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Integrated management of *Phytopthora capsici* foot rot in black pepper

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Abstract: Black pepper (*Piper nigrum* L.) is one of the most commonly used spice crops. Foot rot caused by *Phytopthora capsici* is a major bottleneck in black pepper production, resulting in significant crop losses in pepper-growing areas. To address this issue, a field study was conducted to test the efficacy of potential fungicides, bioagents, and botanicals in combination at two locations during 2017-18. It was found that soil application of *Trichoderma harzianum* @ 50 g/vine + neem cake @ 1 kg/vine before the onset of monsoon followed by drench and spray with fenamidone + mancozeb @ 2g/lit thrice at monthly intervals had the least leaf infection (7.52%), foliar yellowing (5.38%), defoliation (2.17%), and resulted in the highest dry pepper yield 4.70 kg/vine, with a higher benefit-cost ratio. These findings suggest that the use of a combination of bioagents, fungicides, and botanicals can effectively manage *Phytophthora* foot rot in black pepper cultivation, leading to increased yield and higher profitability for farmers.

Keywords: *Phytopthora capsici,* management, fungicide, bioagent, botanical, black pepper

INTRODUCTION

Black pepper (*Piper nigrum* L.), is an economically important spice crop and India is the fourth largest producer of black pepper next to Vietnam, Brazil and Indonesia, contributing more than 8% of the world's black pepper production, is susceptible to various pathogens, in particular to *Phytophthora capsici* which causes foot rot, commonly known as quick wilt considered as the most devastating disease of black pepper, has been reported to cause an annual crop loss of 5-10 per cent (Manohara *et al.,* 2004) but it is significantly higher in India (Shivakumar *et al.,* 2022). In India, foot rot of black pepper usually occurs mainly during the South-West monsoon period (June to September) as the disease is favoured by high soil moisture, poor drainage and well distributed rain rainfall. Disease progress is very rapid and infects all parts of the vine under favorable conditions thereby hindering the prevention and management of the disease. Hence, for effective management of this disease, an integrated strategy incorporating, botanical, biological agent and novel chemical control is required. Currently growers are being following prophylactic application of copper based contact fungicides (KAU, 2011) which in turn do not provide satisfactory control of the disease during heavy monsoon period. Moreover, repeated application of systemic fungicide like metalaxyl has resulted in evolution of insensitivity to metalaxyl has been widely observed in *P. capsici* (Parra *et al.,* 2001; Silvar *et al.,* 2006; Wang *et al.,* 2021). Over the past two decades, a number of new fungicides with recognized effectiveness against this oomycete pathogen have been discovered (Thind, 2011). On the other hand, biological control of diseases based on the application of natural plant and microbial agents against pathogens is thought to be harmless and ought to be promoted, as it requires low amounts of chemicals. Considering the foregoing facts, the current studies were carried out in order to develop effective management strategies involving the new generation molecules and bio-control options which can bring down the pathogen population in soil and can control leaf, stem, spike, root and collar infections in black pepper plantations.

MATERIALS AND METHODS

Field studies were conducted during 2017-18 at two locations: KVK Gonikoppal, Kodagu farm with variety, Penniyur of 10-15 years old and other location at farmer's field, Maldare village of Virajpet taluk, Kodagu district, Karnataka, India. Eight different combinations of fungicides, bio control agent and neem cake and one treatment was kept for combination of chitosan with bioagents and botanicals were used to evaluate their effect against *Phytophthora* foot rot. Neem cake was incorporated into top 10 cm layer of soil around the vines at 1 kg/vine before onset of monsoon. *T. harzianum* (Th-B2) procured from the Department of Plant Pathology, College of Agriculture, UAS, Bangalore was mass multiplied on moist sorghum grains and it was added to soil at rate of 50 g of preparation per vine during pre-monsoon season. The chitosan and fungicides were

Table 1. Disease Rating Scale

Index	Description
0	Healthy
1	1-25% leaf infection, yellowing and defoliation
2	26-50% leaf infection, yellowing and defoliation
3	51-75% leaf infection, yellowing and defoliation
4	76-100% leaf infection, yellowing and defoliation

applied as drench and spray at 30 days intervals thrice. Observation on per cent leaf infection, defoliation, yellowing was recorded using the disease below formula Rajan *et al.* (2002) (Table 1). The complete death of the vines were recorded and presented as per cent wilted vines.

Statistical Analysis

The experiment was carried out in a randomized complete block design (RCBD). The critical difference (CD, $p \leq 0.05$) was used to compare treatment means using Duncan's multiple range test.

RESULTS AND DISCUSSION

The results of pooled analysis from both locations (KVK Farm, Gonikoppal and Maldare village of Virajpet taluk, Kodagu district) revealed that treatment, soil application of *T. aharzianum* @ 50 g/vine + neem cake @ 1kg/vine before onset of monsoon followed by drench and spray with fenamidone + mancozeb @ 2g/lit thrice at monthly intervals out formed with less leaf infection (7.52 %), foliar yellowing (5.38 %), defoliation (2.17 %), no death of vines and highest dry pepper yield of 4.70 kg/vine followed by treatment, soil application of *T. harzianum* @ 50g/vine + neem cake @ 1kg/vine with higher benefit cost ratio of (1:3.52) and which was also found superior treatment over existing management measure i.e., soil application of Arka Microbial Consortia (*Bacillus aryabhattai* + *Pseudomonas thivervalensis* + *Azotobacter tropicalis*) 20 g/lit + drench and spray with Bordeaux mixture (1%) spray before onset of monsoon and followed by copperoxychloride (COC) drench and spray @ 3g/vine. This is followed by drench and spray with Metalaxyl + Mancozeb @ 2g/lit found in the next order with leaf infection, foliar yellowing, defoliation and dry pepper yield of 12.15, 10.21, 4.8 per cent and 4.09 kg/vine respectively in comparison to untreated control where in infection, foliar yellowing, defoliation, death of vines and yield of 44.54, 44.18, 44.33, 26.07 per cent and 1.18 kg/vine recorded respectively with lowest benefit cost ratio of (1:1.64) (Table2).

The mode of action of the fungicides mentioned in the study is well-documented in literature. Copper oxychloride acts as a contact fungicide and kills fungi because of its strong bonding affinity to amino acids and carboxyl groups, reacts with protein and acts as an enzyme inhibitor in target organisms (Mehta *et al.,* 1990). Numerous studies have provided evidence for the effectiveness of metalaxyl-based or mixed fungicides in the suppression of oomycete pathogens (Mayton *et al.,* 2008). Phenylamides such as metalaxyl-M inhibit ribosomal RNA synthesis, specifically polymerization of r-RNA (Davidse, 1995). Fungicides such as famoxadone, fenamidone, pyraclostrobin are well known Quinone outside respiration inhibitors (QoIs) revealed its strong antifungal nature against many oomycete pathogens (Thomas and Naik, 2017; Sindhu *et al.,* 2021; Neupane and Baysal-Gurel, 2022) by interrupting electron transport in cytochrome b (complex III) by binding to the Qo site, the ubiquinol oxidizing pocket which is located at the positive, outer side of mitochondrial membranes (Gisi, 2002).

Rajan *et al.* (2002) reported that *T. harzianum-26* was found to be more effective to control the disease and more adaptable to the rhizosphere of black pepper. Similarly, in a study by Ahmed *et al.* (2000) *T. harzianum* was found to be highly effective in managing *P. capsici* in pepper plants by suppressing pathogen growth and inducing systemic resistance. Moreover, the results also suggest that the efficacy of bio-agents in controlling *P. capsici* can vary depending on the specific strain used. This finding is consistent with previous studies that have reported the efficacy of different strains of *T. harzianum* in managing *P. capsici.* (Timila and Manandhar, 2020).

The field studies in two locations revealed that the treatment involving soil application of *T. harzianum* + neem cake before the onset of monsoon, followed by drench and spray with fenamidone + mancozeb thrice at monthly intervals was the most effective. These treatments were significantly better than the existing management measure. Rini and Remya (2020) observed improved survival of pepper plants in soil that was infested with *P. capsici* when it was subjected to treatment with a combination of fenamidone + mancozeb @ 2g/lit. Similar kind of findings also reported by Shashidhara *et al.* (2009) where in application of Metalaxyl MZ along with *T. harzianum* and *P. fluorescens* found effective to combat foot rot of black pepper.

Table 2. Effect of integrated management practices on foot rot of black pepper (pooled data of two locations)

Treatment	Leaf infection (%)	Yellowing (%)	Defoliation (%)	Wilt incidence (%)	Yield/ Vine (kg)	B:C ratio
T_1= = Copper oxychloride spray and drench (3g l^{-1}) + *Trichoderma harzianum* (50 g vine-1) + neem cake (1 kg $vine^{-1}$)	20.75 c (27.09)	21.47 b (27.60)	13.4 b (21.47)	10.55 c (18.95)	2.41 i (8.93)	2.89
T_2 = Chitosan spray and drench (2g l^{-1}) + *Trichoderma harzianum* (50 g vine-1) + neem cake (1 kg $vine^{-1}$)	27.22 b (31.44)	21.30 bc (27.48)	12.93 b (21.07)	9.44 cd (17.89)	2.51 h (9.11)	2.72
T_3 = Famoxadone + cymoxanil spray and drench (2g l^{-1}) + *Trichoderma harzianum* (50 g vine-1) + neem cake (1 kg $vine^{-1}$)	18.01 de (25.11)	14.65 e (22.50)	8.18 cd (16.62)	0.55 f (4.25)	3.38 d (10.59)	2.71
T_4 = Fenamidone + mancozeb spray and drench (2g l^{-1}) + *Trichoderma harzianum* (50 g vine-1) + neem cake (1 kg $vine^{-1}$)	7.52 g (15.91)	5.38 g (13.41)	2.17 f (8.47)	0.00 f (0.00)	4.70 a (12.52)	3.52
T_5 = Metalaxyl + mancozeb spray and drench (2g l^{-1}) + *Trichoderma harzianum* (50 g $vine^{-1}$) + neem cake (1 kg $vine^{-1}$)	12.15 f (20.40)	10.21 f (18.63)	4.8 e (12.65)	0.00 f (0.00)	4.09 b (11.67)	3..31
T_6 = Fluopicolide + fosetyl spray and drench (2g l^{-1}) + *Trichoderma harzianum* (50 g $vine^{-1}$) + neem cake (1 kg $vine^{-1}$)	18.68 d (25.60)	16.10 de (23.65)	8.6 c (17.05)	9.44 cd (17.89)	3.20 e (10.30)	2.92
T_7 = Iprovalicarb + propineb (2g l^{-1}) Fosetyl spray and drench (2g l^{-1}) + *Trichoderma harzianum* (50 g $vine^{-1}$) + neem cake (1 kg $vine^{-1}$)	16.49 e (23.96)	18.31 cd (25.33)	10.12 c (18.55)	8.88 d (17.33)	3.04 g (10.04)	2.67
T_8 = Pyraclostrobin + metiram Fosetyl spray and drench (2g l^{-1}) + *Trichoderma harzianum* (50 g $vine^{-1}$) + neem cake (1 kg $vine^{-1}$)	18.52 d (25.49)	14.91 e (22.71)	8.16 cd (16.60)	12.22 b (20.46)	3.11 f (10.16)	2.77
T_9 = Bordeaux mixture (1%) spray + copper oxychloride (3g l^{-1}) drench + drenching of Arka Microbial Consortia (20 g^{-1})	13.6 f (21.64)	13.88 e (21.87)	6.10 de (14.30)	4.99 e (12.91)	3.92 c (11.42)	3.23
T_{10} = Control	44.54 a (41.86)	44.18 a (41.65)	44.33 a (41.74)	26.07 a (30.70)	1.18 j (6.24)	1.64
p value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
C.D. (0.05)	1.92	2.98	2.44	1.38	0.58	
CV	5.69	9.64	11.98	9.85	8.17	

Values in table marked with different letters differ significantly; $p < 0.05$, Duncan's multiple range test; Non-significant.

CONCLUSION

In conclusion, the use of an integrated management approach that combines different treatments such as the application of *Trichoderma harzianum*, neem cake and fungicides, can effectively manage foot rot/quick wilt of black pepper. The success of this approach is evident from the significant reduction in disease incidence, less defoliation, and higher yields recorded in the field trials. Moreover, this approach is environmentally friendly and economically feasible, making it a sustainable way of managing plant diseases.

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