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FUNGICIDAL MANGEMENT OF QUICK WILT DISEASE OF PEPPER IN FOREST PLANTATIONS

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SUMMARY

Black pepper, *Piper nigrum* L. is an important spice crop of Kerala. Among the various diseases affecting black pepper, foot rot (quick wilt) disease caused by *Phytophthora capsici* is the most destructive. A fungicidal trial to control the disease was carried out in a pepper plantation of Wayanad Wildlife Sanctuary using bordeaux mixture (I%), copper oxychloride (0.1%) RidomiI (0.1%) and Akomin (0.2%). The basins of the vines were drenched with the fungicide solution @ 5 litershine and sprayed profusely over the leaves as pre-monsoon (south-west) and pre-north east monsoon treatments. The percentage of disease control ranged from approximately 52-66%, 29-55%, 71-82% and 40 to 78% respectively in four treatments given during May 1993, September 1993, December 1993 and June 1994. Mortality of the vines observed at the end of 2-year-period ranged between 13-18% in fungicide-treated plots while it was 59% in untreated control plots. Copper oxychloride was found to be the least effective. The following treatment schedule has been suggested against *Phytophthora* foot rot in forest plantations based on the results of the present study.

After a few pre-monsoon showers in May-June, drench the basins (up to 50 cm radius) of the vines with 1% bordeaux mixture or 0.2% copper oxychloride @ 5 litershine. Spray the foliage of the vines profusely with 1% bordeaux mixture. Apply bordeaux paste (10%) over the stem of the vine up to a height of 1 m above the ground. Subsequently, drench the soil with 0.2 % Akomin @ 5 litershine and spray the vines profusely with Akomin. Repeat drenching the basins and spraying the vines with bordeaux mixture and Akomin during August-September. The effectiveness of application of bordeaux mixture and Akomin has to be evaluated at least for two years and the efficiency of the fungicide vis-a-vis its economic advantage has to be reviewed. Hence, these recommendations against foot rot disease of pepper can be considered only as a preliminary one.

1. INTRODUCTION

Black pepper *(Piper nigrum* L.) is a native of Western Ghats. In India, it is cultivated in Kerala, Karnataka, Tamil Nadu and Assam. About 27 per cent of world pepper production is contributed by India. Black pepper occupies in India an area of 1,36,000 ha of which 96% are in Kerala (Sarma et al., 1991). Of the total export earnings of spices in India, 80.1% were from black pepper alone(Velappan, 1988). Though India has monopoly on black pepper production in the world, its production per hectare is one of the lowest. Some of the important constraints in black pepper production are

ravages due to diseases and pests, high cost of production and consequent neglect of the crop by the farming community (Sarma, et al., 1991).

Black pepper is grown as a pure crop trained on live tree supports of *Erythrina indica, Strychnos nuxvomica, Grevillea robusta,* etc. and also as a mixed crop trained on coconut and arecanut trunks. The crop is grown over hilly slopes in rich forest loams and also in plains having lateritic to sandy loams with soil pH, ranging from 5.0-6.5. The crop is rain-fed in Kerala State whereas it is irrigated in Karnataka where areca-pepper mixed cropping system is popular. In some plantations, cover crops are introduced which are supposed to restrict the movement and spread of contaminated soil through surface water run-off and rain splashes. The cover crops also enhance the organic matter content of top soil and may increase the activity of antagonistic microflora.

1.1. Diseases of black pepper

Black pepper in India is affected by fungi, bacteria, phytoplasma, parasitic nematodes and phanerogamic parasites. Among the diseases caused by fungi, foot rot disease (quick wilt disease) caused by *Phytophthora capsici,* slow decline caused by *Rhizoctonia bataticola* and/or species of *Fusarium* and *Pythium,* anthracnose caused by *Colletotrichum gloeosporioides* and *C. necator,* and thread blight caused by *Corticium solani* and *Marasmiellus scandens* are the most common in plantations. Bacterial leaf spot caused by *Xanthomonas campestris* pv *betlicola* and phyllody and little leaf supposed to be caused by Phytoplasma are the other diseases prevalent in pepper plantations. Plant parasitic nematodes like *Radopholus similis* and *Meloidogyne incognita* are also implicated in slow decline of pepper.

However, among all these diseases foot rot disease is the most destructive one prevalent in all the pepper growing areas of India. Foot rot is also a serious disease in several other pepper growing countries (Sarma and Premkumar, 1991). First noticed in Wayanad region as early as 1902, the *Phytophthora* wilt of black pepper was reported in 1966 (Samraj and Jose, 1966). The disease occurs in Kerala, Karnataka, Tamil Nadu and Assam. A crop loss survey conducted for three years in Calicut (1982-1984) and two years (1985-86) in Cannanore district showed that the incidence of foot rot infection was 3.7% and 9.4% causing an annual loss of 119 and 905 metric tones of black pepper in those two districts, respectively (Balakrishnan et al., 1986; Anandaraj et al., 1988).

The pathogen infects all parts of black pepper like leaf, stem, spike, collar and root. Infection on leaves appear initially as water soaked lesions (Fig. 1) which expand rapidly into dark brown patches with fimbriate margin and sometimes with a greyish ce iter. Foliar infection leads to varying degrees of defoliation depending on the severity of the disease. Infection also occurs on spike resulting in spike shedding. On tender

and woody stems, infection occurs as dark wet spots resulting in progressive rotting leading to die-back symptoms. Collar and root infections are the most serious and generally the infected vine shows rapid wilting, defoliation and quick death of vine (Fig. 2 & 3). The collar (foot) infection spreads upwards and downwards resulting in rotting of stem and roots. The collar infected vines show yellowing, flaccidity of leaves, defoliation, spike shedding and breaking of stem at the nodal regions. Root infection may start from feeder root system or it may spread downwards from collar infection. The foliar symptom of root infection is similar to that of collar infection.

1.2. Disease Spread

Phytophthora capsici of Class Oomycetes can survive in a wide range of environmental conditions. The pathogen survives in the soil on infected plant debris through out the year, which serve as the primary inoculum source. Disease spread is through soil, water, rain splash, root contact, contaminated materials, termites and slugs. Low temperature (22.7-29.6oC), shorter duration of sunshine hours (2.8-2.5 h/day) high rainfall (>16 mm/day) and high relative humidity (>71%) contributed towards increase of disease incidence and severity. The infections are initially noticed with the onset of monsoon during May-June period on tender runner shoots which lay spread on the ground. Abundant spores, produced on rotting shoots get splashed around during rain, infecting nearby leaves and stem. With continuous rain splashing the pathogen spread from lower leaves to upper portion of the vine in a step wise fashion. However, root and collar infections continue so long as soil moisture level is conducive even after monsoon.

1.3. Disease Management

1.3.1. Phytosanitation and cultural practices

An integrated approach involving phytosanitation, appropriate cultural practices, quarantine measures added with timely chemical control measures are necessary for successful management of the disease. Phytosanitation involves, planting disease free cuttings in new plantations, destruction of infected plant materials by burning, treatment of basins with fungicidal drenching, etc. Cultural practices involve timely tying or pruning of runner before south west monsoon, mulching the basins to prevent rain splash, prevention of water stagnation and facilitating proper drainage in the plantation. Establishment of cover crop and minimum tillage to avoid root injury are also found to reduce the incidence of foot rot.

1.3.2. Biological control

Application of nitrogenous organic matter like urea and poultry manure are known to suppress *Phytophthora* sp. in *soii* (Tsao and Oster, 1981) through the formation of ammonia and nitrous acid which are toxic to the fungus. Organic amendments also

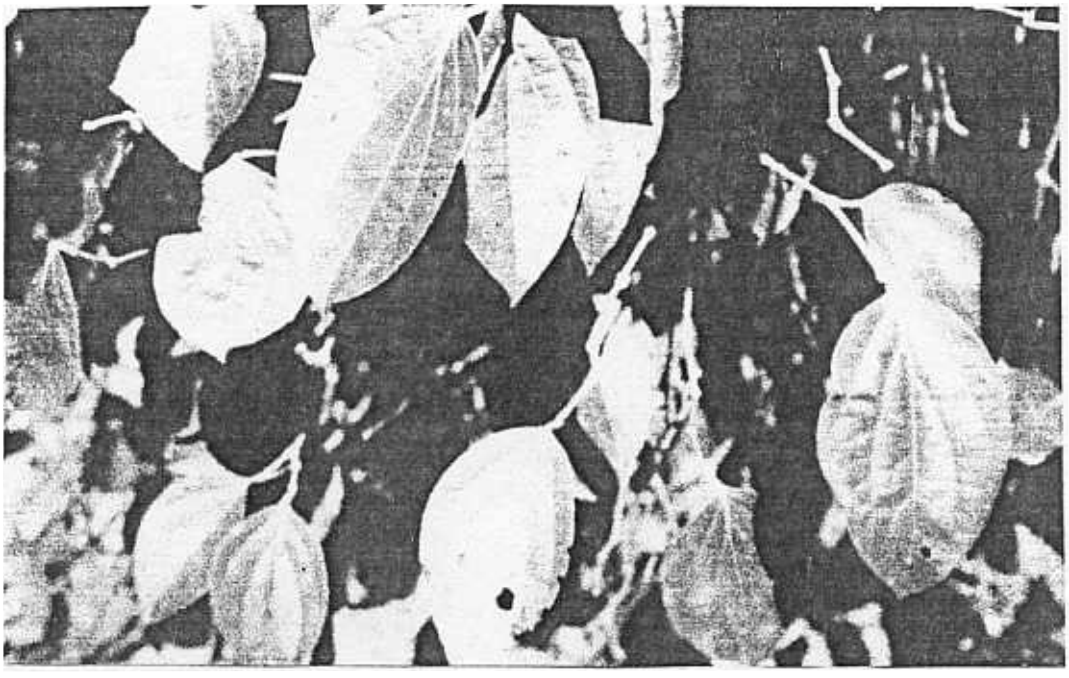

Fig. Pepper leaves infected by *Phytophthora capsici* Note the greyish brown lesions and the yellowing of the leaves

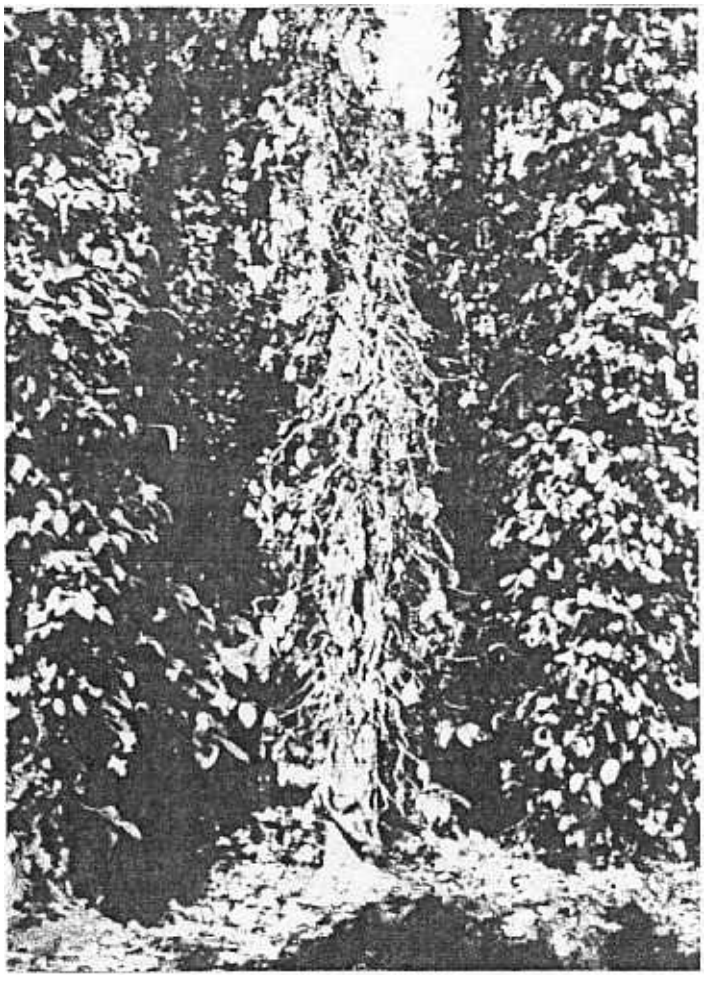

Fig. 2. A pepper vine affected by collar rot

Fig. 3. A rotted collar region of a vine

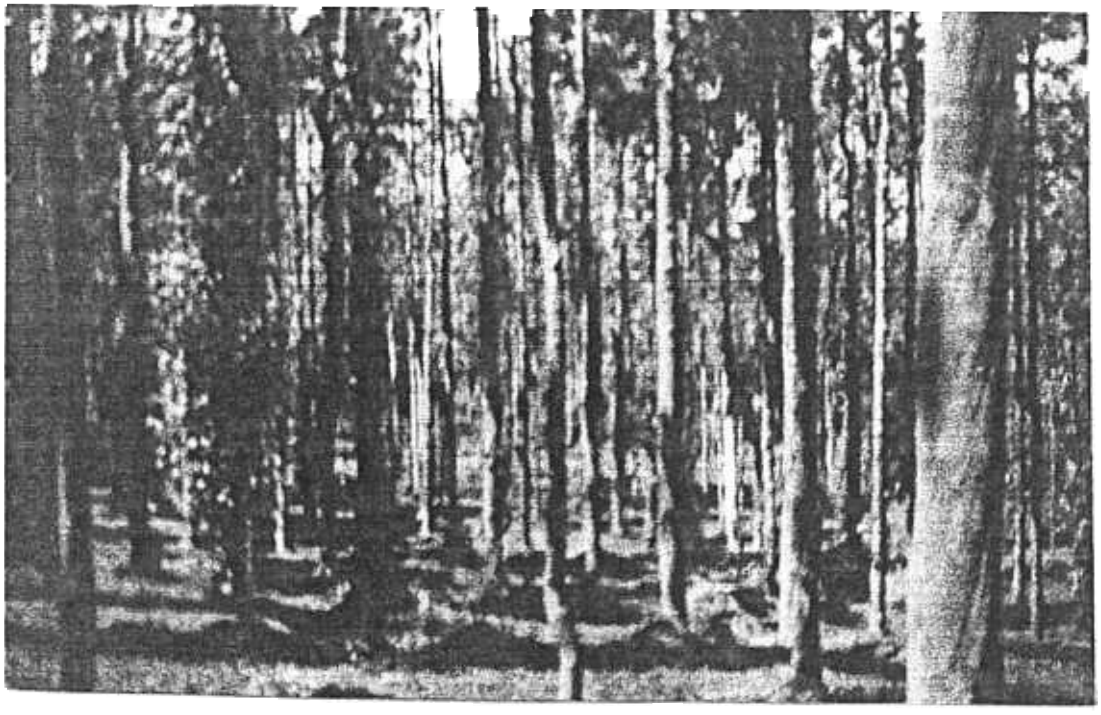

Fig. 4 The heavily diseased control plot. Note the standards devoid of vines

increase the activity of microorganisms antagonistic to *Phytophthora.* Application of bio-pesticides like neem oil cake at the rate of 1 kg/vine during May-June is recommended for suppression of *Phytophthora* as well as nematodes apart from its use as organic manure.

However, all the non-chemical methods alone are not sufficient to achieve satisfactory control of the disease. Adoption of chemical control methods along with non-chemical methods provide fairly good control. Protecting the host by systemic or contact fungicides can be adopted as an ideal prophylactic measure.

1.4 Objective of the present study

Fungicidal spray of black pepper against foot rot disease has been adopted as an integral part of maintenance of pepper plantations of Kerala Forest Department. The practice of spraying fungicides has been routinely carried out in the pepper plantations of Kurichiyat range under Wayanad Wildlife Sanctuary. However, satisfactory control of the disease was not observed resulting in steep fall in pepper yield year after year.

Because of the drastic fall in revenue from pepper plantations due to persistence of foot rot disease in spite of application of fungicides, the wildlife wing of Kerala Forest Department requested KFRI to conduct studies on chemical control of the disease using different fungicides. The request was accepted by KFRI and subsequently a research proposal submitted by KFRI was accepted for funding by the wildlife wing of the Forest Department. The work was carried out in pepper plantation in Kurichiyat Wildlife Sanctuary during the period from May 1993 to April 1995. The result of the study and the recommendations are presented in this report.

2. MATERIALS AND METHODS

2.1. Experimental site

The experimental site was an 18-year-old pepper plantation in Kurichiyat range of Wayanad Wildlife Sanctuary in Wayanad District of Kerala State. The total area of pepper plantation in the range is approximately 200 ha. The silver oak *(Grevillea robusta)*, planted in 3m x 3m spacing in rows was the standard used for growing the pepper vines. The soil was loamy and terrain plain with gentle slope.

Before starting the spray experiment, initial level of disease symptoms on each vine was scored in April 1993. The disease severity ranged from initial leaf infection to

severe root and collar infection. The various plots were demarcated in such a way that the average disease severity indices of the vines in each plot were initially comparable, i.e. before the experiment started.

2.2. Treatments

There were four types of chemicals used - three fungicides viz. bordeaux mixture, Ridomil and copper oxychloride, and Akomin (potassium phosphonate). Ridomil M WP is a combination of Metalaxyl (a.i.8%) and Mancozeb (a.i. 64%); Akomin 40, marketed by Rallis India Ltd. as a plant tonic is a salt of phosphorous acid. Concentration of the fungicides were 0.1% a.i. and Akomin 0.2%. Initially, all the vines were profbsely treated with 1% bordeaux mixture as foliar spray as well as soil drench in the basin of the vines @ 5 liters/vine. Bordeaux paste (10%) was also applied over all the vines up to a height of 90 cm (3 feet) above the ground. Subsequently, each vine was sprayed profbsely with the chemicals of the particular treatment all over the leaves and stem. One hundred and fifty eight vines were sprayed with Ridomil, 242 with copper oxychloride and 151 with Akomin. The number of control trees which did not receive any treatment was 90. The treatments were carried out in May-June 1993, December 1993, May 1994 and in September/October 1994. However, a change was made in the September/October 1994-experiment in order to compare the prophylactic effect of bordeaux mixture itself, ie. without combining with the other fungicides and Akomin. In this experiment, the treatment of vines with bordeaux mixture and paste which was the practice in previous experiments was done for 50 per cent of the vines only. The other half was sprayed with the particular fungicides/Akomin. Thus 74 vines (3 rows) were treated with Ridomil, 137 vines (5 rows) with copper oxychloride and 83 vines (3 rows) with Akomin. The control treatments were left unsprayed.

2.3. Recording of Observation

Observations on the effect of various treatments were recorded either three months after spraying the vines with fungicides/plant tonic or just before the subsequent spraying of the vines,

2.3.1. Disease severity index (DSI)

In order to assess the disease severity in each plot after each round of treatment, a method of indexing the level of disease on a severity scale of 1-4 was formulated depending upon the type of symptom as shown below.

Type of Symptom	Level of disease severity and rating			
	0-25%(I) Rating	25-50% (II) Rating	50-75% (111) Rating	75-100 (IV) Rating
A- Foliar infection	1	1.25	1.50	1.75
B- Spike infection	2	2.25	2.50	2.75
C- Yellowing	3	3.25	3.50	3.75
D- Defoliation	4	4.25	4.50	4.75
E- Collar infection wilting;	5	5.25	5.50	5.75

Average disease severity index/Plant (DSI) = (nA+nB+nC+nD+nE)/N

Where nA, nB, nC, nD and nE are sum of the disease severity for the respective symptom expressed in different levels (i.e. I, II, III and IV).

For example nA(Sum of disease severity of vines showing foliar infection) = (number of vines showing disease severity I x 1.0) + (number of vines showing disease severity II x 1.25) + (number of vines showing disease severity III x 1.50) + (number of vines showing disease severity IV x 1.75).

N = Total number of vines treated with a particular treatment.

2.3.2. Percentage of disease control

Disease severity index (DSI) after each treatment in the treatment plots and in the control plots (without spraying) was calculated using the above formula. The difference in DSI between the control and each treatment was considered as an index of disease control obtained and the percentage of difference over the DSI of control is taken as the percentage of disease control obtained through the spray of fungicide/plant tonic.

2.4. Mortality of vines

The number of dead vines were enumerated in each treatment and the percentage of dead vines calculated in order to compare the efficiency of fungicide/plant tonic spray.

3. RESULTS AND DISCUSSION

3.1. Problems involved in fungicidal control of foot rot disease

Fungicidal control of *Phytophthora* infection in black pepper plantation is hampered by several factors. Because of the peculiarity of the chemical constituents of the mycelial wall of *Phytophthora* (Bruin and Edgington, 1983) several fungicides are insensitive to this pathogen. The infected portion of the host remains in the soil throughout the year which is the primary source of inoculum. The motile zoospores produced during rainy season splash in rain drops and are carried far away in rain water. As a result of the dense foliage and continuous flushing during rainy season it is not possible to protect the leaves through a single application of fungicides. In addition to these problems, the fungicides applied on the leaves get washed away during heavy rain. Hence, application of systemic fungicides is also considered as very important in the

management of *Phytophthora* infection. The management of foot rot disease of pepper is further complicated by the perennial nature of the vine, the problem of fungicide residues in pepper and the inconsistent results obtained in farmers field because of the non-uniformity of the crop and the divergent microecologic conditions prevalent in pepper plantations.

3.2. Effect of fungicide application in the present study

Fungicidal application in the present study was started with drenching the soil at the basin and spraying the vines with 1% bordeaux mixture on all vines except control treatment in May 1993 and further drenching and spray application of Ridomil, copper oxychloride and Akomin. The subsequent applications were done in October 1993, December 1993 and May/June 1994. Observations on the effect of previous application of fungicides were recorded in October 1993, December 1993, May 1994 and February 1995. The results of the treatments in terms of disease severity index and percentage of disease control are provided in Table I

3.2.1. Disease severity index

The table (Table 1)shows that application of fungicides and Akomin can reduce the disease severity in pepper plantation. The DSI ranged from 0.96-2.82, 5.69-12.59 and 1.46-8.00 respectively in the first three experiments and 2.86-13.30 in the fourth experiment, the highest DSI being for the control treatment. In spite of the fungicide/ Akomin spray,, the DSI increased till the second round of spray in September 1993. Subsequently, it came down during the dry season (December 1993-April 1994) probably because of the decreased chance of disease spread during this season and then increased again. As expected the unsprayed (control) plot showed the highest DSI. Except during the third experiment (dry season), the DSI increased consistently till the observations were taken after the fourth experiment.

3.2.2. *The percentage of disease control*

The percentage of disease control ranged from approximately 52-66%, 29-55%, 71-82% and 40-78% respectively in I, 11, III and IV experiments. Generally, the percentage of control was lower during the monsoon seasons i.e. during I and II round of spray than in the dry season i.e. during III experiment. However, during the next monsoon season, the DSI came down remarkably, improving the percentage of control except in the case of copper oxychloride treatment which showed 40% control only. The results showed that even though complete control of disease is not possible through fungicide/Akomin spray alone, the disease can be kept under check to a great extent. ie. UP to 78% througn chemical control measures alone.

Table 1. Effect of fungicidal/plant tonic (Akomin) spray on disease severity index of foot rot disease-affected pepper

Month and year of spray	Month of observation	Name of fungicide/chemical	No. of vines treated	Disease severity index (DSI	Percent. age of control (%)
I. Initial treatment with bordeaux mixture followed by fungicide/Akomin					
May 1993	Sept. 1993	Bordeaux mixture + Ridomil	158	0.96	65.96
		Bordeaux mixture +Copper-oxychloride	242	1.35	52.13
		Bordeaux mixture + Akomin	151	1.32	53.19
		Control	90	2.82	-
Sept. 1993	Dec. 1993	Bordeaux mixture + kdomil	158	5.69	54.81
		Bordeaux mixture +Copper-oxychloride	242	6.42	49.01
		Bordeaux mixture + Akomin	151	8.93	29.07
		Control	90	12.59	-
Dec.1993	April 1994	Bordeaux mixture + Ridomil	158	2.35	70.62
		Bordeaux mixture +Copper-oxychloride	242	1.46	81.75
		Bordeaux mixture-+ Akomin	151	1.64	79.50
		Control	90	8.00	-
June 1994	Feb. 1995	Bordeaux mixture	74	3.32	74.84
		kdomil	83	3.69	72.05
		Bordeaux mixture	137	2.86	78.33
		Copper oxychloride	105	7.98	39.55
		Bordeaux mixture	83	3.54	73.18
		Akomin	68	4.07	69.19

Application of bordeaux mixture alone has provided appreciable control of the disease which is well evident from the fourth experiment in which bordeaux mixture performed better than the other fungicides and Akomin consistently. Hence, effectiveness of bordeaux mixture can be considered similar to that of Ridomil. Akomin also has provided reasonably good percentage of control. The performance of copper oxychloride was poor which gave percentage of control ranging from 39.55 to 52.13% only. An evaluation of the results indicate that among the fungicides, bordeaux mixture and Ridomil are better than copper oxychloride. Akomin is a desirable chemical which can be used along with bordeaux mixture or Ridomil . Because of its systemic action, Akomin will be more suitable with bordeaux mixture than with Ridomil which is also a systemic fungicide. However, for the confirmation of the result, the experiments have to be repeated at least for one more year.

During the season of heavy disease incidence i.e. during south-west and north-east monsoons, treatment of vines with bordeaux mixture and subsequently with Ridomil has given the highest protection against the disease. Comparison of the effect of application of Ridomil, copper oxychloride and Akomin without initial application of bordeaux mixture also showed that Ridomil gave greater control of the disease in rainy season. Except in the dry season i.e. December 1993 to April 1994, copper oxychloride has given poor result, i.e. percentage of control ranging from 39.55-52.13% only. Akomin, marketed by its manufacturers (Rallis India Ltd.) provided disease control through its fungicidal properties. Akomin which is a salt of phosphorous acid is claimed to be suitable for application as pre and post monsoon spray. The increased percentage of control i.e., 70.62%-81.75%, observed during dry season i.e. during December 1993 to April 1994 may be because of low incidence of disease and decreased spread of the disease in summer months.

Comparison of the effect of bordeaux mixture with those of Ridomil, copper oxy chloride and Akomin showed that bordeaux mixture is better than the other two fungicides in reducing the severity of *Phytophthora* foot rot. However, this experiment has to be repeated again as pre-monsoon treatment in May-June and observations taken after 2-3 months in order to confirm the superiority of bordeaux mixture over the other fungicides/Akomin once again. Even though preparation of bordeaux mixture is cumbersome compared to that of Ridomil it has the advantage of low cost and no residue persistence in pepper, which are the two drawbacks of Ridomil. If Ridomil is to be used in pepper plantations, it has to be used at least two months before the emergence of inflorescence. Since, adhering to time schedule in the strict sense is not possible in forest plantations, it is better to avoid the use of Ridomil in pepper plantations owned by the forest department.

3.2.3. *Vine mortality*

The number of dead vines were enumerated at the end of second year in order to assess the mortality of vines in fungicides sprayed and non-sprayed-plots (control). The

enumeration showed that the percentage of dead vines were 12.86%, 13.63%, 17.85% and 58.89% respectively in Ridomil, copper oxychloride, Akomin treatments and control plots (Fig. 4). The results showed that if pepper plots partially infected with *Phytophthora* foot rot is not treated with fungicides, the disease would kill more than 58% of vines within two years.

3.3. NRCS and KAU recommendations of spray schedule

The National Research Center for Spices (NRCS), Calicut recommended fungicide application as prophylactic treatment besides adopting appropriate cultural practices for successful management of foot rot disease of pepper (NRCS, 1990). As fungicide application,NRCS has recommended

i. Foliar spray with 1% bordeaux mixture during May-June and July-August, ii. drenching the vine basin with 0.2% copper oxychloride @ 5 litershine during May-June and August-September, and iii. swabbing the stem up to 1 m with bordeaux paste (l0%) during May-June. For better results NRCS suggested spray of Ridomil 1.25 g/liter of water @ 5 liters/vine for the first round, followed by bordeaux mixture spray after six weeks. A third round of soil drenching with copper oxychloride or bordeaux mixture is recommended during October, if north east monsoon continued.

The phytosanitary recommendations of Kerala Agricultural University (Kerala Agricultural University, 1993) is similar to the recommendation of NRCS. After a few monsoon showers during May-June the basins of the vines are to be drenched over a radius of 45 to 50 cm with 1% bordeaux mixture or 0.2% copper oxychloride @ 5 liters/vine. A foliar spray with 1% bordeaux mixture should be given during this season and stem of the vines treated with bordeaux paste (10%) up to a height of 30-40 cm from the ground level. The drenching and spraying are to be repeated just before the north-east monsoon. A third round of drenching may be given in October if the monsoon is prolonged.

The recommendations from the two sources are more or less the same except for the recommendations of Ridomil by NRCS as a better substitute for at least one round of bordeaux mixture treatment.

4. CONCLUSION AND RECOMMENDATION

Management of foot rot disease of pepper is complicated because of the peculiarities of the pathogen and the chance of persistence of fungicide residues in pepper. Complete control of the disease is extremely difficult to accomplish with the use of

fungicides alone. An integrated approach adopting phytosanitation, appropriate cultural practices, application of bio-pesticides and biofertilisers like mycorrhiza may be needed along with chemical control measures. Among the various fungicides tried by pepper farmers, bordeaux mixture, copper oxychloride and Ridomil were recommended by NRCS Calicut and Bordeaux mixture and Copper oxychloride by Kerala Agricultural University. Akomin was included in the present experiment because of the reported beneficial effect of this 'plant tonic' in suppressing diseases caused by Oomycetous fungi. Since Akomin is found to give good control of the disease, it can be used along with commercial fungicides.

The following treatment schedule of fungicides can be adopted in the pepper plantations of Forest Department

1. After a few pre-monsoon showers in May-June, drench the basins (up to 50 cm radius) of the vines with 1% bordeaux mixture @ 5 litershine. Spray the foliage of the vines profusely with 1% bordeaux mixture. Apply bordeaux paste (10%) over the stem of the vine up to a height of 1 m above the ground. Drench the soil with 0.2 % Akomin @ 5 liters/vine and spray the vines profusely with Akomin.

2. Repeat drenching the basins and spraying the vines with bordeaux mixture and Akomin during August-September.

The effectiveness of application of bordeaux mixture and Akomin has to be evaluated for two years and the efficiency of the fungicides vis-a- vis their economic advantage has to be reviewed. Hence, these recommendations for the pepper plantations in forest areas should be considered as preliminary, subject to review after two years.

5. REFERENCES

Anandaraj, M., Abraham, J. and Balakrishnan, R. 1988. Crop loss due to foot rot (Phyphthora palmivora) disease of black pepper *(Piper nigrum)* in Cannanore district of Kerala. Indian Phytopath. 41: 473-476.

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.

Bruin, G.C.A. and Edgington, L.V. 1983. The chemical control of diseases caused by zoosporic fungi: a many-sided problem. Pages 193-282 In: Zoosporic Plant Pathogens: A Modem Perspective. S.T. Buczacki Ed. Academic Press.

Kerala Agricultural University, 1993. Package of Practices: 'Crops[7]-93. Kerala Agricultural University, Trichur.

NRCS, 1990. Black Pepper. Package of Practices. National Research Center for spices, Calicut.

Ramachandran, N. and Sarma Y.R. 1985. Uptake and Persistence of metalaxyl in black pepper *(Piper nigrum* L.) J. Plant. Crops 13: 38-40.

Ramachandran, N, Sarma, Y.R. and Anandaraj, M. 1991. Management of *Phytophthora* infection in black pepper. Pages 158-174. In: Diseases of Black Pepper. Y.R. Sarma and T. Premkumar, Eds. National Research Center for Spices, Calicut.

Samraj, J. and Jose, P.C. 1966. A *Phytophthora* wilt of pepper. Sci. & Cult. 32: 90-92.

Sarma, Y.R. and Premkumar, T. 1991. Diseases of Black Pepper. Proceedings of the International Pepper Community Workshop on Joint Research for the Control of Black Pepper Diseases, 27-29 October, 1988, Goa, India. National Research Center for Spices, Calicut, India.

Sharma, Y.R. Rarnachandran, N. and Anandaraj, M. 1991. Black pepper diseases in India. Page 55-101 In: Diseases of Black Pepper. Y.R. Sarma, and T. Premkumar eds. National Research Center for Spices, Calicut, India.

Tsao, P.H. and Oster, J.J. 1981. Relation of ammonia and nitrous acid to suppression of *Phytophthora* in soils amended with nitrogenous organic substances. Phytopathology 71

Velappan, E. 1988. Production and development of pepper. Indian Cocoa, Arecanut and Spices Journal 11: 107-109.

Whiley, A.W., Pegg, K.G., Wolstenholme, B.N., Piccone, M.F. and Penny, S.B. 1987. The Phosphorus acid story. Department of Primary Industries, Queensland, Australia.