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Bio-Intensive Intervention of Pest, Drought Management, and Deterring Crop Raiding Wild Elephants in Small Cardamom Plantation

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ABSTRACT: Bio-intensive IPM incorporates ecological and economic factors into agricultural system design and decision-making and addresses public concerns about environmental quality and food safety. The benefits of implementing bio-intensive IPM can include reduced chemical input costs, reduced on-farm and off-farm environmental impacts and more effective and sustainable pest management in small cardamom plantation. An experiment was conducted in the year of 2021 to 2023 for evaluation of different modules for Bio-Intensive Intervention of Pest, Drought Management, and Deterring Crop Raiding Wild Elephants in Small Cardamom Plantation. The present study thus revealed that combination formulation of *B. bassiana + B. thuringiensis* and *Bacillus thuringiensis var kurstaki* were promising against stem borer, panicle and capsule borer coupled with safety to its larval parasitoid, *Apanteles taragamae* and Friona sp and can be opted for inclusion as component in the Integrated Pest Management in Small cardamom. Soil application of the fungus granules reduced capsule damage by thrips significantly compared to control, whereas spray application of the fungus was ineffective. EPNs constitute a cost-effective, value-added approach to promote sustainable agriculture in small cardamom plantation. PPFM association with plant growth can be exploited for eco-friendly and cost-effective practices to promote sustainable agriculture in small cardamom plantation.
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KEYWORDS: Bio-Intensive Intervention of Pest, Drought Management, *Conogethes sp., Elettaria cardamomum*, parasitoids, small cardamom

India has been acclaimed as the land of spices from the time immemorial. Black pepper, rightly called as king of spices is one of the most important and most widely used spices in the world (Ravindran 2000). Cardamom across the world recognized as the queen of spices because of its very pleasant ar oma and taste, and is a native of the moist tropical evergreen forest of the Western Ghats (WG) in southern India. The WG also considered as center of origin and diversity for black pepper (Ravindran 2002). Among pests shoot and capsule borer, thrips, root grub, whitefly, nematodes a nd diseases like capsule and panicle rot, clump rot, Fusarium rot, leaf blight and viral diseases are reported as major threats to commercial cardamom cultivation. Likewise, pests like pollu beetle, scales, top shoot borer, thrips and root mealy bugs as well as diseases such as foot rot, slow wilt, fungal pollu and viral diseases contribute to the loss of black pepper. Indiscriminate use of synthetic pesticides to manage these pest and diseases results in tr emendous buildup of residues in export oriented produce, which has recently invited debate and queries. This had significantly affected the world wide acceptability of the king and queen of spices. Now, the demand for organic spices is growing among consumers at the rate of 20% annually (Krishnakumar 2015). The mission at the moment is to capture India's pre-eminent position as spice bowl of the

world by producing and exporting safer spices and spice products to the world market. For safer and continuous higher sustainable production, attention is needed on good agricultural practices through eco-friendly management of pests and diseases. If India to r ecapture its lost glory of spices, there should be considerable sincere efforts to achieve a quantum jump in the productivity of cardamom and black pepper through adoption of physical/cultural and biological/botanical tools that allow co-existence of natural enemies and beneficial microorganisms which in turn bring backs the ecosystem balance in cardamom and black pepper production system

1. INTRODUCTION

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Cardamom across the world recognized as the queen of spices because of its very pleasant aroma and taste, and is a native of the moist tropical evergreen forest of the Western Ghats (WG) in southern India. The WG also considered as center of origin and diversity for black pepper (Ravindran 2002). Among pests shoot and capsule borer, thrips, root grub, whitefly, nematodes and diseases like capsule and panicle rot, clump rot, Fusarium rot, leaf blight and viral diseases are reported as major threats to commercial cardamom cultivation.. Indiscriminate use of synthetic pesticides to manage these pest and diseases results in tremendous buildup of residues in export oriented produce, which has recently invited debate and queries. This had significantly affected the world wide acceptability of the king and queen of spices. Now, the demand for organic spices is growing among consumers at the rate of 20% annually (Krishnakumar 2015). The mission at the moment is to capture India's pre-eminent position as spice bowl of the world by producing and exporting safer spices and spice products to the world market. For safer and continuous higher sustainable production, attention is needed on good agricultural practices through eco-friendly management of pests and diseases. If India to recapture its lost glory of spices, there should be considerable sincere efforts to achieve a quantum jump in the productivity of cardamom through adoption of physical/cultural and biological/botanical tools that allow co-existence of natural enemies and beneficial microorganisms which in turn bring backs the ecosystem balance in cardamom and black pepper production system.

2. MATERIALS AND METHODS:

A field experiment was conducted in small cardamom plantation at Idukki district of Kerala for two year and an area for 5 ha to evaluate the efficacy of bio-intensive intervention of pest, drought management, and deterring crop raiding wild elephants in small cardamom. Three IPM modules are formulated and the details mentioned below along with the control.

1. Assessment of different biological control agents for the management of pests in small cardamom

Treatments and design of layout the experiment was conducted at Small cardamom plantation in Idukki, Kerala in a Randomized Block Design (R.B.D.) with five treatments, each consisting of three replicates. To determine the efficacy of bio-pesticides, seven sprays were conducted on small cardamom. First spray was done at Panicle initiation stage and second to five sprays was done after 20 days of first spray. The details of treatments with respective dose and method of application has been given in Table 1,2&3.

Three replications are followed for each module to evaluate under Randomized Block Design (RBD) (Pazhanisamy, 2015). The common practices which followed for all the modules.

1. **Stem and Capsule borer**

$$\text{Percent reduction of Stem/Capsule borer} = \frac{\text{Number of stem /capsule infected}}{\text{Total number of stem/Capsule}} \times 100$$

2. **Thrips:**

$$\text{Percent reduction of thrips population} = \frac{\text{Number of Panicle/capsule infected}}{\text{Total number of Panicle/capsule}} \times 100$$

3. **Root grub:**

$$\text{Percent reduction of root grub population} = \frac{\text{Number of plants infected}}{\text{Total number of plants}} \times 100$$

The mean original data of percentage e pod damage was calculated as percentage reduction over with the following formula (Abbott's 1925) $C - T$ Percent Reduction $= \frac{}{} \times 100\ C$

2. Drought mitigation management in small cardamom

The trials of the application of foliar sprays with PPFM and potassium silicates were conducted in

small cardamom plantation.. The vast majority of these experiments were conducted in a randomized complete block design (RCBD) with at least three replications.

3. Assessment of Different Innovative Technologies for Deterring Crop Raiding Wild Elephants

To1-Solar-powered fences to protect fields from elephants,To2-Solar based Krishi Rakshak system is very effective in driving-off the animals from the fields and keeping them away. The device automatically get switch on based on the system time or can be switched on manually using smart phone.,To3-Spray of Panchagavya based herbal extract of small cardamom plantation to keep the crop raiding wild elephant not entered in the field and To4-Place of Bee box to keep away the wild elephants in small cardamom plantation.

3. RESULTS AND DISCUSSION:

The mean population of **stem borer, panicle and capsule borer** larvae in different treatments before and at different intervals after spray is presented in Table 1. The incidence of **stem borer, panicle and capsule borer** before spraying ranged from 1.6 to 2.1 larvae/plant. There was significant reduction in **stem borer, panicle and capsule borer** population after spraying of the microbial and botanical over untreated control.

The results indicate (Table-1) that the efficacy of Btk @1.5ml/L and combination formulation of *Beauveria bassiana + Bacilus thuringiensis* @2mL/L were at par with *Metarhizium anisopliae* in reducing stem borer, panicle and capsule borer (0.0 to 0.1 and 0.0 to 0.3 larvae/plant, respectively) and superior over botanicals and untreated control. The results from the pooled mean data after spray revealed that *Beauveria bassiana + B. thuringiensis* @ 2mL/L was superior and effected 51% reduction in larval population of stem borer, panicle and capsule borer over untreated check followed by Btk (39.5%) and *Beauveria bassiana* @ 10gm/L (39.7%) (Naik DJ et al,.2006).

Combined analysis of data for two years indicated (Table-2) that all the treatments were significantly effective in reducing the damage caused by cardamom thrips on the capsules when compared to control. Plots treated with *Lecanicillium psalliotae* recorded the percentage reduction of 62.90 % that was on par with *Lecanicillium lecanii* 48.4 %, *Lecanicillium saksenae* 51.40 % and Neem Soap 41.90%. The trials indicated that three rounds of soil application of the fungus and spray application of *Lecanicillium psalliotae* reduced stem, Panicle and capsule damage by thrips significantly (Senthil Kumar et al., 2018).

Table 1: Effect of microbial, botanical, parasites on stem borer, panicle and capsule borer (*Conogethes punctiferalis*) in Small Cardamom

Treatments	Shoot Damage (%)						Panicle Damage (%)						Capsule Damage (%)						%Reduction
	PTC	20 DAT	40 DAT	60 DAT	80 DAT	120	PTC	20 DAT	40 DAT	60 DAT	80 DAT	120	PTC	20 DAT	40 DAT	60 DAT	80 DAT	120	
Btk@1.5ml	30.6	27.0	24.2	23.5	21.0	20.1	41.2	31.2	29.1	28.1	28.0	26.4	34.1	31.2	29.2	28.2	27.1	25.7	39.50
B.bassiana + B. thuringiensis@2 ml	32.2	21.2	19.5	18.6	15.5	14.2	30.10	26.4	23.1	22.1	19.2	16.2	31.1	24.0	21.0	17.0	14.0	12.0	51.00
Beauveria @10gm *bassiana*	31	26.0	23.0	21.0	19.0	16.0	36.0	30.0	29.0	27.5	27.5	26.0	32.0	30.0	28.0	26.0	25.4	24.5	39.7
Metarhizium anisopliae@10g m	39	34.0	33.2	32.0	31.0	29.0	33.0	32.5	31.5	30.0	29.4	28.0	34.0	31.0	29.0	28.4	26.0	23.0	36.0
Neem Soap @10gm	32	29.0	26.0	25.4	24.5	23.0	31.0	29.0	28.5	26.4	24.2	23.0	32.0	29.2	26.2	24.2	23.4	21.4	32.0
Apanteles taragamae	38	35.0	35.0	33.0	32.0	31.0	35.0	34.0	31.0	30.1	28.0	24.0	33.0	31.0	29.0	27.0	24.0	20.0	29.0
Friona sp	30	29.0	27.0	26.5	25.0	24.0	38.0	35.0	31.0	27.0	24.0	19.0	38.0	24.0	22.0	21.0	20.0	18.0	34.0
Control Water spray	35	39.0	41.0	46.0	47.0	48.0	40.0	42.0	47.0	49.0	50.0	51.0	41.0	42.0	43.0	49.0	52.0	54.0	-

Table 2.Effect of microbial and neem oil products for the control of cardamom thrips *Sciothrips cardamomi* Ramk in small cardamom

Treatments	Stem Damage (%)					Panicle Damage (%)					Capsule Damage (%)					
	20 DAT	40 DAT	60DAT	80 DAT	120 DAT	20 DAT	40DAT	60DAT	80 DAT	120 DAT	20 DAT	40DAT	60DAT	80 DAT	120 DAT	%Reduction
Lecanicillium psalliotae	21.4	22.0	20.0	18.0	19.0	13.0	11.0	14.0	9.0	8.0	9.0	9.7	8.6	8.2	7.7	62.9
Lecanicillium lecanii	24.0	25.0	23.0	26.0	21.6	19.0	19.0	16.0	16.0	14.0	19.0	17.7	18.6	18.2	16.7	48.4
Lecanicillium saksenae	23.0	21.0	20.0	21.0	21.0	18.0	17.0	14.0	16.0	14.0	17.0	16.	14.6	15.2	14.7	51.4
Neem Soap @10gm	22.4	32.0	31.20	30.70	28.0	31.0	32.0	29.4	28.0	29.2	27.7	26.0	25.7	26.8	26.1	41.9
Control Water spray	48.6	42.1	48.2	46.2	48.4	68.4	64.2	67.5	69.0	71.0	72	76	81	86	79	-

Table 3. Effect of eco-friendly treatments on root grub population for the control of cardamom root grub *Basilepta fulvicorne* in small cardamom

Treatments	Dose / ha	Percentage of reduction over pretreatment				Percentage of reduction over untreated control			
		15 DAT	30 DAT	45 DAT	60 DAT	15 DAT	30 DAT	45 DAT	60 DAT
T1- ICAR-NBAIR EPN (*Heterorhabditis indica*)	8 x 109 nematodes / ha	20.00	30.0	65.00	95.00	10.0	40.0	60.0	87.0
T2- ICAR-NBAIR *Heterorhabditis bacteriophora*	8 x 109 nematodes / ha	15.00	25.00	36.00	65.75	15.0	38.0	75.0	79.0
T3- ICAR-NBAIR *Steinernema carpocapsae*	8 x 109 nematodes / ha	6.75	10.20	32.00	45.70	20.0	32.00	65.0	70.0
Untreated control		-	-	-	-	-	-	-	-

The results indicate (Table-3) that the highest (12.05 % & 20 %) grub population reduction was recorded *Heterorhabditis indica* on 15th day after application followed by *Heterorhabditis bacteriophora* (5.65 % & 15.0%) and *Steinernema carpocapsae* (4.15 % & 6.75%) as compared to untreated check. On 30 days after application, *Heterorhabditis indica* , *Heterorhabditis bacteriophora* and *Steinernema carpocapsae* were significantly effective in reducing root grub population to the tune of 35 %,25 % and 10% respectively as compared to untreated. On 45 days after application, *Heterorhabditis indica* , *Heterorhabditis bacteriophora* and *Steinernema carpocapsae* were significantly effective in reducing root grub population to the tune of 65 %,36 % and 32% respectively as compared to untreated.

Table 4. Effect of effects of the different foliar sprays with PPFM and Potassium silicate in Small cardamom

Parameters	PPFM	Potassium silicate	Uncontrolled
% reduction in Fusarium disease	45	32	21
Days of Irrigation	45 days once during summer	25 days once during summer	7 days once during summer
Number tiller/plant	57-62 per plant	48-51	30-36
Number panicle/plant	228	192	161
Gross cost (Rs/ha)	322000	354000	374000
Gross Return (Rs/ha)	736000	612500	477000

The trial indicate that (Table 4) the PPFM as Microbial Farmers on Small cardamom plantation like little farmers, methylotrophic bacteria play an important role in plant growth and 35 percentage yield increased at par with Potassium silicate . 5L of PPFM recommended per ha for 45 days to help plants to endure water stress. Pink pigmented facultative methylotrophic and PSB significantly recorded maximum plant height, number of panicle and length of panicle, number of capsule and root length of small cardamom plantation. Methylobacterium inoculation was found to increase the photosynthetic activity by enhancing the number of stomata, chlorophyll concentration and malic acid content of crops 45 percent reduced the disease incidence of Fusarium in small cardamom plantation.

Table 4. Effect of effects of the different foliar sprays with PPFM and Potassium silicate in Small cardamom

Parameters	To 1	To 2	To 3	To 4
No. of wild animals raids	14	1	3	8
Per cent of crop damage	68	15	31	43
Yield q/ha	3.8	6.5	5.9	4.1
Gross cost (Rs.)	550000	690000	690000	590000
Gross return (Rs.)	850000	1480000	1200000	1010000
Net return (Rs.)	300000	790000	510000	489000
BC ratio	1.54	2.14	1.73	1.71

The Solar based Krishi Rakshak was recorded highest yield of 6.5 t/ha and Panchagavya based herbal extract with 5.9 t/ha as compared to Demon - FP (3.8 t/ha). It was 21.45 % higher yield than the Farmers practice.The Net income obtained in T2 – Krishi Rakshak was Rs. 790000 /ha and T3- Panchagavya based herbal extract was Rs. 510000 /ha while the check T1- Demon was of Rs. 300000/ha and Higher B:C ratio of 2.14 in T2 as compared to T1 check: 1.54.

4.CONCLUSION:

Chemical insecticides probably continue to be the most effective control strategy to date. However, their detrimental effects are a cause of public concern, which calls for rationalized use of insecticides and reorientation of protection strategies towards ecologically sound pest management. The present study thus revealed that combination formulation of *B. bassiana + B. thuringiensis* and *Bacillus thuringiensis var kurstaki* were promising against stem borer, panicle and capsule borer coupled with safety to its larval parasitoid, *Apanteles taragamae* and Friona sp and can be opted for inclusion as component in the Integrated Pest Management in Small cardamom. The application of methylotrophs as bio-inoculants is common, and their use as an alternative to chemical fertilizers is also increasing. Their association with plant growth can be exploited for eco-friendly and cost-effective practices to promote sustainable agriculture. small cardamom farmers, by the following observations:(1) Foliar application of PPFMs to small cardamom during summer period which enhance the plant growth and increase yield, (2) Treated plants to decrease disease incidence of Fusarium disease caused by Fusarium oxysporum in small cardamom,(3)The PPFMs inoculation induced number of stomata, chlorophyll concentration and malic acid content and led to increased photosynthetic activity,(4)Screening of such kind of bacteria having immense plant growth promoting activities like nitrogen fixation, phytohormone production, alleviating water stress to the plants can be successfully isolated and characterized and integration of such kind of organism in crop production will lead to 35% increased productivity in small cardamom plantation. The farmers harvested small cardamom, recorded highest yield of 6.5 t/ha with an yield advantage of 32.0 % over the check plot (3.8 t/ha). The net income for the demo plot was Rs. 790000 /ha while the check plot was Rs. 300000 /ha with higher B:C ratio of 2.41 (check:1.54).Bio-intensive pest and disease management methods followed and reduce the incidence of pest, disease and helped in mitigating the drought.

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