Indian Journal of Ecology (2025) 52(6) (SI): 1890-1897
DOI: https://doi.org/10.55362/IJE/2025/4750

Manuscript Number: 4750
NAAS Rating: 5.38

First Report of Invasive Nesting Whiteflies (*Paraleyrodes* spp.) Infesting Small Cardamom and Management Strategies

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***Abstract*:** Invasion and establishment of Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae) and nesting whitefly, *Paraleyrodes minei* Iaccarino (Hemiptera: Aleyrodidae) were recorded on small cardamom for the first time in different agro-climatic zones in Kerala, Karnataka and Tamil Nadu of South India. Identities of the species were confirmed through morphological and molecular characteristics. Partial sequences of cytochrome c oxidase I gene (658 bp) for *P. bondari* (PV163890) and *P. minei* (PV163877) were submitted to GenBank, NCBI, India. The incidence of these whiteflies in different agro-climatic zones and their varietal screening in different prevailing varieties and land races of small cardamom indicated that the infestation of *P. bondari* was higher than *P. minei*. Seasonal incidence of both *P. bondari* and *P. minei* population was peaked during November to March, declined during April to May and were negligible during June to October in Cardamom Hill Reserve, Kerala. Rainy days for *P. bondari* and *P. minei* was negatively and significantly correlated with invasive whiteflies population. Field evaluation with few novel insecticides revealed that spinetoram 12% SC @ 0.45 l/ha reduced whitefly populations by > 90% in small cardamom crop.

Keywords: Cardamom, Management, Molecular analysis, Screening, Seasonal incidence, Whiteflies

Small cardamom, *Elettaria cardamomum* (L.) Maton also known as “Queen of Spices” is a high valued spice for its aromatic seeds. It is mainly grown in evergreen forests of the Western Ghats of Kerala, Karnataka and Tamil Nadu of South India and is the third most remunerative spice crop next to saffron and vanilla. The Cardamom Hill Reserve (CHR) of Idukki district of Kerala contributes 70% of the production followed by Karnataka (20%) and Tamil Nadu (10%). Nearly 60 species of insect pests have been reported in small cardamom. Among them, cardamom thrips, *Sciothrips cardamomi* (Ramk.) and shoot/panicle/capsule borer, *Conogethes* sp are major insect pests, occurring throughout the year whereas root grub, *Basilepta fulvicorne* (Jacoby) and plant parasitic nematode, *Meloidogyne* spp. are considered to be seasonal pests. Red spider mite, whitefly, scales, lace-wing bug and aphid are minor insect pests reported as emerging pests of small cardamom. Cardamom is an export orientated crop and always faces the problem of pesticide residues due to intensive cultivation with heavy application of pesticides. Whiteflies, *Dialeurodes citri, Kanakarajiella cardamomi, Aleurotuberculatus cardamomi* are reported so far in small cardamom (Gopakumar and Chandrasekar 2002). Due to climate change, intensive cultivation and indiscriminate pesticide use, several minor pests have recently resurged in cardamom plantations across the CHR, Kerala (Thiyagarajan and Ali 2016, Thiyagarajan et al., 2017). Red spider mite, cardamom whitefly, scales, lace-wing bug and aphid are minor insect pests reported as emerging pests in CHR in recent years (Thiyagarajan et al., 2019). Due to outbreak of invasive whiteflies in different agricultural and horticultural crops in India, the present studies were undertaken and focused on survey, varietal screening, seasonal incidence and management of invasive whiteflies in small cardamom crop grown in different agro zones of small cardamom tracts of Southern India.

MATERIAL AND METHODS

Survey of invasive whiteflies in small cardamom: Survey was conducted in ten places in different agro zones of small cardamom growing areas of the Western and Eastern Ghats of Kerala, Karnataka and Tamil Nadu from August, 2024 to July, 2025 at monthly interval to assess the infestation of invasive whiteflies. From Kerala, small cardamom growing districts *viz.,* Idukki, Wayanad and Palakkad were surveyed. In Idukki, a survey was conducted in different zones of CHR (A, B & C Zones) covering Puttady (Zone A), Pampadumpara (Zone B) and Pallikkunnu (Zone C), Vellimala from Wayanad district and Puliyara from Palakkad district. From Karnataka, Donigal from Hassan District and Ibnivalvadi Rural from Kodagu district were surveyed. From Tamil Nadu, Kothadipatti from Dindigul district, Kurumberbetta from The Nilgiris district and Cakkaraipatti from the Namakkal district were surveyed (Fig. 1). Ten plants of Njallani Green Gold in

all locations were randomly taken from each field and number of whiteflies per leaf was recorded randomly covering three leaves each from top, middle and bottom canopy (Sathyan et al., 2018). An assessment of population level was made using the following qualitative scale i.e. Low (=less than 10 live egg spirals or adults per leaflet), Medium (=11-20 live egg spirals or adults/leaflet) and Severe (=more than 20 live egg spirals or adults/leaflet) protocol developed by Sundararaj et al. (2021). The specimens were collected in 90% ethanol and leaves containing puparium were preserved and identified at ICAR- National Bureau of Agricultural Insect Resources, Bengaluru, India. The genetic classification of invasive whiteflies was made using species confirmation by matching with the original and additional description of the respective species (Sundararaj et al., 2021). Molecular characterization of the partial mitochondrial cytochrome c oxidase I (COI) (658 bp) gene was done with adult whiteflies after morphological identification to confirm the species. Genomic DNA extraction from individual adult whiteflies were done using DNAase Qiagen kit method (Qiagen, Germany). Polymerase chain reaction amplification of the 5′ terminus of the COI gene was done following the standard protocol which involves the cocktail of reactions, using universal primers LCO 1490 5′-GGT CAA ATC ATA AAG ATA TTG G-3 and HCO 2198 5′-TAA ACT TCA GGG TGA CCA AAA AAT CA-3′ (Folmer et al., 1994). The quality of the amplicons was checked in agarose gel electrophoresis and the amplified products were sequenced by Eurofns Genomics India Pvt. Ltd., Bengaluru, Karnataka. The resulting sequence data were manually edited using BioEdit software, before subjected to BLAST analysis in the NCBI database to determine the identity of the specimens. Subsequently, validated DNA sequences, were submitted to the NCBI GenBank to obtain accession numbers.

Varietal screening for invasive whiteflies: A total of fifteen different small cardamom improved varieties and landraces were utilized for the screening for incidence of invasive whiteflies at Germplasm Conservatory, Indian Cardamom Research Institute (ICRI), Myladumpara, Idukki Dt. Kerala, India from November 2024 to April 2025. The improved varieties viz., ICRI-1, ICRI-2, ICRI-5, ICRI-6, ICRI-7, ICRI-10, TCC-9 and landraces including Njallani Green Gold, Panikkulangara-1, Panikkulangara-2, Palakkudi, PNS Vaigai, Thiruthali, Valley Green Bold and Wonder Cardamom were screened. The plot was maintained without any pesticide application. Ten cardamom plants of each improved variety and landraces were selected and tagged for observations and nine leaves per plant were taken randomly covering three leaves each from top, middle and bottom canopy for observation (Sathyan et al., 2018) and whitefly population assessment was made naturally occurred as per the protocol developed by Sundararaj et al. (2021).

Seasonal incidence of invasive whiteflies: The study was conducted at the ICRI, Myladumpara from August 2024 to July 2025 due to a sudden outbreak of invasive whiteflies in small cardamom ecosystem. The weather data such as maximum and minimum temperature, relative humidity (mean), rainfall and rainy days were obtained from the

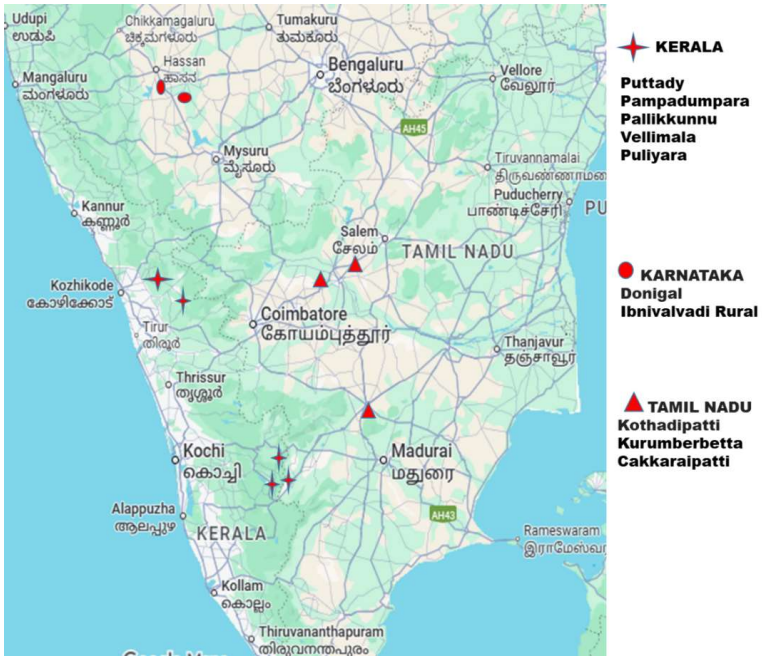

Fig. 1. Map showing locations for survey of whiteflies in small cardamom growing tracts

Meteorological Observatory at ICRI, Myladumpara and used for multiple correlation analysis. The five-year-old Njallani Green Gold cultivar plot was selected for the study and whitefly population count was taken from randomly selected fifty plants which were maintained without pesticide application at monthly intervals throughout study period. Nine leaves per plant were selected randomly each from top, middle and bottom of each plant for observation (Sathyan et al., 2018). Data on seasonal incidence of invasive whiteflies at fixed plot in an acre has been presented as mean data on a monthly basis.

Bio-efficacy of insecticides against invasive whiteflies: **F**ield experiment was conducted at the research farm of the ICRI, Myladumpara, Kerala from November, 2024 to January, 2025 which is peak infestation in a randomized block design with eight treatments replicated three times. Small cardamom which is a perennial crop, five years old Njallani Green Gold a commonly cultivated cultivar was used and each replication had 12 plants. All standard agronomic practices were followed except pesticide applications. The insecticide treatments comprised of eight treatments in which six were new insecticide molecules viz., spirotetramat 150 % OD @ 750 ml/ha, buprofezin 25 % EC @ 1500 ml/ha, spinosad 45 % SC @ 500 ml/ha and spinetoram 12 % SC @ 450 ml/ha, one bio-pesticide (azadirachtin 1 % @ 1000 ml/ha) and CIB&RC recommended insecticides for major cardamom pests as standard check *viz.,* acephate 95 % SG @ 1000 g/ha and diafenthiuron 50 % WP @ 800 g/ha. An untreated control was simultaneously maintained during the study. Among them, the spinosad is used for organic cultivation worldwide and Spinetoram derived from fermentation product of *Saccaropolyspora spinosa.* Insecticide applications were carried out using a high volume knapsack sprayer fitted with a hollow cone nozzle, using 1000L of spray fluid per hectare. The first spraying was done when the invasive whiteflies pest population reached the maximum population, and subsequent spray was given at an interval of 28 days. The population of invasive whiteflies, *P. bondari* and *P. minei* were counted on nine leaves per plant, three each from the top, middle and bottom regions of five randomly selected plants per plot, and before, 14 and 28 days after each spray. The plants in the border rows were excluded. The percentage reduction (PR) of both invasive white flies over the untreated control was calculated as PR [(Control count - Treatment count/Control count) x 100] for each treatment following each spray. Data were analysed using randomized block design in SPSS software version 16, and means were separated using Tukey's HSD test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Molecular confirmation of species identity: Morphological characterization revealed the presence of two invasive whiteflies *viz.,* Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae) and nesting whitefly, *Paraleyrodes minei* Iaccarino (Hemiptera: Aleyrodidae) on small cardamom for the first time in cardamom growing tracts of Kerala, Karnataka and Tamil Nadu. Further, their identity was confirmed through partial sequences of cytochrome c oxidase I gene for *P. bondari* (PV163890) and *P. minei* (PV163877) infesting small cardamom were submitted to GenBank, NCBI, India.

Survey of invasive whiteflies in small cardamom: The adults and its damage symptoms of both *P. bondari* and *P. minei* are represented in Figure 2. Small cardamom leaves heavily infested with both invasive whiteflies showed a cottony white appearance and it was found in the abaxial side of leaves. The population was found to be more in bottom leaves/older leaves, moderate in middle leaves and negligible in top leaves of a plant canopy. The low level of *P. bondari* adult's population was in the Karnataka region particularly Donigal, and Ibnivalvadi, and severe population was recorded in all other locations in Puttady, followed by Pampadumpara, Pallikunnu and Vellimala areas of Kerala. For *P. minei*, Kurumberbetta, Cakkaraipatti of Tamil Nadu and Ibnivalvadi and Donigal of Karnataka recorded low level of population (Fig. 3). Kothadipatti of Tamil Nadu, Puttady, Puliyara, Pampadumpara of Kerala were recorded moderate (medium) level infestation, and Pallikunnu and Vellimala of Kerala recorded severe levels of population. However, *P. bondari* population was higher than *P. minei* in all the locations of Kerala, Karnataka and Tamil Nadu.

In India, *P. bondari* incidence was first reported in coconut palms in Kerala during 2018 (Josephrajkumar et al*.,* 2019). It has been reported in Karnataka, the Andaman and Nicobar Islands (Vidya et al*.,* 2019) and Lakshadweep Islands (Selvaraj et al., 2020). *P. bondari* is polyphagous in nature, it has more than 25 susceptible host plants and is found to infest coconut, banana, guava, citrus sp. avocado, cassava, custard apple, noni and ornamental ficus (Vidya et al*.,* 2019). In India, *P. minei* was also reported in coconut in Kerala during 2018 (Mohan et al., 2019, Sujithra et al., 2019) and further reported in the Andaman and Nicobar Islands (Dubey 2019). Subsequently, this species was found to rapidly spread to different districts of Karnataka and Tamil Nadu. *Paraleyrodes minei* was found to colonize coconut, banana, guava, mango, jamun, *Ixora* sp., and *Heliconia* (Mohan et al., 2019, Sujithra et al., 2019). This host range expansion could be a mechanism to overcome the abiotic constraints and buffer the depletion of optimal resources. Since the above

invasive pests were reported already many crops grown in southern states in India and they can spread from existing host to small cardamom crop and also to the entire small cardamom growing tracts of Kerala, Karnataka and Tamil Nadu which is confirmed by present findings.

Varietal screening for invasive whiteflies: Among fifteen improved varieties and landraces screened, both *P. bondari* and *P. minei* incidence were recorded in all fifteen varieties and land races with varying levels (Table 1). For *P. bondari*, severe population was observed that Panikkulangara-1 followed by Njallani green gold, TCC-9, ICRI-2, ICRI-5, ICRI-10, Panikkulangara-2 and Wonder cardamom. ICRI -1 showed moderate infestation. PNS Vaigai, Palakkudi, ICRI-6, Thiruthali, ICRI-7 and Valley green bold showed low level

Fig. 2. A. Infestation of invasive whiteflies on small cardamom leaf, B. Infestation of invasive whiteflies on small cardamom leaf (enlarged view), C. Adult of *P. minei*, D. Adult of *P. bondari*, E. Egg spirals of *P. minei*, F. Egg spirals of *P. bondari*

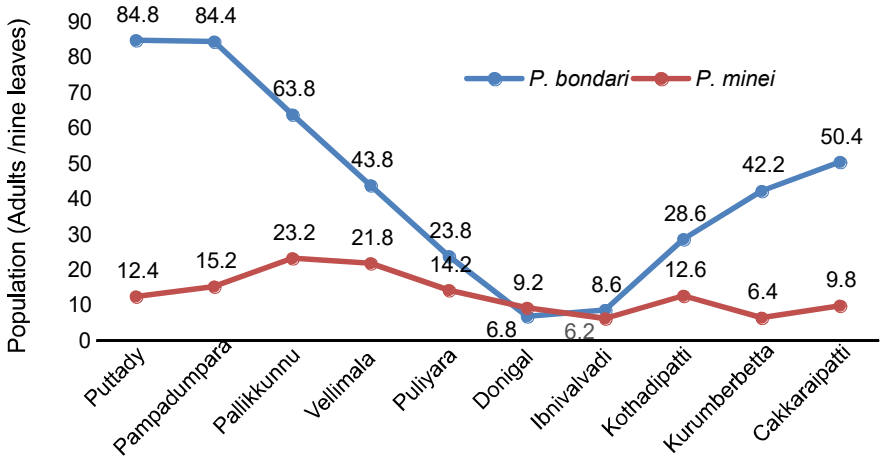

Fig. 3. Incidence of invasive whiteflies in different Indian small cardamom growing tracts

population. For *P. minei*, most of the varieties showed severe infestation were Panikkulangara-2, ICRI-5, ICRI-6, TCC-9, Njallani green gold, ICRI-10, Valley green bold and ICRI-2. Varieties, ICRI-7, ICRI-1 and Palakkudi and Wonder cardamom expressed moderate (medium) level of infestation. Varieties, PNS Vaigai, Panikulankkara-1 and Thiruthali showed low level infestation. Among the varieties and landraces screened, Panikkulangara -1 recorded highest level of *P. bondari* infestation and Panikkulangara-2 recorded highest level of *P. minei* infestation. However, PNS Vaigai and Thiruthali recorded low level infestation of both *P. bondari* and *P. minei*.

The small cardamom varieties and landraces screened against both *P. bondari* and *P. minei* were not completely free from the attack of these whiteflies. Panikkulangara-1, a landrace was recorded maximum population of *P. bondari* followed by Njallani green gold and landraces *viz.,* PNS Vaigai, Palakkudi, Thiruthali, ICRI 7 and Valley green bold had minimum population. Landrace, Panikkulangara-2 recorded maximum population of *P. minei* followed by ICRI 5 and landraces, PNS Vaigai, Panikkulangara-1 and Thiruthali. Njallani green gold, Panikkulangara-1 and ICRI-5 a commonly used variety were more susceptible to *P. bondari* and *P. minei* and whereas, landraces PNS Vaigai and Thiruthali was found be less susceptible to both *P. bondari* and *P. minei*. Nadeem et al. (2014) showed that the different cultivars screened, none of them showed complete resistance against whiteflies however, MH 3153 showed comparatively better resistance against sucking insects. Jacob et al. (2020) observed that, among 180 germplasm accessions screened, none of them were found to be highly resistant and only eight accessions were resistant to cardamom thrips. Among 100 small cardamom germplasm accessions screened only few of them slightly tolerant to cardamom thrips and shoot borer (Thiyagarajan et al., 2020). The both invasive whiteflies population were noticed in almost all the improved varieties and landraces. It might be adapting to favourable micro climate for its niche, might spread to cardamom from alternate hosts which cardamom grown under evergreen forest ecosystem.

Seasonal incidence of invasive whiteflies: Seasonal activity, simple correlation co-efficient and multiple regressions were estimated with weather parameters of appropriate months at Myladumpara for August 2024 to July 2025 (Fig. 4). During the study period, *P. bondari* incidence was first observed during August, 2024 and came to peak during November, 2024 to February 2025 and thereafter declined. In case of *P. minei* the incidence was first observed during September 2024 and peak during November, 2024 to February 2025 (13.75 - 19.60 adults/9 leaves) and thereafter declined. During June and July 2025, the population of *P. bondari* and *P. minei* was zero due to heavy rainfall and more rainy days. The minimum population of *P. bondari* was observed in August 2024 whereas the maximum population was observed during December 2024. The maximum population of *P. minei* was also observed during December 2024 and decline afterwards. Population of *P. minei* was also absent in the months of June, July and August months due to

Table 1. Screening on incidence of invasive whiteflies on improved varieties and landraces in small cardamom

Improved varieties & landraces	*P. bondari*		*P. minei*	
	Adults/ 9 leaves	Scale	Adults/ 9 leaves	Scale
ICRI -1	11.80	Medium	13.60	Medium
ICRI -2	52.40	High	21.60	High
ICRI -5	43.20	High	41.20	High
ICRI -6	4.80	Low	38.20	High
ICRI -7	8.20	Low	11.60	Medium
ICRI -10	41.60	High	22.40	High
TCC-9	52.60	High	35.80	High
Njallani green gold	71.40	High	23.20	High
Panikkulangara - 1	103.40	High	5.60	Low
Panikkulangara - 2	31.20	High	51.40	High
Palakkudi	3.60	Low	14.20	Medium
PNS Vaigai	2.20	Low	5.20	Low
Thiruthali	5.60	Low	9.20	Low
Valley green bold	9.20	Low	22.40	High
Wonder cardamom	22.40	High	16.60	Medium

heavy rainfall indicating a negative correlation between rainfall, rainy days and whitefly population. The peak population of both invasive whiteflies was found during November to March and it was declined during April & May and was negligible during June to September. The abundance of betel vine whitefly was high from November to December (Dahal et al., 2009) and the peak population of whitefly, *K. cardamomi* was noticed during February to March at five locations in small cardamom of CHR, Kerala (Sathyan et al., 2018). These findings also support the present investigation.

Maximum and minimum temperature and relative humidity weren't significantly correlated with invasive whiteflies population. Rainfall and rainy days were negatively and significantly correlated with whiteflies population. Rainy days were more significant than rainfall which shows that an increase in rainfall leads to a significant reduction in population of both *P. bondari* and *P. minei* in small cardamom. The negative correlation between rainfall and whitefly populations suggests that pest outbreaks are likely during extended dry periods. Therefore, continuous field monitoring during November to March is crucial. *P. bondari* population was found to be more in number when compared with population of *P. minei*. Coefficient of determination (R^2) value for *P. bondari* was 0.49 and R^2 value for *P. minei* was 0.48 showing 49 per cent very meager influence of all-weather factors on *P. bondari* population and 48 per cent influence of all-weather factors for *P. minei* population respectively (Table 2). The multiple regression analyses exposed that, the rainy days influenced the both *P. bondari* and *P. minei* populations by 59 per cent and 61 per cent respectively during August 2024 to July 2025. A unit decrease in rainy days increased populations by 3.4 number by *P. bondari* and 0.99 number by *P. menei* during the study period (Table 3). Vijaya Lakshmi et al. (2020) found significant negative correlation with maximum temperature and non-significant negative impact of rain fall with whitefly population in chilli. Rainfall and relative humidity had significant negative correlation with population of adults and nymphs of cotton whitefly (Balbantaray et al., 2018). Swati and Krishna (2020) reported that total rainfall had significant and negative impact on the whitefly adult and nymphal population in Bt cotton. Singh et al. (2017) observed that rainfall directly impacts on whitefly species. These results support the present investigation findings. Sathyan et al. (2018) reported positive correlation of *K. cardamomi* with the maximum temperature and sun shine hours and negative correlation with relative humidity during 2014-15 and again he found that a unit decrease in morning relative humidity, the *K. cardamomi* populations showed an increase 0.13 and 0.07 number/unit during the 2014 and 2015 respectively in small cardamom. Since, population dynamics of invasive whiteflies on *P. bondari* and *P. minei* was having limited studies in crops and these findings will be varying now a day due to sudden change of weather and climate particularly heavy rainfall with more rainy days during 2018, increase of day temperature with drought during 2024 in particular month/year in small cardamom growing tracts in India will change of outbreak and decrease of whitefly population which will support the present findings.

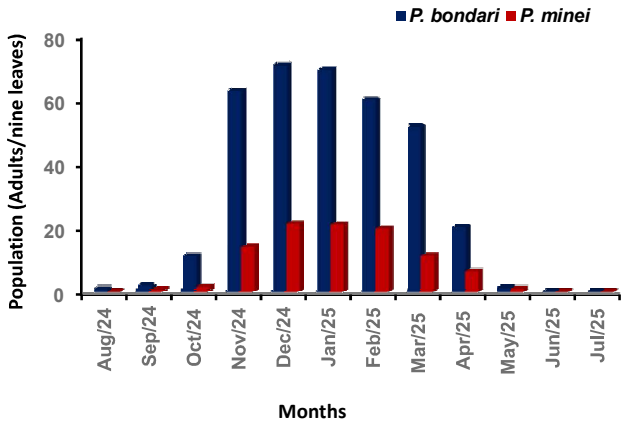

Fig. 4. Monthly variation of *P. bondari* and *P. minei* population on small cardamom from August 2024 to July 2025

Table 2. Estimated correlation co-efficient between weather parameters and incidence of invasive whiteflies in small cardamom

Weather parameters	*P. bondari*	*P. minei*
Maximum temperature	0.105 NS	0.099 NS
Minimum temperature	-0.460 NS	-0.433 NS
RH	-0.443 NS	-0.461 NS
Rainfall	-0.658*	-0.655*
Rainy days	-0.768**	-0.783**

*- Significant at 5% level, ** - Significant at 1% level, NS - Non significant

Bio-efficacy of insecticides against invasive whiteflies: Spinetoram 12 % SC reduced the *P. bondari* population

Table 3. Influence of weather parameters on invasive whiteflies in small cardamom

Pest population	Variable	Mean	Regression coefficient	Std error	t stat	Probability	Intercept	R^2 Value
P. bondari	Rainy days	11.1667	-3.422	0.902	-3.794	0.004	67.452	0.590
P. minei	Rainy days	11.1667	-0.997	0.251	-3.976	0.003	19.132	0.613

Table 4. Effect of new insecticide on *P. bondari* in small cardamom

Treatments with dosage	Number of whitefly (Adults/nine leaves)								
	PTC	1 Spray				2 Spray			
		14 DAT	PR	28 DAT	PR	14 DAT	PR	28 DAT	PR
Spirotetramat 150 % OD @ 750 ml	59.02	31.85^{f}	51.82	40.66^{f}	41.25	21.81^{f}	69.47	24.85^{f}	65.74
Buprofezin 25 % EC @ 1500 ml	59.10	21.66^{d}	67.23	26.62^{d}	61.54	10.95^{d}	84.67	12.48^{d}	82.79
Spinosad 45 % SC @ 500 ml	59.05	20.36^{c}	69.20	24.81^{c}	64.15	10.14^{c}	85.80	12.00^{c}	83.45
Spinetoram 12 % SC @ 450 ml	59.00	14.96^{a}	77.37	16.73^{a}	75.83	3.77^{a}	94.72	4.81^{a}	93.37
Acephate 95 % SG @ 1000 g	59.08	15.62^{b}	76.37	17.81^{b}	74.27	4.77^{b}	93.32	5.11^{b}	92.95
Diafenthiuron 50 % WP @ 800 g	59.04	25.22^{e}	61.85	32.29^{e}	53.35	21.61^{e}	69.75	24.25^{e}	66.57
Azadirachtion 1 % @ 1000 ml	59.06	36.59^{g}	44.65	44.70^{g}	35.42	29.29^{g}	59.00	31.59^{g}	56.45
Untreated control	59.00	66.11^{h}	-	69.22^{h}	-	71.44^{h}	-	72.55^{h}	-

PTC: Pre-Treatment Count, DAT: Days After Treatment, PR: Percent Reduction Over Control
In column, means followed by common letters are not significantly different at (P=0.05) by DMRT

Table 5. Effect of new insecticide on *P. minei* in small cardamom

Treatments with dosage	Number of whitefly (Adults/nine leaves)								
	PTC	1 Spray				2 Spray			
		14 DAT	PR	28 DAT	PR	14 DAT	PR	28 DAT	PR
Spirotetramat 150 % OD @ 750 ml	20.24	12.51^{f}	49.35	18.22^{f}	32.41	10.96^{f}	60.21	7.81^{d}	72.57
Buprofezin 25 % EC @ 1500 ml	20.20	7.85^{d}	68.21	10.48^{d}	61.12	4.25^{d}	84.57	5.85^{c}	79.45
Spinosad 45 % SC @ 500 ml	20.28	7.29^{c}	70.48	9.92^{c}	63.20	3.81^{c}	86.17	5.00^{b}	82.44
Spinetoram 12 % SC @ 450 ml	20.18	4.81^{a}	80.52	7.22^{a}	73.21	1.85^{a}	93.28	2.44^{a}	91.43
Acephate 95 % SG @ 1000 g	20.28	5.44^{b}	77.97	7.59^{b}	71.84	2.37^{b}	91.39	2.70^{a}	90.51
Diafenthiuron 50 % WP @ 800 g	20.00	11.62^{e}	52.95	13.96^{e}	48.21	9.44^{e}	65.73	11.18^{e}	60.74
Azadirachtion 1 % @ 1000 ml	20.26	16.44^{g}	33.44	21.74^{g}	19.36	12.25^{g}	55.53	16.48^{f}	42.13
Untreated Control	20.22	24.70^{h}	-	26.96^{h}	-	27.55^{h}	-	28.48^{g}	-

PTC: Pre-Treatment Count, DAT: Days After Treatment, PR: Percent Reduction Over Control
In column, means followed by common letters are not significantly different at (P=0.05) by DMRT

significantly after 14 days spray, whereas the acephate 95 % SG and spinosad 45 % SC were similar in reducing the *P. bondari* population and also in second rounds of application. The maximum reduction in *P. bondari* population over untreated control was observed after second spray for spinetoram 12 % SC followed by acephate 95 % SG and spinosad (Table 4). Spinetoram 12% SC reduced the *P. minei* population significantly after 14 days' spray followed by acephate 95% SG and spinosad 45% SC (Table 5). The maximum reduction in *P. minei* population over untreated control was observed after second spray for spinetoram 12% SC (91.43%) and the statistically spinetoram 45% SC dose of 450 ml/ha was most effective against both *P. bondari* and *P. minei*. Ambarish et al. (2017) also reported that spinetoram 10% in combination with other pesticides was effective against whitefly in cotton. Gupta et al. (2022) observed 77. 32 % reduction over control against chilli whitefly with acephate, with whereas, azadirachtin 0.15% and NSKE 5% recorded the lowest mortality of whitefly. Acephate 95% SG @ 1000 g/ha is effective for major cardamom insect pests viz., thrips and shoot borer. Thiyagarajan et al. (2025) reported spinetoram 12% SC @ 450 ml/ha also effective in reduction of these major insect pests in small cardamom.

CONCLUSIONS

This study reports the first incidence of *Paraleyrodes bondari* and *P. minei* infesting small cardamom in India. The pests exhibited seasonal peaks during November to March with rainfall and rainy days negatively influencing their abundance. Among the evaluated varieties, PNS Vaigai and Thiruthali showed relative tolerance, while Panikkulangara-1 and Njallani Green Gold were highly susceptible. Spinetoram 12% SC @ 0.45 l/ha timed at early population build-up proved most effective for field management. These findings provide baseline data for integrated pest management and future breeding programs in small cardamom ecosystems.

AUTHOR'S CONTRIBUTION

This study was conducted due to outbreak of invasive whiteflies in small cardamom growing tracts. P. Thiyagarajan involved in the varietal screening and seasonal incidence besides supervision of this work. Vyshnavi Sunil contributed the survey in different tracts and management. K. Selvaraj, G. A. Kavya Yadav contributed for morphological and molecular confirmation of whiteflies. S. Pradeep Kumar assisted for statistical analysis of data. Thania Sara Varghese, O. P. Reji Rani and A. B Rema Shree supported the interpretation of the results.

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Received 14 September, 2025; Accepted 21 November, 2025