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Control Strategies of American Leaf Miner (*Tuta absoluta*) (Meyrick) Adopted by Farmers in Lalitpur District, Nepal

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Abstract This study evaluates the control strategies adopted by vegetable farmers in Lalitpur, Nepal, to combat *Tuta absoluta* during April-May 2023. Five wards in Godawari municipality were selected due to the significant infestation of *Tuta absoluta*. A total of 70 households were chosen through random sampling. Data collection methods included pre-tested interviews, Focus Group Discussions, and Key Informant Surveys for primary information, while secondary information was obtained from relevant publications. The primary vegetables grown were tomato, potato, cauliflower, cabbage, and onion. Farmers faced major issues with diseases and pests, particularly blight and *Tuta absoluta*, which caused yield losses up to 90%, with an average loss of 56%. While 35.7% of farmers used chemical pesticides, 71.4% relied on botanical pesticides and cultural methods. Among control measures, botanical methods were rated most effective with a relative index of 0.933. The study highlights the pressing need for integrated pest management training, as only 25.7% of farmers had received it, and underscores the significance of botanical methods in managing *Tuta absoluta* effectively.

Keywords Biopesticides; Pest control strategies; *Tuta absoluta* control; Vegetable

1 Introduction

For the majority of the population (almost 65%) in Nepal agriculture is the major source of livelihood, which contributes 23.95% in GDP (MoALD, 2022, https://moald.gov.np/). Horticultural crops have a major role in sustaining Agricultural Gross Domestic Product (AGDP) of Nepal. Tomato (*Solanum lycopersicum L.)* belongs to the family Solanaceae, which is a widely grown vegetable in the world as well as in Nepal. In the mid hills of Nepal, it is grown in two seasons – spring and rainy whereas in terai it is grown in winter season. Tomatoes can help improve the economic standard of subsistence farmers by comparatively high returns compared to low returns cereal crops. Its demand in the market is increasing day by day. Tomato is also known as poor man's orange, which is rich in vitamin C, calcium, folate, protein, minerals and antioxidants. Tomatoes are threatened by various pests and diseases such as thrips, aphids, mealy bug, leaf miners, tomato worms, leafhoppers and early leaf blight, late blight, fruit rot, Septoria leaf spot, anthracnose etc. respectively. Tomato leaf miner *Tuta absoluta* (Meyrick) (gelechiidae) is one of the dangerous pests of tomato native to South America (Michereff Filho et al., 2000).

Despite being near to the capital of the country, the availability of inputs such as fertilizers, seeds and required chemicals are not in time, which causes the limitation in production of vegetables including tomato in Lele, Bisankhunarayan and Chapagau village of Lalitpur district. The major causes of limiting production are unavailability of inputs in time, irrigation problems in winter, middle man involvement in the value chain, various pests and disease, biotic and abiotic stresses. Among the various causes the occurrence of pests, especially *Tuta absoluta, is one* of the major problems to reduce quality and quantity of tomato production of tomato (Upreti et al., 2020). Field observation shows that farmers have been using different preventive measures like pheromone traps,

insecticides, and various cultural methods to protect the crops, despite that none of the methods showing the significant solution of problems. Leaf miner is the invasive pest causing the destructive damage either directly by reducing yield or indirectly by reducing the quality of produce or consumer preferences and export. From the year of invasion, it is causing devastating damage in tomato farms of Lalitpur (Lamsal et al., 2018).

Though various efforts made by farmers and pesticide management and quarantine centre for controlling leaf miner infestation by using traps, Integrated Pest Management (IPM) methods and insecticides, the result is not so encouraging. Farmers mostly use the pesticides, but they lack the knowledge about proper way of application and major time in which application is effective. Various research has been done to find out the measures to reduce the damage but most of them lacks to assess which method is most effective. So, this study will help to identify which method is most effective to check the population of the Leaf miners for effective management with the major period of infestation.

2 Materials and Methods

2.1 Experimental site and sub-sector

The research was conducted in Lele VDC of Lalitpur district, which falls under Bagmati province. It covers five wards 2, 5, 6, 10 and 11 of Godawari municipality, assigned under the PMAMP vegetable zone of Lalitpur district. Lalitpur lies within 1,324 m at lower elevation to the 2,300 m at the higher elevation from sea level.

2.2 Preliminary field visit

For the collection of information regarding the social structure, demographic features, topographical features and field condition, preliminary visit was done in the experimental site. The information collected was the basis for the preparation of questionnaire, sampling design and application of sampling techniques.

2.3 Sample and sampling techniques

The sampling frame was designed through the profile of farmers of Godawari municipality ward number 2, 5, 6, 10 and 11 of Lalitpur district. 70 households were drawn by using a disproportionate simple random sampling technique from the sampling frame.

2.4 Research instrument/design

2.4.1 Pre testing

The questionnaire was pre-tested prior to administering to the actual respondents for checking the reliability and validity of questionnaire. The pre-testing was done on 10 percent respondent near to study area. The correction was made in the final questionnaire format.

2.4.2 Household survey

Total 70 individual households were face to face contacted and interviewed through a semi-structured questionnaire including information, knowledge, experience and perception of *Tuta absoluta*, its prevalence status and management practices. Age group above 25 years will be in priority as they are likely to be more experience.

2.4.3 Key informant interview

To develop further idea of the study site, informal discussion and interview with key informant was done. 15 Key Information Interview was done with the progressive farmers, Zone officer and other beneficiaries to obtain key information. For this a separate checklist will be used.

2.4.4 Field observation

Field was observed frequently to verify every collected data from household survey and KII.

2.5 Data and data type

2.5.1 Primary data

Primary data was collected from the farmers of experimental site, who have been experiencing the problem of *T. absoluta.*

2.5.2 Secondary data

Sources of secondary data was annual reports, pamphlets, records of zone, and various Agricultural and horticultural agencies, NGO's and INGO's. Publications and websites of FAO, MOALD will be made accessible for withdrawal of data.

2.6 Data analysis techniques

The various assistive media for the qualitative and quantitative analysis of gathered data were statistical package for social science (SPSS) and Excel. Information collected from household survey, focus group discussion, case study was coded first and entered into computer. Data entry was done by using SPSS, Microsoft excel and descriptive analysis was done to analyse the data.

The data like name, age, year, educational status, occupation and some sensitive data and impact of the *Tuta absoluta* and control measures followed by tomato farmers was studied by estimating frequency, percentage, charts and diagrams and other such tools was used to present the data. Preferential ranking was done by indexing:

$$I\ imp = \Sigma\ (Si \times fi/N)$$

Where, I imp = Index of importance; Si= scale value; N= No. of respondents; fi= Frequency of importance given by respondents

3 Results and Discussion

3.1 Sociodemographic characteristics of farmers

The study results show that 71% of total farmers were the age group of 30-50 followed by 16% were under 30 and 13% were above 50 years. The percentage of males was (57%) and females was (43%), which showed the satisfactory participation of women in agriculture activities compared to other programs. The majority of respondents were Janajati (47.1%) followed by Bramin/Chettri (41.4%). Four-point three percent of respondents belong to Dalit category while 7.1% of respondents belong to others, which includes madeshi, aadhibashi etc. Total 57% migrated from other various districts of Nepal in search of better opportunities whereas, only 43% were the permanent residents of Lalitpur. The main occupation of 75.7% of households was agriculture, followed by foreign employment (10%), service holders (86%) and business (5.7%). This means that agriculture is the main source of income for 75.7% of families in Godawari municipality, Lalitpur. Only about 28.6% percent of the tomato growers were involved in co-operatives/farmers groups whereas 71.4% percent were not involved in any co-operatives/farmers groups.

3.2 Education level of respondent

The literacy level of the farmers has an impact on modernizing the agriculture framework and improvement in the practices (Pudasaini, 1983). The study revealed that 21.4 % were illiterate, 24.5% were only educated primarily, 45.7% were educated in secondary level whereas only 2.9% were educated in higher level (Figure 1). The study also shows that 5.7% were educated JT/JTA.

3.3 Land type and total land of farmers

Most of the farmers 68.6% of them had rented the land for agricultural practices. Only 31.4% of farmers had their own land for agricultural practices. Total 83% of farmers have an irrigation system, whereas 8% of them are facing irrigation problems and 9% of them have land which can be both rainfed and irrigated artificially.

The results revealed that total land holding of farmers ranges from 0.101 to 1.730 hectares with the mean of 0.376 (Table 1). Whereas area under tomato cultivation ranges from 0.050 to 1.272 hectare indicating the commercial tomato production.

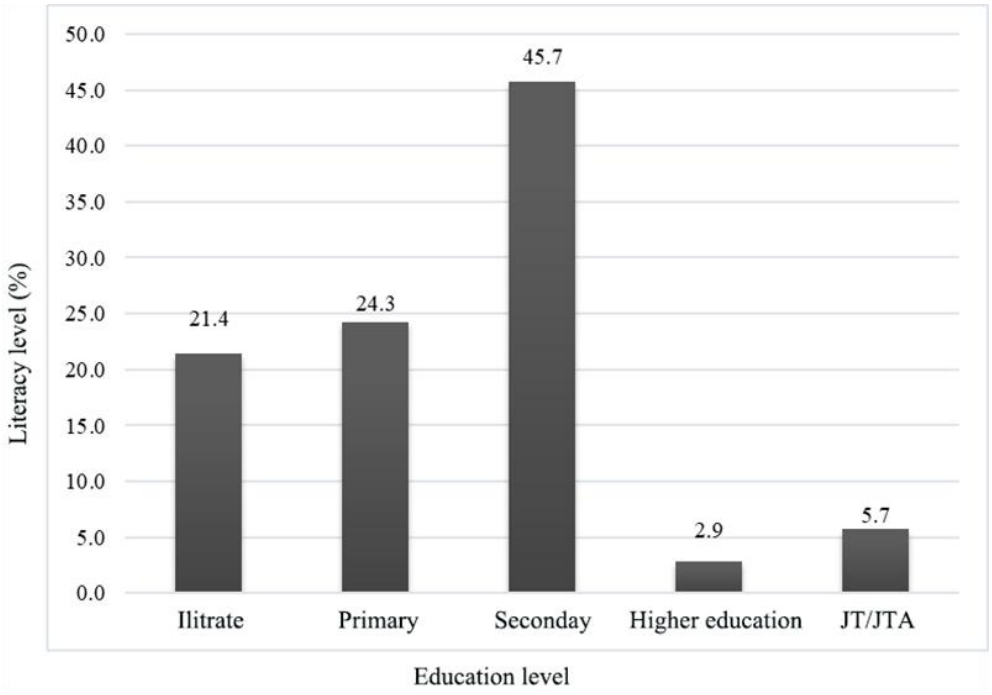

Figure 1 Education level of respondent in Godawari, Lalitpur (Source: Field survey (2023))

Table 1 Total land of respondent in Godawari, Lalitpur

Land (in hector)	Minimum	Maximum	Sum	Mean
Total land holding	0.101	1.730	26.36	0.376
Land under tomato cultivation	0.050	1.272	19.28	0.275

Source: Field survey (2023)

3.4 Tomato cultivation

Most of the farmers cultivate tomatoes in poly houses because of frost problems in this area with holding 77% in this category. A total of 16% of the farmers cultivate tomato in both polyhouses and open field and only 7% farmers cultivate tomato in open field. Out of a total 70 households only 5.7 % farmers did not have polyhouses whereas 94.3 % of them cultivate tomatoes in polyhouses. Mostly tomato cultivation was done in both in Magh-Falgun with 80% cultivation. Out of total, 17.1% farmers cultivate tomato Chaitra-Baisakh and 2.8% farmers only in Baisakh-Jestha. Total 62.9 % of farmers are involved in commercial cultivation of tomato for selling purpose followed by 32.9 % of farmers cultivate tomato for both home consumption and selling purpose and 4.3% of farmers cultivate tomato for only home consumption purpose. The study revealed that 42.9 percent of the respondents had experience of tomato farming from 1 to 3 years whereas 35.7 percent had experience of 4 to 7 years. Similarly, 12 percent had experience of 7 to 10 years and 3 percent had more than 10 years of experience on commercial tomato farming.

3.4.1 Number of polyhouses

Study revealed that the number of polyhouses of individual farmers in Godawari municipality Lalitpur ranges from 1 to 100 with the mean of 16.12 and total sum of 66 households were 1064 (Table 2).

Table 2 Number of poly houses in farmers field in Godawari, Lalitpur

Polyhouses	Minimum	Maximum	Mean	Sum
Number of polyhouses	1	100	16.12	1064

Source: Field survey (2023)

3.4.2 Preferred variety by farmers

Study revealed that 57.1% of farmers prefer *Srijana* variety because of suitable size which is preferred by consumers and has high market value (Figure 2). Both Super *Srijana* and improved *Srijana* were preferred by 17.1% of farmers. Similarly, *Samjhana* and *Dalila* varieties of tomato were cultivated by 5.7% and 2.9% of farmers respectively.

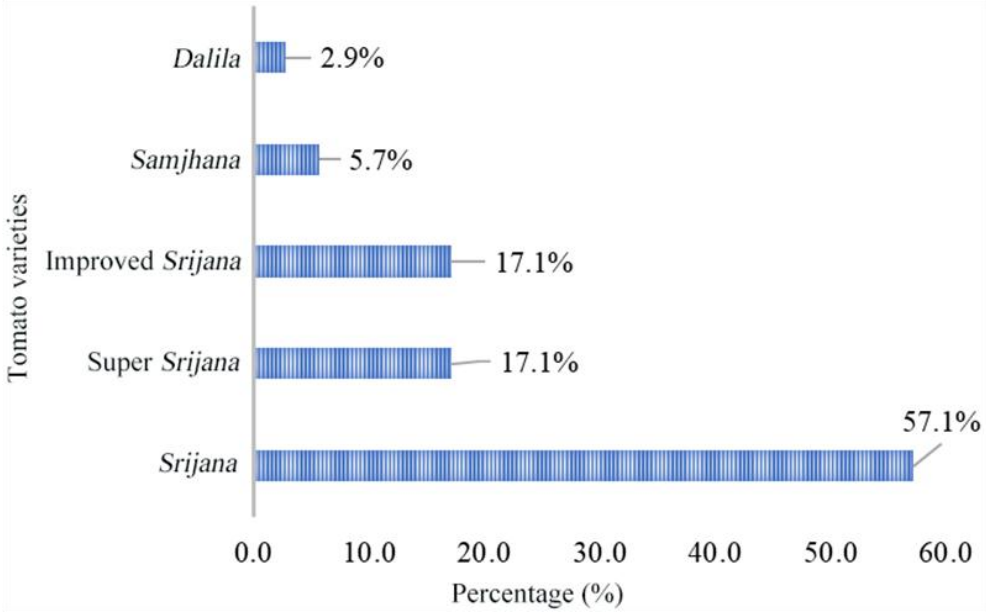

Figure 2 Preferred variety by farmers in Godawari, Lalitpur (Source: Field survey (2023))

3.5 Problems in production aspect of tomato

3.5.1 Production problem ranking in tomato

Tomato growers have many problems related to production out of which main problems are in disease and pests, unavailability of inputs, soil testing problems and lack of technical know-how etc. The severity of the problems in tomato production was studied using forced ranking. The severity index showed that disease and pests was the most severe problem with an index of 0.888 followed by unavailability of inputs with an index of 0.689 (Table 3). Soil testing problem was the third most severe problem with an index of 0.667. Similarly, natural calamities, lack of techniques to know how and irrigation problem was found as the fourth, fifth and sixth problem with an index of 0.458, 0.443 and 0.367, respectively.

Table 3 Production problem ranking in tomato in Godawari, Lalitpur

Problems	P1	P2	P3	P4	P5	P6	Weight	Index	Rank
Unavailability of inputs	8	18	29	8	4	3	48.247	0.689	II
Disease and pests	16	7	3	2	2	0	62.199	0.888	I
Lack of techniques to know how	4	5	5	13	2	0	31.054	0.443	V
Irrigation problem	5	4	4	8	15	34	25.708	0.367	VI
Soil testing problem	6	31	12	6	8	7	46.748	0.667	III
Natural calamities	1	6	6	34	7	16	32.062	0.458	IV

Source: Field survey (2023)

3.5.2 Insect pest ranking on the basis of severity in tomato production

Three different pests were observed in tomatoes in different proportions of infestation during a preliminary visit to the study site. All of them were listed and asked to rank in terms of infestation range through interviews, FGD and questionnaires. P implies the problematic pest, similarly P1 implies for highly major pest, P2 implies Moderately significant pest and P3 for minor pest (Table 4).

Table 4 Ranking of pests of tomato on the basis of severity in Godawari, Lalitpur

Pests of tomato	P1	P2	P3	Index	Rank
Tomato leaf miner	53	10	3	0.959	I
Whitefly	9	45	12	0.821	II
Tomato fruit borer	5	11	50	0.722	III

Source: Field survey (2023)

Index value was given to each pest according to the priority placed by respondents. Responses recorded showed tomato leaf miner on the 1st rank, then after whitefly followed by tomato fruit borer on 2nd and 3rd rank respectively. Tomato leaf miner has created a severe decrement in the overall yield. Production and marketing range vary greatly due to the worse impact of tomato leaf miner pests. Tomato fruit borer and tomato mosaic virus are two of the most important problems, but a new threat has emerged with the introduction of a new pest, *Tuta absoluta* (Saidov et al., 2018; Simkhada et al., 2019).

3.5.3 Diseases ranking on the basis of severity in tomato production

The severity index showed that among diseases, late blight was the most severe affecting the profitability of tomatoes with an index of 0.919 (Table 5). Tomato mosaic virus diseases and damping off were found second and third most severe diseases with an index value of 0.799 and 0.733, respectively. Similarly, Wilting was found least severe with an index of 0.554.

Table 5 Ranking of tomato diseases on the basis of severity in Godawari, Lalitpur

Diseases of tomato	P1	P2	P3	P4	Index	Rank
Blight disease	46	11	6	3	0.919	I
Tomato mosaic virus	15	23	27	1	0.799	II
Damping off	3	28	27	8	0.733	III
Wilting	3	3	6	54	0.554	V

Source: Field survey (2023)

3.6 Consultation for problem

When various problems are encountered during farming 51.4% farmers consult agrovet, followed by 32.9% to friends/neighbours (Table 6) Only 7% and 4 % of them consult with NGO/INGOs and government agencies respectively.

Table 6 Different places for the consultation of problems faced by farmers in Godawari, Lalitpur

Consultation	Frequency	Percentage (%)
Friends/Neighbours	23	32.9
Government agencies	4	5.7
Agrovet	36	51.4
NGO/INGO	7	10

Source: Field survey (2023)

3.7 *Tuta absoluta*

Tuta absoluta has been a serious issue in tomato cultivation around here. As study had uncovered 80-100 percent of yield loss happened because of this pest and more than $50 million USD (Desneux et al., 2010).

3.7.1 Infestation of *Tuta absoluta* in the study area

This pest started from Kathmandu and spread to Lalitpur, Bhaktapur, Kavre, and Dhading and to Kaski, Baglung, Parbat, Tanahun and also seen in Myagdi. Studies carried out by the Nepal Agricultural Research Council (NARC) in May and June of 2016 identified and confirmed the presence of the pest in 14 locations in the first five districts

mentioned above (Bajracharya et al., 2016). From the survey research it was found that there is no infestation in 20% i.e., 14 farmers (Figure 3). So further questions were asked only to the 80% i.e 56 respondents out of 70.

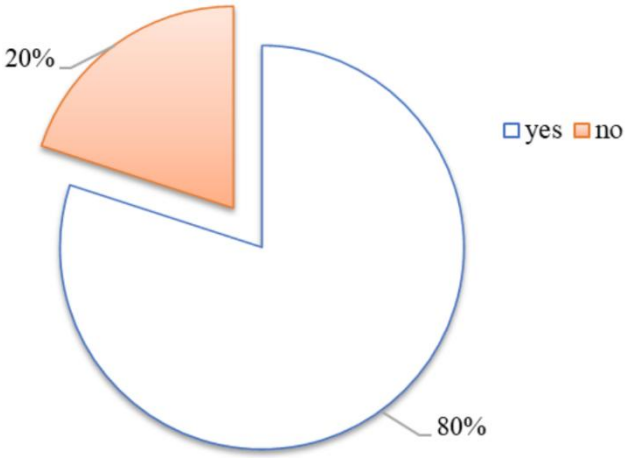

Figure 3 Infestation of TLM in Godawari, Lalitpur (Source: Field survey (2023))

3.7.2 Damage symptoms of *Tuta absoluta*

Leaves, stems and fruits of tomato are majorly affected by *Tuta absoluta*. It mainly attacks the leaf and, on advancement, affects the other parts (Illakwahhi et al., 2017; Alam et al., 2019). Larva of this insect mines on the fruit, stem and leaves of tomato. Common signs and symptoms of *Tuta absoluta* on fruit and stems include puncture marks, abnormal shape, exit holes, rot due to secondary infective agents. Fruits show puncture marks on the surface where the larva has entered the plant. Leaves dry out completely and flying moths can be seen around the plant in the severe condition.

3.7.3 Most damaging stage of crop by *Tuta absoluta*

Tuta absoluta effects in all stages of crop however the damage mostly occurs in early stages compared to late stages of crops. According to the survey results (Table 7), 57.1% farmers faced the damages in all stages while 23.2% and 17.9% of farmers faced damage in vegetative and fruiting stages of crop respectively. Only 1.8% of farmers faced damage in ripening stages of crop.

Table 7 Damaging stages of crops by TLM in Godawari, Lalitpur

Stage of crop	Frequency	Percentage (%)
Vegetative	13	23.2
Fruiting	10	17.9
Ripening	1	1.8
Equally in all growth stages	32	57.1
Total	56	100

Source: Field survey (2023)

3.7.4 Ranking of *Tuta absoluta* out of many problems

Tuta absoluta was found the most problematic of all problems among 64.3% of the respondent, more problematic than other insects, pest, disease and disorders among 23.2% and as problematic as other insects and pest, diseases and disorder among 8.9% of respondents (Figure 4). It was not as problematic as other insects, pests, diseases and disorder among 3.6% of the respondents. The result showed that the havoc of *Tuta absoluta* was the highest in Lalitpur.

3.7.5 Knowledge level on life cycle of *Tuta absoluta*

It can be seen that out of the 70 respondents, 81% were unaware about the life cycle of *Tuta absoluta* (Figure 5). Only 19% of them had knowledge on the life cycle of this insect.

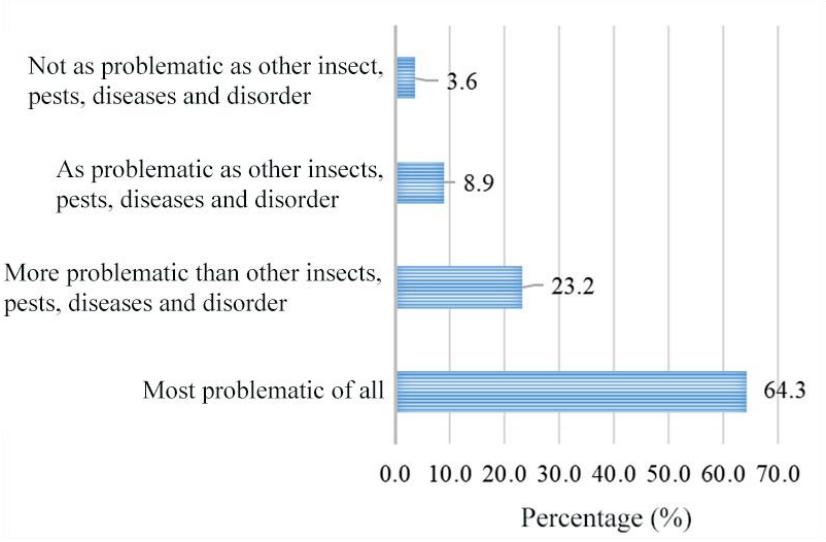

Figure 4 Ranking of TLM out of many other problems by farmers in Godawari, Lalitpur (Source: Field survey (2023))

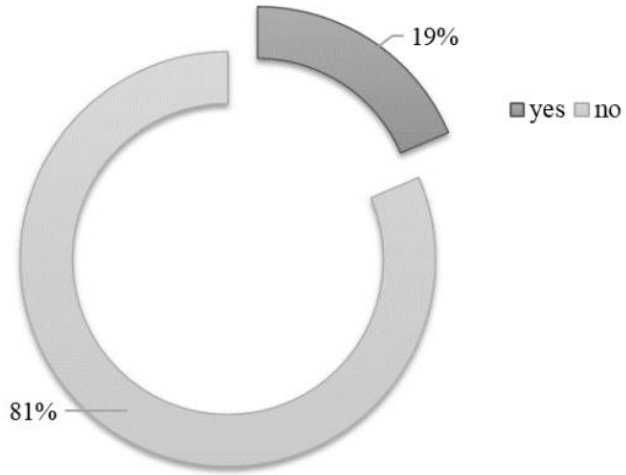

Figure 5 Knowledge level on life cycle of TLM among farmers in Godawari, Lalitpur (Source: Field survey (2023))

3.7.6 Yield loss due to *Tuta absoluta*

In the study area the yield loss ranges from 10% minimum to 90% maximum. 56.52% was the mean yield loss due to the infestation of this pest (Table 8). But in most severe cases it can cause loss up to 80%-100% (Sah et al., 2017). Economic losses due to *Tuta absoluta* in tomatoes have been reported to be up to 100% in some countries in Africa particularly Sudan, Kenya, and Ethiopia. Chidege et al. (2016) reported a yield loss of 80%-100% by this pest from countries in Northern and Western Africa.

Table 8 Yield loss due to TLM in Godawari, Lalitpur

Loss (in percent)	Minimum	Maximum	Mean
Yield loss	10	90	56.52

Source: Field survey (2023)

3.8 Control measures

The complete eradication of *Tuta absoluta* is impossible. But all the farmers are using control measures to minimize its adverse effect. These control methods include chemical pesticides, bioagents, and mass traps using pheromones and botanical extracts. *B. thuringiensis* has been demonstrated to be quite effective at minimizing damage (González-Cabrera et al., 2011). Biological method of pest management was not used by any of the farmers due to lack of availability and technical know-how. Multiple responses of the respondent were employed

as a tool for analysis of the most adopted management practices, so the total percent was more than 100. Out of the survey population all of them are using cultural methods, 81.4% following botanical methods, 72.9% are using traps followed by 41.9 % using insect net and only 35.7% using chemical methods to control and manage the *Tuta absoluta* below the economic injury level (Figure 6).

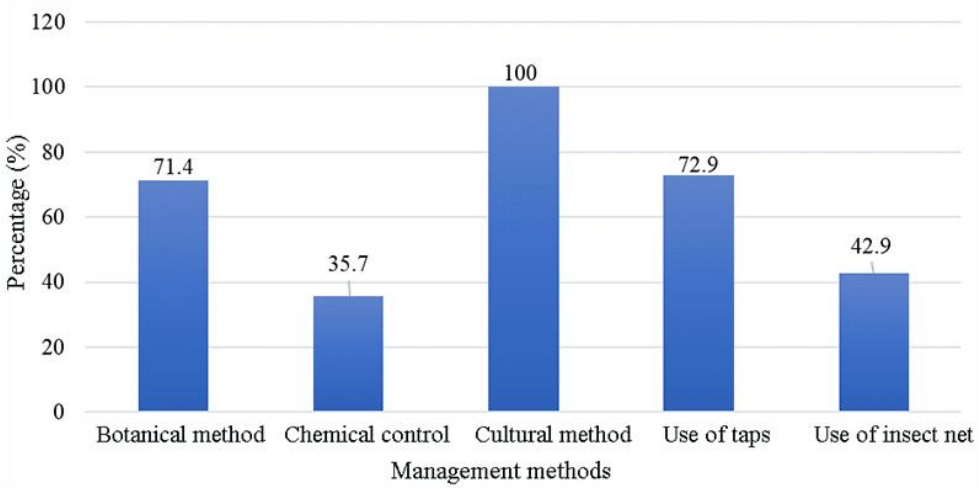

Figure 6 Different methods adopted to control TLM in Godawari, Lalitpur (Source: Field survey (2023))

3.8.1 Checking of pest period

Most of the respondents were only involved in agriculture therefore the majority of them spent all working hours of day in the field. 64.3% of farmers check in the pest on a daily basis which is followed by 19.6% checking a couple times a week (Table 9). Similarly, 12.5% and 3.6 % checks for pests once a week and not very often respectively.

Table 9 Period of check on the pests in Godawari, Lalitpur

Period pf checking	Frequency	Percent (%)
Daily	36	64.3
Couple a times a week	11	19.6
Once a week	7	12.5
Not very often	2	3.6

Source: Field survey (2023)

3.8.2 Training on Integrated pest management (IPM)

Out of surveyed populations where actual infestation of *Tuta* occurs only 25.7% were taking the training on IPM but 74.3%, those who hadn't taken training were also using IPM methods within their knowledge limits (Table 10). The IPM program was designed and implemented with an ecologically based participatory IPM strategy (Norton et al., 2005).

Table 10 Training on Integrated Pest Management (IPM) in Godawari, Lalitpur

Training on IPM	Frequency	Percent (%)
Yes	18	25.7
No	52	74.3

Source: Field survey (2023)

3.8.3 Mechanical method of pest management

Various mechanical methods had been used by farmers. Among them 72.9 % use traps, 42.9% use insect nets and 51.8 % pick up the larvae by hand and kill them manually (Table 11; Table 12; Table 13). Considering all 70

respondents for insect net and traps used and only 56 respondents for picking up the larva where TLM infestation has occurred.

Table 11 Use of insect net for pest management in Godawari, Lalitpur

Use of insect net	Frequency	Percentage (%)
Yes	30	42.9
No	40	57.1

Source: Field survey (2023)

Table 12 Use of various traps for pest management in Godawari, Lalitpur

Use of traps	Frequency	Percentage (%)e
Yes	51	72.9
No	19l	27.1

Source: Field survey (2023)

Table 13 Hand picking of larva for TLM management in Godawari, Lalitpur

Hand picking of larva	Frequency	Percentage (%)
Yes	29	51.8
No	27	48.2
Total	56	100

Source: Field survey (2023)

3.8.4 Knowledge about TLM Pheromone lure

The results showed that only 43% of farmers had knowledge about TLM lure while 57% did not know about TLM Lure even though they use it by others recommendations (Figure 7).

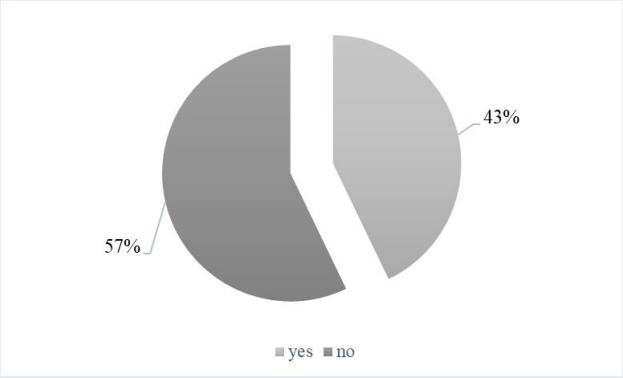

Figure 7 Knowledge about TLM Lure among the farmers in Godawari, Lalitpur (Source: Field survey (2023))

3.8.5 Types of traps used by farmers

Among the various traps none of the farmers used light traps because of difficulty in instalment and maintenance. 56.9% used both Wotta t traps and sticky traps whereas 31.4% and 11.8% used Sticky traps and Wotta T traps respectively (Table 14).

Table 14 Types of traps used by farmers in Godawari, Llaitpur

Traps	Frequency	Percent
Sticky traps	16	31.3
Wotta T traps	6	11.8
Both	29	56.9
Light traps	0	0
Total	51	100

Source: Field survey (2023)

3.8.6 Cultural method of pest management

All of the farmers use cultural methods for keeping the pests under control. But the majority of farmers 82.1% remove infested parts of plants while only 12.5% remove whole plants after severe infestation (Table 15). Crop rotation is not really common which is only 5.4% among the farmers of Lalitpur specially among those farmers who rented the land for farming. Intercropping of tomatoes is also done with other vegetables.

Table 15 Cultural methods of pest management used by farmers in Lalitpur

Cultural practices followed	Frequency	Percent (%)
Removal of infested plants parts	46	82.1
Removal of host plants	7	12.5
Crop Rotation	3	5.4
Total	56	100

Source: Field survey (2023)

3.8.7 Botanical pesticides used for pest management

Farmers of Lalitpur knowingly and unknowingly preferred botanicals over chemical pesticides. Out of the surveyed farmers 48% sprayed neem-based pesticides, 34% sprayed Dada gourd plus and 18% sprayed *Jholmal* made by using urine of cow, *Neem, Asuro, Sisno, Titepati,* Chilly, Garlic, etc (Table 16). They made the paste out of it and mixed it with water in varying ratios depending upon seedlings or older plants.

Table 16 Different types of botanical pesticides used by farmers in Lalitpur

Botanical pesticides	Frequency	Percent (%)
Neem based pesticides	24	48
Dada gourd plus	17	34
Jholmal	9	18
Total	50	100

Source: Field survey (2023)

3.8.8 Chemical pesticides used for pest management

Among the various chemical pesticides, Chlorantraniliprole and Emamectine benzoate were used by 12% of farmers each (Table 17). Thirty-six percent of farmers used the pesticides but didn't know the chemical name of them. Similarly, as the table describes Chloropyriphos and cypermethrin is used by 20% of them. Whereas, 8% sprayed Spinosad and Thiomethoxam each and only 4% sprayed Dimethoate for pest management.

Table 17 Different chemical pesticides used by farmers in Lalitpur

Chemical pesticides	Frequency	Percent (%)
Chlorantaniliprole	3	12
Emamectine Benzoate	3	12
Chloropyriphos and cypermenthrin	5	20
Spinosad	2	8
Dimethoate	1	4
Thiomethoxam	2	8
Use but do not know the name	9	36
Total	25	100

Source: Field survey (2023)

3.8.9 Mode of application of pesticides

Survey study revealed that 77.1% use protection measures while spraying pesticides (Table 18). Among the various measures 48.1% only use masks, 25.9% only use masks and gloves, 16.7% only use masks, gloves and

glasses and only 9.3% of them use all masks, gloves, glass and separate clothes while spraying the pesticides (Table 19). 22.9 percent of farmers sprayed the pesticides without using any protection measures. Consequently, vegetable farmers excessively use pesticides without any consideration of health and environment (Karmacharya, 2012).

Table 18 Different mode of application of pesticides adopted by farmers in Godawari, Lalitpur

Mode of application	Frequency	Percent (%)
By using protection measures	54	77.1
Without any protection measures	16	22.9

Source: Field survey (2023)

Table 19 Different method of using protection measures adopted by farmers in Godawari, Lalitpur

Measures	Frequency	Percent (%)
Use of mask	26	48.1
Use of mask and gloves	14	25.9
Use of mask, gloves and glass	9	16.7
Use of mask, gloves, glass and separate cloth	5	9.3
Total	54	100

Source: Field survey (2023)

3.8.10 Effective control measures

Among all the different control methods used by farmers, our research objective was also to investigate the effective control measures for *Tuta absoluta* from the farmer's perspective. The highly effective (1) measure in farmers perspective was botanical methods with index 0.933, followed by chemical methods (0.8) as effective measure with index 0.920 (Table 20). Use of traps and lures were ranked as moderately effective (0.6) and cultural methods as less effective (0.4) measure with index 0.779 and 0.517 respectively.

Table 20 Effective control measures according to farmer's perception in Godawari, Lalitpur

Effective control measures	Level of best measures				Total	Index	Rank
	1	0.8	0.6	0.4			
Botanical methods	32	16	2	0	50	0.933	I
Cultural methods	2	8	27	19	56	0.517	IV
Chemical control	15	8	2	0	25	0.920	II
Use of traps/lures	7	23	18	3	51	0.779	III

Source: Field survey (2023)

3.9 The influence of training on IPM on different variables

3.9.1 Use of insect net

The results revealed that out of 18 respondents who participated in training, 12 respondents used insect net while 6 respondents did not use insect net (Table 21). Similarly, out of 52 respondents who did not participate in IPM training, 18 respondents used insect net whereas 34 did not use net as control measures. Chi square test was performed to determine the association. The chi square value was 5.609 and p value = 0.018, significant at 5% level of significance. This result signifies that the association between IPM training and use of insect net is statistically significant.

3.9.2 Knowledge about TLM Pheromones

The results revealed that out of 15 respondents who participated in training, 14 respondents had knowledge about TLM Pheromones while 1 respondent was not aware about TLM Pheromones (Table 22). Similarly, out of 41 respondents who did not participate in IPM training, 10 respondents had knowledge about TLM Pheromones whereas 31 respondents were unaware about TLM Pheromones which are used in control measures. Chi square

test was performed to determine the association. The chi square value was 21.315 and p value = <0.001, significant at 1% level of significance. This result signifies that the association between IPM training and knowledge about TLM Pheromones is statistically significant.

Table 21 Association of IPM Training on use of insect net used by farmers in Godawari, Lalitpur

Use of insect net	IPM training		Total
	Yes	No	
Yes	12	18	30
No	6	34	40
Total	18	52	70

Source: Field survey (2023)

Table 22 Association of IPM Training on knowledge about TLM Pheromones on farmer's level in Godawari, Lalitpur

Knowledge about TLM Pheromones	IPM training		Total
	Yes	No	
Yes	14	10	24
No	1	31	32
Total	15	41	53

Source: Field survey (2023)

4 Conclusion

The study conducted in Godawari municipality, Lalitpur, highlights significant insights into tomato cultivation and pest management strategies among local farmers. Despite the high tomato productivity in Lalitpur compared to national averages, the infestation by *Tuta absoluta*, a major pest, poses severe challenges. The study reveals that 80% of farmers experience *Tuta absoluta* infestations, causing substantial yield losses ranging from 10% to 90%, with an average loss of 56.52%. Notably, only 19% of farmers are aware of the pest's life cycle, indicating a critical gap in knowledge. Among the control measures, botanical methods emerged as the most effective, with 71.4% of farmers employing them, followed by mechanical methods such as traps and insect nets. Chemical pesticides are used by 35.7% of farmers, while biological methods are absent due to a lack of knowledge.

This study underscores the urgent need for enhanced farmer education on Integrated Pest Management (IPM) and *Tuta absoluta*'s life cycle. Future research should focus on developing and disseminating effective IPM strategies and increasing awareness and training for farmers to better manage and mitigate the impact of *Tuta absoluta* on tomato crops.

Authors' contributions

SA designed and implemented the survey, collected data, interpreted and analyzed the results, and wrote the manuscript. SGS, RK, and DS analyzed data, interpreted the results, and contributed to writing the manuscript. SA and RG collected data and prepared the manuscript. SM evaluated and edited the manuscript. All authors read and approved the final manuscript.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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