Biological Forum – An International Journal **13(4): 719-727(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Insect pests, Pesticide use and Usage Pattern in Beetroot Crop Cultivated in Tamil Nadu

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(Received 09 September 2021, Accepted 09 November, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: A detailed purposive random survey was conducted to understand the farmers behavior on pesticide use and usage pattern in four major beetroot growing districts of Tamil Nadu, India. Beet leaf miner, cut worm, beet leafhopper, green peach aphid and flea beetle were found to infest beetroot crop among which beet leaf miner caused more damage (52.5%). The most commonly used insecticides for leaf miner and other sucking pest management were thiamethoxam 12.6 + lambda cyhalothrin 9.5ZC, profenofos 50EC, quinalphos 25EC, fenvalerate 20EC and cypermethrin 25EC. The source of information for farmers on pesticide recommendations are majorly pesticide retailers (51.25%). A double field experiment conducted in farmer's field for evaluating the insecticides against leaf miner revealed that cyantraniliprole 10.26 OD @ 60ga.i.ha^{-1} and thiamethoxam + lambdacyhalothrin 9.5ZC@ 27.5ga.i.ha^{-1} were effective in reducing leaf miner damage. Knowledge level of farmers on pesticide use and usage pattern and effective pesticide for management of beetroot leaf miner were identified.

Keywords: Beetroot, Survey, Pesticide, Cyantraniliprole, Leaf miner, Bio-efficacy.

INTRODUCTION

Beetroot, *Beta vulgaris* ssp. *vulgaris* L. (Chenopodiaceae) is one of the most important root vegetables consumed all over the world. It appears in several colors, shapes, and sizes. The cultivated forms of *Beta vulgaris* are beetroot (table beet or garden beet), leaf beets (spinach beet and chard), sugar beet and fodder beet (Lange *et al.*, 1999). It is mainly cultivated for human consumption, commercial sugar production, fodder and natural dye extraction. It is a vegetable rich in carbohydrates, lipids, fat, micro nutrients and bioactive compounds like betain, betalins, carotenoids, flavonoids and polyphenols (Chhikara *et al*., 2019; Lim, 2016). The nutrient composition of beetroot is 87.5 g water, 9.56 g carbohydrate, 6.76 g total sugar, 2.8 g fiber, 1.61 g protein and1.25 g ash and it provides 43 kcal energy per 100 g (USDA-ARS, 2014). The juice extracted from beetroot contains vitamins (B_3, B_6, B_7 & B_{12}) and minerals (Phosphorus, iron, calcium, magnesium, sodium) (Wootton-Beard *et al.*, 2011).

In Tamil Nadu, it is cultivated in the Nilgiris and Kodaikanal from early 19th century where it is raised the whole year. The total area cultivated in Tamil Nadu is around 2,113 ha with a production of 50,558 tones and average productivity of 23.93 t ha^{-1} (INDIASTAT, 2019-20). Beet root crop experiences various biotic and abiotic stresses during its growth period. Among biotic stress, insects play a crucial role in determining the yield of beetroot. More than 150 pests species affects beet crop growth and yield which includes leaf miner, tobacco caterpillar, cut worm, leafhopper, thrips, aphids, mites and flea beetles (Lange *et al*., 1999). Literature pertaining to beetroot crop pests in India are meager. Survey conducted among beetroot growing farmers in major beetroot growing tracts such as The Nilgiris, Theni, Erode and Dindigul District of Tamil Nadu revealed that leaf miner, cut worm, beet leaf hopper, green peach aphids and flea beetle are the major insect pests attacking beetroot. Beet leaf minerincidence was reported to occur in major form in the last two years in the temperate tracts of Tamil Nadu where as in plains, beet army worm caused more economic damage. To manage the insect pests, farmers are following more of chemical control, as the crop is of short duration. Beetroot though an important vegetable, was not studied thoroughly about its insect pest dynamics and pest management measures. With this background, this study was conducted to survey the insect pests attacking beetroot crop, pesticide use pattern, usage of pesticides and efficacy of insecticides against leaf miner.

MATERIALS AND METHODS

A detailed purposive random survey was conducted in beetroot growing regions of Tamil Nadu, *viz.*, The Nilgiris, Dindigul, Theni and Erode districts during January and February, 2021 to collect data on different elements of pesticide usage pattern, such as source of information, type of pesticide usage, dose, frequency, safety precautions, and health issues, as well as farmers socio-economic status from twenty randomly selected farmers from each district.

A. Details of study area

A detailed survey was conducted to understand the pest status and pesticide usage pattern of beetroot ecosystem in Tamil Nadu. The Nilgiris, Dindigul, Theni and Erode districts (Fig. 1) were purposively selected based on the extent of cultivation (788, 249, 237 and 148 ha, respectively) and surveyed block and village details are presented in table 1.

Table 1: Details of beetroot fields surveyed in Tamil Nadu.

Sr. No.	District	Block	Village	Number of respondents per village	Number of respondents per village
1	The Nilgiris	Udhagai	Kagguchi	4	20
			Kookalthorai	7	
			Ajjoor	1	
			Sulligudu	3	
		Kotagiri	Nedugula	2	
			Selakorai	3	
2	Erode	Sathiyamangalam	Arasur	7	20
			Guthiyalathur	4	
		Thalavadi	Ikkarainegamam	3	
			Koothampalayam	6	
3	Dindigul	Oddanchatram	Edayakottai	3	20
			Kethaiyurumbu	2	
			Chatrapatti	2	
			Thangachiammapatti	3	
		Reddiarchatram	Palakanuthu	2	
			Puduchatram	2	
			Neelamalaikottai	4	
			Dharmathupatti	2	
4	Theni	Chinnamanur	Appibatti	4	20
			Ayyampatti	5	
			Kanniservaipatty	6	
			Seepalakottai	2	
			Erasakkanayakanur	3	

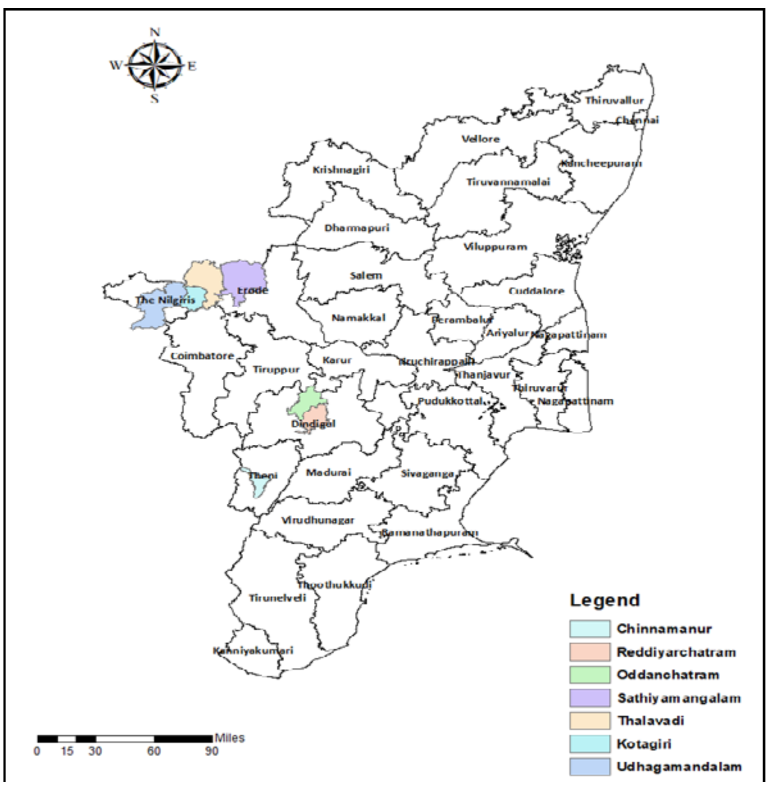

Fig. 1. Major beetroot growing tracts of Tamil Nadu surveyed for insect pest and pesticide usage pattern.

B. Nature and source of data

The information on pest status and pesticide usage pattern of beetroot crop was collected randomly from twenty selected farmers from each district. In this study, a total of 80 samples were collected with the use of suitable questionnaire format. Farmers basically rely on pesticide recommendations for beetroot from unauthorized sources. Hence, the purpose and importance of study were clearly explained to the farmers for their fullest cooperation. Information from the farmers were collected individually in the study area using the prepared questionnaire.

Questionnaire consisted of three major parts.

Part 1: General information about the farmers (Farmer name, age, education details, family details)

Part 2: Crop production information (Size of holding, crop related data, previous crop grown)

Part 3: Crop protection information (Pest status, pesticide usage pattern which includes pesticides used, source of information on recommended pesticides, awareness about label information, pesticide application details, safety precautions, spray count, spray intervals, waiting period).

The interview was conducted from January 2021 to March 2021.

Questions were asked in order from first to last, giving participants adequate time to consider the question and provide an appropriate response. Sometimes it was required to clarify the questions to the respondents since they were illiterate or only had a primary education. The respondents were completely volunteers and had freedom to refuse to give responses in time of explanation. However, no farmers denied giving the interview.

C. Field Experiment

Supervised field trials for evaluating the insecticides against leaf miner, *Liriomyza* spp. were conducted in farmer's field at two different locations in Kookalthorai (11.481351°N and 76.827544°E), Udhagamandalam block of The Nilgiris from Juneto August, 2021 following Randomized Block Design (RBD) wherein, 7 treatments and 3 replications were maintained. The insecticides for bioefficacy studies were selected based on the survey (Table 6) among beetroot growing farmers. Cyantraniliprole is recommended againstleaf miner and few other pests in grapes, pomegranate, chilli, cabbage, tomato and gherkins by Central Insecticide Board and Registration Committee of India (CIB&RC, 2021). However, pesticide recommendation is not specifically given for leaf miner management in beetroot crop. This might be due to insufficient supporting research work in that area.

The commercial formulation of all the studied insecticides were locally purchased and doses were fixed as per the recommendations of CIBRC. Date of expiry and product quality were checked before sparying. Insecticides were sprayed with the help of battery powered knapsack sprayer, that was washed thoroughly before spraying. First spraying was done 30 days after planting the crop and the subsequent second spraying was done 10 days later.

Observations were made a day before and on three, five, seven, and fourteen days after the first and second sprays. Number of infested leaves were counted and percent infestation was calculated by dividing number of leaf miner infested leaf with total number of leaves per plant and expressed in percentage.

D. Morphological identification of beetroot leaf miner

Leaf miner adult insects were collected from beet root fields of Nilgiris, preserved in 70 per cent alcohol for taxonomic identification. The identification was done by Taxonomy Unit, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore.

E. Data Analysis

To derive meaningful conclusions, the obtained survey date was categorized according to the required information and analysed using several descriptive statistical techniques such as mean, percentage and standard deviation to analyse the factors influencing pesticide use and usage pattern.

For bioefficacy analysis, the per cent infestation was transformed into an Arc sine (Angular) value and Duncan's test was followed to distinguish the means of the treatments that were significantly different ($P<0.05$). The significance threshold was set to $\alpha = 0.05$. SPSS software was used for all of these operations.

RESULTS AND DISCUSSION

A. Selected socio-economic factors of the farmers

The findings of the survey revealed that majority of the beetroot farmers were male (69%), while female participation was less (31%). This result was in accordance with United Nations Human Development Report which indicates 32.8% of Indian women formally participate in the agriculture labor force and men constitute 81.1 per cent (UNHDR, 2011). Average age of the respondents were 46.22 ± 9.78 years and their average family size was 4.17 ± 1.12 (Table 2). Land holding of beetroot growing farmers differs from area to area. Because of the smaller amount of agricultural land availability in hilly areas, The Niligiris district farmers had a lower land holding than other district farmers, which prompted that to go for short duration crops like beetroot, carrot and cabbage. Survey indicates that land holding broadly ranged from < 1 acre to 10 acres and percentage of marginal, small and semi medium farmers were 62.8, 31.7 and 5.5 per cent, respectively. Moreover, majority of the beetroot farmers belonged to marginal land holders category. This was similar with All India Report on Agricultural Census (AIRAC, 2015) which reported that, 77.19 per cent of total Tamil Nadu farmers belonged to marginal farmers category and 14.55 and 6.19 per cent of farmers comes under small and semi medium category, respectively. Farmer's educational background was good with an average schooling year of 7.46 ± 4.77 years. Though majority of the farmers surveyed were literate, knowledge acquirement on scientific practices of pest management were found to be less.

Table 2: Socio-economic factors of the farmers.

Variables	Mean	Standard deviation
Age (Years)	46.22	9.78
Family size (No.)	4.17	1.12
Education (Years)	7.46	4.77
Size of the holding (Acre)	2.27	1.59
Farming experience (Years)	14.43	6.82

B. Pest status in beetroot ecosystem

Insect pests infesting beetroot across different beetroot ecosystems of Tamil Nadu are presented in Table 3. Survey results revealed that beet leaf miner (*Liriomyza* spp.) caused more damage (52.5%), followed by aphids (37.5%), tobacco caterpillar (30%), leaf hopper (28.75%), thrips (26.25%), flea beetle (23.75%), cut worms (20%) and plant bugs (15%) are the major pests inflicting damage to beetroot crop. The leaf miner infesting beetroot in Nilgiris was identified as, *Liriomyza huidobrensis* Blanchard based on male genitalia characters (Fig. 2) and this is the first study to report the incidence of *L. huidobrensis* in beetroot for the first time in Tamil Nadu. District wise, leaf miner incidence was high in Nilgiris followed by Erode as reported by the respondents. Across the insect pest spectrum infesting beetroot, again leaf miner appeared as major pest of beetroot.

In the Nilgiris particularly, the previous crop was potato or carrot as reported by most of the respondents. In other districts, the major previous crops varied were maize, potato, cauliflower and other vegetable crops. Duration of beetroot crop slightly varied from region to region, in the range between 70 to 90 days. Around 85% of the farmers followed multiple cropping systems while 15% of the farmers practiced beet root mono cropping system. Rauf *et al*., (2000) reported more than 23 economically important species under genus *Liriomyza* that caused damage to various agricultural, horticultural and ornamental crops. The existing species in India are *Liriomyza trifolii* (Burgess), *L. huidobrensis* (Blanchard), *L. sativae (Blanchard)*, *L. bryoniae* (Kaltenbach) and *L. longei* (Frick) (Lanzoni *et al.,* 2002). *L. trifolii* is an exotic and extremely polyphagous pest recorded from 25 families including beans, celery, chrysanthemums, cucumbers, gerberas, gypsophila, lettuce, onions, potatoes and tomatoes (Spencer, 1989). *L. huidobrensis* is also extremely polyphagous and has been known to have 365 host plant species (Weintraub *et al*., 2017). During the survey, it was found that *Liriomyza* incidence in beetroot has increased during the last two cropping seasons (year 2020-21). According to the respondents, the leaf miner incidence was highest in Nilgiris, followed by Erode. Across the insect pest spectrum infesting beetroot, again leaf miner appeared as major pest of beetroot. Major reasons for the sudden rise of leaf miner incidence in beetroot grown in cooler regions might be due to change in crop ecosystem, microclimate, favourable hybrids, failure in quarantine measures, a lack of basic bio ecological studies, and improper use of pesticides. In Nilgris particularly, the previous crop was potato or carrot as reported by most of the respondents. This might be a reason for higher leaf miner incidence in following beetroot crop, as both potato and carrot are alternate hosts.

Table 3: Pest scenario of beetroot crop in surveyed areas and crop production information.

Pest status			Percentage respondents				Mean (%)
Common name	**Scientific name**	**Family / Order**	**The Nilgiris**	**Erode**	**Dindigul**	**Theni**	
I) Defoliators							
Leaf miner	*Liriomyza* spp.	Agromyzidae; Diptera	95	65	10	40	52.50
II) Leaf feeders							
Tobacco caterpillar	*Spodoptera* spp.	Noctuidae; Lepidoptera	35	20	55	10	30.00
Cut worm	*Agrotisipsilon*	Noctuidae; Lepidoptera	30	15	25	10	20.00
Flea beetle	*Monoleptasignata*	Chrysomelidae; Coleoptera	50	20	15	10	23.75
III) Sap feeders							
Aphid	*Myzuspersicae*	Aphididae; Hemiptera	75	25	15	35	37.50
Leaf Hopper	*Circulifer tenellus*	Cicadellidae; Hemiptera	60	25	10	20	28.75
Plant bug	*Dysdercus* spp.	Pyrrocoridae; Hemiptera	15	25	-	20	15.00
Thrips	*Thrips* spp.	Thripidae; Thysanoptera	40	25	15	25	26.25

Sr. No.	Crop production information		The Nilgiris	Erode	Dindigul	Theni
1	Previous crops		Carrot, potato, lettuce, and cabbage.	Potato and cauliflower	Maize, tobacco and onion.	Brinjal, maize and tomato.
2	Beet root crop duration		85-90 Days	75-80 Days	70-75 Days	70-75 Days
3	Cropping pattern	Mono cropping	10	5	-	15
		Multiple cropping	90	95	100	85

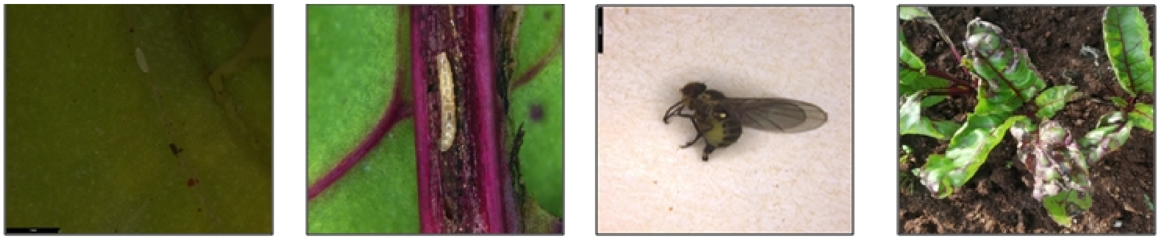

Fig. 2. Life stages and damage symptom of beetroot leaf miner – *Liriomyza huidobrensis*.

C. Pesticides used in beetroot ecosystem

Survey results revealed that the most commonly used insecticides for leaf miner and other sucking pest management are thiamethoxam 12.6% + lambda-cyhalothrin 9.5% followed by profenofos 50% EC, quinalphos 25% EC, fenvalerate 20% EC, cypermethrin 25% EC 26.25%, chlorpyriphos 20% EC, chlorpyriphos 20% EC, emamectin benzoate 5% SG, thiamethoxam 25% WG, chlorantraniliprole 18.5% SC, lambda cyhalothrin 5% EC, flupyradifurone 200% SL and triazophos 40% EC (Table 4). Beetroot crops are also susceptible to diseases such as leaf spot, beet yellows, downy mildew, and beet curly top virus infestations, which result in significant yield loss. To manage the disease incidence, farmers applied fungicides such asmancozeb 75% WP, cymoxanil 22.1% + famoxadone 16.6% SC, tricyclazole 18 % + mancozeb 60 % WP. As per CIBRC, cyantraniliprole 10.26 OD, quinalphos 25 EC and lambda cyhalothrin 5% EC are approved for management of leaf miner in some crops and majority of insecticides used by the farmers in the surveyed areas are found to be non-recommended for its use against leaf miner (CIBRC, 2021). Out of 20 pesticides used in beetroot, 3 were found to be premix combinations and 17 were individual pesticides. Use of non-recommended premix combination products may induce cross resistance in insects attacking beetroot crop. Among the insecticides applied, organophosphorous and pyrethroid groups dominated while newer insecticides with greener chemistry such as emamectin benzoate were less used. This shows lack of awareness among beetroot farmers on the less persistent and effective newer insecticide molecules. Though the majority of the farmers were literate, it didn't have much influence on the selection of insecticides.

D. Pesticide usage pattern in beetroot ecosystem

Detailed pesticide usage pattern practiced by the beetroot growing farmers depicts (Table 5) that the sources of information on pesticide recommendation are obtained majorly from the pesticide retailers (51.25%) followed by fellow farmers (26.25%). The information sought from State Department of Horticulture (15%) and Tamil Nadu Agricultural University (7.5%) was comparatively very less.Similar findings were also reported by many previous researchers (Rashid *et al.*, 2008; Shetty *et al.*, 2010; Jamali *et al.*, 2014; Afari-Sefa *et al.*, 2015; Singh *et al.*, 2016).

Table 4: List of pesticides used in beetroot ecosystem of Tamil Nadu.

Sr. No	Pesticides used	Chemical group	Percentage respondents				Mean (%)
			The Nilgiris	Erode	Dindigul	Theni	
Pesticide mixtures							
1.	Thiamethoxam12.6% + Lambda Cyhalothrin 9.5% ZC	Neonicotinoid + Synthetic pyrethroid	80.00	55.00	40.00	55.00	57.50
2.	Tricyclazole 18 % + Mancozeb 60 % WP	Trizolobensothiazole+ Organic sulphur	70.00	20.00	10.00	25.00	31.25
3.	Cymoxanil 22.1% + Famoxadone 16.6 % SC	--	65.00	35.00	30.00	45.00	43.75
Insecticides							
4.	Chlorpyriphos 20 % EC	Organophosphate	45.00	15.00	5.00	-	15.00
5.	Chlorpyriphos 50 % EC	Organophosphate	25.00	10.00	-	20.00	13.75
6.	Quinalphos 25 % EC	Organophosphate	45.00	35.00	30.00	45.00	38.75
7.	Profenofos 50 % EC	Organophosphate	55.00	10.00	15.00	45.00	31.25
8.	Triazophos 40 % EC	Organophosphate	20.00	-	-	5.00	6.25
9.	Thiamethoxam 25 % WG	Neonicotinoid	10.00	5.00	-	25.00	10.00
10.	Cypermethrin 25 % EC	Synthetic pyrethroid	50.00	15.00	5.00	35.00	26.25
11.	Fenvalerate 20 % EC	Synthetic pyrethroid	60.00	15.00	15.00	25.00	28.75
12.	Lambda Cyhalothrin 5%EC	Synthetic pyrethroid	15.00	10.00	-	-	6.25
13.	Chlorantraniliprole 18.5%SC	Diamide	5.00	-	-	25.00	7.5
14.	Emamectin benzoate 5%SG	Avermectin	20.00	15.00	5.00	5.00	11.25
15.	Flupyradifurone 200 % SL	Butenolides	5.00	10.00	-	10.00	6.25
Fungicides							
16.	Chlorothalonil 75 % WP	Triazole compound	35.00	-	-	15.00	12.50
17.	Difenaconazole 25 % EC	Organic sulphur	15.00	20.00	25.00	-	15.00
18.	Mancozeb 75 % WP	Triazole compound	80.00	75.00	60.00	65.00	70.00
19.	Tebuconazole 25.9 % EC	Trizolobensothiazole	15.00	10.00	-	25.00	12.50
20.	Tricyclazole 75 % WP	Miscellaneous	45.00	-	10.00	5.00	15.00

Table 5: Knowledge level of Beetroot farmers on pesticide use and usage pattern.

Sr. No.	Parameters	Percentage respondents				
		Nilgiris	Erode	Dindigul	Theni	Mean %
Source of information on pesticide recommendation						
1.	Department of Horticulture Tamil Nadu	25	10	15	10	15.00
2.	Fellow farmers	10	30	35	30	26.25
3.	Pesticide retailers	60	55	35	55	51.25
4.	TNAU	5	5	15	5	7.50
Attention towards label						
5.	Do not read the label before use	85	100	95	95	93.75
6.	Reading label before use	15	0	5	5	6.25
Dosage application						
7.	Approximate usage	65	85	80	90	80.00
8.	As per recommended dose	35	15	20	10	20.00
Mixing of chemical						
9.	Hand	0	0	0	0	0
10.	Stick	100	100	100	100	100
Total number of sprays						
11.	3 Times	30	65	25	15	33.75
12.	5 Times	50	35	60	75	55.00
13.	7 Times	20	0	15	10	11.25
Temporal frequency of pesticide application in beetroot						
14.	Based on pest occurrence	15	20	5	15	13.75
15.	Weekly interval (5-7 days)	55	0	15	10	20.00
16.	Fortnight interval (12-14 days)	30	80	80	75	66.25
Waiting period / Harvest interval						
17.	No waiting period	90	95	100	90	93.75
18.	Waiting period followed	10	5	-	10	6.25
Type of sprayer used						
19.	Knapsack power sprayer	90	95	100	100	96.25
20.	Hand operated sprayer	10	5	0	0	3.75
Safety precautions while spraying						
21.	No safety precautions	65	80	75	85	76.25
22.	Usage of mask and gloves	35	20	25	15	23.75
Disposal of pesticide containers						
23.	Burial in soil	5	0	0	0	1.25
24.	Thrown out of field	85	95	80	85	86.25
25.	Leaving them in the field itself	10	5	20	15	12.50

This study also revealed that 93.75 percent of farmers do not pay attention to pesticide label information. Only 20% of the farmers have the practice of spraying pesticides as per the recommended dose and remaining follow approximate dosages. Though most of the farmers (76.25%) did not follow any safety measures while undertaking spraying operation, all the farmer have used stick for mixing of pesticides (Meenambigai *et al.,* 2017; Devi, 2010). Most of the farmers (98.75%) disposed empty pesticide containers either in their own field itself or in neglected areas and only few farmers practiced disposing the used containers by soil burial. Contrastingly, Reddy (2011) reported that 50 per cent of the farmers disposed used containers by burial inside the soil. Mostly knapsack power sprayer was preferred by the farmers for pesticide application. Majority of the farmers (93.75%) did not have the knowledge on waiting period after pesticide application. All the findings on pesticide use and usage pattern revealed that lot of interventions are needed to promote safer use of insecticides in beetroot crop, which is an important food and fodder crop.

E. Bio efficacy of different insecticides against beet leaf miner, Liriomyza spp.

In the first field experiment, the incidence of leafminer before imposing treatment ranged from 35.14 to 38.78 percent (Table 6). At 7 days after first spray, cyantraniliprole 10.26 OD recorded the least damage incidence (16.53%) followed by thiamethoxam 12.6 + lambda cyhalothrin 9.5ZC (20.54%), fenvalerate 20 EC (21.03%),cypermethrin 25EC(23.22%),quinalphos 25 EC (26.82%) and profenofos 20 EC (32.51%). The mean percent incidence 14 days after first spray was lowest in cyantraniliprole 10.26% OD (19.04%) treatment which was significantly lower than thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC (21.86%) treatment. The other chemicals that followed werecypermethrin 25 EC(24.51%) and fenvalerate 20 EC (23.67%) which were on par with each other in their effect. The highest damage incidence was recorded in profenofos 20% EC (32.51) next to control (42.89). After second spray, the order of effectiveness of different insecticides in terms of percent reduction over control wascyantraniliprole 10.26OD (91.64%) >thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC (90.79%)>cypermethrin 25 EC (80.37%)>fenvalerate 20 EC (75.37%)>quinalphos 25 EC (69.62%)>profenofos 20 EC (57.27%).

In the second field experiment, the pretreatment damage incidence of leafminer ranged from 22.05 to 27.32 (Table 7). After 7 days of first spray, cyantraniliprole 10.26% OD recorded least damage (13.34%) followed by thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC (14.43%), cypermethrin 25% EC(16.25%), fenvalerate 20% EC (17.22%), quinalphos 25% EC (19.45%) and profenofos 20% EC (21.12%).

After 14 days of first spray, still lower incidence was noticed. The damage incidence recorded was lowest for cyantraniliprole 10.26% OD (14.16) treatment and significantly differed from the next best treatment thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC (15.54%). The next, quinalphos 25EC (16.23%) was found to be on par with cypermethrin 25EC(16.42%) and after first spray. At the end of second spray, thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC (5.09%) and cyantraniliprole 10.26 OD (5.11%) recorded the least percent incidence and were found on par with each other. The next best treatments were cypermethrin 20 EC (8.49%), fenvalerate 20 EC (9.62%), quinalphos 25 EC (11.88%) and profenofos 20EC (13.61%). The order of effectiveness of different insecticides in terms of percent reduction over control was cyantraniliprole 10.26(90.70%) > thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC (90.24%) >cypermethrin 25 EC(79.81%) >fenvalerate 20 EC (73.21%) > quinalphos 25 EC (72.57%) >profenofos 20 EC (60.57%).

The efficacy of cyantraniliprole was also reported against citrus leaf miner by Rao *et al.*, (2019) (18.55% incidence) and Rashmika *et al.*, (2021) in acid lime (12.36%). Misra (2015) reported an 86.03 to 93.59% reduction of leaf miner *L. trifolii* over control in gherkin crop after spraying with cyantraniliprole 10.26 OD. To the best of our knowledge, there is no report on efficacy of cyantraniliprole10.26 OD against leaf miner in beet root.

Table 6: Effect of different insecticides on leaf miner incidence in beetroot – Trial I.

TREATMENT	Incidence of leaf miner in/on beetroot (Percent leaf damage)													
	After first spray							After second spray						PRC
	PTC	3 DAS	5 DAS	7 DAS	10 DAS	14 DAS	MEAN	3 DAS	5 DAS	7 DAS	10 DAS	14 DAS	MEAN	
Cyantraniliprole10.26%OD@60g a.i.ha^{-1}	36.28	32.45	24.12	16.53	12.27	9.83	19.04	7.25	5.27	3.33	2.87	1.42	4.03	91.64
	(37.04)	(34.73)	(29.41)	(23.99)	(20.50)	(18.27)	(25.87)^{f}	(15.62)	(13.27)	(10.51)	(9.75)	(6.84)	(11.58)^{g}	
Thiamethoxam 12.6% + Lambda cyhalothrin9.5% ZC @ 27.5g a.i.ha^{-1}	35.14	33.32	28.25	20.54	15.84	11.35	21.86	8.32	6.53	3.76	2.26	1.33	4.44	90.79
	(36.36)	(35.26)	(32.11)	(26.95)	(23.45)	(19.69)	(27.88)^{e}	(16.76)	(14.81)	(11.18)	(8.65)	(6.62)	(12.16)^{f}	
Cypermethrin25% EC@ 30g a.i.ha^{-1}	37.45	33.27	27.56	23.22	20.05	18.45	24.51	15.33	11.75	8.56	6.24	5.43	9.46	80.37
	(37.73)	(35.23)	(31.67)	(28.81)	(26.60)	(25.44)	(29.67)^{d}	(23.05)	(20.05)	(17.01)	(14.47)	(13.48)	(17.91)^{e}	
Fenvalerate20%EC@ 60g a.i.ha^{-1}	37.66	34.34	25.95	21.03	19.34	17.68	23.67	16.09	15.55	11.36	9.47	6.88	11.87	75.37
	(37.86)	(35.87)	(30.62)	(27.30)	(26.09)	(24.86)	(29.11)^{d}	(23.65)	(23.22)	(19.70)	(17.92)	(15.21)	(20.15)^{d}	
Quinalphos25%EC@ 250g a.i.ha^{-1}	37.67	32.76	29.45	26.82	24.07	22.12	27.04	19.23	17.33	14.54	12.02	10.10	14.64	69.62
	(37.86)	(34.92)	(32.87)	(31.19)	(29.38)	(28.06)	(31.33)^{c}	(26.01)	(24.60)	(22.42)	(20.29)	(18.53)	(22.50)^{c}	
Profenofos50%EC@ 500g a.i.ha^{-1}	38.78	35.05	33.24	32.51	31.52	30.23	32.51	25.34	22.54	20.75	18.22	16.12	20.59	57.27
	(38.52)	(36.30)	(35.21)	(34.76)	(34.15)	(33.35)	(34.76)^{b}	(30.22)	(28.34)	(27.10)	(25.27)	(23.67)	(26.99)^{b}	
Untreated control	37.34	40.35	41.78	42.27	44.53	45.54	42.89	46.24	47.28)	48.12	49.11	50.25	48.20	
	(36.36)	(35.26)	(32.11)	(26.95)	(23.45)	(19.69)	(27.88)^{a}	(16.76)	(14.81	(11.18)	(8.65)	(6.62)	(12.16)^{a}	
SE(d)	**0.419**	**0.413**	**0.432**	**0.286**	**0.264**	**0.267**	**0.34**	**0.24**	**0.348**	**0.296**	**0.377**	**0.236**	**0.301**	
CD	**0.924**	**0.909**	**0.951**	**0.631**	**0.581**	**0.589**	**0.755**	**0.528**	**0.766**	**0.653**	**0.83**	**0.52**	**0.663**	

DAT - Days after treatment; PTC – Pretreatment count; PRC – Percent reduction over untreated control

*Figures in parentheses are Arc sine transformed values.

Treatment means with letter(s) in common are not significant by DMRT at 5% level of significance.

Table 7: Effect of different insecticides on leaf miner incidence in beetroot – Trial II.

Treatment	Incidence of leaf miner in/on beetroot (Percent leaf damage)													
	After first spray							After second spray						PRC
	PTC	3 DAS	5 DAS	7 DAS	10 DAS	14DAS	MEAN	3 DAS	5 DAS	7 DAS	10 DAS	14DAS	MEAN	
Cyantraniliprole10.26%OD@60g a.i.ha^{-1}	23.34	19.23	16.11	13.34	12.25	9.89	14.16	8.23	6.23	5.23	3.56	2.32	5.11	90.70
	(28.89)	(26.01)	(23.66)	(21.42)	(20.49)	(18.33)	(22.11)^{f}	(16.67)	(14.45)	(13.22)	(10.88)	(8.76)	(13.07)^{e}	
Thiamethoxam 12.6% + Lambda cyhalothrin9.5% ZC @ 27.5 g a.i.ha^{-1}	24.45	22.29	16.56	14.43	13.23	11.17	15.54	8.23	6.55	5.11	3.24	2.33	5.09	90.24
	(29.63)	(28.17)	(24.01)	(22.33)	(21.33)	(19.52)	(23.21)^{e}	(16.67)	(14.83)	(13.06)	(10.37)	(8.78)	(13.04)^{e}	
Cypermethrin25% EC@ 30g a.i.ha^{-1}	23.23	21.22	18.33	16.25	14.22	12.09	16.42	11.02	9.27	8.26	7.77	6.12	8.49	79.81
	(28.81)	(27.43)	(25.35)	(23.77)	(22.15)	(20.35)	(23.91)^{d}	(19.39)	(17.73)	(16.70)	(16.19)	(14.32)	(16.94)^{d}	
Fenvalerate20%EC @ 60g a.i.ha^{-1}	24.22	22.13	19.54	17.22	15.44	13.93	17.65	12.20	11.12	9.22	8.23	7.34	9.62	73.21
	(29.48)	(28.06)	(26.23)	(24.52)	(23.14)	(21.91)	(24.84)^{c}	(20.44)	(19.48)	(17.68)	(16.67)	(15.72)	(18.07)^{c}	
Quinalphos25%EC @ 250g a.i.ha^{-1}	26.43	24.22	20.15	19.45	17.71	16.19	16.23	14.15	13.65	11.45	10.23	9.93	11.88	72.57
	(30.94)	(29.48)	(26.67)	(26.17)	(24.89)	(23.73)	(23.76)^{de}	(22.10)	(21.68)	(19.78)	(18.65)	(18.37)	(20.16)^{c}	
Profenofos50%EC @ 500g a.i.ha^{-1}	27.32	25.34	23.33	21.12	20.04	19.56	21.88	18.12	15.23	13.23	11.24	10.23	13.61	60.57
	(31.51)	(30.22)	(28.88)	(27.36)	(26.59)	(26.25)	(27.89)^{b}	(25.19)	(22.97)	(21.33)	(19.59)	(18.65)	(21.65)^{b}	
Untreated control	22.05	25.34	28.23	32.23	33.56	39.54	31.78	38.56	43.65	47.87	55.46	56.98	48.50	
	(28.01)	(30.22)	(32.09)	(34.59)	(35.40)	(38.96)	(34.31)^{a}	(38.39)	(41.35)	(43.78)	(48.13)	(49.01	(44.14)^{a}	
SE(d)	**0.24**	**0.33**	**0.29**	**0.19**	**0.22**	**0.36**	**0.35**	**0.38**	**0.26**	**0.27**	**0.42**	**0.36**	**0.29**	
CD	**0.53**	**0.72**	**0.64**	**0.41**	**0.48**	**0.80**	**0.77**	**0.84**	**0.58**	**0.60**	**0.93**	**0.80**	**0.647**	

DAT - Days after treatment; PTC – Pretreatment count; PRC – Percent reduction over untreated control

*Figures in parentheses are Arc sine transformed values.

Treatment means with letter(s) in common are not significant by DMRT at 5% level of significance.

CONCLUSION

Survey results revealed beetroot crop is invaded by beet leaf miner, aphids, tobacco caterpillar, leaf hopper, thrips, flea beetle, cut worms and plant bugs and severe infestation of beet leaf miner was observed. In the changing pest scenario, leaf miner is becoming dominant in beetroot. Farmers used both recommended and not recommended pesticides in the beetroot ecosystem. Among the insecticides applied, organophosphorous and pyrethroid groups dominated while newer insecticides with green chemistry such as emamectin benzoate were less used. Though the majority of the farmers were literate, it didn't have much influence on selection of insecticides. The use of a stick for mixing pesticides, use of measuring caps, and avoiding reusing pesticide containers for domestic purposes were all seen as signs of a changing trend in farmers awareness on pesticide risk. Farmers understanding of pesticide recommendation from authorised sources, dosages, waiting period, pesticide label information and importance of safety protection equipment while spraying operations, on the other hand, was lacking. There is a greater need for educating the farmers about the importance of following of proper waiting period, selection of appropriate pesticides, importance of spraying pesticides as per the recommended doses, pesticide hazard related problems on environment as well as humans. The bio efficacy study with insecticides against leaf miner revealed that cyantraniliprole10.26 OD @ 60 g a.i. $ha^{-1}$and Thiamethoxam 12.6% + lambda cyhalothrin 9.5%ZC @ 27.5 g a.i. ha^{-1}were effective and may be recommended in alternation for the management of leaf miner in beetroot.

Conflict of interest. The authors declare that they have no conflict of interest.

Acknowledgement. The authors are grateful to Pesticide Toxicology Laboratory, Department of Agricultural Entomology, Centre for Plant Protection Studies (CPPS), Tamil Nadu Agricultural University, Coimbatore, India for providing necessary facilities during the study.

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How to cite this article: Prakash, P. N.; Suganthi, A.; Bhuvaneswari, K. and Kumar, M. S. (2021). Insect pests, Pesticide use and Usage Pattern in Beetroot Crop Cultivated in Tamil Nadu. *Biological Forum – An International Journal*, *13*(4): 719-727.