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Bio-intensive pest management of root mealybugs, *Xenococcus annandalei* (Silvestri) in small cardamom plantation

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Abstract
Field experiments were carried out to evaluate the efficacy of certain treatments against the Root melay bugs in 2021 and 2022. Five commercial formulated insecticides were used based on the Ministry of agriculture recommends for each insecticide to control sucking insects under field conditions. The root mealybug, *Xenococcus Annandalei* (Silvestri) was affected differently with the tested insecticides. Significant differences were found between the insecticides in their effects against the populations of nymphs during. After one week, these tests revealed that the most striking reduction in the populations of nymphs was achieved by mineral oil (75.20%) followed by spirotetramat (71.20%), thiamethoxam (60.50%), imidacloprid (59.21%) and *V. lecanii* (24.50%), respectively. After four weeks, the used mineral oil and spirotetramat achieved the highest mean reduction percentages of the treated population exhibiting 81.39 % and 80.46% reduction, respectively. The least effective insecticide against the nymphs was *V. lecanii* as it caused 40.61% reduction in the treated population. During the sunset application, the highest population reduction of the nymphs after four weeks was achieved by the used mineral oil, which caused 95.44% reduction in the treated nymph population. The least effective treatments during the sunset application were *V. lecanii* with 57.02% reduction and imidacloprid with 64.93% reduction, respectively in the treated adult population. The adult population reduction effects after the sunset application were achieved differently according to the tested insecticide as they were arranged in desending order as the following: the used mineral oil, spirotetramat, thiamethoxam, imidacloprid and *V. lecanii* as they respectively reduced the treated population with 86.15%, 85.10%, 76.21%, 71.15 % and 49.50% reduction in the same array.

Keywords: Root mealy bug, *Xenococcus annandalei*, Small cardamom, Insecticides

Introduction

India has become known as the "land of spices" and is one of the world's leading producers and exporters of spices. In addition to contributing 20-25% of the global spice trade, the nation also uses a lot of spices for seasoning and food and other product flavoring (Rathore *et al.*). Approximately sixty of the world's 109 spices are farmed in India (Vinod Kumar Paswan *et al.*). India is fortunate to have a variety of agroclimatic conditions that allow for the growth of most spices, including tropical, subtropical, and temperate varieties. Indian spices are in high demand for export due to their high quality and maximal essential oil, oleoresin, and active principle content. Small cardamom (*Elettaria cardamomum* (L.) Maton, Zingiberaceae) is a premier Indian export spice. Indigenous to the moist evergreen forests of the Western Ghats, it is cultivated intensively for its aromatic capsules in the Cardamom Hills of southern India (Murugan *et al.*, 2013) [11]. India ranks as the world's largest consumer and the second-largest producer, harvesting about 24 463 t of dried capsules from roughly 70 410 ha. Kerala dominates production, accounting for 57 % of the cultivated area (≈ 40 345 ha) and nearly 90 % of the national output (≈ 22 165 t), followed by Karnataka (35 % of the area) and Tamil Nadu (7%). The Cardamom Hill Reserves in Idukki district, Kerala, form a high-altitude evergreen rainforest bounded by the Periyar Tiger Reserve to the south, the Munnar highlands to the north, the Idukki Reserve Forest to the west, and the Cumbum-Kothakudy valleys to the east (Kuruvila *et al.*, 2022) [9]. India ranks as the world's second-largest exporter and a major consumer of cardamom, shipping on average 1850 t per year during 2019-20. Over recent decades, rising cardamom output has been accompanied by a sharp increase in the use of synthetic fertilizers and pesticides. Consequently, India's share of global cardamom exports fell from 28 % in 1988 to 9 % in 2020 by volume, and from 42.5 % to 9 % by value, with trade now largely confined to Middle-Eastern markets. In 2019, India's deliveries to Saudi Arabia declined after several consignments were rejected because of excessive pesticide residues. The heightened vulnerability of cardamom to insect pests and diseases is now seen as a key obstacle to sustainable production in the country. Among more than 56 recorded insect species (Gopakumar and Chandrasekar, 2002) [11] attacking various parts of the plant, the shoot and capsule borer (*Conogethes punctiferalis*), the cardamom thrips (*Sciothrips cardamom*), the root grub (*Basilepta fulvicornis*), Mealybugs (*Xenococcus annandalei*)and the whitefly (*Singhiella cardamom*) are responsible for the greatest insecticide demand (Murugan *et al*., 2013) [11]. Mealybugs are serious pests that also act as vectors for numerous plant diseases. They feed by extracting sap, injecting toxins, and excreting honey-dew, which promotes sooty-mould growth and impairs photosynthesis. Among them, root mealybugs feed on the roots and fine rootlets, causing stunted growth, yellowing, loss of vigor, and eventual plant death. These insects are frequently tended by ants, which are attracted to the sugary honey-dew they produce. Recent reports indicate a rise in root-mealybug infestations in small-cardamom nurseries and newly transplanted fields. Growers currently rely on a soil drench of the organophosphate dimethoate 30 EC (3.3 ml L^{-1} water) to control the pest, a practice that has been in use since 1992. Because of the risk of resistance development and potential resurgence, an alternative strategy is needed. This study therefore evaluated 97 insecticides and insecticide combinations as possible replacements for dimethoate 30 EC in managing root mealybugs.

Nature of damage and host range

The mealybug has been recorded on a broad range of host plants, spanning 14 families and 18 species, with 17 of those species representing new host records. Economically significant crops such as cardamom (*Elettaria cardamomum*, Zingiberaceae), black pepper (*Piper nigrum*, Piperaceae), coffee (*Coffea arabica*, Rubiaceae), cocoa (*Theobroma cacao*, Malvaceae), tea (*Camellia sinensis*, Theaceae), nutmeg (*Myristica fragrans*, Myristicaceae), banana (*Musa* spp., Musaceae), wild jack (*Artocarpus hirsutus*, Moraceae), jackfruit (*Artocarpus heterophyllus*, Moraceae), ginger (*Zingiber officinale*, Zingiberaceae), turmeric (*Curcuma longa*, Zingiberaceae) and mango (*Mangifera indica*, Anacardiaceae) have all shown infestation. Typical symptoms include yellowing followed by wilting, and heavy attacks can lead to complete desiccation of the plant. Additional hosts include coral tree (*Erythrina indica*, Fabaceae), garden croton (*Codiaeum variegatum*, Euphorbiaceae), and several weed species such as hen's nettle (*Lecanthus interrupta*, Urticaceae), black nightshade (*Solanum nigrum*, Solanaceae), *Ficus obtusa* (Euphorbiaceae) and coat-buttons (*Tridax procumbens*, Asteraceae). Population dynamics vary with season: during the rainy period the insects concentrate in the upper soil layer (5-15 cm), whereas in cold, dry conditions they move deeper (up to 60 cm). Because the pest is cryptic and often tended by ants, thorough inspection of planting material and implementation of appropriate management practices are essential to limit its spread to pest-free regions. Regular field monitoring is therefore crucial for early detection and intervention.

Materials and Methods

The study was carried out at the Krishi Vigyan Kendra in Idukki, Kerala from 2021 to 2023 to assess the efficacy of several commercial insecticides against the root mealybug of small cardamom. A set of water-drenched seedlings was kept as an untreated control. The tested products were Imidacloprid 17.8 SL, Thiamethoxam 12.6 SL, Spirotetramat 11.01 % + mineral oil, and *Verticillium lecanii*. The experiment followed a randomized block design with five replications; each replication contained ten plants. Before applying any treatment, two plants per replication were chosen at random. The nursery bags were opened carefully, and the root-soil medium was examined with a 10× hand lens. Live mealybugs were counted using a fine brush to stimulate movement, and the numbers were recorded as the pre-treatment baseline. Treatments were applied as a 30 ml soil drench to the base of each bag. Subsequent live-bug counts were performed weekly using the same procedure, and the results were compared with the initial counts to determine treatment effectiveness. Data were analyzed according to standard statistical methods for a randomized block design.

Results and Discussion

The present study investigated the impact of various insecticides applied as a foliar treatment against the nymph and adult of root mealybug, *Xenococcus Annandalei* (Silvestri) during 2021 and 2022 seasons. In the past decade, the economic losses resulting from root mealybug infestations have increased.

Table 1: Effect of different foliar applied insecticides on the population of root mealybug, *Xenococcus Annandalei* (Silvestri) in small cardamom plantation

Time of Application	Mean population of nymphs per plants before after different periods of spray											
	Mineral oil		Spirotetramat		Thiamethoxam		Imidacloprid		*V. lecanii*		Control	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
First week	21.76	16.36	22.58	16.08	16.35	9.89	21.33	12.63	23.54	5.77	22.58	-
Second Week	36.95	29.60	37.88	31.10	39.32	28.11	35.69	21.81	32.44	14.02	35.89	-
Third week	41.85	35.20	28.65	23.84	35.42	25.95	29.47	20.11	38.31	17.34	34.74	-
Fourth week	66.35	57.16	62.55	53.23	60.87	46.39	65.55	46.64	68.24	33.87	65.32	-

Table 2: Effect of different foliar applied insecticides on the percentage reduction of root mealybug, *Xenococcus Annandalei* (Silvestri) in small cardamom plantation

Time of Application	Mean population of percentage reduction of (nymphs / plants) after different periods of spray						Mean no. of interval days
	Mineral oil	Spirotetramat	Thiamethoxam	Imidacloprid	*V. lecanii*	Control	
First week	75.20	71.20	60.50	59.21	24.50	24.91	40.06 d
Second Week	80.10	82.10	71.50	61.12	43.21	26.12	53.49 c
Third week	84.12	83.21	73.25	68.25	45.25	27.15	63.52 b
Fourth week	86.15	85.10	76.21	71.15	49.50	29.16	66.19 a

*Means followed with the same letter (s) are not significantly different from each other at P= 0.05.

The root mealybug, *Xenococcus Annandalei* (Silvestri) was affected differently with the tested insecticides. Significant differences were found between the insecticides in their effects against the populations of nymphs during. After one week, these tests revealed that the most striking reduction in the populations of nymphs was achieved by mineral oil (75.20%) followed by spirotetramat (71.20%), thiamethoxam (60.50%), imidacloprid (59.21%) and *V. lecanii* (24.50%), respectively. After four weeks, the used mineral oil and spirotetramat achieved the highest mean reduction percentages of the treated population exhibiting 81.39 % and 80.46% reduction, respectively. The least effective insecticide against the nymphs was *V. lecanii* as it caused 40.61% reduction in the treated population. During the sunset application, the highest population reduction of the nymphs after four weeks was achieved by the used mineral oil, which caused 95.44% reduction in the treated nymph population. The least effective treatments during the sunset application were *V. lecanii* with 57.02% reduction and imidacloprid with 64.93% reduction, respectively in the treated adult population. The adult population reduction effects after the sunset application were achieved differently according to the tested insecticide as they were arranged in descending order as the following: the used mineral oil, spirotetramat, thiamethoxam, imidacloprid and *V. lecanii* as they respectively reduced the treated population with 86.15%, 85.10%, 76.21%, 71.15 % and 49.50% reduction in the same array. For the successful management of any pest in question, resistance monitoring is required. The use of conventional pesticides against Mealybug has been proved unsatisfactory and is difficult as the pest is covered with the waxy material (Joshi *et al*., 2010) [13]. By knowing the levels of resistance developed by a particular pest against any insecticide, it becomes easier to tender suggestion of appropriate insecticides for effective management. The chemical control of Mealybug provides rapid control of the pest it also threatens natural enemies of the pest and predators leaving hazardous effects for human beings. According to Dhawan *et al*. (2009) [15], the best combination for lowering pest infestation was spirotetramate (12%) + imidacloprid (36%) @ 625 ml/ha. After ten days of application, profenophos alone resulted in the greatest reduction in mealybug infestation, at 96.5%. Sanghi *et al*. (2015) found that Prophenophos was quite successful in lowering the mealybug population, with 97% mortality after the seventh day of the post-treatment period. Imidacloprid and Dimethoate were next, with 90.8 and 82% mortality, respectively. Several researcher reported that citrus pests are among the numerous crops that mineral oils have long been used to combat (Buteler and Stadler, 2011) [16]. Because mineral oils are less poisonous to beneficial insects than traditional synthetic insecticides, they were considered safer and more environmentally friendly. Despite the precise cause of mineral oil toxicity is unknown, some research has indicated that oils may obstruct insects' spiracles, resulting in suffocation death (Helmy *et al*. 2012) [18]. Cranshaw and Baxendale (2011) [17] reported that oils can interfere with normal insect metabolism and feeding behavior by interacting with fatty acids.

Conclusion

The present investigation specifically indicated that mineral oil (75.20%) followed by spirotetramat (71.20%), were significantly higher in root mealybug suppression in small cardamom plantation during summer conditions. The same conclusion was drawn from a number of workers, both in India and abroad, as evidenced by field and laboratory studies against root mealy bugs of different crops. Mineral oil and Spirotetramat may therefore be the best option and, in its absence, imidacloprid may be an alternative for the management of small cardamom root mealybug.

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