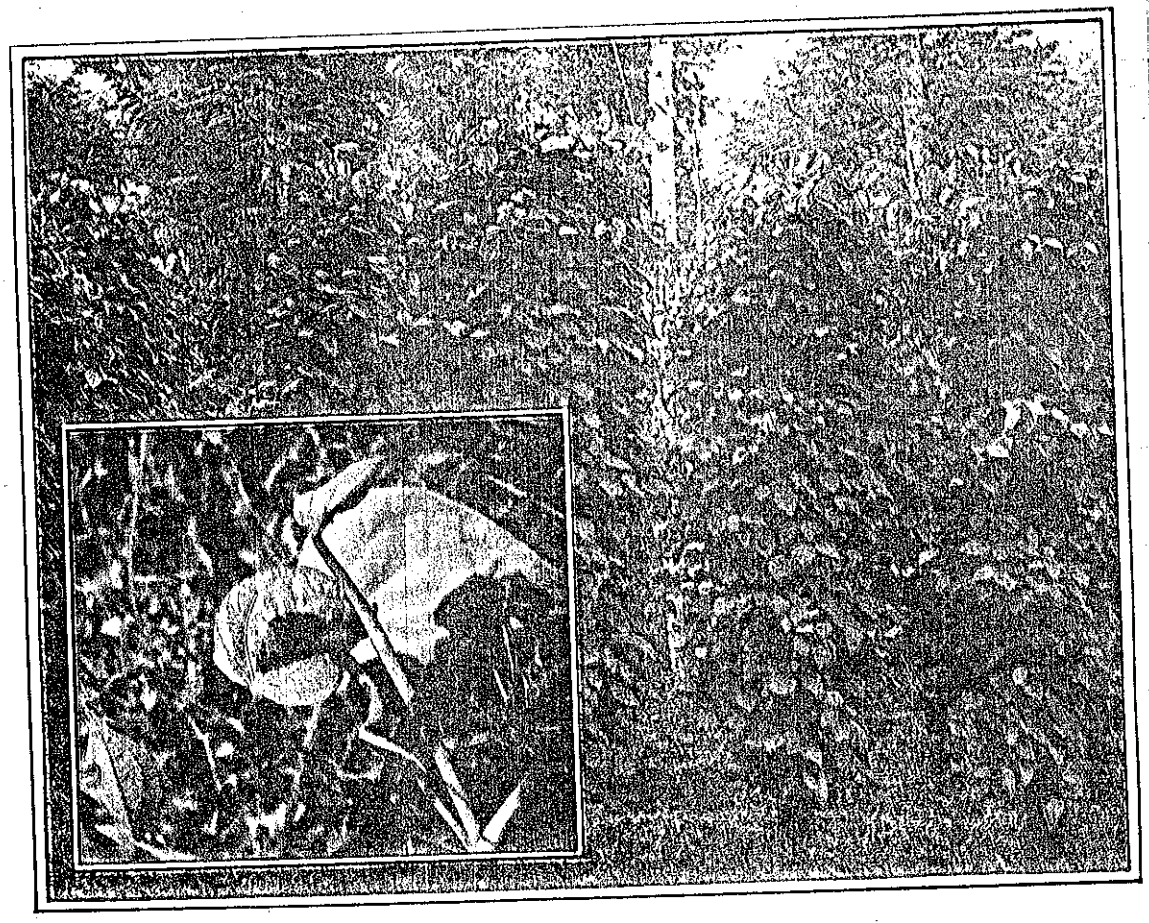
भाकृअनुप
ICAR

DISEASES OF BLACK PEPPER



NATIONAL RESEARCH CENTRE FOR SPICES
CALICUT, KERALA, INDIA

BLACK PEPPER DISEASES IN INDIA*

Y. R. SARMA, N. RAMACHANDRAN and M. ANANDARAJ
National Research Centre for Spices, Calicut 673 012, *Kerala, India*

In India black pepper is grown over an area of 1,36,000 ha, producing 32,000 tonnes. India accounts for 54.1% and 26.6% of the total world area and production of black pepper respectively. Of the total Rs. 2,870 million of the export earnings of spices in India for a quantity of 67,432 tonnes, 80.1% of the export earnings are from black pepper (Velappan, 1988). Though India had monopoly on the black pepper production in the world, its position dwindled in recent times and the per hectare production is the lowest. Ravages due to diseases and pests, high cost of production and consequent neglect of the crop by the farming community are some of the important constraints in black pepper production. Thus the efficient, economically viable disease and pest management forms one of the thrust areas to boost up the black pepper production in India.

Black pepper in India is affected by fungi, bacteria, mycoplasma (?), plant parasitic nematodes and a phanerogamic parasite. The disease problems of black pepper have been reviewed earlier (Nambiar, 1977; Abicheeran and Mathew, 1984) and the number of diseases since then have increased in recent years (Table I). However, foot rot (quick wilt) and slow wilt (pepper yellows) are most important because of their severity.

The terminology of these has been changed to *Phytophthora* foot rot and slow decline diseases respectively since 1988 (Nair and Sarma, 1988).

For a better understanding of the disease problems and their management, it is relevant to mention

* Status paper from India.

Table 1. *Diseases of black pepper in India*

Diseases	Parts affected	Causal agents
Major diseases		
Foot rot	Leaf/Spikes/Stem/Root	*Phytophthora capsici* (*P. palmivora*' MF_4)
Slow decline	Roots	i) Plant parasitic nematodes *Radopholus similis* *Meloidogyne incognita*
		ii) *Weak pathogenic fungi* *Rhizoctonia bataticola* *Fusarium* Sp. *Pythium* Sp.
		iii) Adverse soil conditions
Minor diseases		
Anthracnose (Fungal pollu)	Leaf/Spikes/Berries	*Colletotrichum necator* *Colletotrichum gloeosporioides*
Leaf spot (Bacterial)	Leaf	*Xanthomonas campestris* pv *betlicola*
Thread blight	Leaf/Spikes/Stem	*Corticium solani* *Marasmiellus scandens*
Stump rot	Root	*Rosellinia bunodes*
Red Rust (Algal)	Leaf/Spikes/Berries	*Cephaleuros mycoidea*
Dodder	Stems	*Cuscuta* Sp.
Nursery diseases		
Blight	Leaf/Stem/Root	*Rhizoctonia solani* *Pythium* Sp.
Leaf spot/Stem rot	Leaf/Stem	*Phytophthora capsici*
Basal wilt	Leaf/Stem	*Sclerotium rolfsii*

Diseases	Parts affected	Causal agents
Diseases of unknown etiology		
Phyllody	Whole plant	Mycoplasma
Little leaf/Stunt	Whole plant	Mycoplasma ?
Velvet blight	Branches-Berries	*Septobasidium* Sp.
Black spot	Leaf	*Pestalotia ?*
Brown spot	Leaf	
White/Yellow spot	Leaf	Lichens

briefly about the crop itself. Black pepper is a native of Western Ghats of India and is mainly confined to Kerala (96%) and Karnataka (3%). It is grown as pure crop trained on live tree supports of *Erythrina indica* etc. and also as a mixed crop trained on coconut and arecanut trunks. Areca-pepper, (Fig. 1) coconut-pepper, (Fig. 2) areca-cocoa-pepper-cardamom, coffee-pepper, (Fig. 3) and cardamom-pepper (rarely rubber-pepper) are the mixed cropping systems which are in vogue. The crop is grown in hilly slopes in rich forest loams and also in plains which are predominantly lateritic to sandy loams with the soil pH ranging from 5.0–6.5. Application of leaf mulch, farm yard manure and bone-meal and other organic manures is common. Application of chemical fertilizers @ 100:40:140 g of NPK per vine in two splits once during April-May (pre-monsoon) and again during August-September (post-monsoon) period is recommended. In pure crop systems shade regulation is done during May-June period by lopping the branches of the live standards to ensure better light penetration in the plantations. Some farmers practice clean cultivation and some retain the grass/green cover undisturbed. The crop is rainfed in Kerala state and whereas it is irrigated in Karnataka state where areca-pepper mixed cropping system is popular

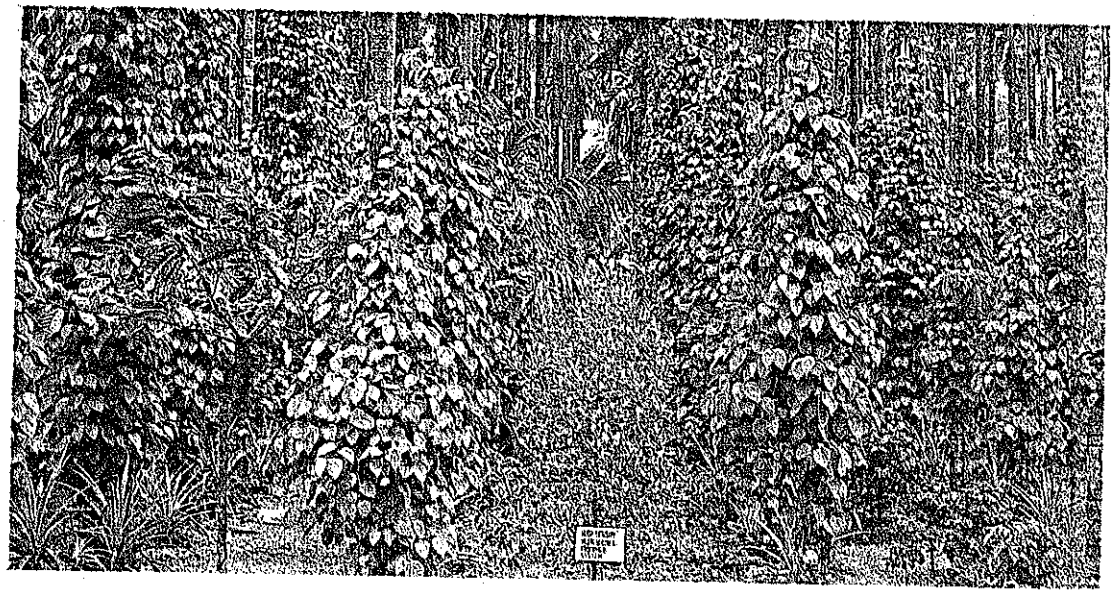


Fig. 1. Areca – pepper mixed cropping system

Fig. 2. Coconut – pepper mixed cropping system

Fig. 3. Coffee – pepper mixed cropping system

FOOT ROT (QUICK WILT) *'PHYTOPHTHORA CAPSICI'* (*'P. PALMIVORA'* MF_4)

The term 'wilts' used in black pepper *i. e.*, 'Quick wilt' and 'Slow wilt' are loose and are not true vascular wilts in strict phytopathological sense. The term quick wilt is used because of quick death of black pepper vines due to *Phytophthora*. Foot rot is the most destructive disease prevalent in all pepper growing tracts of India and takes a heavy toll of the crop. The losses are so heavy that farmer gets disheartened and abandons the crop.

History and distribution

In India the disease was known as early as in 1902 when severe vine deaths were noticed in Wynad region of erstwhile Madras state (Menon, 1949). This was investigated by Barber (1902, 1903, 1905) and Butler (1906, 1918) but the investigations were inconclusive and the etiology remained unresolved. The difficulties in isolation of *Phytophthora* in earlier days in the absence of selective media (Tsao and Guy, 1977) might have been the major factor in correct diagnosis of the causal agent. Isolation from infected roots and collar of black pepper remained difficult. Although isolation of *Phytophthora* was reported in Mysore area (Venkata Rao, 1929) it was Samraj and Jose (1966) reported the '*Phytophthora* wilt' of black pepper in Kerala adopting the identification of Muller (1936) as *P. palmivora* var. *piperina*. The disease is known in Kerala, Karnataka, Tamilnadu states and recently in Assam state (Sarkar et al., 1985). Detailed investigations on this disease were carried

out only since then (Sarma and Nambiar, 1982).

Crop loss

Precise crop loss figures due to this disease are lacking. About 20–30% of vine death has been recorded in Cannanore and Calicut districts (Samraj and Jose, 1966; Nambiar and Sarma, 1977). Crop loss survey conducted for three years (1982–1984) in Calicut and two years (1985-86) in Cannanore districts of Kerala has shown that the foot rot incidence is 3.7 and 9.4% causing vine deaths of about 1,88,947 and 1,016, 425 amounting to an annual loss of 119 and 905 metric tonnes of black pepper in Calicut and Cannanore districts of Kerala respectively (Balakrishnan et al., 1986: Anandaraj, Jose Abraham and Balakrishnan, 1988).

Symptoms

Detailed symptomatology of the disease has been described (Sarma and Nambiar, 1982). The fungus infects all parts of black pepper. Cropping system and the microclimate appear to be the deciding factors of the type of infection.

Foliar infection : Infection on the leaves start as water soaked lesions and rapidly expands into large dark brown spots (Fig. 4) with a fimbriate margin. The leaf spots may remain uniformly dark or they may show concentric zonation with a greyish centre. Tender leaves are more susceptible than mature leaves. Infection is noticed on the spikes (Fig. 5) resulting in spike shedding. Infection is noticed on tender to woody stems as dark wet spots and later rotting sets in causing die back symptoms. Foliar infection is more serious in areca-pepper mixed cropping system because of the conducive micro-climate and it is prevalent in pure plantations also. Foliar infection leads to varying degrees of defoliation depending on the severity of the disease. Rarely it leads to death of the vine.

Collar infection: Collar and root infections are fatal and the infected vine succumbs in 10–20 days and hence the often locally used term 'quick' wilt'. Collar and root infections go unnoticed until foliar yellowing is noticed. Infection starts as wet slimy dark patch on the collar (foot) and rotting occurs as the disease progresses. Vascular discolouration in the stems is noticed beyond the point of infection. The collar infections progress upwards and also downwards (Fig. 6).

Fig. 4. Leaf infection – lesions

The collar infected vine shows foliar yellowing, (Fig. 7) flaccidity of leaves, defoliation and breaking of stem at the nodal regions and spike shedding.

Root infection : Eventhough infection progresses from collar region to root region exclusive root infections are also noticed (Fig. 8). The foliar symptoms will be similar to collar infections. The studies carried out recently under simulated field conditions clearly established that feeder root infection leads to collar rot and subsequent death. The collar rot is possibly the culmination of cumulative root infection starting from the feeder root system, over a period of 2-3 years eventhough exclusive collar rot is common. The details of the nature of root damage are dealt elsewhere.

Identity of black pepper *Phytophthora*

Taxonomy of black pepper *Phytophthora* received greater attention in recent times stressing the im-

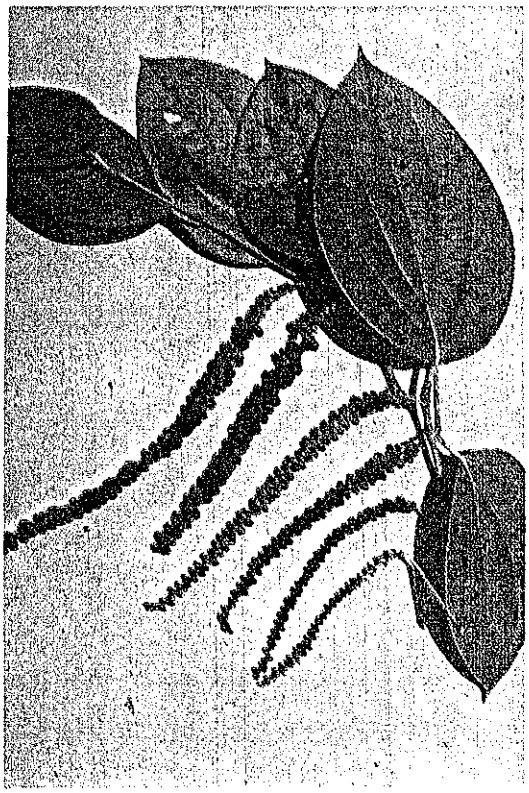


Fig. 5. Spike infection - infected spikes

portance of the sporangial ontogeny, sporangial morphology, pedicel length, caducity of sporangia, and chromosomal type (Tsao, 1977; Tsao and Tummakate, 1977; Brasier and Griffin, 1979; Tsao et al., 1985). Black pepper isolate from India was identified as *'P. palmivora'* MF_4 (Sarma, Ramachandran, and Nambiar, 1982; Tsao et al., 1985). Detailed investigation carried out by the senior author in collaboration with Prof. P. H. Tsao at University of California, Riverside, with 10 isolates collected from different geographical regions of Kerala and Karnataka, further confirmed their identity as *'P. palmivora'* MF_4 (Tsao et al., 1985; Sarma, 1985; Sarma and Tsao, Unpublished).

In general, umbelloid sporangial ontogeny was noticed in all the isolates. The sporangial shapes

Fig. 6. Collar infection (Foot rot)

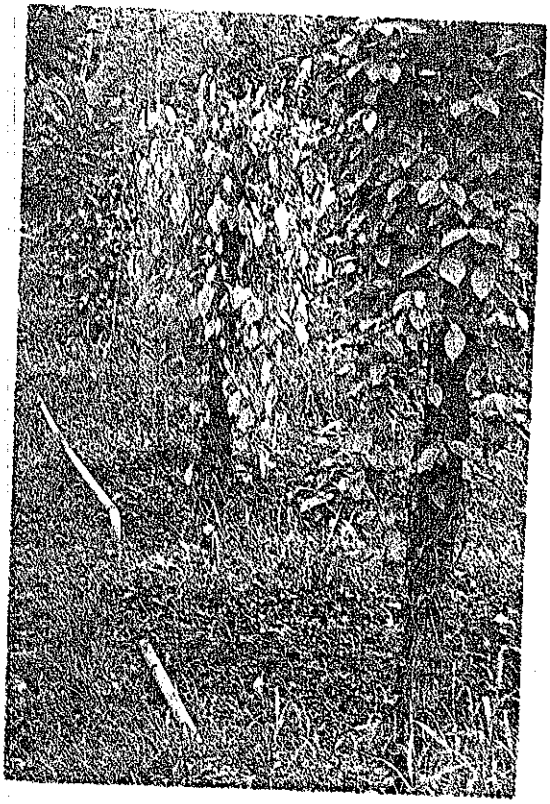


Fig. 7. Foliar yellowing symptoms due to foot rot/root rot

were ovoid to obovoid, pyriform with a tapering base or fusiform and were highly variable (Fig. 9). Double septate sporangia were also noticed in some of the isolates. All the isolates showed caducous sporangia. The measurements of sporangia are presented in Table II. The average L/B ratios ranged from 1.7-2.8 even though the general range was from 0.9–5.7. This is in general, slightly higher than those of Indonesian and Malaysian isolates reported. Similarly the average pedicel length ranged from 6.7–125.7 μm even-though the general range is 22.6–220.7 μm. The sex organs of all the isolates are variable in size (Table III). The mean oospore diameter ranges from 20.7–29.9 μm. All the ten isolates studied belong to A–1 mating type. However, presence of both A–1 and A–2 mating types has been reported from Karnataka (Sastry, 1982). The isolates are capable of growing at 35°C. In general, carrot agar supported better growth compared to V8 juice

Fig. 8. Root infection – root rot

Table II. *Measurements of size, length/breadth (L/B) ratios and pedicel length of sporangia of ten* Phytophthora *isolates of black pepper from India*

Isolate	Length (μm)	Breadth (μm)	L/B ratio	Pedicel (μm)
S—5	43.6±7.0 (25.5—59.4)*	21.5±3.1 (14.2—28.3)	2.0±0.3 (0.9—2.8)	123.9±41.3 (42.5—122.3)
S—6	43.0±5.9 (28.3—53.8)	19.3±3.4 (14.2—25.5)	2.3±0.3 (1.6—2.9)	9.71±42.7 (36.8—203.8)
S—7	44.1±5.7 (32.5—55.2)	21.2±3.7 (14.2—28.3)	2.1±0.3 (1.6—2.5)	109.2±42.7 (31.1—212.3)
S—8	45.3±6.5 (25.5—63.7)	20.4±2.8 (14.2—25.5)	2.2±0.2 (1.6—2.8)	113.8±36.2 (48.1—192.4)
S—9	52.1±10.5 (31.1—70.8)	19.5±2.8 (15.6—25.2)	2.7±0.6 (2.0—5.7)	85.7±31.9 (25.5—175.5)
S—10	53.5±7.9 (38.2—72.2)	20.9±2.3 (16.9—25.5)	2.6±0.3 (1.9—3.2)	125.7±48.9 (31.3—297.15)
S—11	60.6±7.6 (45.3—79.2)	24.1±3.4 (16.9—29.7)	2.5±0.3 (1.9—3.5)	67.1±17.5 (22.6—101.9)
S—12**	39.6±8.6 (22.6—59.4)	23.5±4.5 (15.6—32.6)	1.7±0.3 (1.2—2.8)	104.4±39.1 (39.6—220.7)
S—13	55.8±10.5 (31.1—79.3)	19.8±2.3 (15.6—22.6)	2.8±0.5 (1.8—4.0)	89.7±26.6 (42.5—138.7)
S—14	56.9±9.3 (39.6—73.6)	21.8±5.1 (16.9—50.9)	2.6±0.4 (1.4—4.2)	86.3±28.6 (31.1—161.3)

* Average of 50 measurements with range in parentheses (Sarma and Tsao unpublished)
** Sporangia measurements from 'disc method'

agar and this is reflected in the rate of growth (Table IV).

Another important feature is the presence of chlamydospores to

Table III. *Sex organ dimensions of* Phytophthora *isolates of black pepper from India, paired on V8 juice agar*

Isolate	Mating type	Antheridia		Oogonia	Oospores
		Vertical	Horizontal		
S—9**	A_1	12.5±1.9 (8.5—19.8)	14.7±1.7* (11.3—22.6)	34.2±2.8 (21.2—40.3)	28.9±3.1 (17.0—34.0)
S—10	A_1	11.9±1.4 (8.5—14.2)	13.6±1.7 (11.3—18.4)	35.9±2.8 (30.4—41.0)	29.9±3.4 (22.6—35.4)
S—11	A_1	13.0±3.4 (8.5—19.8)	14.2±2.3 (11.3—19.8)	35.9±2.8 (19.8—28.3)	29.2±3.4 (14.2—25.5)
S—12	A_1	11.3±1.4 (8.5—14.2	13.0±1.1 (9.9-15.6)	24.0±1.7 (19.8—28.3)	20.7±1.9 (14.2—25.5)
S–13	A_1	11.6±2.3 (8.5—17.0)	12.7±1.9 (8.5—17.0)	33.4±2.54 (26.9—37.5)	28.±61.9 (22.6—31.1)
S—14	A_1	11.3±1.7 (8.5—14.2)	11.5±1.4 (8.5—14.2)	32.5±2.83 (25.5—38.2)	28.9±2.8 (22.6—33.9)

* Average of 50 measurements with range in parentheses (Sarma and Tsao unpublished)

** Isolates S–5 to S–8 were of A_1 mating type but measurements were not recorded due to low frequency of sex organ formation

varying degrees in some of the isolates in old cultures. Eventhough *P. capsici* and *'P. palmivora'* MF_4 types are given separate species status, several features like long pedicel of sporangia, caducity and ability to grow at 35°C etc. remain common. But the present description of *P. capsici* is incomplete to merge it with 'P. palmivora' (Alizadeh, 1983). Based on their comparative study both morphologically and physiologically it was proposed to merge both the species with a rediscription of the existing *P. capsici* incorporating features of *'P. palmivora'* MF_4 (Alizadeh, 1983; Alizadeh and Tsao, 1983).

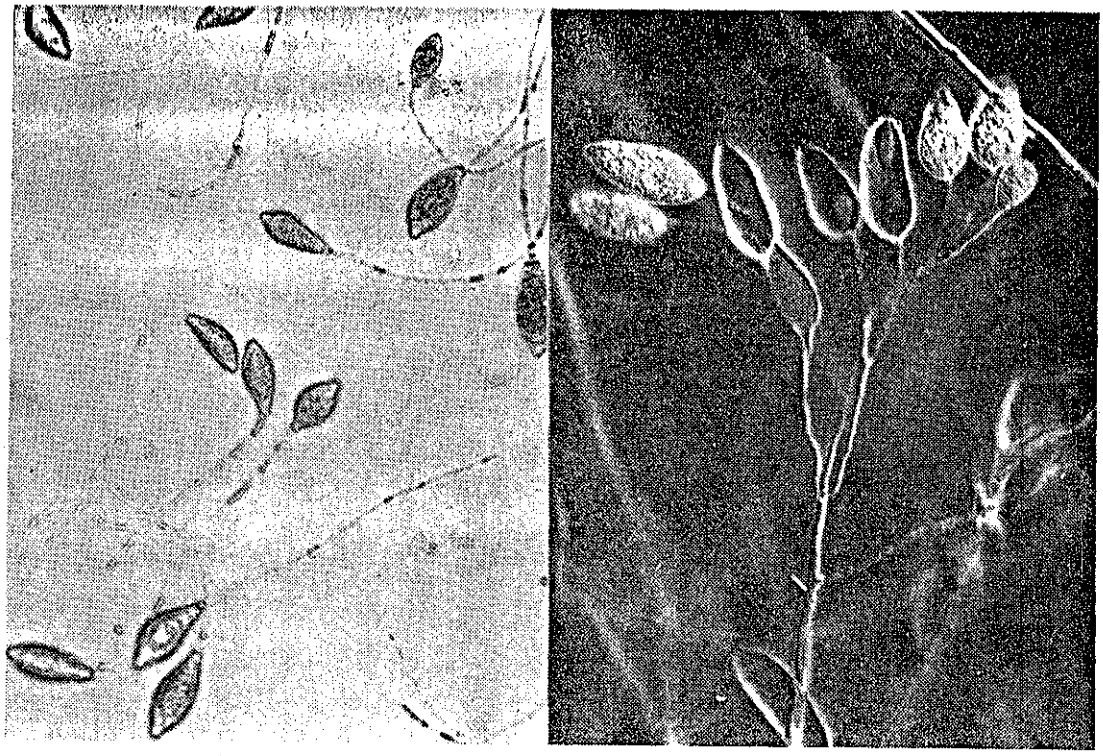


Fig. 9. Sporangia with long pedicels and umbellate sporangiophore

Biology and physiology of *'P. palmivora'*

The organism grows luxuriantly on carrot agar medium. The colony characters of the isolates are variable but they are predominantly of petaloid type but isolates with fluffy growth are also noticed (Fig. 10). Profuse sporulation was noticed in solid agar cultures exposed to light. Sporulation is sparse in dark. Chlamydospore production is not seen in fresh cultures. However, cultures of more than 10 day old produced chlamydospores in carrot agar and the production varied among isolates. In a comparative study with 12 natural media, soybean meal agar, sugarcane juice agar, wheat meal agar, potato dextrose agar, barley meal agar and carrot agar supported maximum growth (Santhakumari, 1987). Oospore formation was favoured by cholesterol, cholesterol acetate, and β-sitosterol. β-glucoronidase at 1 ppm gave 80%

Table IV. *Effect of temperature on linear growth (mm/day) of ten* Phytophthora *isolates of black pepper from India*

Isolates	Temperature			
	35°C		28°C	
	Carrot agar	V8 agar	Carrot agar	V8 agar
S–5	0.7	0.5	11.5	9.2
S–6	1.3	1.4	14.0	11.8
S–7	3.3	2.2	11.9	9.8
S–8	3.6	1.9	10.8	8.9
S–9	4.0	2.8	8.9	4.6
S–10	5.2	3.9	11.4	6.1
S–11	3.3	2.7	11.9	7.2
S–12	2.2	1.6	12.1	6.4
S–13	5.9	4.2	11.3	5.2
S–14	5.5	4.3	10.6	6.0

(Sarma and Tsao unpublished)

ermination of oospores (Santha-umari, 1987). Germination was ticed when the oospores were reated with snail (*Cryptozona semi-gata*) gut extract (Dutta, Hegde d Anahosur, 1984). Horse urine nfusion gave good germination of spores (Santhakumari, 1987).

Growth was maximum between 25–30°C. Two day old cultures supported maximum sporulation with 'discs in water' under light intensity of 2000 lux. Indirect germination of sporangia was highest at pH 6 and was poor at pH 3 where direct germination was noticed. The zoospores germinate in a thin film of water within 15–20 minutes after the encystment.

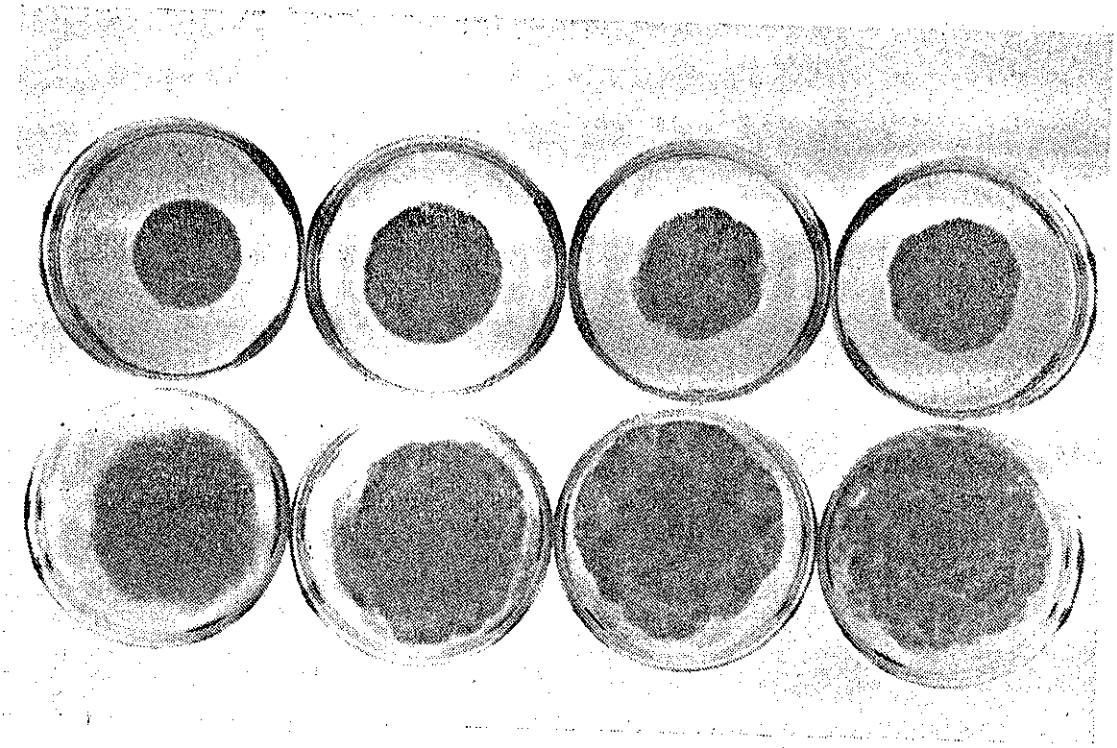


Fig. 10. *Phytophthora* isolates in culture – colony morphology
Upper: on V8 juice agar Lower: on carrot agar

Toxin production

Cell free culture filtrates induced vascular browning and flaccidity of the cut shoots of black pepper indicating the involvement of toxins (Anonymous, 1979).

Epidemiology

Epidemiology of foot rot has been dealt in detail in a separate chapter.

Primary source of inoculum and survival of the fungus: The fungus is soil borne and thrives in the plantation soils as infected plant debris throughout the year. Detectability of the pathogen was maximum during wet period (July-August) (Nambiar and Sarma, 1979). Distribution of inoculum decreased with distance from the vine and depth of soil (Ramachandran, Sarma and Nambiar, 1986). Infected plant debris and soil serve as primary source of inoculum (Nambiar and Sarma, 1977; Sastry, 1982). However, the mode of survival needs

indepth study since this will be of relevance for the future programmes on biological control. The methodology on the quantification of inoculum in the soil has been discussed elsewhere. A clear cut correlation of the inoculum levels to disease incidence has been reported (Sastry, 1982).

Disease spread: Disease spread is through soil, water and root contact between healthy and infected vines in a plantation (Sarma and Nambiar, 1982). Splash dispersal is the main mode of spread of foliar infection (Nambiar and Sarma, 1982; Ramachandran, Sarma and Anandaraj, 1990). Termites and slugs (Fig. 11) were found to be passive carriers of inoculum (Sarma, Ramachandran and Nambiar, 1981). The disease spreads in centrifugal form from the source of infection. Scattered disease incidence was also noticed but further spread would be centrifugal (Nambiar and Sarma, 1982). This non-random type of spread is typical of soil borne pathogens. The disease spread monitored in a pure plantation clearly indicated the compound interest type of disease model. The value 'r' the apparent rate of spread of infection was estimated to be 0.67 per infected plant/year

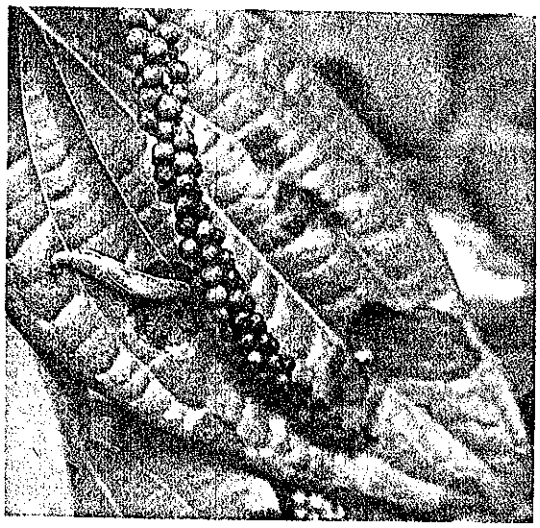


Fig. 11. Slugs feeding on foliar lesions and infected spike

(Ramachandran et al., Unpublished).

Role of climatic factors on disease initiation and spread: The disease is generally noticed during June-September period coinciding with south-west monsoon. A positive correlation of disease incidence to rainfall, number of rainy days, relative humidity and negative correlation with temperature and sunshine hours was noticed. Increasing phase of foliar infection in an areca-pepper mixed cropping system showed that low temperature (22.7–29.6°C), shorter duration of sunshine hours (2.8–3.5 h/day) and high rainfall (15.8 23.0 mm/day)

and relative humidity (81–99%) contributed to increase in disease (Ramachandran et al., 1988).

The micro-environmental conditions in a given area determine the foliar infection and its severity. In majority of the areca-black pepper mixed crop stands and also in pure pepper plantations, the infections are initially noticed with the onset of monsoon during May-June period, on tender runner shoots spreading on the ground. The infected tender stems or leaves rot and produce abundant sporulation. With constant rain splashes, the pathogen spreads first to the leaves of the lower region of the bush and then gradually to the upper region in a step-wise fashion and causes defoliation. However root infection continues as long as soil moisture levels are conducive even after cessation of south west monsoon. Intermittant showers during September-October period of north east monsoon would ensure enough soil moisture. Based on the available information, a disease cycle has been formulated which indicates the possible approaches of disease control (Fig. 12).

Relevance of cross inoculation studies

In view of the occurrence of different species of *Phytophthora* in multi-storeyed cropping system, it has been opined that the possibilities of development of inter-specific hybrids are high and may result in development of new strains of *Phytophthora* with high virulence (Sastry, 1982; Santhakumari, 1987).

The cross infectivity results of *Phytophthora* isolates from rubber, arecanut, coconut, cardamom, and cocoa are variable. *'P. palmivora'* MF_4 isolates from pepper in Kerala, infected roots of *P. betle, P. longum, P. attenuatum,* cocoa pods, tender leaves of rubber, castor and caused mild rotting of capsules of cardamom. *Phytophthora* isolates from cocoa, cardamom, betel vine, palmyrah, oil palm, areca and *Ficus* showed differential reaction on leaves and root system of black pepper (Sarma and Nambiar, 1982). Based on the cross inoculation tests, sporangial ontogeny and morphology, it has been reported that arecanut, rubber, cocoa, coconut and cardamom serve as the collateral hosts for quick wilt of black pepper. They also considered that *Phytophthora* of these hosts belongs to *P. palmivova* (Manmohandas, 1982;

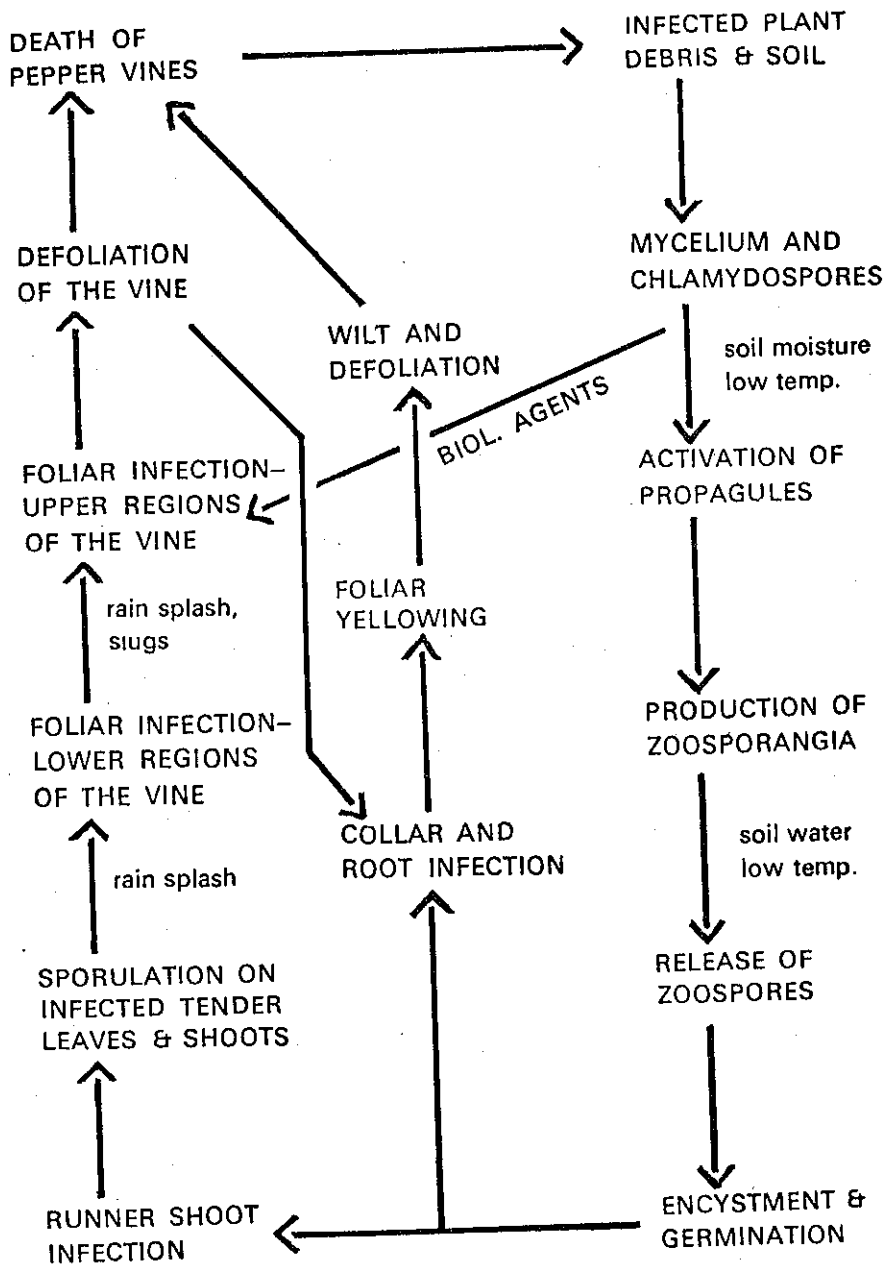


Fig. 12. Disease cycle of *Phytophthora* in black pepper

Manmohandas and Abicheeran, 1985). The information on positive cross inoculation of different *P. palmivora* on pepper, though important, is not of epidemiological significance unless the same strains are isolated from the infected pepper tissues. The pepper isolates examined so far by the authors are distinct from the *'Phytophthora'* isolates from rubber, cocoa, palmyrah and cardamom (Sarma and Nambiar, 1982).

Disease management

Early detection of the disease and timely plant protection measures are important for an effective disease management.

Integrated disease management involving chemical, cultural and biological methods besides host resistance is perhaps the most ideal strategy to combat any plant disease (Sarma et al., 1988; Sarma, Ramachandran and Anandaraj, 1988).

Plant hygiene : Phytosanitation and plant hygiene are of greater relevance in the control of black pepper *Phytophthora.* Disease free rooted cuttings precludes the possible entry of the pathogen into fresh plantations and hence nurseries should be raised from disease free planting material in fumigated nursery mixture (Sarma et al., 1988).

Infected plant debris in soil forms a potential source of inoculum and the infected vines in a garden should be removed, along with their root system and burnt to reduce the build up of inoculum. Once removed, such spots should be further drenched with copper-oxychloride to knock down the pathogen population.

Cultural practices: Micro - climate is the deciding factor in the incidence of *Phytophthora* infection and practices that reduce or alter such conditions should be adopted. Lopping of the branches of the live supporting standards and shade trees in a plantation, ensures sunlight penetration and reduces humidity in the garden.

Pruning of runner shoots : In a known infected garden, the tender, succulent runner shoots are prone to infection during May - June. Such infected runner shoots which support abundant sporulation form the main source of secondary spread. Hence, runner shoots should be tied back to the main bush or pruned off before the onset of monsoon. The basins should

be covered with a thick dried leaf mulch so as to reduce the soil splash and also to prevent the new runner shoots coming in contact with soil.

Since water stagnation favours the disease, better drainage in a plantation has to be ensured.

Disease spread is rapid in plantations where clean cultivation (without a grass cover) is practiced compared to plantation where grass or legume cover crop is retained (Anonymous, 1988). In view of this, it is advisable to have a cover crop in the garden. Cover crop might reduce the soil splash during rainy days and the movement of disease propagules. It is also possible that the build up of microbial population suppressive to *Phytophthora* might be responsible for the lower disease incidence under the cover crop conditions. This needs further investigation.

Movement of personnel from diseased to healthy garden and usage of the same farm implements used in the diseased garden should be avoided in healthy garden unless they are cleaned with a disinfectant.

Minimum tillage is an important concept in black pepper cultivation. Soil digging operation should be minimum to avoid injury to the root system thus reducing the chances of infection. In areca black pepper plantations, digging is a regular practice. To reduce the chances of injury to pepper root system, digging operation should be avoided in the portion/sector where maximum pepper root system is distributed. Hence, utmost care should be exercised during this operation to avoid any injury to the underground parts of the vines.

Chemical control

Chemical control of the disease by protecting the susceptible host parts by the residual/contact fungicides can be adopted only as a prophylactic measure. They will not be of any use at the post-infection stage as they lack systemic action. The problem in black pepper is all the more complicated in view of the susceptibility of all parts of the plant to *'Phytophthora'*. Out of several dithiocarbamates and copper fungicides tested both as foliar sprays and soil drenches, bordeaux mixture treatment was found to be effective. Pre monsoon painting the collar with bordeaux paste besides spraying the foliage

and drenching the soil with 1% bordeaux mixture once during May-June (pre-monsoon) and again in July-August (postmonsoon) was found to be effective (Mammootty, Abicheeran and Peethambaran,1979; Sasikumaram et al., 1981; Sarma and Nambiar, 1982; Sarma and Ramachandran, 1984). Studies carried out on the sequence of new flush emergence in black pepper indicated the necessity of timing spray schedule according to the new flush emergence. The monsoon showers trigger the new flush emergence which prolongs upto August. The foliage that emerges after the first round of spray remain vulnerable to infection. Hence, the timing of the spray should be so adjusted as to cover maximum foliage possible. The emergence of new flush differs from place to place depending on the rain fall pattern and hence the timing and need-based application of the chemicals are important.

In view of the heavy rainfall during south-west monsoon and consequent leaching off of the contact fungicides like bordeaux mixture, systemic fungicides with selective action on *Phytophthora* and with high efficacy in disease control were tested. Among the three systemic fungicides namely metalaxyl (Ridomil), fosetyl-Al (Aliette) and ethazole (Terrazole) both as foliar sprays as well as soil drenches, Metalaxyl–Ziram and fosetyl-Al were found to be highly effective in checking the disease incidence under field conditions (Ramachandran, Sarma and Nambiar,1982; Ramachandran and Sarma, 1985a; 1985b). Efficacy of metalaxyl in checking *Phytophthora* infection in black pepper has been reported (Sastry, 1982). Besides soil application of granular formulations of metalaxyl, (Ridomil 5 G) @20 g/ vine was equally effective (Ramachandran, 1990). Incidentally metalaxyl was found to be compatible with quinalphos and endosulfan, the insecticides used for the control of 'pollu' beetle damage in black pepper. The insecticides are also inhibitory to *P. palmivora'* both *in vitro* and *in vivo* (Ramachandran and Sarma, 1988). This finding is of practical significance since combined spray of fungicide and insecticide would reduce the cost of plant protection operation, in black pepper in general.

Biological control

Biological control of plant pathogens is receiving attention in recent

years. Soils suppressive to *P. cinnamomi* have been reported (Broadbent and Baker, 1975). Black pepper being a native of Western Ghats, soils in the undisturbed forest areas of Silent Valley were tested for the presence of *Phytophthora*, eventhough *Phytophthora* infections are seldom noticed. The soils were positive for *Phytophthora* and absence of infection indicates suppressiveness of the soil which needs an indepth study. The possible suppression if any and the antagonists available should be isolated and exploited for biological control. Effects of organic amendments to the soil and their effects on population of *P. capsici* needs investigation since there is a practice among few farmers to apply neem oil cakes. Addition of cotton seed oil meal and groundnut cake to pepper wilt sick soils greatly suppressed *'P. palmivora'* population. *Taloromyces wartmanii* and *Penicillium variable* were antagonistic to *'P. palmivora'* (Dutta, 1984). Association of VAM with black pepper has been established (Ramesh, 1982). Disease suppressive nature of Vesicular arbuscular mycorrhiza (VAM) need to be studied for their role in root infections.

Host nutrition in relation to disease suppression is another area to be looked into. Low K, Mg and Ca levels in diseased tissues and soils was noticed and hence application of Ca, Mg and potash fertilizers is recommended. Suppression of *P. cinnamomi* and *P. parasitica* in 0.1 % urea amended soil has been reported (Tsao and Zentmyer, 1979).

Disease resistance

Identification of resistance/tolerance to *P. capsici* is of high priority. Programmes on disease resistance involved screening of open pollinated and irradiated seedling progenies of cultivars and assessing their relative degree of resistance / tolerance of cultivars, selections and hybrids. Earlier, root dip method of inoculation of rooted cuttings was adopted (Sarma and Nambiar, 1979). Later the following root inoculation technique to screen seedling progenies and stem inoculation technique to screen rooted cuttings were adopted.

Methodology of screening

Root inoculation technique: Technique consists of inoculation of seedlings at 2–3 leaf stage (70–80 days old) raised in polythene basins with zoospore suspension. Based on inoculation tests with

different doses of zoospore inoculum, using seedlings of cultivar Karimunda, a dose of 10^5 zoospores/ml/seedling that gave 100% seedling death was fixed.

Stem inoculation technique : To assess the relative degree of tolerance /resistance, stem inoculation technique was adopted. All the seedling selections made will be subjected to this method of screening. Three month old rooted cuttings with 3 or 4 nodes were used for inoculation. Since collar is a major site of infection, stem was chosen for test. The technique consists of making a pin prick/minute cut with sharp blade at the centre of the second internode from the top and placing a 3 mm inoculum disc of 3 day old culture of *P. capsici* at the point of pin prick. Later it is covered with a wet cotton wad and tied with a polythene strip (Fig. 13). The inoculated cuttings are incubated for four days in a humid chamber at 25–28°C. After four days, the infected stem is split open (Fig. 14) and lesion length is measured and visual rating is given for rotting and scored as follows. Ten rooted cuttings are used per accession and their average score indicates its reaction.

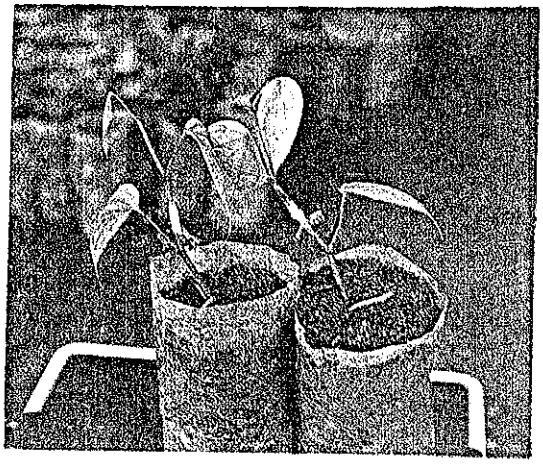


Fig. 13. Stem inoculation–inoculum disc on the pinprick covered by wet cotton and tied with polythene strip

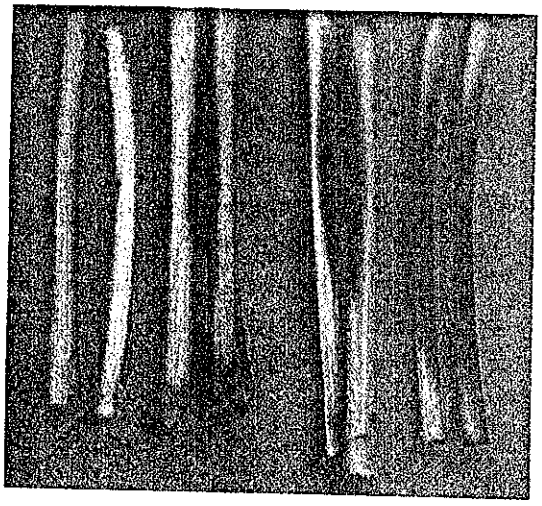


Fig. 14. Infected stem split open to measure the lesion length

Rating of black pepper types for their reaction to P. capsici

Lesion rating
No lesion – immune = I
1–5 mm – resistant = R
6–20 mm – tolerant = T
21–30 mm – susceptible = S
>31 mm – highly susceptible = HS

Rot rating (visual)
1 = 100% rotting = HS
2 = 25–75% „ = S
3 = 24% and below = T
4 = Hyper sensitive = R

Of the 41 cultivars and 73 wild types of *Piper* sp. tested, cultivars Narayakodi, Kalluvally, Uthirankotta and Balankotta were found to be tolerant whereas all the wild types tested were found susceptible (Sarma, Nambiar and Nair, 1982). Fifteen cultivars out of 99 and 12 hybrids out of 174, screened recently showed tolerance. None of the selections from Cvs Karimunda and Kottanadan were found tolerant.

The present studies indicated that high degree of resistance is lacking in the available germplasm. However, available tolerance is being utilised in the present hybridisation programmes to isolate resistant genotypes possibly through transgressive segregation or recombination. The cultivar Karimunda, a uniformly high yielder is cultivated extensively. However, its high susceptibility may pose a problem once disease incidence occurs in a monoculture. Hence, it is desirable to cultivate a mixture of cultivars / selections with variable tolerance to avoid epiphytotics. The immunity of *P. colubrinum* to *P. capsici* should be exploited, eventhough the results of the grafting trials in the past with black pepper scions on root stocks of *P. colubrinum* were variable and less encouraging. The fact that *P. colubrinum* is immune to *Phytophthora, Radopholus similis* and *Meloidogyne incognita* makes it an ideal candidate for the future studies on disease resistance.

Besides *P. capsici*, the root infections caused by *R. similis* and *Meloidogyne* are very important. In nature spatial segregation of pathogenic fungi especially *P. capsici* and nematodes is an impossibility. Hence, greater priority is to identify cultivars with multiple resistance/ tolerance to *P. capsici*, *R. similis* and *M. incognita* and also to 'pollu'

agents *i. e., Colletotrichum gloeosporioides* and the major pest flea beetle *Longitarsus nigripennis.*

Future outlook

Studies are warranted on early detection of disease especially root infection caused by *Phytophthora* and nematodes which remains incipient with long incubation periods without any visual symptoms. Serological diagnostic (both polyclonal and monoclonal) methods and also physiological parameters like stomatal resistance and water potentials of the host are of great promise for early diagnosis. Serological methods would become more handy to screen nursery stocks of black pepper.

The importance of biotechnological means to induce disease resistance in black pepper through *in vitro* screening of cell and callus cultures of black pepper with toxins of *Phytophthora,* isolation of toxin insensitive cell/calli and regeneration to plantlet level becomes highly relevant. Such plants ought to be screened for their reaction to the live cultures of *P. capsici* since the toxin being nonspecific. The possibilities of protoplast fusion of *P. colubrinum* and *P. nigrum* should be explored with an aim to evolve hybrid lines of multiple resistance and productivity (Sarma and Ramadasan, 1990).

Studies on the interaction of VAM associated with black pepper and *Phytophthora* needs to be studied. Identification of cultivars with horizontal resistance and high productivity, organic amendments that support optimum microbial population that suppress *Phytophthora,* exploiting hypovirulence if any in *Phytophthora* for disease control are some of the priority programmes. Isolation and field testing of potential antagonists of *Phytophthora* and standardising cheap and cost effective agronomic practices that ensure optimum health and productivity of black pepper are the lines of work that hold promise.

SLOW DECLINE DISEASE

Slow decline (Slow wilt), a debilitating disease of pepper is prevalent in all pepper growing tracts of Kerala and Karnataka and appears to be similar to 'pepper yellows' reported from Indonesia (Christie, 1957; Thorne, 1961; Waard, 1979). The problem has been dealt in detail in a separate paper.

Symptomatology

Foliar yellowing, die-back of aerial stems, occasional tip burn symptoms, interveinal chlorosis and flaccidity of leaves, are some of the foliar symptoms. The root system of the affected vines show the presence of root-knots and root necrosis leading to varying degrees of root degeneration (Nambiar and Sarma, 1976; 1977). This leads to the gradual loss of vigour and productivity of the vine and may succumb after a period of 2–5 years. Hence, the earlier term 'slow wilt'. Foliar yellowing starts after the north-east monsoon from October-November period and reaches its maximum during April coinciding with depletion of soil moisture. Some of the affected vines recover with the onset of monsoon indicating moisture stress. However, the symptoms reappear in subsequent dry season.

Etiology

The disease is considered as a fungal nematodal complex coupled with moisture stress and malnutrition (Nambiar and Sarma, 1979). The role of plant parasitic nematodes in 'slow wilt' was reported (Ramana, 1986; Ramana, Mohandas and Balakrishnan, 1987).

Role of plant parasitic nematodes: Association of root-knot nematode with black pepper was reported from Wynad region of Kerala (Butler, 1906). Various plant parasitic nematodes associated with black pepper and other spices in India have been reviewed earlier (Sundararaju and Koshy, 1979). Association of burrowing nematode *Radopholus similis* with black pepper was reported from coffee-pepper mixed cropping system in Karnataka (D'Souza et al., 1970). Pathogenicity of *M. incognita* and *R. similis* on black pepper was established and *R. similis* was found to be 'banana race' (Koshy and Sosamma, 1979; Venkitesan, 1976). A detailed survey of plant parasitic nematodes associated with black pepper in Kerala and Karnataka lead to the identification of 14 nematode genera in the rhizosphere of black pepper (Ramana and Mohandas, 1987). An endoparasitic nematode, *Trophotylenchulus piperis* was noticed in association with root system of black pepper (Mohandas, Ramana and Raski, 1985). Though the pathogenicity of the two endoparasitic nematodes *M. incognita* and *R. similis* was established, all the symptoms of slow decline could not

be reproduced. However, a detailed pathogenicity test in black pepper with *M. incognita* and *R. similis* alone and in combination conducted in simulated field conditions with adequate moisture and nutrients showed that *R. similis* alone with or without *M. incognita* could reproduce the foliar yellowing, root degeneration and decline, the symptom of slow wilt disease (Mohandas and Ramana, Unpublished). Incidentally the field survey results showed the combined association of *R. similis* and *M. incognita* consistently with 'slow wilt' affected vines (Ramana and Mohandas, 1987). Slow decline affected vines treated with nematicides showed remission of foliar yellowing, reduction in nematode population and increased vigour of the vine, thus indicating indirectly the role of plant parasitic nematodes in the etiology of the slow decline (Anonymous, 1985).

Role of fungi: Association of *Rhizoctonia* sp., *Fusarium* sp. and *Diplodia* sp. with root systems of wilt affected black pepper was reported (Menon, 1949). The authors isolated *R. bataticola* and *Fusarium* sp. from the roots of slow decline affected black pepper. No pathogenic bacterium was isolated. A detailed study was undertaken on the fungal association with slow decline affected black pepper root system using non-specific (corn meal agar) and selective media $P_{10}VP$ (Pimaricin - Vancomycin and Pentachloronitrobenzene) for *Pythium* and *Phytophthora* and PVPH (Pimaricin, Vancomycin, Pentachloronitrobenzene and Hymexazol) for *Phytophthora* (Tsao and Guy, 1977). Percentage of isolation of *Fusarium solani* / *R. bataticola* was 51.8; and 14.7 for *Pythium* and 0.5 for *Phytophthora* (Sarma unpublished). However, pathogenicity could not be established with *Fusarium solani, R. bataticola* and *Pythium* sp. However *'P. palmivora'* MF_4 could induce root rotting in rooted cuttings of black pepper and also was infective to pepper leaves. This indicated the natural infection of pepper by *'P. palmivora'* MF_4 the causal agent of foot rot. Monitoring the *Phytophthora* population in the soil might further clarify the role of *'P. palmivora'*. Though incidental, the pathogenic potential of *'P. palmivora'* is of importance since spatial separation of nematodes and *Phytophthora* under field conditions may not exist. Alleviation of disease symptoms with soil application of Ridomil 5G granules + phorate lends support

to this (Anonymous, 1988). This further warrants detailed studies on fungal nematodal interaction on the root health of black pepper and its importance if any on the overall health of black pepper.

Role of nutrients: Since the slow decline incidence is generally noticed more in neglected gardens, studies were undertaken on the role of nutrients in soils and plants of slow decline affected black pepper. Analysis of leaf and soil samples from slow decline affected and healthy gardens showed lower levels of P and K in both leaves of affected vines as well as the soils (Table V) (Nambiar and Sarma, 1979). Similarly deficiency of N and K was noticed in slow wilt affected black pepper (Wahid, Kamalam and Venugopal, 1982). The importance of adverse soil condition in slow wilt was stressed (Sukumara Pillay and Sasikumaran, 1984). It is possible that the weakened and degenerating root system of the vine due to nematode and fungal infection, resulted in poor nutrient uptake and consequent malnutrition. Such affected plants appeared to be more vulnerable to moisture stress. Thus it is the primary root damage and poor root health that is responsible for the slow decline and the plant parasitic nematodes have a predominant role in the slow decline etiology.

Disease management

Since the plant parasitic nematodes play a predominant role in the slow decline etiology, any disease control programme should be aimed to keep the nematode population under economic threshold level which can ensure productivity of the vines. An integrated disease management involving host resistance, chemical and biological control and cultural practices that ensure optimum health and productivity of the vine are of greater relevance.

Clean nursery stock: In view of the preponderance of nematode population in many of the plantations, raising of rooted cuttings in methyl bromide fumigated nursery mixture is suggested. This would eliminate the nematodal infection at nursery stage and preclude their entry into newly established gardens.

Cultural practices: Application of green mulch of *Eupatorium odoratum* @ 45 ton/ha to black pepper controlled root damage by the nematodes and fungi (Litzenberger and Lip, 1961). Timely application

Table V. *Nutrient status of leaves and soil from slow wilt affected and healthy pepper gardens in Cannanore district*

Nutrients	Healthy gardens	Diseased gardens	
	Healthy vines	Healthy	Diseased
	LEAVES		
Nitrogen %	2.606	2.219	1.889
Phosphorus %	0.111	0.121	0.092
Potassium %	1.110	1.280	0.700
Calcium %	2.190	2.080	2.160
Magnesium %	0.480	0.500	0.500
	SOIL		
Total nitrogen %			
0–15 cm depth	0.026	0.027	0.024
Bray–1 Phosphorus ppm			
0–15 cm depth	4.60	4.00	2.00
16–45 cm depth	Traces	Traces	Traces
Available potassium ppm			
0–15 cm depth	77	89	62
16–30 cm depth	63	58	39
31–45 cm depth	46	43	34

Nambiar and Sarma, 1979.

of fertilizer is essential to boost up the vigour of the vine and to support optimum root regeneration. It is the ratio of root loss to root regeneration that determines the health of the vine.

The popular multiple cropping system involving various combinations of coconut, arecanut, black pepper, cardamom, banana and ginger are the known susceptible crops to *R. similis* and *M. incognita* and the chances for population build up of both these nematodes are very high. Hence, suitable management practices such as soil application / incorporation of nematicides and crop residues / oil cakes and judicious choice of crop combination that keeps the nematode population under economic threshold levels are called for.

Live standards: In pure crop system when live standards are used as supports to train pepper, it is important to choose standards tolerant / resistant to *R. similis* and *M. incognita*. *Garuga pinnata* and *Erythrina indica* are less susceptible to *M.. incognita* and hence are recommended (Koshy, Sosamma and Sundararaju, 1977).

Chemical control: Soil application of aldicarb, carbofuran and phorate @ 3 g a. i./vine/year reduced the nematode population levels, gave remission of foliar yellowing and boosted the vigour of the vines (Anonymous, 1985). Aldicarb sulfone and fensulfothion @8 kg/ha was found to be effective in checking *R. similis* infestation of black pepper (Venkitesan, 1976).

Resistance : A cultivar, resistant to *M. incognita* has been identified and is under field evaluation (Ramana and Mohandas, 1986). None of the cultivars screened so far showed any tolerance to *R. similis* (Ramana, Mohandas and Ravindran, 1987b).

Biological control: The beneficial effects of VA Mycorrhizal association with root system of many crops are increased nutrient and water uptake, decreased transplant injury to help plants to withstand high temperature and reduced root infection (Schenck, 1981).

In coconut based multi-storeyed cropping system consisting of coconut, cocoa, cinnamon and black pepper, various degrees of association of VAM fungi *viz., Gigaspora gigantea, G. gilmorei, Glomus fasciculatus, G. macrocarpa* and *G. microcarpa* with root system of black pepper has been reported (Ramesh, 1982). The beneficial role of these VAM isolates in reducing the root infestation by nematodes needs an indepth study. VAM and other biotic agents should be exploited for biological control of nematodes.

Thus an integrated disease management is warranted to tackle this 'slow decline' disease.

ANTHRACNOSE (FUNGAL 'POLLU') (*COLLETOTRICHUM NECATOR; C. GLOEOSPORIOIDES*)

This disease is on the increase in recent years and received considerable attention. The problem was first identified in north Malabar of Kerala as 'berry spot' and 'berry split' (Ramakrishna Ayyar, 1921). Later the disease was named as fungal 'pollu' caused by *C. necator* (Ramachandra Rao, 1926). However, the recent reports indicated that *C. gloeosporioides* is the causal agent.

Symptoms

The fungus infects leaves causing angular to irregular leaf spots yellowish brown to dark brown in colour, with a chlorotic halo (Fig 15). Infection of the stalks of the spike starts as dark spot which rots

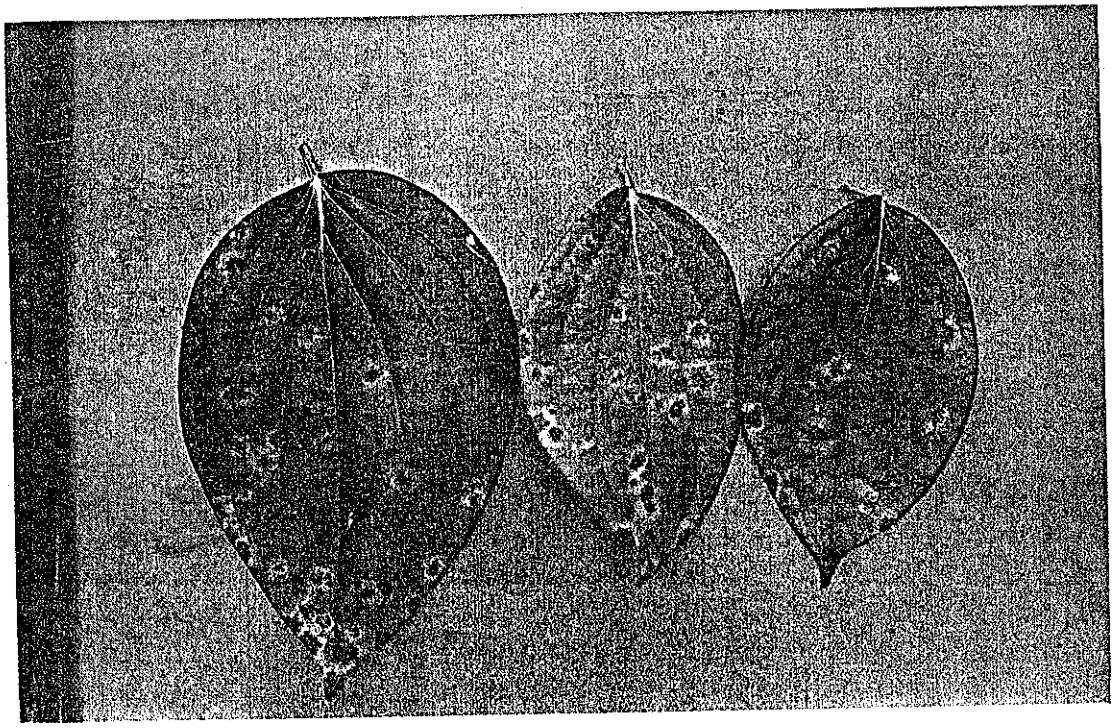


Fig. 15. Leaf spots – Anthracnose ('pollu' disease)

subsequently resulting in spike shedding. When infection is noticed on young immature developing berries (early infection) their subsequent development is arrested. Berries shrink, become chaffy, causing hollow ("Pollu") berry. When infection occurs on developed berries, cracks develop on the pericarp or berry splits leading to dry weight loss. Spike shedding due to anthracnose ranged from 1.93–9.54% in pure crop system (Unnikrishnan Nair, Sasikumaran and Sukumara Pillay, 1987).

Crop loss

Early infection results in a weight loss of berries upto 77% and late infection upto 56% (Unnikrishnan Nair et al., 1987).

Epidemiology

Infection is generally noticed throughout the year on some part of the plant and as such inoculum perpetuates throughout. Though infection is noticed during June at the time of spike emergence, maximum damage is noticed during August-September period and ranges from 28–34% (Unnikrishnan Nair et al., 1987). *Dioscorea triphylla* has been reported as an alternate host of the fungus (Wilson, 1960).

Under coconut-pepper mixed cropping system the percentage of berry infection was 23.2 in Panniyur–1, 19 in Balankotta, 16.3 in Narayakodi, 9.8 in Kottanadan and 9.3 the least in Karimunda (Radhakrishnan and Jayaprakash Nair, 1983).

Chemical control

Premonsoon prophylactic bordeaux mixture sprays against *Phytophthora*, checks this disease also. The efficacy of bordeaux mixture in checking this disease was reported (Sundararaman, 1928). Recent studies showed that three rounds of spray with 1% bordeaux mixture or difolatan (0.2%) checked the disease (Sebastian, 1982). The importance of timely spraying based on early or late infection has been stressed. Two rounds of bordeaux mixture sprays prior to flowering and one after berry formation was effective. The percentage of berry infection was 0.67 and 1.3 in treated vines during early and late infection phases respectively, compared to 1.56 and 3.17 in untreated controls (Unnikrishnan Nair et al., 1987).

Further studies are warranted on the cultural practices that can reduce the build up of inoculum.

BACTERIAL LEAF SPOT (*XANTHOMONAS CAMPESTRIS pv BETLICOLA*)

The disease is not wide spread and is noticed in stray cases. It has been reported from Kerala (Mathew, Cherian and Abraham, 1978). It is a serious problem in betel vine and is also noticed on *P. longum* (Bhale, Nayak and Chourasia, 1984).

The disease appears as minute water soaked lesions on the leaves and on the leaf margins. The lesions on leaves enlarge, turn dark brown, and appear angular to irregular with a chlorotic halo. (Fig. 16). During rainy season under wet humid conditions the infection spreads rapidly and defoliation occurs in severe cases (Mathew et al., 1978).

Though chloramphenicol has been reported to inhibit the bacterium at 200 ppm (Mathew, Abraham and Wilson, 1979) this may not be a practical control measure. However, copper fungicides like 1% bordeaux mixture might help in checking the disease (Sarma et al., 1988). Phytosanitary measures and clean nursery stock would help in checking its further spread.

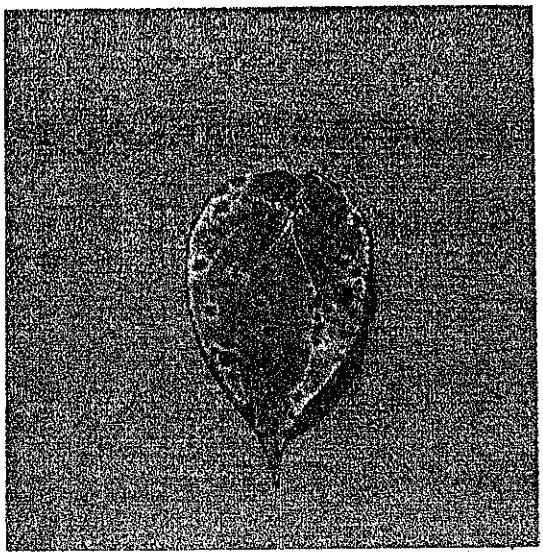


Fig. 16. Bacterial leaf spot

THREAD BLIGHT (*CORTICIUM SOLANI / MARASMIELLUS SCANDENS*)

This is a foliar disease and is noticed sporadically in Calicut and Wynad districts of Kerala and was reported on leaves and spikes (Ramakrishnan, 1957).

Whitish fungal threads traverse along the stem and spread underneath leaves and also on the spikes. The infection results in drying and death of leaves and stems. Dried up leaves hanging in the infected

bush gives a blighted appearance from the distance (Fig. 17). The dried up leaves blown over by wind appear to aid in disease spread. An infected dried leaf when falls on fresh bush develops contact through quick proliferation of fungal threads and subsequent colonisation of the host causing fresh infection. Infected spikes turn dark and dry up. During August - September, 1988 severe incidence (5–10%) was noticed near Peruvannamuzhi of Calicut district. No detailed studies were carried out in view of the sporadic nature and bordeaux mixture sprays did check this.

Fig. 17. Foliar symptoms caused by thread blight

STUMP ROT (*ROSELLINIA BUNODES*)

The disease was first noticed in Mysore area of Karnataka during 1895 (Butler, 1918). The fungus infects root system and the affected vines gradually dry up. The leaves turn brown, wither and drop off. The disease spreads in circles. *Grevillea robusta* and *Holigarna longifolia* in the forests are also affected by the disease and may serve as collateral hosts of the fungus. Removal of dead vines and isolation of the diseased vines by taking trenches, has been suggested as a control measure.

RED RUST (*CEPHALEUROS MYCOIDEA*)

This is an algal parasite noticed sporadically on older leaves as reddish brown cushony spots from October onwards and seen upto next May before commencement of south-west monsoon. The affected berries when dried appeared light greyish as compared to black coloured healthy berries. This is noticed

in severe form in some plantations in Wynad district. However, no black berry complex as in Malaysia is noticed in India.

DODDER, *CUSCUTA* Sp.

In coffee - black pepper mixed cropping system which is popular in Wynad district in Kerala, both coffee as well as black pepper are infected by dodder. *Cuscuta,* a non-chlorophyllous leafless yellowish to greenish yellow thread like plant is a total phanerogamic parasite. The phanerogam parasite coils round the foliage (Fig. 18). Once it colonises host plant after its germination, the strands establish haustoria on the host stems and draw nourishment. Though it may not kill the vine outright, it gradually debilitates the vine. Phased eradication of the vegetative threads before flowering is the only practical solution for the control.

Fig. 18. Dodder infection on black pepper

NURSERY DISEASES

Disease problems of black pepper nursery have been reviewed recently (Sarma et al., 1987). Healthy, robust and disease free rooted cuttings reduce the chances of disease incidence in main plantation. *Rhizoctonia solani* - *Pythium* and *Colletotrichum* complex (Mammootty and Sukumara Pillay, 1981). *Sclerotium rolfsii* (Brahma, Nambiar and Sarma 1980, Chowdhary, 1943) *'Phytophthora palmivora'* MF_4 are some of the soil borne plant pathogens which affect the nursery stock. In addition to *M. incognita,* the root-knot nematode, the burrowing nematode, *R. similis* also damages the root system (Sarma et al., 1987).

Since many of the nursery problems are soil borne, raising

cuttings in fumigated soil has been recommended. When conventional method of raising three noded rooted cuttings from runner shoots is adopted procurement of planting materials from infected gardens should be avoided. Runner shoots arising from the vine during November-December period are coiled round and kept on a raised stake to reduce the chances of soil contamination. Maintenance of hygienic conditions in the nursery, correct identification of the problem and timely plant protection measures have been stressed (Sarma et al., 1987).

DISEASES OF UNKNOWN ETIOLOGY

Little leaf disease

A disease which is termed as 'little leaf' of black pepper is on the increase both in Idukki and Wynad districts of Kerala. This disease was also recorded in the pepper nursery and in the orchard at Neriyamangalam, Kerala during 1975 (Paily et al, 1981).

The affected plants exhibit shortening of the nodes and internodes to varying degrees. The leaves in this affected branches appear very small and narrow, thick and leathery with chlorotic spots/streaks (Fig. 19). Eventhough consistant insect association was not noticed, marginal gall thrips are noticed in the affected plants. In a single vine both healthy and infected shoots are noticed. Some of the cuttings raised from infected shoots also exhibited the disease symptoms indicating the transmission of the disease through cuttings. However the etiology of the disease is yet to be understood.

Fig. 19. Little leaf disease-foliar symptoms

'Phyllody' disease

This is another disease which has been recorded in Puthady area of Wynad district during 1986 (Sukumara Pillay et al, 1987; Sarma et al, 1988). This appears to be slightly different from 'little leaf' disease. The affected vines exhibit varying degrees of malformation of spikes and flowers. The stalk of the affected spike elongates considerably compared to that of healthy. The floral buds in the spike showed abortion and transformed into narrow leaf like structures giving the appearance of a brush (Fig. 20). The leaves also become small and chlorotic and occasionally tufts of leaves are noticed. The flower buds also developed into small vegetative branches resembling the fruiting laterals with nodes and internodes with narrow leaf like structures. The tender berries appear oval in the infected vine compared to round healthy berries. The affected vines showed general foliar yellowing. However, some of the affected vines showed normal foliage and spikes. The affected plants showed association of thrips and jassids. Electron microscopic studies revealed the presence of MLO's in sieve elements of the affected spikes (Fig. 21) (Solomon and Sarma, Unpublished). However, the etiology of the disease is yet to be understood clearly.

Control: In view of the increased incidence and lack of information on the etiology of these two new diseases, it is advisable to remove and destroy such vines to check their further spread. Correct identification of the disease problem, adoption of timely and effective disease management strategies are essential to check the crop losses.

Velvet blight

This is similar to the disease caused by *Septobasidium* sp. (Fig. 22) in Malaysia and is very rare in occurrence. Whitish cushony growth which later turns to light pink to cream coloured, is noticed on branches, spikes and also on leaves. The cushony growth can be peeled off and the parts remained unaffected. Occasionally some of the colonised branches dry up.

Sooty moulds are noticed occasionally on older leaves and are of very minor importance.

Black spot

This disease appears as dark spots, spreading irregularly as fine

Fig. 20. Phyllody symptoms–Malformation of spikes

Fig. 21. MLO's in the sieve elements

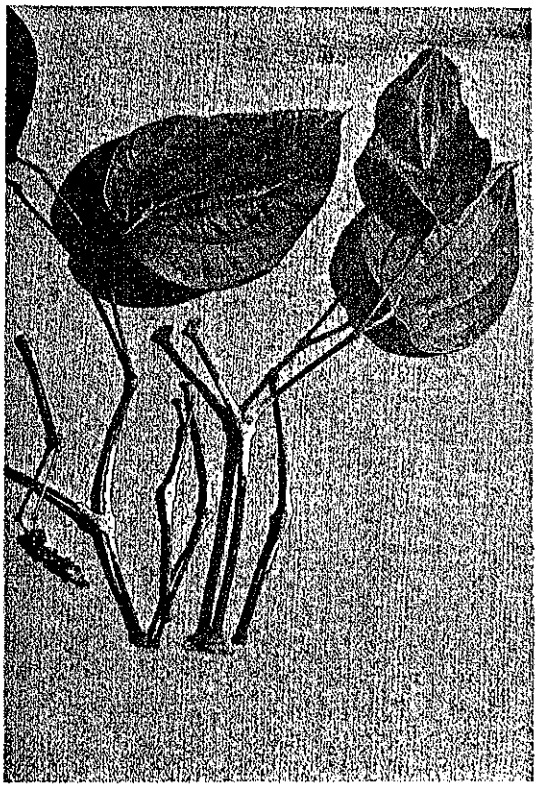


Fig. 22. Velvet blight-cushony growth on the stem

streaks on the upper surface of the leaves. The lesions do not spread to the lower side of the leaf. The leaves exhibit yellowing symptoms in severe cases. *Pestalotia* sp. has been isolated from the spots. This is noticed in Calicut and Wynad districts of Kerala.

Brown spot

Typical brown to dark circular spots are noticed on the underneath of older leaves in some of the pepper plantations. However, spots never spread to the upper surface of the leaves. Fungal and insect associations are noticed.

White/Yellow spots

Colonisation of leaves by foliculous lichens is noticed in some gardens (Fig. 23) The spots appear as circular to irregular crusty areas which are white or grey or yellow in colour. No detailed investigation have been carried out since they are of occasional occurrence and very minor in nature.

STATUS OF RESEARCH

In India, black pepper cultivation is mainly confined to Southern states *viz.*, Kerala, Karnataka and Tamil Nadu. It is gradually spreading to states like Andhra Pradesh, Orissa and north eastern states like Assam which are nontraditional areas.

Research on black pepper is mainly carried out by Indian Council of Agricultural Research (ICAR), New Delhi through its research centre, National Research Centre for Spices (NRCS) earlier known as Central Plantation Crops Research Institute Regional Station, Calicut and also through a network of stations under

Fig. 23. Yellow/white spots

the All India Coordinated Research Project on Spices, at Pepper Research Station, Panniyur (Kerala Agricultural University) at Sirsi (University of Agricultural Sciences , Dharwad, Karnataka) and at Chinthapalli (Andhra Pradesh Agricultural University). National Research Centre for Spices, Calicut and Pepper Research Station, Panniyur maintain the germplasm of black pepper. Integrated disease management of *Phytophthora* foot rot and slow decline diseases is a high priority programme of NRCS with a major emphasis on multidisciplinary approach involving plant pathologists, nematologists, plant breeders and agronomists. Latest tools of biotechnology will be utilised in future programmes to evolve disease resistant and productive types. Introduction of germplasm is through National Bureau of Plant Genetic Resources (NBPGR) of ICAR, New Delhi, which maintains strict plant quarantine regulations.

The developmental programmes are undertaken by the respective state departments of Agriculture and Horticulture. Besides, Ministry of Agriculture, Government of India, through its Directorate of Arecanut, Cocoa and Spices Development, Calicut, funds the state departments in their developmental activities to popularise scientific methods of the black pepper cultivation and plant protection.

The foregoing account calls for greater awareness of the new disease problems cropping up, eventhough some of the existing disease problems are still elusive. The disease problems of black pepper in India is

almost similar to the problems encountered in other IPC member countries. This calls for a cooperative and coordinated approach among IPC member countries to tackle the major diseases; the *Phytophthora* foot rot and slow decline diseases.

REFERENCES

ABICHEERAN and MATHEW, S. K. 1984. Diseases of pepper. *Indian Cocoa, Arecanut and Spices Journal*. 7: 73–76.

ALIZADEH, A. 1983. Comparative morphology and reproductive physiology of *Phytophthora capsici* and '*P. palmivora*' MF_4 from black pepper and other hosts, Ph.D. thesis. University of California. Riverside, USA.

ALIZADEH, A. and TSAO, P. H. 1983. *Phytophthora capsici* and '*P. palmivora*' MF4: Are they same? (Abstr.), *Mycological Society of America Newsletter*. **34** (1): 13.

ANANDARAJ, M., JOSE ABRAHAM and BALAKRISHNAN, R. 1988. Crop loss due to foot rot (*Phytophthora palmivora* MF_4) disease of black pepper (*Piper nigrum* L). in Cannanore district of Kerala. *Indian Phytopath*. **41**: 473–476.

ANONYMOUS, 1979. Central Plantation Crops Research Institute, Annual Report for 1977, Kasaragod, India.

ANONYMOUS, 1985. Central Plantation Crops Research Institute, Annual Report for 1984. Kasaragod, Kerala.

ANONYMOUS. 1988. National Research Centre for Spices, Annual Report for 1986, Calicut, Kerala, India.

BALAKRISHNAN, R., ANANDARAJ, M., NAMBIAR, K. K. N., SARMA, Y. R., BRAHMA, R.N. and GEORGE, M. V. 1986. Estimates on the extent of loss due to quick wilt disease of black pepper (*Piper nigrum* L.) in Calicut district of Kerala. *J. Plant. Crops*. **14**: 15–18.

BARBER, C. A. 1902. Ann. Rep. for 1901–1902. Dep. Agric. Madras.

BARBER, C. A. 1903. Pepper disease in the Wynad. *Trop. Agric.* (Colombo): **22**: 805–807.

BARBER, C. A. 1905. The Government pepper farm in Malabar. *Tropic. Agric.* (*Colombo*) **25**: 564.

BHALE, N. B., NAYAK, M. I. and CHOURASIA, R. D. 1984. New bacterial disease of betel vine. *Indian Phytopath*. **37**: 373.

BRAHMA, R. N., NAMBIAR, K. K. N. and SARMA, Y. R. 1980. Basal wilt of black pepper and its control. *J. Plant. Crops*. **8**: 107–109.

BRASIER, C. M. and GRIFFIN, M. J. 1979. Taxonomy of *Phytophthora palmivora* on cocoa. *Trans. Br. mycol. Soc.* **72:** 111–143.

BROADBENT, P. and BAKER, K. F. 1975. Soils suppressive to *Phytophthora* root rot in eastern Australia. pp. 152–157. *In* Biology and control of soil-borne plant pathogens' (Ed.) G.N. Bruehl. Am. Phytopath. Soc. St. Paul, Minnesota.

BUTLER, E. J. 1906. The wilt disease of pigeon pea and pepper. *Agric. J. India.* **1:** 25–36.

BUTLER, E. J. 1918. Fungi and diseases in plants. Thacker & Spink, Calcutta pp. 598.

CHOWDHARY, S. 1943. A sclerotial disease of black pepper. *Indian J. agric. Sci.* **13:** 566.

CHRISTIE, J. R. 1957. The yellows diseases of pepper and spreading decline of citrus. *Pl. Dis. Reptr.* **41:** 267–268.

D'SOUZA, G. I, KUMAR, A. C., VISWANADHAN, P. R. K. and SHAMANNA, H. U. 1970. Relative distribution and prevalence of plant parasitic nematodes in coffee tracts of South-Western India. *Indian Coffee.* **34:** 329–330 and 342.

DUTTA, P. K. 1984. Studies on two *Phytophthora* diseases (Koleroga of arecanut and black pepper within Shimoga district, Karnataka State) Ph.D. thesis, University of Agricultural Sciences, Dharwad, pp. 121

DUTTA, P. K., HEGDE, R. K. and ANAHOSUR, K. H. 1984. An assured *in vitro* technique for germination of oospores of *Phytophthora palmivora. Curr. Sci.* **53:** 655–656.

KOSHY, P. K. and SOSAMMA, V. K. 1975. Host range of the burrowing nematode, *Radopholus similis* (Cobb. 1893) Thorne, 1949. *Indian J. Nematol.* **5:** 255–257.

KOSHY, P. K., SOSAMMA V. K. and SUNDARARAJU, P. 1977. Screening of plants used as pepper standards against root-knot nematode. *Indian Phytopath.* **30:** 128–129.

LITZENBERGER, S. C. and LIP, H. T. 1961. Utilising *Eupatorium odoratum* L. to improve crop yields in Cambodia. *Agron. J.* **55:** 221–324.

MAMMOOTTY, K. P., ABICHEERAN and PEETHAMBARAN, C. K. 1979. Studies on the control of quick wilt disease of pepper. *Indian Phytopath.* **32:** 159–160. (Abstract).

MAMMOOTTY, K P., ABICHEERAN and PEETHAMBARAN, C. K. 1980. *Rhizoctonia* stem rot of pepper (*Piper nigrum*) rooted cuttings. *Indian Cocoa Arecanut and Spices Journal.* **4:** 31.

MAMMOOTTY, K. P. and SUKUMARA PILLAY, V. 1981. Studies on chemical control of rotting disease of pepper cuttings in nursery. *Indian Phytopath.* **34:** 240.

MANMOHANDAS, T. P. 1982. Survey of collateral hosts of *Phytophthora*

palmivora (Butler) Butler. in pepper gardens. M. Sc. (Ag.) Thesis, Kerala Agril. Univ. pp. 106.

MANMOHANDAS, T. P. and ABICHEERAN, 1985. Sporangial ontogeny of *Phytophthora palmivora* (Butler) Butler from black pepper, (*Piper nigrum* Linn). *Agric. Res. J. Kerala.* **23:** 129–134.

MATHEW, J., CHERIAN, M. T. and ABRAHAM, K. 1978. *Piper nigrum* a new host of *Xanthomonas betlicola.* Patel et al., *Curr. Sci.* **47:** 956–957.

MATHEW, J., ABRAHAM, K. and WILSON, K. I. 1979. *In vitro* effects of certain antibiotics against *Xanthomonas betlicola* causing leaf spot of pepper. pp. 401–402. *In* Proc. PLACROSYM II (Ed. C. S. Venkataram), Indian Soc. Plant. Crops., CPCRI, Kasaragod 670 124, Kerala, India.

MENON, K. K. 1949. Survey of 'pollu' (hollow berry disease) and root disease of pepper. *Indian. J. Agric. Sci.* **119:** 89–136.

MOHANDAS, C., RAMANA, K. V. and RASKI, D. J. 1985. *Trophotylenchulus piperis* n. sp. parasitic on *Piper nigrum* L. in Kerala, India (Nematoda : Tylenchulidae). *Revue. Nematol.* **8:** 97–102.

MULLER, H. R. A. 1936. The *Phytophthora* foot rot of pepper (*Piper nigrum*) in the Dutch East Indies (in Dutch). Meded. Inst. PiZiekt. Batavia. No. 88.

NAIR, M. K. and SARMA, Y. R. 1988. International Pepper Community Workshop on Joint Research for the Control of Black Pepper Diseases, October 27–29, 1988 at Goa. A Report. *J. Plant. Crops.* **16:** 146–149.

NAMBIAR, K. K. N. 1977. Diseases of pepper in India. pp. 11–14. In Proc. Natl. Seminar on Pepper held at CPCRI, Regional Station, Calicut, December 19, 1977, (Eds) M. K. Nair and M. Haridasan. Central Plantation Crops Research Institute, Kasaragod, India.

NAMBIAR, K. K. N. and SARMA, Y. R. 1976. Quick wilt (foot-rot) diseases of pepper. *Arecanut and Spices Bull.* **7:** 89–91.

NAMBIAR, K. K. N. and SARMA, Y. R. 1977. Wilt diseases of black pepper. *J. Plant. Crops.* **5:** 92–103.

NAMBIAR, K. K. N. and SARMA, Y. R. 1979. Factors associated with slow wilt of pepper. pp. 386–397. *In* Proc. of PLACROSYM–II. 1979. (Ed. C. S. Venkataram), Indian Soc. Plant. Crops, CPCRI, Kasaragod, Kerala, India.

NAMBIAR, K. K. N. and SARMA, Y. R. 1982. Some aspects of epidemiology of foot rot of black pepper. pp. 225–232 *In* Proc. of the Workshop on *Phytophthora* Diseases of Tropical Cultivated Plants. (Ed. K. K. N. Nambiar), Central Plantation Crops Research Institute, Kasaragod, Kerala, India.

NAMBIAR, P. K. V., SUKUMARA PILLAY, V., SASIKUMARAN, S. and CHANDY, K. C. 1978. Pepper research at Panniyur – A resume. *J. Plant. Crops.* **6:** 1 – 11.

PAILY, P. V., REMADEVI, L., NAIR, V. G., MENON, M. R. and NAIR, M. R. G. K. 1981. Malformation of leaves in black pepper. *J. Plant. Crops.* **9:** 61–62.

RADHAKRISHNAN, T. C. and JAYAPRAKASH NAIR, B. 1983. Varietal reaction and loss of yield in pepper due to fungal pollu under coconut shade. *Indian Cocoa, Arecanut and Spices Journal.* **6**(4): 91–92.

RAMACHANDRAN, N. 1990. Bioefficacy of systemic fungicides against *Phytophthora* infections in black pepper (*Piper nigrum*, L.) Ph.D. Thesis, Dept. of Botany, University of Calicut, Kerala, India.

RAMACHANDRAN, N. and SARMA, Y. R. 1985 a. Efficacy of three systemic fungicides in controlling *Phytophthora* infection of black pepper. *Indian Phytopath.* **38:** 160–162.

RAMACHANDRAN, N. and SARMA, Y. R. 1985 b. Uptake and persistance of metalaxyl in black pepper (*Piper nigrum* L.). *J. Plant. Crops.* **13:** 38–40.

RAMACHANDRAN, N. and SARMA, Y. R. 1988. Fungitoxic effect of endosulfan and quinalphos on *Phytophthora palmivora* the foot rot pathogen of black pepper. Tests of Agro-Chemicals and Cultivars No. 9. *Ann. Appl. Biol.* **112** (Supplement) : 26–27.

RAMACHANDRAN, N., SARMA, Y. R. and NAMBIAR, K. K. N. 1982. Effect of two systemic fungicides, Aliette and Ridomil on *Phytophthora palmivora* isolate of *Piper nigrum.* pp. 248–251. *In.* Proc. of the Workshop on *Phytophthora* diseases of tropical cultivated plants, (Ed. K. K. N. Nambiar), Central Plantation Crops Research Institute, Kasaragod, Kerala, India.

RAMACHANDRAN, N., SARMA, Y. R. and NAMBIAR, K. K. N. 1986. Spatial distribution of *Phytophthora palmivora* MF_4 in the root zones of *Piper nigrum. Indian Phytopath.* **39:** 414–417.

RAMACHANDRAN, N., SARMA, Y. R. and ANANDARAJ, M. 1990. Vertical progression and spread of *Phytophthora* leaf infection in black pepper in arecanut –black pepper mixed cropping system. *Indian Phytopath.* **43:** 414 – 419.

RAMACHANDRAN, N., SARMA, Y. R., ANANDARAJ, M. and JOSE ABRAHAM. 1988. Effect of climatic factors on *Phytophthora* leaf infection in black pepper grown in arecanut-black pepper mixed cropping system. *J. Plant. Crops.* **16:** 110–118.

RAMACHANDRA RAO. 1926. The 'pollu' disease of pepper. *Journal of Madras Agric. Students Union.* **14** (1): 5–10.

RAMAKRISHNA AYYAR, T. K. 1921. A preliminary investigation of the pollu disease of pepper in north Malabar in 1918. *Madras Agricultural Year Book* 1921. pp. 18–31.

RAMAKRISHNAN, T. S. 1957. Notes on some fungi from South India – VI. *Proc. Indian Acad. Sci. Sect. B.* **46** (3): 149–154.

RAMANA, K. V. 1986. Slow wilt disease of black pepper and the role of plant parasitic nematodes in its etiology. *J. Coffee Res.* (*Suppl.*) **16:** 17–21.

RAMANA, K. V. and MOHANDAS, C. 1986. Reaction of black pepper germplasm to root-knot nematode, *Meloidogyne incognita*. *Indian J. Nematol.* **16:** 138–139.

RAMANA, K. V. and MOHANDAS, C. 1987. Plant parasitic nematodes associated with black pepper (*Piper nigrum* L.) in Kerala. *Indian J. Nematol.* **17:** 62–66.

RAMANA, K. V., MOHANDAS, C. and BALAKRISHNAN, R. 1987. Role of plant parasitic nematodes in the slow wilt disease complex of black pepper (*Piper nigrum* L.) in Kerala. *Indian J. Nematol.* **17:** 225–230.

RAMANA, K. V., MOHANDAS, C. and RAVINDRAN, P. N. 1987. Reaction of black pepper germplasm to the burrowing nematode (*Radopholus similis*). *J. Plant. Crops.* **15:** 65–66.

RAMESH, C. R. 1982. Root infection and population density of V.A. Mycorrhizal fungi in a coconut based multistoreyed cropping system. pp. 548–554. *In* Proc. PLACROSYM V,1982. Central Plantation Crops Research Institute, Kasaragod, Kerala, India.

SAMRAJ, J. and JOSE, P. C. 1966. A *Phytophthora* wilt of pepper. *Sci. & Cult.* **32:** 90–92.

SANTHAKUMARI, P. 1987. Studies on *Phytophthora* diseases of plantation crops. Ph.D. thesis, University of Agricultural Sciences, Dharwad, pp. 139.

SARKAR, B. B., CHOUDARY, D. M., NATH, S. C., BHATTACHARJEE, N. R. and DEB BARMA, T. C. 1985. Wilt disease of pepper and its control in Thripura. *Indian Cocoa, Arecanut and Spices Journal.* **8:** 63–66.

SARMA, Y. R. 1985. Deputation report of Y. R. Sarma on his training in USA and UK under the Kerala Agricultural Development Project (October 12 to December, 1984). pp. 49 (Mimeographed).

SARMA, Y. R. and NAMBIAR, K. K. N. 1979. Screening of pepper (*Piper nigrum* L.) against *Phytophthora palmivora*. pp. 403–406. *In* Proc. of PLACROSYM–II 1979 (Ed. C. S. Venkataram), Indian Soc. Plant. Crops, CPCRI, Kasaragod, Kerala, India.

SARMA, Y. R. and NAMBIAR, K. K. N. 1982. Foot rot disease of black pepper, (*Piper nigrum* L.). pp. 209–224. *In* Proc. of the Workshop on *Phytophthora* diseases of tropical cultivated plants. (Ed. K. K. N. Nambiar), Central Plantation Crops Research Institute, Kasaragod, Kerala, India.

SARMA, Y. R. NAMBIAR, K. K. N. and NAIR, M. K. 1982. Screening of black pepper, *Piper nigrum* L. and *Piper* spp. against *Phytophthora palmivora*. pp. 242–247. *In* Proc. of the Workshop on *Phytophthora* disease of tropical cultivated plants, (Ed. K. K. N. Nambiar),

Central Plantation Crops Research Institute, Kasaragod, Kerala, India.

SARMA, Y. R., PREMKUMAR, T., RAMANA, K. V., RAMACHANDRAN, N. and ANANDARAJ, M. 1987. Disease and pest management in black pepper nurseries. *Indian Cocoa, Arecanut and Spices Journal.* **11:** 45–49.

SARMA, Y. R. and RAMACHANDRAN, N. 1984. Quick wilt disease of black pepper, CPCRI Extension Folder No. 5.

SARMA, Y. R., RAMACHANDRAN, N. and NAMBIAR, K. K. N. 1981. Sources of inoculum of *Phytophthora palmivora* of black pepper (*Piper nigrum*) in disease spread and the importance of morphology of the fungus. Paper presented in the Third International Symposium on Plant Pathology, New Delhi, December 14–18, 1981. Abstracts. p. 59. Indian Phytopathological Society, IARI, New Delhi, India.

SARMA, Y. R., RAMACHANDRAN, N. and NAMBIAR, K. K. N. 1982. Morphology of black pepper *Phytophthora* isolates from India. pp. 232–236. *In* Proc. of the Workshop on *Phytophthora* diseases of tropical cultivated plants, 1980 (Ed. K. K. N. Nambiar), Central Plantation Crops Research Institute, Kasaragod, Kerala, India.

SARMA, Y. R., RAMACHANDRAN, N. and ANANDARAJ, M. 1988. Integrated disease management of quick wilt (foot rot) of black pepper (*Piper nigrum* L.) caused by '*Phytophthora palmivora*' MF_4. Proceedings of the workshop on strategies on the management of root diseases in plantation crops. 18–19 January, 1988 Central Coffee Research Institute, Coffee Research Station, *J. Coffee. Res.* **18** (Supplement): 61–67.

SARMA, Y. R., RAMACHANDRAN, N., ANANDARAJ, M. and RAMANA, K. V. 1988. Disease management in black pepper. *Indian Cocoa, Arecanut and Spices Journal.* **11:** 123–127.

SARMA, Y. R. and RAMADASAN, A. 1990. Scope of biotechnology in Disease management in spice crops – A review, pp 10–11. *In* Genetic engineering and tissue culture for crop pest and disease management. Vol. I, (Ed. P. Vidhyasekaran). TNAU – UGC International Symposium–Tamil Nadu Agricultural University, Coimbatore, 641 003.

SARMA, Y. R., SOLOMON, J. J., RAMACHANDRAN, N and ANANDARAJ, M. 1988. Phyllody disease of black pepper (*Piper nigrum* L). *J. Plant. Crops.* **16:** 69–72.

SASIKUMARAN, S., MAMMOOTTY, K. P., ABICHEERAN and SUKUMARA PILLAY, V. 1981. Field trials for the control of quick wilt (foot rot) disease of pepper p. 128. *In* Abstracts – Third International Symposium on Plant Pathology, December 14–18, 1981, IARI, New Delhi.

SASTRY, M. N. L. 1982. Studies on species of *Phytophthora* affecting plantation crops in Karnataka with special reference to Koleroga of arecanut and wilt of black pepper. Ph.D. thesis, University of Agricultural Sciences, Bangalore, College of Agriculture, Dharwad, pp. 188.

SASTRY, M. N. L. and HEGDE, R. K. 1982. Distribution of *Phytophthora palmivora* (Butler). Butler in North Kanara soils and its role in wilt of pepper. pp. 237–241. *In* Proc. of the workshop on *Phytophthora* disease of tropical cultivated plants 19–23 September 1980 (Ed. K. K. N. Nambiar), Central Plantation Crops Research Institute, Kasaragod, India. pp. 284.

SCHENCK, N. C. 1981. Can mycorrhizae control root diseases. *Plant Disease.* **65**: 231–234.

SEBASTIAN. 1982. Study on the etiology and ecology of fungal 'pollu' in pepper. M.Sc. (Ag.) thesis, Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

SUKUMARA PILLAY V. and SASIKUMARAN, S. 1983. The slow wilt disease of pepper – A new outlook. *Indian Cocoa, Arecanut and Spices Journal* **7**: 77–78.

SUKUMARA PILLAY, V., SASIKUMARAN, S., IBRAHIM, K. K. and UNNIKRISHNAN NAIR, P.K. 1987. Antholysis in pepper (*Piper nigrum* L.). *Agric. Res. J. Kerala.* **25**: 140–141.

SUNDARARAJU, P. and KOSHY, P. K. 1979. Plant parasitic nematodes associated with spices. *J. Plant. Crops.* **7**: 15–26.

SUNDARARAMAN. 1928. Administration Report of the Govt. Mycologist, Coimbatore for 1927–28. Dept. of Agric. Madras for the year 1927–28. pp. 355–372.

THORNE, G. 1961. Yellows diseases of pepper. In Principles of Nematology. PP. 229–231. McGraw Hill Book Company Inc.

TSAO, P. H. 1977. Importance of sporangium caducity, pedicel length and ontogeny in *Phytophthora* speciation. p. 678. *In* Abstracts of the second International Mycological Congress, Tampa, Florida, 27 August–3 September, 1977.

TSAO, P. H. and GUY, S. O. 1977. Inhibition of *Mortierella* and *Pythium* in a *Phytophthora* isolation medium containing hymexazol. *Phytopathology.* **67**: 796–801.

TSAO, P. H. and TUMMAKATE, A. 1977. The identity of a *Phytophthora* species from black pepper in Thailand. *Mycologia.* **69**: 631–637.

TSAO, P. H., SARMA, Y. R., KASIM, R., MUSTIKA, I. and KUEH, T. K. 1985. Variation in '*Phytophthora palmivora*' MF_4 (*P. capsici*) isolates from black pepper in India, Indonesia and Malaysia. *Phytopathology.* **75**: 1315. (Abstract).

TSAO, P. H. and ZENTMYER, G. A. 1979. Suppression of *Phytophthora cinnamomi* and *P. parasitica* in urea amended soils. pp. 191–199. *In* Soil-borne plant pathogens. (Eds. B. Schippers and W. Gams.) Academic Press, London.

UNNIKRISHNAN NAIR, P. K., SASIKUMARAN, S., SUKUMARA PILLAY, V. and IBRAHIM, K. K. 1983. Etiological studies on anthracnose disease of pepper, *Indian Cocoa, Arecanut and Spices Journal.* **9**: 37–39.

UNNIKRISHNAN NAIR, P. K., SASIKUMARAN, S. and SUKUMARA PILLAY, V. 1987. Time of application of fungicide for control of anthracnose disease of pepper (fungal pollu). *Agric. Res. J. Kerala.* **25:** 136–139.

VELAPPAN, E. 1988. Production and development of pepper. *Indian Cocoa, Arecanut and Spices* Journal. **11:** 107–109.

VENKATA RAO, M. K. 1929. Ann. Rept. for 1927–1928, pp. 19–22, Dept. Agric., Mysore.

VENKITESAN, T. S. 1976. Studies on burrowing nematode *Radopholus similis* (Cobb 1893) Thorne 1949 on pepper (*Piper nigrum* L.) and its role in slow wilt disease. Ph.D. Thesis, University of Agricultural Sciences, Bangalore. pp 118.

VENKITESAN, T. S, and SETTY, K.G.H. 1979. Pathogenicity of *Radopholus similis* to black pepper (*Piper nigrum* L.) *Indian J. Nematol.* 7: 17–26.

VENKITESAN, T. S. and SETTY, K. G. H. 1978. Reaction of 27 black pepper cultivars and wild forms to the burrowing nematode *Radopholus similis* (Cobb), Thorne. *J. Plant. crops.* **6:** 81–84.

WAARD, P.W.F. de. 1979. 'Yellow disease' complex in black pepper on the island of Bangka, Indonesia. *J. Plant. Crops.* 7: 42–49.

WAHID, P. A., KAMALAM, N. V. and VENUGOPAL, V. K. 1982. Mineral nutrition of slow wilt affected black pepper (*Piper nigrum* L.) *J. Plant. Crops.* **10:** 21–25.

WILSON, K. I. 1960. A new host of *Colletotrichum necator* from Kerala. *Sci. & Cult.* **25**: 604–605.