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## Integrating biological pest management, drought resilience, and elephant deterrence for sustainable small-scale cardamom production

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### Abstract

Bio-intensive integrated pest management (IPM) integrates ecological and economic considerations into the design and decision-making of agricultural systems, addressing public concerns regarding environmental quality and food safety. Implementing such approaches in small-scale cardamom plantations can lower chemical input expenses, diminish on-farm and off-farm ecological footprints, and provide more effective, sustainable pest control. A field trial conducted from 2021 to 2023 evaluated several bio-intensive modules aimed at managing pests, drought, and wild-elephant crop raiding in cardamom. Results indicated that a combined formulation of *Beauveria bassiana* and *Bacillus thuringiensis* (including the *kurstaki* strain) effectively suppressed stem, panicle, and capsule borers while remaining safe to the larval parasitoids *Apanteles taragamae* and *Friona* spp., making it suitable for inclusion in cardamom IPM programs. Soil-applied fungal granules significantly reduced thrips-induced capsule damage compared with the untreated control, whereas foliar sprays of the same fungus were ineffective. Entomopathogenic nematodes (EPNs) offer a cost-effective, value-added tool for promoting sustainable cardamom agriculture. Additionally, plant-growth-promoting microbial formulations (PPFM) can be leveraged for eco-friendly, economical practices that support sustainable cardamom production.

**Keywords:** Bio-intensive intervention of pest, drought management, *Conogethes* sp., *Elettaria cardamomum*, parasitoids, small cardamom

### Introduction

Cardamom, celebrated worldwide as the “queen of spices” for its distinctive aroma and flavor, originates from the moist tropical evergreen forests of India’s Western Ghats a region also regarded as the centre of origin and diversity for black pepper. Commercial cardamom production faces several major constraints, including shoot and capsule borers, thrips, root grubs, whiteflies, nematodes, and a suite of diseases such as capsule and panicle rot, clump rot, Fusarium rot, leaf blight and various viral infections. The indiscriminate application of synthetic pesticides to control these pests and pathogens has led to elevated residue levels in export-oriented produce, prompting growing regulatory and consumer concerns. Consequently, the global reputation of this premium spice has been challenged. Meanwhile, demand for organic spices is expanding at roughly 20% per year (Krishnakumar, 2015) [8]. To re-establish India’s leadership as the “spice bowl of the world” and supply safer products to international markets, a shift toward sustainable, higher-yield production is essential. This will require the adoption of good agricultural practices that emphasize eco-friendly pest and disease management, integrating physical, cultural, biological and botanical tools that conserve natural enemies and beneficial microorganisms, thereby restoring ecosystem balance in cardamom and black-pepper systems.

### Materials and Methods

A two-year field trial was carried out on a 5-hectare small-scale cardamom farm in Idukki, Kerala, to assess the performance of a bio-intensive approach targeting pests, drought stress, and

wild-elephant damage. Three integrated-pest-management (IPM) packages were designed and compared with an untreated control.

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

A field trial was carried out in a small-scale cardamom plantation near Idukki, Kerala, using a randomized block design (RBD). The layout comprised five treatments, each replicated three times. Bio-pesticide efficacy was assessed through seven spray applications on the cardamom plants. The initial spray was timed at the panicle-initiation stage, followed by four additional sprays at 20-day intervals. Details of the treatments, including the applied doses and application methods, are presented in Tables 1, 2 and 3.

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

calculated as percentage reduction over with the following formula (Abbott's 1925) Percent Reduction =  $(C - T) / C \times 100$

### 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 Detering 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.

### Results and Discussion

The average numbers of stem-borer, panicle-borer and capsule-borer larvae recorded for each treatment before and at various intervals after treatment are summarized in Table 1. Prior to spraying, the incidence of these borers ranged from 1.6 to 2.1 larvae per plant across the treatments. Following application of the microbial and botanical products, a statistically significant decline in larval populations was observed compared with the untreated control.

**Table 1:** Effect of microbial and botanical pesticides and 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@2ml | 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@10gm       | 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 | -           |

The data (Table 1) show that Btk applied at 1.5 mL L<sup>-1</sup> and a combined treatment of Beauveria bassiana + Bacillus thuringiensis at 2 mL L<sup>-1</sup> performed as effectively as Metarhizium anisopliae in suppressing stem-borer, panicle-borer and capsule-borer larvae (0.0-0.1 and 0.0-0.3 larvae plant<sup>-1</sup>, respectively) and outperformed the botanical treatments and the

untreated control. Pooled post-spray results indicate that the B. bassiana + B. thuringiensis mixture at 2 mL L<sup>-1</sup> achieved the greatest reduction, lowering larval numbers of all three borers by 51% relative to the untreated check, followed by Btk (39.5%) and B. bassiana alone at 10 g L<sup>-1</sup> (39.7%) (Naik *et al.*, 2006) <sup>[4]</sup>.

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

| Treatments               | Stem Damage (%) |        |        |        |         | Panicle Damage (%) |        |        |        |         | Capsule Damage (%) |        |        |        |         | % Reduction |
|--------------------------|-----------------|--------|--------|--------|---------|--------------------|--------|--------|--------|---------|--------------------|--------|--------|--------|---------|-------------|
|                          | 20 DAT          | 40 DAT | 60 DAT | 80 DAT | 120 DAT | 20 DAT             | 40 DAT | 60 DAT | 80 DAT | 120 DAT | 20 DAT             | 40 DAT | 60 DAT | 80 DAT | 120 DAT |             |
| 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      | -           |

A two-year combined analysis (Table 2) showed that every treatment markedly lowered thrips-induced capsule damage compared with the untreated control. The greatest reduction, 62.9%, was recorded in plots treated with *Lecanicillium psalliotae*, which was statistically comparable to *L. lecanii*

(48.4%), *L. saksenae* (51.4%) and neem soap (41.9%). Additionally, three soil applications of the fungal agent followed by a foliar spray of *L. psalliotae* significantly decreased stem, panicle and capsule injury caused by thrips (Senthil Kumar *et al.*, 2018) [1].

**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 ( <i>Heterorhabditis indica</i> ) | 8x10 <sup>9</sup> nematodes / ha | 20.00                                     | 30.0   | 65.00  | 95.00  | 10.0                                           | 40.0   | 60.0   | 87.0   |
| T2- ICAR-NBAIR <i>Heterorhabditis bacteriophora</i>  | 8x10 <sup>9</sup> nematodes / ha | 15.00                                     | 25.00  | 36.00  | 65.75  | 15.0                                           | 38.0   | 75.0   | 79.0   |
| T3- ICAR-NBAIR <i>Steinernema carpocapsae</i>        | 8x10 <sup>9</sup> 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 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                    |

This experimental results indicate that (Table-4) the PPFM plays 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.

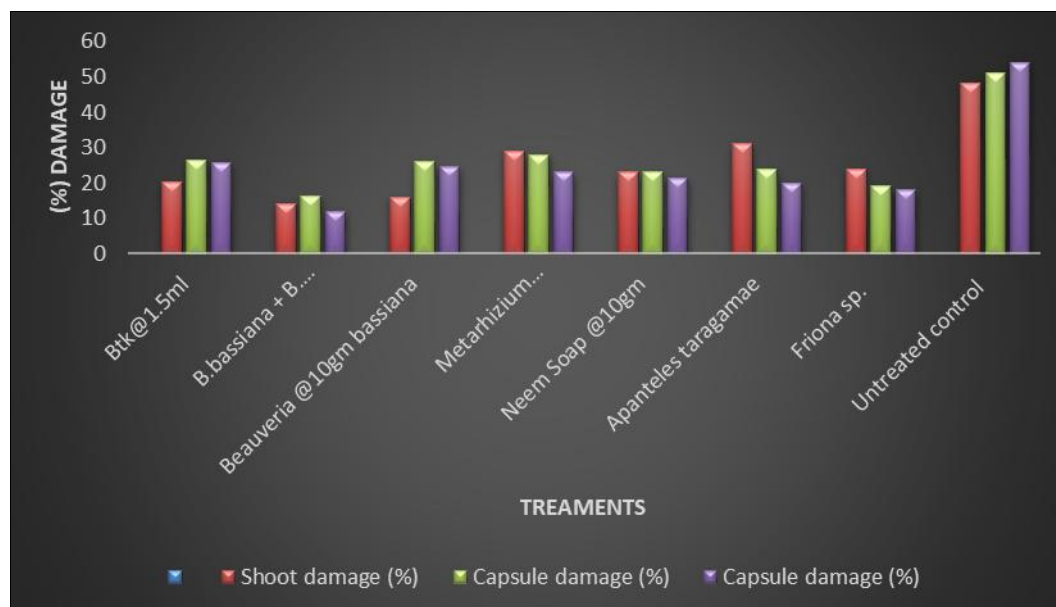


**Fig 1:** Effect of different treatments on shoot and capsule damage (%).

### Conclusion

The study demonstrated that a combined preparation of *Beauveria bassiana* + *Bacillus thuringiensis* and *B. thuringiensis* var. *kurstaki* effectively suppressed stem, panicle and capsule borers while remaining harmless to the larval parasitoids *Apanteles taragamae* and *Friona* spp.; consequently, this mixture is suitable for incorporation into integrated pest-management programmes for small-scale cardamom. Methylo-trophic bacteria are widely employed as bio-inoculants and are increasingly being considered as alternatives to synthetic fertilizers, offering eco-friendly, low-cost options that enhance plant growth and support sustainable agriculture. In the trial, the highest cardamom yield was  $6.5 \text{ t ha}^{-1}$ , representing a 32% increase over the control plot ( $3.8 \text{ t ha}^{-1}$ ). Economic analysis showed a net income of ₹ 790,000  $\text{ha}^{-1}$  for the treated plot versus ₹ 300,000  $\text{ha}^{-1}$  for the untreated plot, yielding benefit-cost ratios of 2.41 and 1.54, respectively. The bio-intensive pest- and disease-management strategies reduced pest and disease incidence and also helped mitigate drought stress.

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### References

1. Senthil Kumar CM, Jacob TK, Devasahayam S, D'Silva S, Kumar NK. Isolation and characterization of a *Lecanicillium psalliotae* isolate infecting cardamom thrips (*Sciothrips cardamomi*) in India. *BioControl*. 2015;60(3):363-373.
2. Askary TH, Ahmad MJ. Entomopathogenic nematodes: Mass production, formulation and application. In: Askary TH, Ahmad MJ, editors. *Biocontrol agents: Entomopathogenic and slug parasitic nematodes*. Wallingford (UK): CABI; 2017. p. 261-286.
3. Dillman AR, Chaston JM, Adams BJ, Ciche TA, Goodrich-Blair H, Stock SP, Sternberg PW. An entomopathogenic nematode by any other name. *PLoS Pathogens*. 2012;8(3):e1002527. <https://doi.org/10.1371/journal.ppat.1002527>

4. Naik DJ, Belavadi VV, Thippesha D, Kumar MD, Madaiah D. Field efficacy of neem products against thrips and capsule borer of small cardamom. In: *Proceedings of the National Symposium on Cardamom Research*; 2006; India. p. 1-6.
5. Chinnadurai C, Balachandar D, Sundaram SP. Characterization of 1-aminocyclopropane-1-carboxylate deaminase producing methylobacteria from phyllosphere of rice and their role in ethylene regulation. *World Journal of Microbiology and Biotechnology*. 2009;25(8):1403-1411. <https://doi.org/10.1007/s11274-009-0020-3>
6. Reeburgh WS. The role of methylo-trophy in the global methane budget. In: Lidstrom ME, Tabita FR, editors. *Microbial growth on C1 compounds*. Dordrecht: Springer; 1994. p. 1-14. [https://doi.org/10.1007/978-94-011-0922-4\\_1](https://doi.org/10.1007/978-94-011-0922-4_1)
7. Josephraj Kumar A, Backiyarani S, Sivakumar G. Fifty years of cardamom research station, Pampadumpara—An update. *Gleanings in Cardamom*. 2007;9:9-18.
8. Krishnakumar NK. Spices Way forward. In: Krishnamurthy KS, Biju CN, Jayashree E, Prasath D, Dinesh R, Suresh J, Babu NK, editors. *Proceedings of the Symposium on Spices, Medicinal and Aromatic Crops (SYMSAC-VIII)*; 2015 Dec 16-18; Coimbatore, India. Coimbatore: Tamil Nadu Agricultural University; 2015. p. 6.