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RESEARCH

Menace of Tomato Leaf Miner (*Tuta absoluta* [Meyrick,1917]): Its Impacts and Control Measures by Nepalese Farmers

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Abstract

A multi-site study was conducted in Kathmandu, Bhaktapur, Kavre, and Pokhara, Nepal, to assess the impact of *Tuta absoluta* and identify effective control measures from the farmers' perspective. A total of 480 tomato-growing households were randomly selected for the study. The pest posed a significant threat to tomato production, resulting in increased labor requirements (29.96%), increased expenditures on crop protection and control measures (62.18%), and significant yield losses of up to 85%. The results showed that the pest was ranked as the most important pest of tomatoes by the majority of respondents (88%), with the flowering stage being highly susceptible (99.73%). The study highlighted that the overuse of chemical pesticides disrupts integrated pest management practices, while all the respondents affected by *T. absoluta* used chemical and cultural control methods without using biological control methods due to a lack of knowledge. About 77.27% of the respondents used physical control methods. Among the control methods used, tomato leaf miner (TLM) bait (0.764) was rated as the most effective, followed by chemical pesticides (0.586) and sanitation (0.502). The research highlights the importance of raising awareness of integrated pest management strategies, including the use of biological control methods, for effective and sustainable management of *T. absoluta*. These findings will help improve pest management practices and support the long-term sustainability of tomato production in Nepal.

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Statement of Sustainability: This research emphasizes the significance of crop protection and sustainability as affected by *T. absoluta* on tomatoes. Since *T. absoluta* can cause severe allergic responses in people who ingest infected tomatoes, our research contributes to SDG 3 (Good Health and Well-Being) by revealing important information about the pest's effects on human health. Additionally, because the work investigates the sustainability of tomato farming and helps to preserve biodiversity, it is consistent with SDG 15 (Life on Land).

1. Introduction

Tomato (*Solanum lycopersicum* L.) is a warm-season primary vegetable crop (Poudel-Chhetri et al., 2023) produced worldwide and belongs to the nightshade family Solanaceae (Bauch et al., 2012; Demissew et al., 2017; Hassan et al., 2021). The optimum night temperature of 20°C and day temperature of 30°C are required for the proper growth and development of the plant (Shamshiri et al., 2018). Vegetable cultivation is increasingly gaining importance in Nepal (Ghimire et al., 2018). Tomato cultivation in Nepal expanded to about 20,000 hectares in the 2013/14 fiscal year, with an average production of 0.3 million tons (15 tons per hectare) (MoALD, 2020). By the fiscal year 2018/19, the cultivated area had increased to 22,566 hectares, with a productivity of 18 tons per hectare (MoALD, 2020). However, its production is subject to various biotic and abiotic constraints (Ochilo et al., 2019). Tomatoes are at high risk of pest infestation. 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).

T. absoluta, earlier called Phthorimaea absoluta, belonging to the order Lepidoptera and family Gelechiidae (Gebremariam, 2015), is considered a devastating pest of tomatoes (Cuthbertson et al., 2013; Sevcan, 2013). Its larvae feed on the leaves, buds, stems, and fruit of tomatoes. *T. absoluta* prefers tomatoes, but it can also grow and breed on weeds, which offers it a significant advantage over dying out when tomatoes aren't available (Ögür et al., 2014). It mainly attacks the leaf and, on advancement, affects the other parts (Illakwahhi et al., 2017; Alam et al., 2019). Fruit rot occurs due to secondary pathogen invasion in fruits bored by the pest (Bajracharya et al., 2016; Srivastava et al., 2018). It can reduce yield by 80–100% (Desneux et al., 2010) and the quality of tomatoes in newly invaded areas both in the field and in greenhouse conditions if control measures are not applied timely (Sah, 2017).

T. absoluta's life cycle comprises four development stages, viz., egg, larva, pupa, and adult, which is completed within 24 days at 27 °C. It is a solanaceous crop-related neotropical oligophagous moth (Tosevski et al., 2011). It has been found more prominently in tomatoes growing at an altitude of 1000 meters within mean sea level in open conditions and mostly in tomatoes grown in the plastic house (Neupane et al., 2020). This pest is becoming a threat to our country, as it can spread even into new locations where tomatoes are not cultivated and even in the absence of solanaceous crops (Abdul-Ridha et al., 2012; Abdul-Rassoul, 2014).

T. absoluta was recorded first in 1917 and as a tomato pest in the 1960s in Peru (Seplyarsky et al., 2010). The first occurrence of this pest in Nepal was reported by Bajracharya and his team on May 16, 2016, and was identified by examining the genitalia and external morphology of a tomato farm in Tarakeshwor Municipality of Kathmandu (Bajracharya et al., 2016). The pest spread to surrounding districts and was later recorded in Kathmandu, Lalitpur, Bhaktapur, Kavrepalanchowk, and Dhading districts. Due to open borders, lax quarantine, and the import of tomatoes and packing supplies from India, the threat of this pest attacking Nepalese tomato production has always existed. When it was just started in Kathmandu, a 25–30% loss was reported (Gautam et al., 2018). There are four possible entrance points for this pest into an uninfested area, viz., tomato fruits from infected areas, containers, packaging equipment, and vehicles; plants for growing tomatoes, and plants for growing ornamental Solanaceae.

It is important to identify this newly introduced pest and farmers should use appropriate control strategies as early as possible before it spreads throughout the country. 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). Although there have been several studies on *T. absoluta*, the impact of this pest on Nepalese farmers and their management practices has been relatively overlooked. There is a need for fresh insights into the occurrence of *T. absoluta* in Nepal, the extent of damage it inflicts on tomato crops, and the preventive measures adopted by Nepalese farmers. By studying this pest and its impact, valuable knowledge can be gained to develop effective strategies for its management, ultimately benefiting the agricultural sector in Nepal. Such a study is of great importance due to its novelty and the urgent need to address the economic losses caused by *T. absoluta* infestation.

The study is aimed to examine the effects of *T. absoluta* on tomato production, analyze the pest control methods employed by farmers and determine the most effective control measures from their perspective.

2. Materials and methods

2.1. Study site

The study was conducted in four different districts of Nepal, *viz.,* Kathmandu, Bhaktapur, Kavre, and Kaski, from November 2022 to January 2023. The sites were purposefully selected due to the prominence of the *T. absoluta* problem in these localities.

2.2. Sample and Sampling Technique

A total of 480 households were selected through a random sampling technique that was actively involved in tomato cultivation. A total of 120 farmers were chosen from each district.

2.3. Research Instruments and Design

2.3.1. Preliminary Study

The preliminary study was carried out to collect information regarding the socio-economic, demographic, and topographical settings of the site. The information was used in the preparation of the semi-structured questionnaire and was asked individually by each tomato grower.

2.3.2. Pre-testing of the Questionnaire

The questionnaire was pretested before the field survey to check its reliability and validity. Then the necessary adjustments were made as per requirement after administering the questionnaire to 5% of farmers in the vicinity area.

2.3.3. Household Survey

The household survey was conducted to collect information, knowledge, experience, and perceptions of *T. absoluta*. The target groups of farmers were asked a series of open-ended and closed-ended questions about *T. absoluta*, its impact on tomatoes, and the farmers' control procedures.

2.3.4. Observation

Frequent visits were made during the growing season of tomatoes from November onward.

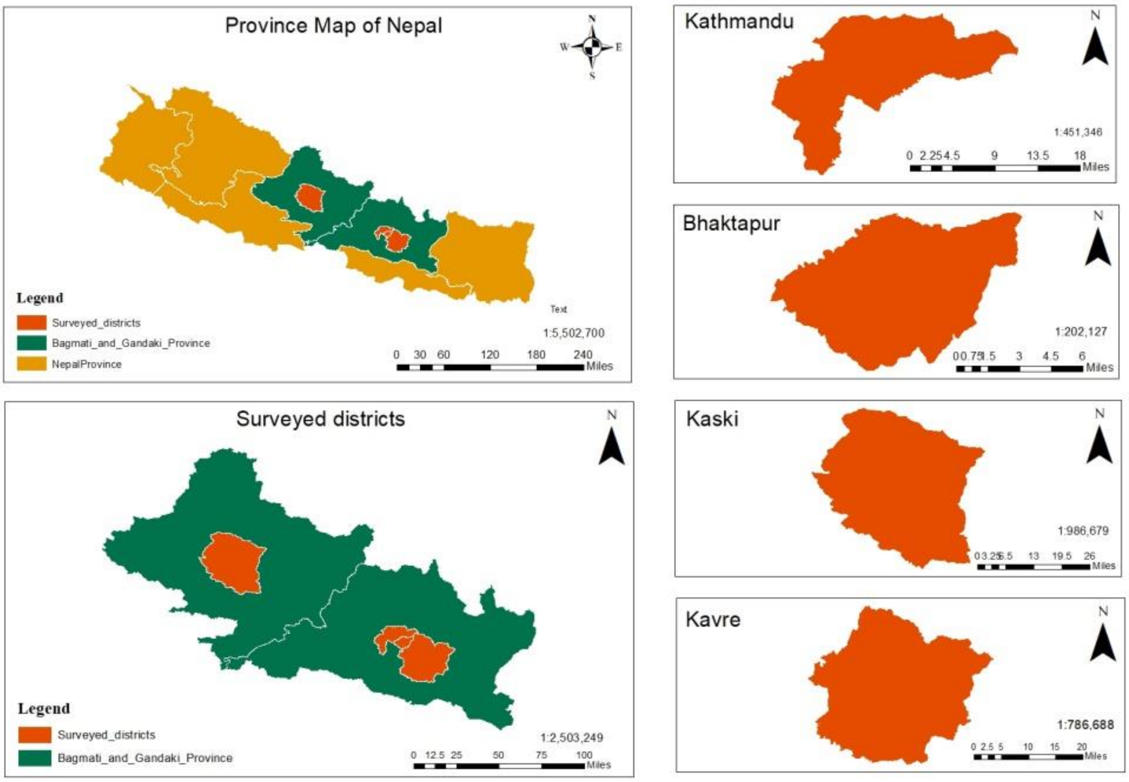

Figure 1. Study area mapping showing Kathmandu, Bhaktapur, Kaski, and Kavre districts of Nepal.

2.4. Data Sources

2.4.1. Primary Data

The primary data was collected from the farmers at the site who have been experiencing the impact of *T. absoluta*. Primary data collection was conducted through a questionnaire. It was used to collect data, share experiences, take actual recent information on *T. absoluta*, and find out real problems mostly faced by tomato farmers. A face-to-face interview was done to fill out questionnaires from randomly selected farmers.

2.4.2. Secondary Data

Secondary information was collected from various sources: statistical data from annual reports, newsletters, bulletins, relevant articles, journals, magazines, and the Central Bureau of Statistics (CBS).

2.4.3. Analysis Techniques

The various assistive media for the qualitative and quantitative analysis of the gathered data were SPSS (IBM Statistics 28; New York, USA) and MS-Excel 2010 (Microsoft Corp., Washington, USA). Information collected from the household survey was coded first and entered into the computer for analysis. Data entry was done using SPSS and Microsoft Excel and descriptive analysis was done to analyze the data. Means, standard deviations, frequencies, percentages, charts, diagrams, and other such tools were used to present the data.

3. Results and Discussion

3.1. Socio-demographic Characteristics

3.1.1. Age Group of Farmers

The study results showed that 70% of total farmers in the age group of 36–57 years were actively involved in tomato cultivation. The population was successively followed by an age group of less than 36 years, with 16% involved in tomato farming. The age group of more than 57 years was least involved in the production, with only 14% involvement. This showed that the age group of 36–57 was dominating tomato cultivation.

3.1.2. Gender of Farmers

The results of the study showed that 66% of the male and 34% of the female population were involved in tomato cultivation. This demonstrated the adequate involvement of women in cultivation compared to other programs.

3.1.3. Total Family Members in the Household

There were 480 families in the survey, with the household population ranging from 2 to 10 in the number of people involved in tomato cultivation. The mean family size was 5.36, showing that most of the households have 5–6 members.

3.1.4. Main occupation of the family

Study results revealed that the primary profession of 80% of households was agriculture, followed by service holder, business (4%), and others (2%) which include foreign employment. This means that agriculture is the main source of income for 80% of families in Kathmandu, Bhaktapur, Kavre, and Kaski. In Nepal, 65.7% of the population as a whole is involved in agriculture (MoAD, 2016).

3.1.5. Total Land Holdings of Farmers

The total land holding of farmers ranged from 0.25 to 5.30 acres, with a total of 673.41 acres and the mean land holding of that area is 1.40 acres. The average area used for vegetable cultivation was determined to be 0.38 acres, indicating professional vegetable production in the region.

3.2. Vegetable Cultivation

People were upgrading their cultivation level from subsistence to commercial level. Fifty-six percent of farmers were involved in commercial vegetable production, which was successfully followed by 42% of farmers who practiced intermediate farming techniques. The study revealed that subsistence farmers constituted approximately 2% of the population in the study sites, which aligns with the prevalence of subsistence farming in Nepal (Subramanya et al., 2021; Aryal et al., 2023).

3.3. Tomato Cultivation

3.3.1. Tomato Cultivation Level

Results indicate that 24% of farmers were involved in commercial tomato production. At least three tunnels were needed for commercial tomato production. This means that 28% of farmers have three or more tunnels. A total of 76% of farmers were involved in mixed cultivation levels as they cultivate tomatoes for subsistence as well as commercial purposes.

3.3.2. Tomato Cultivation Method

Most of the farmers cultivate tomatoes in both open fields and tunnels in these areas, with 64% in this category. A total of 34% of the farmers cultivate tomatoes in the tunnel only and only 2% cultivate tomatoes in an open field (Table 1) as tunnels provide a protected environment that shields against pests, diseases, wind, and low temperatures (Kandel et al., 2020).

Table 1. Distribution of tomato cultivation methods among farmers.

Method of tomato cultivation	Frequency	Percentage
Tunnels	10	2
Open field	163	34
Both open fields and tunnels	307	64
Total	480	100

3.3.3. Number of Tomato Tunnels

The study revealed that 54% of the population had only one tunnel. Out of the whole population, 115 farmers have three or more tunnels (Table 2).

Table 2. Distribution of plastic tunnels among farmers.

Number of plastic tunnels	Frequency	Percentage
0	10	2
1	259	54
2	96	20
3	29	6
4	29	6
5	29	6
7	9	2
8	10	2
10	9	2
Total	480	100

3.3.4. Tomato Crops per Year

The result showed that 54% of total farmers grow 2 tomato crops per year and 46% grow 1 crop per year.

3.3.5. Month of Tomato Cultivation

Maximum tomato cultivation was done in both August-September and February-March, accounting for 54% of cultivation. Out of the total, 22% of farmers cultivate tomatoes only in August–September and 1% in February–March.

3.3.6. Varieties of Tomatoes Cultivated

Most of the tomato farmers had a greater preference for Srijana than Samjhana varieties of tomatoes. A total of 72% of respondents cultivate the Srijana variety, whereas the Samjhana variety is cultivated by 1% and 26% of respondents cultivate both varieties.

3.3.7. Problems Seen in Tomato Cultivation

Farmers frequently deal with multiple issues at once (Abera et al., 2020). Important problems seen in tomato cultivation were pests, diseases, lack of technical support, marketing, and input supply. As given in Table 3, the pest problem was ranked first, followed by disease, marketing problems, lack of technical support, and lack of input supply, respectively. The result revealed that pest and disease problems were major in tomato cultivation.

Table 3. Problems encountered in tomato cultivation among farmers (I as the highest and V as the lowest).

Problems	Level of Problem					Total	Weight	Index	Rank
	1	0.8	0.6	0.4	0.2				
Pests	336	77	67	0	0	480	437.8	0.912	I
Disease	58	288	134	0	0	480	368.8	0.768	II
Technical support	0	67	48	125	240	480	180.4	0.375	IV
Marketing	10	77	85	106	202	480	205.4	0.427	III
Lack of input supply	0	28	58	77	317	480	151.4	0.315	V

3.3.8. Major Diseases in Tomatoes

Major diseases seen in the study area were blight, damping off, and tomato mosaic virus (Table 4). The majority of respondents ranked blight as a big issue in the tomato crop, making it the most significant disease in this region and ranking it first on the list. The respondents selected damping off and tomato mosaic virus as the second and third damaging diseases respectively.

Table 4. Major diseases encountered in tomato cultivation among farmers (I as the highest and V as the lowest).

Diseases	Level of problem			Total	Weight	Index	Rank
	1	0.66	0.33				
Blight	422	39	19	480	454.01	0.945	I
Damping off	38	288	154	480	278.9	0.581	II
Tomato mosaic virus (TMV)	0	96	384	480	190.08	0.396	III

3.3.9. Major Pests in Tomatoes

T. absoluta was the major pest reported by 88% of respondents and tomato fruit borer was the second major pest.

3.4. Tomato Leaf Miner

T. absoluta has caused an 80–100% loss in tomatoes and an account loss of more than $50 million for the industry.

3.4.1. Infestation of T. absoluta

According to the statistics, *T. absoluta* was an issue for 88% of all farms, whereas it was not found in 12% of farmers' fields (Table 5), similar to the findings of Bastola et al. (2021). So, the further questions were asked only to 88% of respondents, *i.e.,* 422 respondents.

Table 5. Prevalence of TLM infestation among farmers.

Infestation	Frequency	Percentage
Found	371	88
Not-found	51	12
Total	422	100

3.4.2. Damage Symptoms

Damage symptoms were seen in the leaves, stem, and fruit of the tomato. Larvae of this pest fed on the green portion of the leaves, leaving behind pale, erratic patches as well as black excretions and larvae visible inside the leaves. They made a hole in the fruit and entered it. Mining damage to the stems caused malformations in the plant. In an extreme situation, leaves were entirely drying out, and flying moths were seen all around the plant.

3.4.3 Stage of Plant Mostly Affected

This pest affects all stages of the plant. According to the survey result, 97.63% of the damage was seen in the flowering stage and 2.36% in the seedling stage, as shown in Table 6.

Table 6. Distribution of TLM damage by plant stage.

Stage of the plant affected	Frequency	Percentage
Seeding	10	2.36
Flowering	412	12
Total	422	100

3.5. Impacts of *T. absoluta*

The impacts of *T. absoluta* were studied mainly based on yield loss and an increase in production costs.

3.5.1. Yield Loss Owing to T. absoluta

T. absoluta infestation can lead to significant yield reductions in tomato crops. The damage caused by this pest, including leaf mining, tunneling, and feeding on plant tissues, can impair photosynthesis, hinder plant growth, and ultimately result in lower fruit production. The study revealed that the minimum yield loss due to this pest was 10% and the maximum loss was 85%. The mean yield loss due to this pest was 35%. However, in severe cases, it is likely to cause 80–100% yield loss in tomatoes (Sah, 2017). High yield loss means high economic damage due to this pest; farmers are losing faith in tomato cultivation as it is a risky business (Overton et al., 2021). As a result of an increase in the use of synthetic fertilizers, crop protection costs ultimately have an impact on tomato prices. As a result, more chemical pesticides are being used carelessly, disrupting Integrated Pest Management (IPM) and as a result, many nations have banned the sale of tomato products, including seedlings.

3.5.2. Increase in Production Costs due to T. absoluta Infestation

The normal mean cost for human labor is recorded at Rs. 11,250 per hectare, while the increased cost due to TLM was Rs. 14,625 per hectare, indicating a 29.96% increase (Figure 2). Similarly, the normal mean cost for plant protection and control measures was Rs. 25,345 per hectare, but the expenses rise to Rs. 41,105 per hectare in the presence of TLM, representing a significant increase of 62.18%. Furthermore, with the normal mean yield of 21.2 tons per hectare dropping to 13.38 tons per hectare, reflecting a decrease of 35%, these figures highlight the financial burden faced by farmers due to increased costs for labor and plant protection measures, as well as the substantial reduction in yield resulting from TLM infestations.

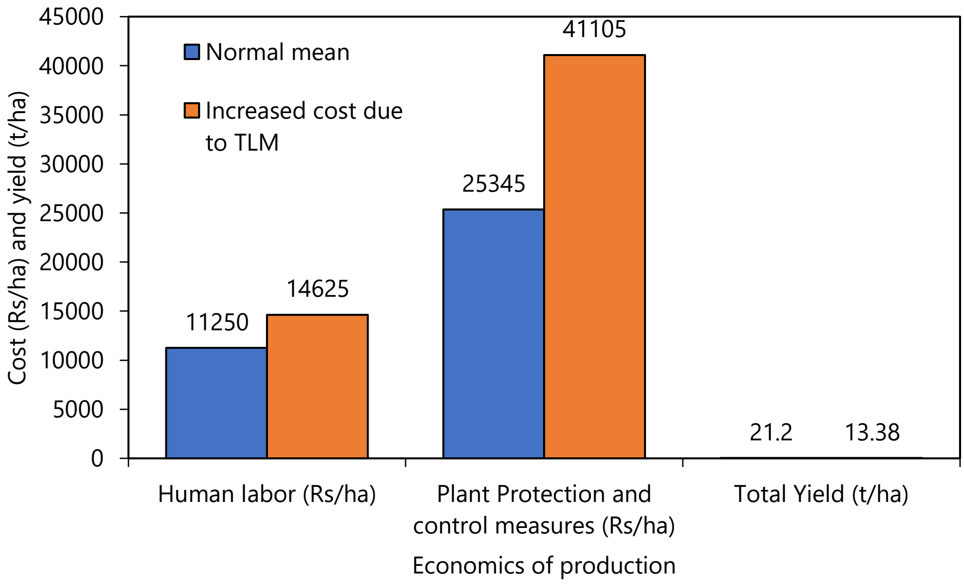

Figure 2. Impact of TLM on the economics of production.

3.6. Control Measures

Since *T. absoluta* had already been introduced in the study areas, its impact on tomato crops was substantial. Consequently, the implementation of effective control measures became paramount. Complete eradication of this pest was deemed unattainable. Nonetheless, numerous farmers were employing various control measures. It is worth noting that a decrease in both yield and quality leads to economic losses, as consumers are unwilling to pay for goods of inferior quality.

3.6.1. Ideas and Control Measures for TLM and their Adoption

All the farmers had an idea about control measures for this pest and were adopting different control measures to control it. The main control measures were cultural, chemical, and physical techniques. The biological method of control was not used by any respondents due to a lack of knowledge about proper chemicals. Farmers were using pesticides like Roger and Nuvan, which were not recommended to control the pest. Different control measures adopted by farmers were sanitation, TLM lures, light traps, and sticky traps. They were using homemade traps, which they learned from training about the control measure of *T. absoluta*. The study result showed that 100% of farmers affected by the pest were adopting chemical and cultural methods as control measures (Figure 3). The physical method was used by 77.27%. Chemical and cultural methods were adopted by all farmers due to their ease. Physical measures were used less than other measures (chemical and cultural) due to a lack of knowledge.

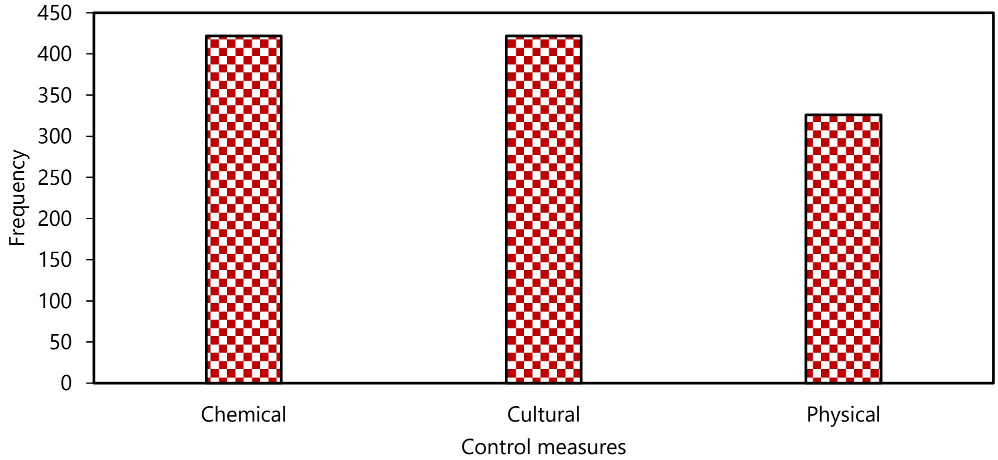

Figure 3. Types of control measures of TLM adopted among farmers.

3.6.2. Source of Knowledge About Control Measures for T. absoluta

The main source of knowledge about control measures was from friends and family, government offices, and others, which included training, as shown in Table 7.

Table 7. Source of knowledge about control measures of TLM among farmers

Source of knowledge	Frequency	Percentage
Friends/family	422	100
Government agencies	393	93.18
Others (training)	326	77.25

3.6.3. Use of Integrated Pest Management

T. absoluta infestation was discovered in 422 out of 480 households. Only in those households did further questionnaires continue. The survey showed that all farmers were familiar with IPM and used cultural and physical control measures to control the pest.

3.6.4. Knowledge About TLM (Pheromone) Lure

In this, 88.64% of farmers knew about the TLM lure and 11.36% of farmers did not know about this lure.

3.6.5. TLM Lure Used

The result showed that 77.27% of affected farmers were using TLM lure and 22.73% of farmers were not using TLM lure.

3.6.6. Number of TLM Lures Used

There were 663 traps used in total, with a minimum of 0 and a maximum of 6. The mean lure used by farmers was found to be 1.57.

3.6.7. Availability of TLM Lures

These TLM lures were not easily available on the market. Due to the heavy infestation of tomato leaf miners, various governmental bodies like the Department of Agriculture Development Office and the Prime Minister Agriculture Modernization Project provided these lures to the tomato growers at 100% subsidy in the affected area.

3.6.8. Chemical Pesticides

Farmers had no proper knowledge about the use of proper chemical pesticides for this pest, so almost all farmers were using Nuvan (Dichlorvos) and Roger (Dimethoate) for this pest.

3.6.9. Availability of Chemical Pesticides

Chemical pesticides were easily available on the market, as there were many agro-vets. The result showed that all the farmers used chemical pesticides for pest control purposes, but their use was minimal.

3.6.10. Best Control Measures

Among all these different control methods used by farmers, the use of TLM lure was the best measure, as 77.27% (Figure 3) of affected farmers only used it and most of them found that TLM lure is the most effective to control *T. absoluta*, as shown in Table 8. Pheromone traps might be quite effective in controlling this pest, even in an intense infestation (Caparros et al., 2013; Rwomushana et al., 2019 Helvaci, 2020). The second-best option was to employ chemical pesticides to control the infestation. From Figure 3, we discovered that all the impacted farmers were employing chemical pesticides to control this pest because it is the simplest method (Sharifzadeh et al., 2018). Also, respondents ranked good agricultural practices as the third best control measure to control *T. absoluta*, as good agricultural practices alone cannot control the pest after a heavy infestation but can be used as a preventive measure. Farmers were using different practices such as plowing, mulching, sanitation, crop rotation, removing infected parts, and destruction of infested plants.

Table 8. Control measures ranked by respondent perception for TLM (I as the highest and V as the lowest).

Best control measures	Level of Best Measures			Total	Weight	Index	Rank
	1	0.66	0.33				
TLM lure	316	10	0	326	322.6	0.764	I
Sanitation	38	144	240	422	212.24	0.502	III
Chemical pesticides	67	192	163	422	247.51	0.586	II

5. Conclusion and Recommendations

The study revealed that *T. absoluta* is a significant threat to tomato production in Nepal, causing a significant increase in human labor (29.96%), plant protection and control measures (62.18%), and yield loss (up to 85%), with an average loss of 35%. The study found that the flowering stage of tomatoes was highly susceptible to *T. absoluta* infestation (99.73%). All affected respondents used chemical and cultural control methods but lacked knowledge about biological control. About 77.27% of the respondents used physical control methods. The most effective control methods were Tomato Leaf Miner (TLM) bait (0.764), chemical pesticides (0.586), and sanitation (0.502). The results highlight the importance of promoting sustainable and integrated pest management strategies, including the use of biological control methods, to effectively manage the pest and reduce over-reliance on chemical pesticides. The study findings are critical for policymakers, researchers, and practitioners working to improve food security and rural development in Nepal and beyond. Further research and knowledge sharing are needed to address the complex and evolving challenges faced by smallholder farmers in Nepal and other developing countries.

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