Pesticide-induced resurgence a hindrance in sustainable forestry: a case study with whitefly *Aleurolobus nandiensis* and mealybug *Planococcus bendovi* infesting *Gmelina arborea* in Tamil Nadu

O ressurgimento induzido por pesticidas é um obstáculo à silvicultura sustentável: um estudo de caso com a mosca-branca *Aleurolobus nandiensis* e a cochonilha *Planococcus bendovi* infestando *Gmelina arborea* em Tamil Nadu

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ABSTRACT
Gmelina arborea an indigenous tree species valued for its medicinal and timber properties is often attacked by numerous insect defoliators, miners, borers, sap feeders throughout the year including some major pests namely- *Calopepla leayana*, *Tingis beesoni*, *Prioptera punctipennis*, *Alcidodes ludificator*, *Myllocerus sp. etc*. As in agriculture the easiest management measure in forestry also comes in the form of different chemical pesticide treatments when the pest population is high and alarming. This investigation is a case study of such pesticide-induced resurgence among secondary insects of *G. arborea* in nurseries and plantations of Tamil Nadu. Two rare sap feeding insects *Planococcus bendovi* and *Aleurolobus nandiensis* in the nursery condition have been exposed directly and indirectly to the different concentrations of chemical pesticide treatment from 2020-2022 repeatedly. Over time the maximum dose of organophosphate pesticide dimethoate 30% EC (Rogor) failed to reach LC_{50} during insecticide efficacy (E_A) testing against *P. bendovi* bioassay. Similarly, neonicotinoids thiamethoxam 25% WG (Actara) with maximum dose failed in *A. nandiensis* bioassay. Resurgence index (E_{HT}) showed the higher abundance of *A. nandiensis* and *P. bendovi* in treated nursery beds compared to untreated nursery and field conditions by causing the mortality of 10 to 20 % (average) of planting stocks respectively.

Keywords: secondary pest outbreak, pesticide-induced resurgence, Gamhar pest.

RESUMO
A Gmelina arborea, uma espécie de árvore indígena valorizada por suas propriedades medicinais e madeireiras, é frequentemente atacada por vários insetos desfolhadores, mineradores, broqueadores e alimentadores de seiva durante todo o ano, incluindo algumas das principais pragas, a saber: Calopepla leayana, Tingis beesoni, Prioptera punctipennis, Alcidodes ludificator, Myllocerus sp. etc. Assim como na agricultura, a medida de manejo mais fácil na silvicultura também se apresenta na forma de diferentes tratamentos com pesticidas químicos quando a população de pragas é alta e alarmante. Esta pesquisa é um estudo de caso desse ressurgimento induzido por pesticidas entre os insetos secundários da G. arborea em viveiros e plantações de Tamil Nadu. Dois insetos raros que se alimentam de seiva, Planococcus bendovi e Aleurolobus nandiensis, em condições de viveiro, foram expostos direta e indiretamente a diferentes concentrações de tratamento com pesticidas químicos de 2020 a 2022 repetidamente. Ao longo do tempo, a dose máxima do pesticida organofosforado dimetoato 30% EC (Rogor) não conseguiu atingir a CL50 durante o teste de eficácia do inseticida (EA) contra o bioensaio de P. bendovi. Da mesma forma, os neonicotinoides tiametoxam 25% WG (Actara) com dose máxima falharam no bioensaio de A. nandiensis. O índice de ressurgência (EHT) mostrou a maior abundância de A. nandiensis e P. bendovi nos viveiros tratados em comparação com os viveiros não tratados e as condições de campo, causando a mortalidade de 10 a 20% (média) das mudas de plantio, respectivamente.

Palavras-chave: surto de praga secundária, ressurgimento induzido por pesticida, praga Gamhar.

1 INTRODUCTION

Gmelina arborea (Lamiaceae) commonly known as Gamhar is a recognized medicinal crop listed in the book 'Hortus Malabaricus' by Hendrik Van Rheede during 1678. Besides, this forestry crop has also gained popularity in plywood industries. Looking into the economic benefits of this crop it has been considered for tree improvement program. In this regard the trait of being insect tolerant or insect resistant is considered as one of the essential features for candidate tree selection. Therefore, many supporting studies have been carried out in the past for the pest assessment where ample number of insects were reported including *Calopepla leayana, Tingis beesoni*, *Indarbela quadrinotata*, *Alcidodes ludificator, Prioptera punctipennis, Ectropis bhurmita* as important as pests [1-3]. Although, the Strengthening and Modernization of Pest Management Approach (SMPMA) guidelines advocate bio-control agents for pest population control, in contrast previous researches has revealed broad-spectrum chemical pesticides as farmers' first preference for controlling the pests of any edible or non-edible crops and ironically the increased pesticide use is unable to control both crop loss or pest population [4-6].

This investigation is an experimental case study which addressed the damage of *G. arborea* by two secondary pests, one a rare mealybug *P. bendovi, and* the other a whitefly *A. nandiensis.* The prevalence of these pests in nurseries and fields has also been studied.

2 MATERIALS AND METHODS

2.1 STUDY AREA

The experimental study of this research was carried out in the research nurseries of Institute of Forest Genetics and Tree Breeding (IFGTB), situated in Coimbatore. Field locations namely Devarayapuram in Pollachi, Forest College and Research Institute (FCRI) in Mettupalayam, Anaikatty reserve forest located in Coimbatore district, Setrapatti in Dharmapuri district and Neyveli IFGTB plantation in Cuddalore district were screened for the pest occurrence during peak seasons.

2.2 METHODOLOGY

Regular monitoring was done from 2020 January to December 2022 in the nurseries of IFGTB including glass house, mother bed and seasonally in the fields. Adult female of *P. bendovi* and puparia of *A. nandiensis* the target insects were collected from nurseries and fields and permanent slide was prepared following the method given by ARS USDA systematic entomology laboratory with slight modifications and identified with the help of morphological characters [7,8].

Secondary pest assessment was done in block count method selecting equal number of plants (10) from each block depending on infestation level.The population of *P. bendovi* was estimated by counting the number of insects per inch square area in every stem of a infected plant in replications whereas, the population of *A. nandiensis* was estimated by direct count after aspirator collection without disturbing the plants. The population count data was collected in nurseries during pre and post treatment. To estimate the level, population was categorized into three groups based on average number of insects in each block i.e., nil, low, medium, and high; where, nil=0, low=1-5, medium=6-10, high = >10.

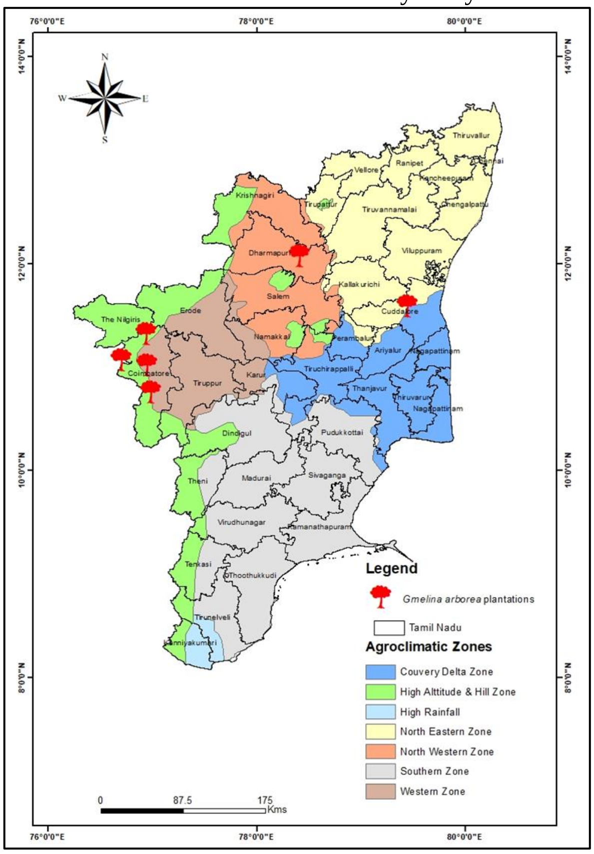
Pesticide treatments were done with one control (T_1) with water spray, one botanical i.e., Neem oil emulsion- 10-12 ml/litre (T_2) and two chemical pesticides viz. dimethoate 30% EC (Rogor) 1.5 – 2.5/ litre (T_3) for *P. bendovi* and thiamethoxam 25% WG (Actara) 1-2 g/litre (T_4) for *A. nandiensis* management. While performing the treatment the nursery bed was partitioned into three groups (eg. T_1, T_2, T_3 or T_4). Further, pesticide efficacy (E_A) bio-assay LC50 was assessed after 72 hours and resurgence index (E_{HT}) was calculated using following the Henderson & Tilton's formulae (Abbott,1987 9; Henderson & Tilton, 1955 10)

$$E_{H^T} = 100\ x\ [1 - (N_{ta} \div N_{ca}\ x\ N_{cb} \div N_{tb})]$$

Where, N_{cb} = live individuals in the control before treatment; N_{tb} = live individuals in the treatment before treatment; N_{ca} = live individuals in the control after treatment; N_{ta} = live individuals in the treatment after treatment.

3 RESULTS

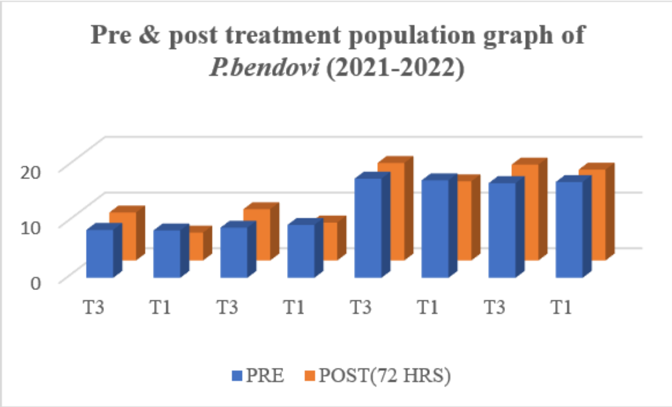
Figure 1: Selected *G. arborea* field and nursery study sites in TamilNadu



Source: By the author

Experimental study site i.e., the research nurseries of IFGTB, Coimbatore has got the highest population of *P. bendovi* and *A. nandiensis* during February 2022 (≥17) and January 2022 (≥10) respectively. In contrast no incidence of *P. bendovi* was observed in fields and low level of *A. nandiensis* was found in Devarayapuram (Pollachi) and Setrapatti (Dharmapuri).

Figure 2: Population graph of *P. bendovi* during control and treatment with (T_3) dimethoate 30% EC (Rogor) on the left and resurgence index E_{HT} (%) on the right.



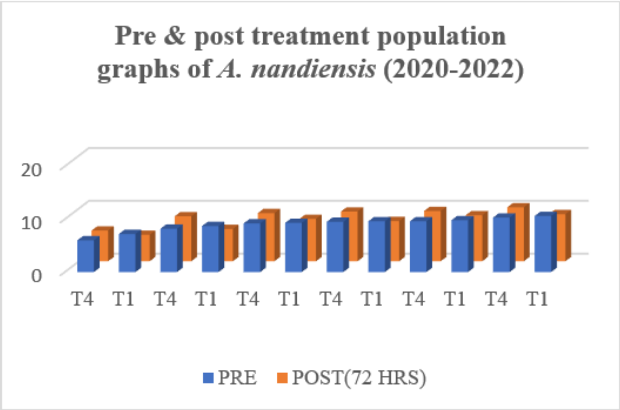
TREATMENT T3 (Dimethoate 30% EC)	E_{HT} (%)
T3 (1.5ml/lit)	-70
T3 (1.5ml/lit)	-42
T3 (2ml/lit)	-21.16
T3 (2.5ml/lit)	-6.76

Source: By the author

Figure 2 has represented the fluctuation graph in the population of *P. bendovi* before and after the chemical treatment as well as population in the control which occurred in the nursery bed during January to April 2021 and 2022. The incidence of *P. bendovi* was low during 2021 and substantially increased during 2022 after several times of treatment. The population in the T_3 (dimethoate) treated bed was found higher compared to T_1(control). Highest concentration of T_3 i.e., 2.5 ml/lit showed 6.76 % of resurgence and serious injuries with 20% loss of planting stocks at the same time. Untreated field did not get the mealybug *P. bendovi* incidence even during the peak period.

During the bioassay of both the insects *P. bendovi* and *A. nandiensis* the botanical neem oil emulsion (T_2) produced 99-100 % mortality within 72 hours of treatment.

Figure 3: Population graph of *A. nandiensis* during control and treatment with thiamethoxam 25% WG (Actara) on the left and resurgence index E_{HT} (%) on the right.



TREATMENT T4 (Thiamethoxam 25 % WG)	E_{HT} (%)
T4 (1g/lit)	-39.2
T4 (1g/lit)	-47.84
T4 (1.5g/lit)	-14.98
T4 (1.5g/lit)	-24.98
T4 (2g/lit)	-11.47
T4 (2g/lit)	-17.94

Source: By the author

Similarly, figure 3 depicts the result of chemical experiments which was carried out in nurseries for another secondary pest of *G. arborea* i.e., a whitefly *A. nandiensis.* Chemical treatment with different concentrations were performed in nurseries depending on the population level during 2020-2022. The highest dose of T_4 i.e., thiamethoxam 25% WG (Actara) caused 11.47 % resurgence of the species and approximately 10% casualty of the host plant during peak period. Throughout the study period the target whitefly was found at low level in untreated field conditions.

Figure 4: *P. bendovi* on the branches of *G. arborea* on nursery bed of IFGTB (left), the slide mounted female specimen (right)

Source: By the author

Figure 5: *A.nandiensis* infected *G.arborea* leaf adaxial surface (left) and puparia on the abaxial surface of leaves

Source: By the author

4 DISCUSSION

P. bendovi, a rare species of mealybug was reported for the first time as type specimens on *Arachis hypogaea* from India in 2004 by Williams [11] and in recent past from *Loranthus pentandrus* in Indonesia by Zarkani et al.,2022 [7] whereas in this investigation *P. bendovi* has been found as a seasonal secondary nursery pests of *G. arborea*, which occurred at a low level initially but, over time and after repetitive chemical treatments developed a resistance to dimethoate. Pesticide induced resurgence of *P. bendovi* also caused significant casualty of nursery stalks. Earlier studies have also recorded the resistance of insects against organophosphate pesticides such as dimethoate, profenophos, dichlorvos, chlorpyriphos, methamidophos etc [12-14]. Whiteflies, aphids and many more insects have been reported developing resistance to dimethoate [15-17]. Additionally, organophosphates are the group of pesticides which are most widely used for broad spectrum pest control [18].

Another target pest of this study whitefly *A. nandiensis* have transformed from minor to a major pest by developing resistance to thiamethoxam during the investigation period in nursery condition. Population of *A. nandiensis* was also found in all other study locations. Unlike *P. bendovi*, the whitefly *A. nandiensis* has already been reported from *G. arborea* at Nandi hills in Karnataka but, not surveyed earlier for their pest status [8]. This is not the first incidence of whiteflies showing resistance to thiamethoxam. Different neonicotinoid pesticides in past research failed to control whiteflies and other insects developing resistance [19, 20].

Treatment of both insects by neem oil emulsion successfully controlled the population which is why the botanical neem has been considered as better biocide for plant pests' control in the past as well as for the future [21; 22]

5 CONCLUSION

The investigation has not only reported *P. bendovi* as a pest of *G. arborea* for the first time but also described their resistance and resurgence to dimethoate. The study has also put light on another whitefly *A. nandiensis* which was failed to be controlled by thiamethoxam. This case study with secondary pests of *G. arborea* and broad-spectrum chemical pesticide treatments have revealed that the outbreak of secondary pest and pesticide-induced resurgence is obvious when the application of chemicals are repetitive and improper. Treatment with botanical neem oil emulsion is found to be a better option to avoid such circumstances of pest resurgence.

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REFERENCES

[1] Kumar A, Chandra G. Insect pest infestation on *Gmelina arborea* Roxb. in different agroclimatic zones of Jharkhand, India. Arthropods. 2017. 8-20.

[2] Senthilkumar N, Murugesan S. Insect pests of important trees species in South India and their management information, published by Institute of Forest Genetics and Tree Breeding (IFGTB), (Indian Council of Forestry Research & Education), Coimbatore, TamilNadu.2015. p. 8-19.

[3] Mathur RN, Singh B. A list of insect pest of forest plants in India and the adjacent country. Ind For Bull. 1959; 171:1-165

[4] Muhammad Mubushar FO, Aldosari MB, Baig BM, Alotaibi AQK. Assessment of farmers on their knowledge regarding pesticide usage and biosafety, Sau J Bio Sc, 2019.26:7.

[5] Hill MP, Macfadyen S, Nash MA. Broad spectrum pesticide application alters natural enemy communities and may facilitate secondary pest outbreaks. PeerJ. 2017 Dec 19;5:e4179. doi: 10.7717/peerj.4179.

[6] Altieri MA, Nicholls CI. Biodiversity and pest management in agrosystems. 2nd ed. CRC Press: Boca Raton; 2004.

[7] Zarkani A, Apriyanto D, Djamilah N et al.*Planococcus bendovi* Williams (Hemiptera: Coccomorpha: Pseudococcidae), a First Record of Mealybug in Southeast Asia. Serangga 2022; 27:1–11.

[8] Sundararaj R, Vimala D. Description of two new aleyrodids of the genus Aleurolobus Quaintance & Baker (Hemiptera: Aleyrodidae) from India. J of Ins Bio.2018;7:24-32. https://doi.org/10.12976/jib/2018.07.2.1.

[9] Abbott WS. A method of computing the effectiveness of an insecticide. 1925. J Am Mosq Control Assoc. 1987;3:302-303.

[10] Henderson CF, Tilton EW. Tests with acaricides against the brow wheat mite, J. Econ. Entomol. 1955; 48:157-161.

[11] Williams DJ. Mealybugs of Southern Asia. Kuala Lumpur: The Natural History Museum jointly with Southdene.2004.

[12] Saddiq B, Shad S, Khan A, Ejaz M, Afzal M. Resistance in the mealybug *Phenacoccus solenopsis* Tinsley (Homoptera: Pseudococcidae) in Pakistan to selected organophosphate and pyrethroid insecticides. Crop Protection. 2014; 66:29–33. 10.1016/j.cropro.2014.08.006.

[13] Cao CW, Zhang J, Gao X, Liang P, Guo HL. Overexpression of carboxylesterase gene associated with organophosphorus insecticide resistance in cotton aphids, *Aphis gossypii* (Glover). Pestic Biochem Physiol.2008; 90:175-180. 10.1016/j.pestbp.2007.11.004.

[14] Nagrare VS, Fand BB, Chinna Babu NV. et al. Resistance development in Cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) to insecticides from Organophosphate, Thiadiazines and Thiourea derivatives. Int J Trop Insect Sci 40, 181–188 2020. https://doi.org/10.1007/s42690-019-00068-9.

[15] Ahmed AHM, Elhag EA, Bashir NHH. Insecticide resistance in the cotton whitefly *Bemisia tabaci* (Genn.) in the Sudan Gezira, Tropical Pest Management, 1987;33: 67-72. doi:10.1080/09670878709371118.

[16] Alam M, Waqas Sumra M, Ahmad D, Shah RM, Binyameen M, Ali Shad S. Selection, realized heritability, and fitness cost associated with dimethoate resistance in a field population of *Culex quinquefasciatus* (Diptera: Culicidae). J Econ Entomol. 2017;110:1252-1258. doi:10.1093/jee/tox049.

[17] Lokeshwari D, Krishna Kumar NK, Manjunatha H, Multiple Mutations on the second acetylcholinesterase gene associated with dimethoate resistance in the melon aphid, *Aphis gossypii* (Hemiptera: Aphididae) , J Eco Entomol,2016;109:887–897.

[18] Visuthismajarn P, Jatuphot W, Khamnalrat A. Status and Health Impact for Chemical Use in the Agricultural Sector: Case Study of Bang Rieng Sub-District, Khuan Neing District, Songkhla Province. Songkhla, Thailand: Nonthaburi: Health System Research Institute; 2005. [Google Scholar]

[19] Barman M, Samanta S, Upadhyaya G, Thakur H, Chakraborty S, Samanta A, Tarafdar J. Unraveling the Basis of Neonicotinoid Resistance in Whitefly Species Complex: Role of Endosymbiotic Bacteria and Insecticide Resistance Genes. Front Microbiol. 2022.
doi: 10.3389/fmicb.2022.901793.

[20] Khan HA, Akram W, Iqbal J, Naeem-Ullah U. Thiamethoxam Resistance in the House Fly, *Musca domestica* L.: Current Status, Resistance Selection, Cross-Resistance Potential and Possible Biochemical Mechanisms. PLoS One. 2015. doi:10.1371/journal.pone.0125850.

[21] Adusei S, Azupio S. Neem: A Novel Biocide for Pest and Disease Control of Plants. J of Chem. 2022. 1-12. 10.1155/2022/6778554.

[22] Campos E, Oliveira J, Pascoli M, Lima R & Fraceto L. Neem Oil and Crop Protection: From Now to the Future. Front in Plant Sc.2016.10.3389/fpls.2016.01494.