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Integrated management of pod rot disease of cocoa in hilly tracts of Karnataka

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Abstract

Cocoa suffers heavily due to pod rot disease caused by *Phytophthora palmivora,* causing yield losses ranging from 30 to 60 per cent. For devising strategies for effective management of pod rot disease, the present study was conducted during *Kharif* seasons of 2012-13 and 2013-14 in farmer's field in the hilly tracts of Uttara Kannada district of Karnataka State, India. The results revealed that sequential spray of Metalaxyl MZ 68WP at 0.2 per cent followed by 1 per cent *Pseudomonas fluorescens* at 15 days interval significantly reduced the severity of pod rot disease (20.1%) in cocoa. This was followed by spraying of Mancozeb at 0.25 per cent + *P. fluorescens* at 1 per cent and spraying of Bordeaux mixture (1%) + *P. fluorescens* at 1 per cent. The reduction in disease severity has reflected in increased crop yield. The plots sprayed with Metalaxyl MZ 68WP + *P. fluorescens* has recorded the highest yield of 518.2 kg of dry beans ha^{-1} followed by 436.2 and 433.6 kg ha^{-1}, respectively, in Mancozeb + *P. fluorescens* and Bordeaux mixture + *P. fluorescens*. The maximum disease severity was recorded in untreated control plots (46.2%) with a minimum yield of 337.3 kg ha^{-1}. The highest net return of ₹ 62,007 was recorded in plots sprayed with Metalaxyl MZ 68WP + *P. fluorescens* sprayed plots. Thus, the integration of chemicals with a biological control agent was found to be promising not only in the management of pod rot disease but also in obtaining higher net returns in cocoa.

Keywords: Cocoa, integrated management, Metalaxyl MZ, *Pseudomonas fluorescens*

Introduction

Among the *Phytophthora* diseases of cocoa occurring in India, pod rot disease caused by *Phytophthora palmivora* (Butler) is the most prevalent and destructive disease. More than 80 per cent of the cocoa gardens surveyed in the southern states of India have been exposed to pod rot infection (Peter and Chandramohanan, 2014). *P. palmivora* causes global yield loss of 20-30 per cent and casualty of 10 per cent annually (Guest, 2007). Hence, pod rot is one of the major constraints in cocoa production, causing significant pod losses.

In India, cocoa (*Theobroma cacao* L.) is mainly cultivated as a mixed crop in coconut (*Cocos nucifera* L.) and arecanut (*Areca catechu* L.) gardens in the four southern states of India *viz*., Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. The shady conditions in the cropping systems, coupled with congenial climatic conditions (heavy rains and high moisture conditions) during south-west monsoon (June-October) season, provide favourable conditions for the development and spread of pod rot diseases (Jayalakshmi *et al.,* 2017). This pathogen, if left uncontrolled, can result in severe yield reduction, causing a yield loss of up to 1/3rd of the total annual yield (Akrofi *et al*., 2017). The most prominent visual symptom of the disease is the black mummified look on the fruits of the cocoa tree.

The value of the cocoa industry throughout the world is significant, and therefore, research has focused on efforts to control *Phytophthora* spp. The United States chocolate industry consumes US$ 1.4 billion worth of cocoa and supplies around 68,450 jobs throughout the USA (www.icco.org. 2018). The incidence and severity of the disease are increasing *vis-à-vis* increase in the area under cultivation

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leading to heavy economic losses. It has been reported that fungicidal sprays could control this disease only to a limited extent as the heavy rains result in the washing off of the fungicides from plant surface (Anderson and Guest, 1990; Guest and Grant, 1991). According to Mc Gregor (1983) and Fagan (1984), the profitability of fungicide spraying is decided by the yield and cocoa price.

Continuous and heavy application of synthetic fungicide would eventually lead to the development of fungicide resistant strains of the pathogen and causing soil and water pollutions. Only a little attempt has been made in India to develop disease management strategies by the use of biological control agents and integrated disease management. Hence, the more sustainable and environmental friendly method should be established with chemical fungicide in combination with biological control. Because of high disease pressure and environmental concerns, alternative measures to chemical fungicides are needed to control *P. palmivora* in cocoa. Biological control, using antagonistic microbes, is one of the alternative approaches for managing pod rot disease (Alit and Susanta, 2010). The main challenges and new approaches of black pod management can be achieved if an integrated pest management strategy is established, with a combination of biological and chemical methods (Guerrero *et al*., 2012; Deberdt *et al*., 2008). Thus, considering the importance of pod rot disease, management study with new chemical fungicides, a biological agent and their combinations were undertaken to develop an effective and economically viable disease management practice.

Materials and methods

Field management trials were conducted during *Kharif* season of 2012-13 at Sirsi (Janmane) and during 2013-14 at Siddapur (Bilagi) in cocoa-arecanut mixed gardens of hilly tracts of Uttara Kannada district, Karnataka. These areas had a previous history of a high incidence of *Phytophthora* diseases in cocoa. These gardens had approximately 140-150 plants per acre, and they were 6 to 7-year old plantations. The causal organism of black pod disease in both the localities was identified as *P. palmivora* based on the laboratory examination of samples collected randomly from different locations during the south-west monsoon period of 2010 and 2011. There were nine treatments with 20 plants per treatment in three replications in each location. The spacing between plants was 4 ft x 4 ft. The first spray was given soon after disease appearance and subsequent, at 15 days interval. The fresh microbial culture of *P. fluorescens* (talc-based) containing $2x10^8$ colony forming units was obtained from Institute of Organic Farming, University of Agricultural Sciences, Dharwad and sprayed by dissolving 10 g in one litre of water (1%). The per cent disease index was calculated. All the fungicides were sprayed to pods, main stem and branches, except control. Cultural practices including integrated nutrient management (INM), plant and field hygiene, pruning and other recommended cultivation practices, were adopted in all the treatments. The first spray was given soon after disease appearance (first fortnight of August during both the years) and subsequent spray at after 15 days interval.

Following are the treatment details:

Sl. No.	Treatments
1.	Metalaxyl MZ 68 WP @ 0.2% (2 sprays)
2.	Mancozeb @ 0.25% (2 sprays)
3.	Bordeaux mixture 1% (2 sprays)
4.	*P. fluorescens* (IOF strain) @ 1% (2 sprays)
5.	Potassium phosphonate @ 0.3% (2 sprays)
6.	Bordeaux mixture 1% + *P. fluorescens* @ 1%
7.	Metalaxyl MZ 68WP @ 0.2% + *P. fluorescens* @ 1%
8.	Mancozeb @ 0.25% + *P. fluorescens* @ 1%
9.	Untreated control

Cost economics: The cost of dry beans was considered for calculating gross returns. Further, the cost of expenditure was deducted from gross returns to obtain net returns. The cost-benefit ratio was calculated by the formula:

$$\frac{\text{Net returns}}{\text{Total expenditure}}$$

Results and discussion

Effect of spraying on disease incidence

During 2012-13 the treatment wherein the cocoa plants were sprayed twice with Metalaxyl

Mz 68WP @ 0.2 per cent had a considerable reduction in pod rot incidence (14.2%) followed by spray with Metalaxyl MZ 68WP @ 0.2 per cent alternated with *P. fluorescens* @ 1 per cent (20.6%). However, sprays with Mancozeb @ 0.25 per cent (24.7%) and Bordeaux mixture @ 1 per cent (23.6%) were found as next best treatments. The maximum pod rot incidence was recorded in the untreated control plots (47.1%) (Table 1).

During 2013-14 the lower pod rot incidence was recorded in the plots sprayed with Metalaxyl MZ 68WP @ 0.2 per cent (12.5%) followed by spray with Metalaxyl MZ 68WP @ 0.2 per cent alternated with *P. fluorescens* @ 1 per cent (19.6%).The highest pod rot incidence was recorded in the untreated control plots (45.2%).

The pooled analysis of 2012-13 and 2013-14 revealed the same trend wherein cocoa plants sprayed twice with Metalaxyl MZ 68WP @ 0.2 per cent was found promising in reducing the pod rot incidence (13.4%) while, spray with Metalaxyl MZ 68WP @ 0.2 per cent alternated with *P. fluorescens* @ 1 per cent (20.1%) was found next effective treatment.

Effect on yield (of dry beans)

The maximum yield during 2012-13 was recorded in the plots sprayed twice with Metalaxyl MZ 68WP @ 0.2 per cent (561.5 kg ha^{-1}) followed by the plots sprayed with Metalaxyl MZ 68WP @ 0.2 per cent and *P. fluorescens* @ 1 per cent (542.6 kg ha^{-1}). A similar trend was recorded during 2013-14, where, highest yields were recorded in the plots sprayed with Metalaxyl MZ 68WP @ 0.2 per cent (515.3 kg ha^{-1}) followed by 495.6 kg ha^{-1} in the plots spayed with Metalaxyl MZ 68WP @ 0.2 per cent and *P. fluorescens* @ 1 per cent. The lower yields were recorded in the untreated control (368.5 kg ha^{-1} and 310.0 kg ha^{-1}) during 2012-13 and 2013-14, respectively. The pooled analysis also revealed that Metalaxyl Mz 68WP was superior (537.2 kg ha^{-1}) and alternate sprays with Metalaxyl Mz 68WP @ 0.2 per cent and *P. fluorescens* @ 1 per cent was the next best (518.2 kg ha^{-1}) in obtaining the yields. The least yields were recorded in the untreated control plots (337.3 kg ha^{-1}) (Table 1).

Cost economics (₹ ha^{-1})

The cost of expenditure, gross returns, net returns and the benefit-cost ratio is presented in Table 2. The total expenditure in all the treatments ranged from ₹ 15,000 to ₹ 16,950, including the spraying cost of pesticide and biopesticide. The highest gross returns were obtained in the plots sprayed with Metalaxyl MZ 68WP @ 0.2 per cent (₹ 80,757), Metalaxyl MZ 68WP @ 0.2 per cent and *P. fluorescens* @ 1% (₹ 77,857) and the lowest gross returns recorded in untreated control (₹ 50,887).

Table 1. Integrated management of pod rot of cocoa

Sl. No.	Treatment	Per cent disease index 2012-13 (Sirsi)	2013-14 (Siddapur)	Pooled	Yield (kg ha^{-1}) dry beans 2012-13	2013-14	Pooled
1.	Metalaxyl MZ 68 WP @ 0.2%	**14.2(22.3)**	**12.5(20.7)**	**13.4(21.5)**	**561.5**	**515.3**	537.2
2.	Mancozeb @ 0.25%	24.7(29.8)	21.3(27.6)	23.0(28.7)	469.5	415.3	441.1
3.	Bordeaux mixture 1%	**23.6(29.1)**	**23.2(28.8)**	**23.4(28.9)**	**472.6**	**427.2**	**446.3**
4.	*P. fluorescens @ 1%*	26.3(30.9)	26.2(20.8)	26.3(30.8)	460.1	423.2	441.7
5.	Potassium phosphonate @ 0.3%	32.1(34.5)	30.7(33.6)	31.38(34.1)	446.3	413.2	428.7
6.	Bordeaux mixture 1%-*P. fluorescens @ 1%*	27.2(31.4)	24.8(29.9)	26.0(30.6)	452.6	419.0	433.6
7.	Metalaxyl MZ 68WP @ 0.2% -*P. fluorescens @ 1%*	**20.6(27.0)**	**19.6(26.3)**	**20.1(26.6)**	**542.6**	**495.5**	518.2
8.	Mancozeb @ 0.25%-*P. fluorescens @ 1%*	26.5(31.0)	23.4(28.9)	24.9(29.9)	456.2	419.4	436.2
9.	Untreated control	**47.1(43.3)**	**45.2(42.3)**	**46.2(42.8)**	**368.5**	**310.0**	**337.3**
	SEm +	1.4	1.3	1.3	4.1	3.9	4.2
	CD @ *5%*	3.3	3.2	3.3	12.4	9.6	12.9

Figures in parenthesis are angular transformed values

It is revealed that ₹ 64,557 was the highest net returns obtained in the Metalaxyl MZ 68WP @ 0.2 per cent sprayed plots followed by ₹ 62,007 in Metalaxyl MZ 68WP @ 0.2 per cent and *P. fluorescens* @ 1 per cent and the lowest was obtained in the untreated control (₹ 35,887). The maximum benefit of 4.0 and 3.9 was recorded in Metalaxyl MZ 68WP @ 0.2 per cent and Metalaxyl MZ 68WP @ 0.2 per cent and *P. fluorescens* @ 1 per cent sprayed plots.

The two year data in two locations revealed that all the fungi toxicants, either sole or in combination were found promising compared to untreated control to manage pod rot of cocoa. Among the chemical fungicides, the two sprays of Metalxyl MZ @ 0.2 per cent was found significantly superior (13.4%) while, integration of Metalaxyl MZ @ 0.2 per cent followed by biological agent *P. fluorescens* @ 1 per cent was the next effective treatment (20.1%) for successful management of pod rot of cocoa.

Opoku *et al.* (2007) stated that the systemic fungicide metalaxyl (alone or combined with copper compounds) is one of the effective management practices and it should be applied at three or four week intervals to control black pods. Metalaxyl is a systemic fungicide which is rapidly taken up by the green plant part and transport upwards in the sap stream and is distributed, leading to management of fungi within the plant. Mancozeb provides a protective film over plant surfaces and inhibits germination of the fungal spores. The effectiveness of Metalxyl MZ as disease management practice for the management of heart rot of pineapple caused by *P. parasitica* was reported by Hegde (2015).

As the application of chemical inputs for disease management and prevention considered being costly and hazardous to the environment, there is an increasing tendency to use microorganisms as an alternative approach for plant disease management (Deberdt *et al.,* 2008; Hanada *et al.,* 2009). In cocoa, several works had successfully used microorganisms for the control of pod rot (Peter and Chandramohanan, 2014). The application of microorganisms in integrated disease management is attractive to producers, as they consider it as one of the safest and most affordable management strategies. However, field results may vary with different agro-ecological conditions, and the complete control of the disease is not achieved (Ndoumbe-Nkeng *et al*., 2004). Besides, it is necessary to evaluate the real economic benefit

Table 2. Cost economics of management of pod rot of cocoa

Sl. No.	Treatments	Cost economics (₹ ha^{-1}) PDI pooled	Yield (kg ha^{-1})	Total expenditure (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit cost (BC) ratio
1.	Metalaxyl MZ 68 WP @ 0.2%	13.4(21.5)	537.2	16,200.00	80,757.00	64,557.00	4.0
2.	Mancozeb @ 0.25%	23.0(28.7)	441.1	15,500.00	66,363.00	50,863.00	3.3
3.	Bordeaux mixture 1%	23.4(28.9)	446.3	18,500.00	67,482.00	48,982.00	2.6
4.	*P. fluorescens* @ 1%	26.3(30.8)	441.74	15,500.00	66,246.00	50,746.00	3.3
5.	Potassium Phoshonate @ 0.3%	31.4(34.1)	428.7	15,450.00	64,467.00	49,017.00	3.2
6.	Bordeaux mixture 1% - *Pseudomonas fluorescens* @ 1%	26.0(30.6)	433.6	16,950.00	65,373.00	48,423.00	2.8
7.	Metalaxyl MZ 68WP @ 0.2% - *Pseudomonas fluorescens* @ 1%	20.1(26.6)	518.2	15,850.00	77,857.00	62,007.00	3.9
8.	Mancozeb @ 0.25% - *Pseudomonas fluorescens* @ 1%	24.9(29.9)	436.2	15,500.00	65,668.00	50,168.00	3.2
9.	Untreated control	46.2(42.8)	337.3	15,000.00	50,887.00	35.887.00	2.4
	SEm +	1.3	4.2				
	CD @ 5%	3.3	12.88				

derived from biocontrol strategies versus chemical control regarding cocoa yield.

Some plant growth-promoting bacteria have been used as antagonists against *Phytophthora*, such as *P. aeruginosa* (Bhavani *et al*., 2007) and *P. fluorescens* (Bhavani *et al.,* 2005). *P. fluorescens* is a proven biological control agent wherein; they control several fungal and bacterial disease in cereals, horticultural crops, oilseeds and other crops. The efficacy of bacterial antagonism in controlling diseases was often better than with fungicides. However, the bacterial antagonism, in combination with fungicides, sometimes improved efficacy in controlling diseases (Ganeshan and Manoj Kumar, 2005). Individual members of the *P. fluorescens* are potential agents for the biocontrol which suppress plant diseases by protecting the seeds and roots from fungal infection. They are known to enhance plant growth promotion and reduce the severity of many fungal diseases. This effect is the result of the production of several secondary metabolites, including antibiotics, siderophores and hydrogen cyanide. Haas and Defago (2005) reported the mechanisms by which *P. fluorescens* control pathogenic microorganisms in detail. Competitive exclusion of pathogens as the result of rapid colonization of the rhizosphere by *P. fluorescens* may also be an important factor in disease management.

Conclusion

The two sprays with Metalaxyl MZ 68WP at 0.2 per cent was found very promising in pod rot management of cocoa followed by sequential spray with Metalaxyl MZ 68WP @ 0.2 per cent and *P. fluorescens* @ 1 per cent. Thus, under a high disease pressure, the farmers can use Metalaxyl MZ 68WP at 0.2 per cent and under low to moderate disease pressure farmers can make use Metalaxyl MZ 68WP at 0.2 per cent in integration with *P. fluorescens* @ 1 per cent.

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