptachlor, chlordane and sulphur dust was conducted from 1966 to 1969. The palms treated with heptachlor showed minimum disease intensity (Anon., 1981b). Stem injection of 2.5 ml monocrotophos in 100 ml of water showed variable results regarding disease intensity, though the treatment marginally increased nut yield (Anon., 1983).

11.6 Management by Tapping 'Neera'

With a view finding out the effect of tapping 'neera' on disease intensity, tapping experiments were conducted from May to October or from September to February in palms with different disease intensities and in apparently healthy palms. In both the experiments, tapping in mildly and moderately diseased palms reduced the disease index and the effect persisted even one year after completion of tapping (Table 9) (Vijayaraghavan *et al.*, 1986, 1987; Anon., 1990; Bhaskaran, 1990).

11.7 Biological Control

Trichoderma harzianum and T. viride were found to be antagonistic to *G. lucidum*. Application of neem cake (5 or 10 kg per palm per year) encouraged the saprophytic soil microflora especially *Trichoderma* in coconut basins and was effective in the control of *Ganoderma* wilt (Tables 10 and 11) (Gunasekaran *et al.*, 1986; Bhaskaran *et al.*, 1988a; Bhaskaran, 1990).

A number of plant extracts were tested for their effect on the growth of *G. lucidum*. Neem cake extract completely exhibited its growth. Banana rhizome extract and *Tephrosia purpurea* root extract gave 86 and 54 per cent inhibition respectively (Bhaskaran *et al.*,

Table 9 : Effect of tapping for Neera production on *Ganoderma* wilt intensity (Anon., 1990)

Stage of the disease	Disease index	
	At the time of completion of tapping	One year after completion of tapping
Tapped palms		
Mild	0.92	1.18
Moderate	3.53	4.68
Severe	15.86	21.00
Untapped palms		
Mild	6.62	36.75
Moderate	5.75	33.93
Severe	9.29	32.04

Table 10 : Efficacy of neem cake in the management of *Ganoderma* wilt (Bhaskaran *et al.*, 1988a)

Treatments	Disease index	
	1985	1986
Neem cake 5 kg per palm (NC)	9.36	12.15
Neem cake 10 kg per palm	9.12	12.10
Bordeaux mixture + Aureofungin-sol + NC	8.18	10.62
Control	23.85	62.99
C.D. (P=0.05)	0.60	1.30

Table 11 : Effect of neem cake on microbial population* in soil (Bhaskaran *et al.*, 1988a)

Treatments	Fungi (10^3)		Bacteria (10^5)		Actinomycetes (10^2)		Trichoderma (10^1)	
	A	B	A	B	A	B	A	B
Neem cake 5 kg per palm (NC)	44	178	18	190	11	21	9	72
Neem cake 10 kg per palm	36	173	18	182	13	26	6	64
Bordeaux mixture + Aureofungin-sol + NC	41	72	20	175	16	24	11	22
Control	39	40	17	19	12	15	8	6
C.D. (P=0.05)	NS	11	NS	21	NS	6	NS	8

*CFU per g of air dry soil.

A—Initial population, B—one month after the treatment, NS—Not significant.

1987; Bhaskaran *et al.*, 1988b). As banana is one of the profitable intercrops in coconut gardens and *Tephrosia* is a green manure crop raised in coconut garden, growing banana and applying *Tephrosia* in coconut basins, where the disease is endemic, may offer scope for reducing the intensity of the disease.

11.8 Integrated Management

On-farm trials conducted by Coconut Research Station, Veppankulam, Tamil Nadu and Agricultural Research Station, Ambajipet, Andhra Pradesh showed that an integrated approach with cultural, chemical and biological methods involving the following practices was very effective for containing the disease (Anon., 1990; Bhaskaran *et al.*, 1989) :

1. Removal of dead palms and palms in advanced stages of the disease and destruction of the bole and root bits of these palms.
2. Isolation of diseased palms from healthy palms by digging isolation trenches of 1 m deep and 30 cm wide.
3. Regular basin irrigation during summer months or moisture conservation by coconut husk burial (250 husk/palm).
4. Avoiding flood irrigation or ploughing in infected gardens to prevent spread of the inoculum.
5. Addition of 50 kg of farm yard manure or green leaves or 200 kg tank silt per palm per year.
6. Application of 5 kg neem cake per palm per year.
7. Raising banana as intercrop wherever irrigation is possible.
8. Soil drenching with 40 l of 1 per cent Bordeaux mixture thrice a year for one year.
9. Root feeding of 2 g of Aureofungin-sol + 1 g of copper sulphate in 100 ml of water thrice a year at quarterly interval. Alternatively, Calixin (tridemorph) (2 ml/100 ml) can also be used for root feeding instead of Aureofungin sol. Fungicide treatments will be effective only for palms in early stages of the disease (I and II).
10. If *Xyleborus* attack is found in the stem, smearing with BHC wettable powder or heptachlor and/or root feeding with 5 ml of monocrotophos may be done.

In the on-farm trials conducted by adopting the above management practices, the disease index in the managed plots was low and yield was high both at Veppankulam and Ambajipet Centres (Table 12) (Anon., 1990).

12. FUTURE RESEARCH THRUSTS

12.1 Etiology

Unequivocal proof of the causal agent is necessary by establishing Koch's postulates. Intensive research efforts are needed to prove pathogenicity of *Ganoderma*

Table 12 : Effect of management practices on *Ganoderma* wilt of coconut at Veppankulam (Anon., 1990)

Garden Number	Treatments	Disease index	Mean nut yield/palm 1987	1988	1989
1	Management practices	0:77	60	47	98
	Control	6.92	45	40	67
2	Management practices	1.86	145	98	110
	Control	10.81	135	50	86

or otherwise by massive addition of virulent inoculum in big soil tanks with sterilized soil and by adopting various methods of inoculation in adult trees. The relationshiip of *Ganoderma* affecting different palms species as also other trees should also be studied.

12.2 Epidemiology

Factors favouring the development of the disease including soil factors, predisposition of the trees to infection due to adverse soil conditions like deficiency or toxicity of nutrients in soil, role of soil moisture in disease incidence, and the role of collateral hosts and basidiospores in the disease spread have to be investigated in detail.

12.3 Early Detection

The disease could be contained by management practices, only if detected in the early stages. Hence, standardisation of an effective and efficient early detection methods like serological and fluorescent antibody techniques, ELISA technique or other biochemical methods will be useful to take up management practices before the disease takes upper hand.

12.4 Physiology

The physiological aspects of the affected palm need to studied in depth. The physiology of diseased palms showing difference in symptoms (e.g., palms with or without bleeding symptoms) vis-a-vis healthy palms will have to be studied to understand the deranged metabolism of the affected palm in relation to symptom development. The role of toxins and enzymes in disease needs to be studied in detail.

12.5 Histology

Ganoderma could be isolated only from the roots and not from above ground parts of the palms, though bleeding in stem and drooping of leaves are common in the affected palms. A study of the histology of the different affected parts will help to understand the morbid anatomy and extent of spread of the pathogen in the palm.

12.6 Management

For containing the disease, use of biocontrol agents like antagonistic microflora and mycorrhizal fungi, methods for sustaining the survival of antagonistic flora in soils,

use of organic and inorganic amendments for improving the vigour of the palm and increasing the antagonistic microflora, etc., have to be studied in detail. Locating resistant trees in hot spot areas and using them in long term resistant breeding programme should receive attention.

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