Research Article

FARMERS' MANAGEMENT PRACTICES AGAINST TOMATO LEAF MINER *Tuta absoluta* (Myrick) (Lepidoptera: Gelechiidae) IN SURKHET, NEPAL

K. Lamsal[1]*, R. Sapkota[2], K.C. Dahal[2], N. Upadhyaya[2] and D. Khanal[2*]

ABSTRACT

Tuta absoluta (Myrick) is one of the most destructive pests of tomato globally. In order to study its current status and management practices adopted by farmers, a household survey was conducted in February 2019 at three road corridors (Surkhet-Jumla, Surkhet-Dailekh and Surkhet-Jajarkot) and Birendranagar valley of Surkhet district. Amongst the tomato growers listed at the government offices and local key informants, a purposive random sampling method was employed to select the 60 tomato producers, 30 from Birendranagar Municipality, 15 from Barahatal Municipality (Surkhet-Jumla), 10 from Bheriganga Municipality (Surkhet-Jajarkot) and 5 from Gurans Municipality (Surkhet-Dailekh). Majority of tomato growers (52%) claimed *T. absoluta* as their major pest and most of them well aware about the symptoms of the pest in leaves as well as fruits. Majority of the farmers were found to be (33%) relied on chemical means while 27% on cultural methods, 18% used tomato leaf miner lure (TLM lure), 13% used botanicals, 5% used physical, and 3% used mechanical method for the management of *T. absoluta*. Chemicals means being very quick and more effective to other techniques in solitary were practiced by many but without reading the label, without measuring before use (57%), without any protective wear (53%) and lack of know-how on waiting period (78%). Most of the farmers having dependent on Agrovets (85%) for technical assistance were bound to continue the false practices. The efficacy of extension was found to be very poor exhibiting the urgency of pesticide use literacy for the farmers and the knowledge of IPM for pest management. Farmers should be taught about the harmful effects of chemical pesticides, methods of handling pesticides, use of protective gears and keep chemical as last resort. Other alternative means like use of TLM lures, botanical pesticides, use of nets etc. should be encouraged.

Keywords: *Botanicals, IPM, lure, TLM, PPE*

[1] Agriculture Sector Development Programme, MoALD, Surkhet, Nepal
[2] Institute of Agriculture and Animal Science, Tribhuvan University, Nepal
* Email for correspondence: lamsalkrishna531@gmail.com; dipakbabu@ hotmail.com

INTRODUCTION

South American tomato leaf miner, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) has become one of the challenging and pandemic pests in tomato production in recent years. It is a polyphagous pest that feeds on other host plants from the solanaceous family especially tomato (Vargas, 1970). *T. absoluta*, an invasive South American moth that has been a major tomato pest in South America since the 1960s, was found to be accidentally introduced to Spain in 2006 (Urbaneja *et al*., 2012). Later on, it spread all over Europe and from Europe to other continents. It was first identified in Maharashtra, India, in October of 2014 (Shashank *et a*l., 2015). Because of the open border, insufficient quarantine, and the import of tomatoes from India, the danger of the pest invading Nepalese tomato growing has always remained since its introduction to India. The pest eventually found its way from India to Nepal in 2016 (iDE and Virginia Tech, 2017). Since then, tomato production in Nepal is greatly affected by this pest. As per Bajracharya *et al.* (2016) tomato fruit imported from India to meet the demand of the Kathmandu valley could be a likely source of its entrance into Nepal. Tomatoes being one of Nepal's most cultivated vegetable crops, NARC, PPD, iDE Nepal, and other concerned authorities started immediate actions to develop and advertise efficient control techniques as quickly as possible. Studies show that the severe infestation of this pest may cause damage in quantity up to 80-100% in newly invaded areas, both in field and greenhouse conditions (Desneux *et a*l., 2010; Zekeya *et al*., 2016). As a result, this pest can hamper post-harvest procedures, leading to a commercial downgrading of the whole tomato lots during storage and shipment. Furthermore, the international spread of this pest is likely to be aided by trading in unintentionally affected tomato lots (Desneux *et al*., 2010). The larvae feeds on tomato leaves, buds, stems, and fruits. Gradually the infestation results in secondary pathogen invasion causing fruit rot. As the pest favors solanaceous crops, in absence of a primary host it completes its life cycle in weeds like *Solanum nigrum* and *Datura stramonium.*

In absence of pre-research and inadequate knowledge among farmers, *T. absoluta* was commonly managed by farmers with a variety of chemical pesticides (Khanal *et al*., 2021), which were not recommended for its management (Bajracharya *et al*., 2018). Tomatoes worth $7,200/ha were damaged, accounting for 25-30% of total production in areas where *T. absoluta* was detected (Sah, 2017). The potential yield and financial loss in Nepal as a result of this pest could be as high as 80-100 percent and $ 50 million per year, respectively. Despite its newness, it caused significant agricultural damage, resulting in massive economic and ecological imbalances. The primary objective behind this study was to document the management strategies practiced by farmers in the Surkhet district to control this particular pest (*T. absoluta*).

MATERIALS AND METHODS

The survey was carried out during the early summer of February 2019. Tomato-producing farmers at Surkhet-Jumla Road Corridor, Surkhet-Jajarkot Road Corridor, Surkhet-Dailekh

Road Corridor, and Birendranagar Valley were the targeted population for this study as they produce tomatoes on a commercial scale. The informal list of 152 tomato-producing farmers in the selected areas was retrieved with the help of government officials along with the local key informants of respective sites. After that, the respondents were selected randomly by applying the purposive random sampling technique. Altogether 60 respondents (10% margin error of total informal list) were selected from four road corridors (Table 1) through a Focused Group Discussion. The sample size was based on the desired accuracy with a confidence level of 95%, Variance of the population (P = 50%) (Johnson and Gill, 2010), and was calculated using Slovin's formula (Ellen, 2012).

$$n = \frac{N}{1+N(e)^2}$$

Where n= number of samples required
N= Population
e= error margin

Table 1. The sample distribution of the study area

Areas	Sample
Birendranagar Municipality (Birendranagar Valley)	30
Barahataal Rural Municipality (Surkhet-Jumla Road Corridor)	15
Bheriganga Municipality (Surkhet-Jajarkot Road Corridor)	10
Gurans Rural Municipality (Surkhet-Dailekh Road Corridor)	5
Total	**60**

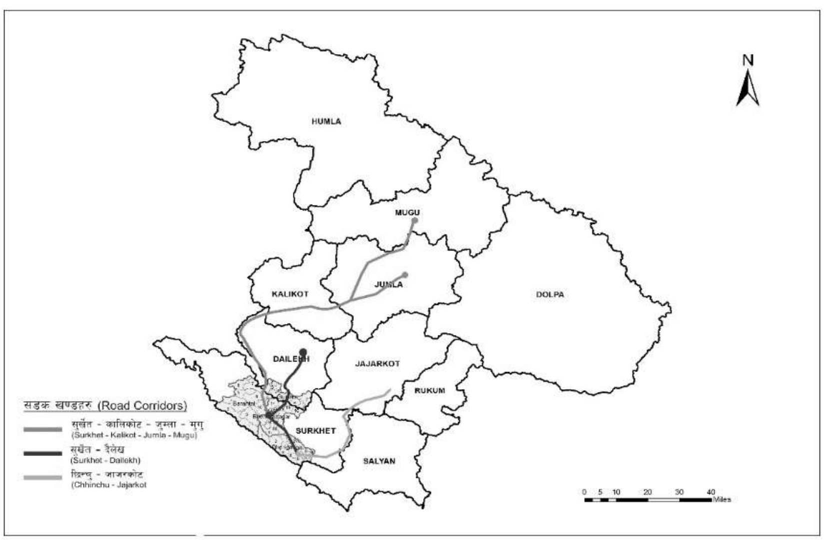

Fig. 1. Map section of Nepal indicating the study area

The study was mainly based on the primary data obtained from the respondents (tomato producers). For interviewing respondents, a semi-structured questionnaire was designed and pre-tested among 5% of respondents who were not part of the actual survey. The core bases of the questionnaire were farmers' perspectives and knowledge on the pest, issues in the semi-intensive production system, and management measures employed by farmers. The primary data were cross validated in reference to the local government agricultural bodies. Secondary data were gathered from several published and unpublished sources, such as related journals, books, papers, and unpublished reports.

Statistical Analysis

The data were mainly subjected to descriptive analysis. A Chi-square ($\chi 2$) test ($p<0.05$) was used to investigate if there was a link between socio-demographic characteristics, pesticide use patterns, exposure, and other qualitative variables. Data entry, and processing and analysis were done using Microsoft Office Excel 2019 (Microsoft Corp., Redmond, WA, USA). Further analysis was done using SPSS ver. 21 (IBM Corp., Armonk, NY, USA) and Microsoft Excel 2019 to analyze the data.

RESULTS AND DISCUSSION

Demography and socioeconomic status of tomato growers in Surkhet, Nepal

The table exhibited that most of the respondents belonged to the age group 31–50 years old followed by those belonging above 50 years and 16-30 years (Table 2). The involvement of younger farmers (below 50 years old) in tomato production provides a strong hope to train novel and sound pest management techniques compared to the older farmers (Damalas and Hashemi, 2010). Most of the respondents (32%) had completed secondary school (10th grade), followed by primary school (25%) and illiterate (20%), literate (10%), university degree (8%), and higher secondary (12th grade) education (5%). This shows there is equal interest among the different levels of education groups in tomato cultivation. The caste or ethnic group of farmers have impact on their economic and social status. Lower caste groups (Dalit and other Terai/Madhesi) have lower school attendance, less access to mobile phones, and lower literacy rates, according to the 2011 Nepal Population and Housing Census, which can influence a household's decision to adopt complex IPM practices (McGowan, 2022).

Most of the tomato producing farmers (55%) had less than 5 ropanies of land, only 7% of farmers had a land holding of more than 20 ropanies, while 30% having 6-10 ropanies (Table 2). The size of a farm can be considered as an indicator of prosperity or higher living standard as well. Larger farms are more likely to be able to afford more expenses associated with adopting modern technologies. Small-scale farmers cannot afford more risk as they possess financial limitations, limiting their capacity to adopt new technology (Feder, 1979). Most of the tomato growers of the Surkhet were Kshetri (42%), followed by Brahmin (30%), Janjati (20%), Dalit and Thakuri (3%) and Majhi (2%). Most (57%) of the respondents raised tomatoes in subsistence level i.e., home consumption and the remaining (43%) raised commercially targeting the local market. Most of the farmers (55%) were new with experience of 2-5 years, 25% have been growing for 6-10 years and 12% were found to have recently started (at least 1 year).

Table 2. Socio-demographic status of surveyed tomato growers in Surkhet, Nepal

Attributes	Category	Frequency (%)	χ^2 Value	p-Value
Age (years)			6.652	0.354
	Below 15	0 (0)		
	16-30	7 (12)		
	31-50	36 (60)		
	Above 50	17 (28)		
Education Level			98.582	<0.001
	Illiterate	12 (20)		
	Literate	6 (10)		
	Primary Level	15 (25)		
	Secondary Level	19 (32)		
	Higher Secondary Level	3 (5)		
	University	5 (8)		
Land holding (ropani)			8.409	0.752
	Below 5	33 (55)		
	6-10	18 (30)		
	11-15	4 (7)		
	16-20	1 (2)		
	Above 20	4 (7)		
Ethnicity of Tomato growers			21.076	0.134
	Brahmin	18 (30)		
	Kshetri	25 (42)		
	Janajati	12 (20)		
	Dalit	2 (3)		
	Majhi	1 (2)		
	Thakuri	2 (3)		
Purpose of Agriculture			11.674	0.009
	Subsistence	34 (57)		
	Commercial	26 (43)		
Experience of tomato Cultivation			112.641	<0.001
	At least 1 year	7 (12)		
	2-5 years	33 (55)		
	6-10 years	15 (25)		
	More than 10 Years	5 (8)		

Note: Figure inside the parenthesis indicates percentage.

Current production variables and pest (*T. absoulta)* management practices

Majority of the respondents (42%) were found to have adopted Gaurab-555 as their first preferred variety followed by Srijana hybrid (27%), Manisha (15%), Samjhana F1 (13%) and Surya & local (2%). Considering the major constraints for production, insects (58%) was ranked first followed by diseases (25%) and unpredictable weather (13%). Among the insects, tomato leaf miner (*T. absoluta*) was found to be the most severe insect (52%) whereas late blight (*Phytopthora infestans* (Mont.) de Bary) (45%) was the most severe disease affecting sustainable tomato business. Literatures also suggest late blight amongt the primary disease vegetables produced in plastic houses (Budhathoki, 2006; Regmi, 2005). Sah (2017) and Adhikari *et al*. (2018) also reported that the major insect pest under plastic tunnel at Kavre district was found to be *T. absoluta* followed by root knot nematode, wilt, leaf blight, whitefly, aphids, and tomato fruit borer. Responses were in favor of I/NGOs like iDE Nepal as one of the major sources of information about the *T. absoluta* followed by Agro-vets. Substantial number of the farmers (85%) were dependent on agro-vets for the technical guidance followed by government agencies (7%) like Agriculture Development Office (ADO), Ministry of Land Management, Agriculture and Cooperative (MoLMAC) and Agriculture Service Center (ASC) (Table 3). A study by Rijal *et al*. (2018) reports in favor, states that the Agro-vets were the key sources of information on pesticide use and selection. However, the misery was those Agro-vet, in general, had no technical experience, and the information they provide was often misleading. Furthermore, because these are private and profit oriented, there might be a conflict of interest in teaching the optimal way of product control and selling.

Table 3. Current tomato production status and constraints in Surkhet, Nepal

Attributes Category		Frequency (%)	χ^2 Value	p-Value
Variety cultivated			93.734	<0.001
	Srijana F1	16 (27)		
	Local	1 (2)		
	Gaurabh-555	25 (42)		
	Manisha	9 (15)		
	Samjhana F1	8 (13)		
	Surya	1 (2)		
Major problem of tomato farming			15.429	0.219
	Insect	35 (58)		
	Disease	15 (25)		
	Unpredictable weather	8 (13)		
	Unavailability of inputs	1 (2)		
	Lack of technical knowhow	1 (2)		

Attributes Category		Frequency (%)	χ^2 Value	p-Value
Most problematic insect			159.794	<0.001
	Tomato Leaf Miner (*T. absoluta)*	31 (52)		
	Tomato Fruit Borer	14 (23)		
	Aphids	9 (15)		
	White Fly	5 (8)		
	Cutworm	1 (2)		
Most problematic disease			43.819	<0.001
	Late Blight	27 (45)		
	Diseases caused by virus	16(27)		
	Wilt	12 (20)		
	Damping off	05 (08)		
Ranking of *T. absoluta* out of many other problem			52.404	<0.001
	Most problematic of all	31 (52)		
	Not as problematic as other insect pest, disease and disorders	13 (22)		
	The least problematic	8 (13)		
	As problematic as other insect pest, disease and disorders	8 (13)		
Source of information about *T. absoluta*			80.1	<0.001
	Training/seminars	05 (08)		
	Agro-vet	15 (25)		
	I/NGO	20 (33)		
	ASC	10 (17)		
	Progressive farmers	10 (17)		
Technical assistance on *T. absoluta*			4.255	0.894
	Agrovet	51 (85)		
	ADO/ASC/MoLMAC	4 (7)		
	I/NGO	3 (5)		
	Progressive Farmers	2 (3)		

Note: Figure inside the parenthesis indicates percentage.

Farmer's knowledge about life cycle and damage symptoms of *T. absoluta* in Surkhet, Nepal

One of the positives in the respondents was they were well aware about the *T. absoluta*, its stage of damage and symptoms of damage in leaves and fruits. Most of the producers claimed to have observed damage mostly during the vegetative stage (37%), followed by fruiting (35%), flowering (20%) and seedling stage (9%). Most identified mining of leaves (50%) to be the key symptom followed by white spots (25%) and combination of both (25%). In fruits, most of the respondents considered holes bored in fruits (50%) as key symptom, followed by black feaces in the fruits (22%).

Table 4. Farmer's knowledge stage of damage and symptoms of *T. absoluta* damage in Surkhet, Nepal

Attributes	Category	Frequency (%)	χ^2 Value	p-Value
Stage of damage			24.713	0.003
	Seedling	5 (8)		
	Vegetative	22 (37)		
	Flowering	12 (20)		
	Fruiting	21 (35)		
Damage symptoms of *T. absoluta* on leaves			40.533	<0.001
	Mining of leaves	30 (50)		
	White spot blotches in leaves	15 (25)		
	Both	15 (25)		
Damage symptoms of *T. absoluta* on fruits			29.973	<0.001
	Holes in fruits	30 (50)		
	Black feaces matters in fruits	13 (22)		
	Both	17 (28)		

Note: Figure inside the parenthesis indicates percentage

Current *T. absoluta* management practices among tomato growers in Surkhet, Nepal

One third of the respondents were observed to follow chemical means of management, while 27% were practicing cultural methods, 18% using TLM lure, 3% using mechanical methods, 5% physical methods, and 13% used botanicals. Farmers considered chemicals means to be the most effective means followed by the use of pheromone traps. In contrast, 2018 research among Nepalese farmers revealed that, while most farmers were aware of pesticides' negative effects, they were still using pesticide as their major way of pest control on their crops because they were increasingly depending on a variety of synthetic pesticides (Rijal *et al.*, 2018). According Adhikari *et al.* (2018), most effective, safe, economic, and practical method of *T. absoluta* control used by the farmer of Kavre, Bhaktapur and Lalitpur districts was pheromone traps, followed by cultural methods. Among the cultural method employed, most of them practiced removal of infested plant part (82%) followed by crop rotation (15%) and removal of host plants (3%). Amongst following the mechanical methods, 72% practiced yellow sticky trap, 23% practiced pest exclusion net and 5% hand picking of the larva. Between those who chose botanical means, about two-third (60%) were found to use Jholmol followed by neem-based pesticides (40%). For those using chemical management strategy 28% used chloropyrifos and cypermethrin, dichlorvus (25%), chlorantraniliprole & spinosad (8%) and emamectin benzoate (3%) (Table 5). Most of the respondents were found to be choosing chemical resort because of its quick results and straightforward application methods. A study at Bara and Dhading districts also exhibited the prevalence of high reliance on chemical pesticides in vegetable (Mainali *et al.*, 2014)

Table 5. Current *T. absoluta* management practices among tomato growers in Surkhet, Nepal

Attributes/Category	Frequency (%)	χ^2 Value	p-Value
Management practice of *T. absoluta*		47.299	<0.001
Cultural	16 (27)		
Botanicals	8 (13)		
Physical	3 (5)		
Mechanical	2 (3)		
TLM lures	11 (18)		
Chemical pesticides	20 (33)		
Cultural methods		13.469	0.036
Removal of infested plant parts	49 (82)		
Removal of host plants	2 (3)		
Crop rotation	9 (15)		
Mechanical methods		10.764	0.096
Hand Picking of the larva	3 (5)		
Use of insect exclusion net	14 (23)		
Use of yellow sticky traps	43 (72)		
Botanical pesticides		3.000	0.392
Neem based pesticides	20 (33)		
Jholmol	40 (67)		
Chemical pesticides		49.588	<0.001
Chlorantraniliprole	5 (8)		
Emamectin benzoate	2 (3)		
Chloropyriphos and cypermethrin	17 (28)		
Spinosad	5 (8)		
Dichlorovos	15 (25)		
Use pesticide but do not know its name	16 (27)		

Note: Figure inside the parenthesis indicates percentage

Pesticide use pattern and safety practices to prevent pesticide exposure

It is very essential to read the pesticide label and follow the application directions for safe handling. In contrary, only 22% of farmers were aware of the risks and side effects of pesticides, while 55% were inadequately aware of dangerous pesticide concentrations, and the remaining 25% were completely unaware of the hazards and side effects (Table 6). According to a study by Khan *et al.* (2015), 12.3% of Pakistani growers feel pesticides are completely safe and require no caution while using it. Before applying pesticides, only a few numbers of farmers actually read the label. Less than half (47%) of the respondents reported wearing personal protective equipment (PPE) while spraying and remaining do not use personal protection equipment (PPE) such as gloves, long sleeve shirts, shoes, or any of them. According to a similar study by Koirala *et al*. (2010), exhibited that roughly 30% of vegetable producers in Nepal do not wear any kind of personal protective equipment. This is a very common problem that prevails in many poor communities across the globe. More than half of farmers don't wear any kind of personal protective equipment in Iran while spraying pesticide (Hashemi *et al*., 2012). Only 22% of the farmers were found to be well aware about the waiting period of the pesticide and rest either have incomplete knowledge (35%) or completely unaware (43%). More than half of the farmers didn't even practice measuring pesticides before spraying. Despite the fact that developing countries use fewer pesticides than developed and industrialized countries, pesticide poisoning is more common in developing countries (Khanal *et al.*, 2021). When it comes to pesticide exposure, this scenario is extremely dangerous for farmers and field workers as they stand in front row throughout the use process. To minimize the use of hazardous pesticides and to manage T. absoluta effectively, most of them accepted the use of TLM lure and trap (63%), use of ecofriendly pesticide (20%) and rational use of pesticide (13%) as an alternative use of hazardous chemicals.

Table 6. Pesticide use pattern and safety practices to prevent pesticide exposure among tomato growers in Surkhet, Nepal

Attributes	Category	Frequency (%)	χ^2 Value	*p*-Value
Knowledge about the harmful level of pesticide			11.712	0.069
	Well known	12 (20)		
	Little bit	33(55)		
	No	15(25)		
Pesticide measurement while spraying			7.783	0.049
	Yes	26(43)		
	No	34(57)		

Attributes	Category	Frequency (%)	χ^2 Value	*p*-Value
Knowledge about waiting period			12.527	0.512
	Well known	13(22)		
	Little bit	21(35)		
	No	26(43)		
Use of safety gadgets (PPE, mask, gloves)			5.893	0.117
	Yes	28(47)		
	No	32(53)		
New practice to manage *T. absoluta*			39.570	<0.001
	Rational use of pesticide	8 (13)		
	Use of TLM lure and trap	38 (63)		
	Use of botanical pesticide	12 (20)		
	Any other	2 (3)		

Note: Figure inside the parenthesis indicates percentage

CONCLUSION

Drawing inference to the overall study, the problem of insect in tomato production, especially *T. absoluta* seems to be a serious constraint followed by diseases like late blight. The damage exhibited by this pest is accepted and experienced by most of the farmers. However, the sound technical resources seem to be inefficient and inaccessible to the real farmers. They tend to be over dependent on Agrovets whom they tend to face quite often for input procurement for production but sadly unfit to deliver the required technical knowledge for the producers. Farmers seem to be aware of several management techniques like cultural, physical, mechanical, pheromone lures, and botanical/biopesticides and chemical methods for the management of *T. absoluta*. However, they choose chemical pathway because of its quick action and also because of inadequate knowhow on impact of those chemicals on non-targeted organisms. Thus, most of them fail protecting themselves while using these deadly chemicals either through PPE, gloves, mask etc. or any one of them. Most of the farmers do not read the pesticide label and are also unaware about the waiting period of the pesticides. Farmers were found to accept other methods like use of TLM lure for pest management, use of botanicals etc. as alternate means to pesticide use. Majority of the farmers were not even measuring the pesticides, exhibits the immense need to give them pesticide use literacy. Farmers should be taught to follow multiple aspects of integrated pest management (IPM) to make pest management effective and choose chemicals resort as the last one. Chemical use must be done based on the hazard category to make it safer to some extent. A comprehensive study is required to examine the current situation of this pest in other areas as well.

ACKNOWLEDGEMENTS

The authors are thankful to respondent farmers, Institute of Agriculture and Animal Science (IAAS), MoLMAC Karnali Province, Agriculture Development Directorate Office, Surkhet, Municipal Agriculture Development Section Barahatal Rural Municipality, Birendranagar Municipality and Bheriganga Municiplaity for their support on performing this study.

LITERATURE CITED

Adhikari, D., R. Subedi, S. Gautam, D.P. Pandit, and D.R. Sharma. 2019. Monitoring and management of tomato leaf miner (*Tuta absoluta*, Meyrick) in Kavrepalanchowk, Nepal. Journal of Agriculture and Environment. 20:1-9.

ADS. 2015. Agriculture development strategy (ADS) 2015 to 2035. Government of Nepal, Ministry of Agricultural Development (MOAD), Singhdurbar, Kathmandu, Nepal.

Bajracharya, A.S.R., R.P. Mainali, B. Bhat, S. Bista, P.R. Shashank and N.M. Meshram. 2016. The first record of South American tomato leaf miner, *Tuta absoluta* (Meyrick 1917)(Lepidoptera: Gelechiidae) in Nepal. Journal of Entomology and Zoology Studies. 4(4), 1359-1363.

Bajracharya, A.S.R., B, Bhat, and P.N. Sharma. 2018. Geographical distribution of South American Tomato Leaf Miner Tutaabsoluta (Meyrick1917) (Lepidoptera: Gelechiidae) in Nepal. Journal of Plant Protection Society Nepal. 5: 1-15.

Budhathoki, K, 2006. Market oriented, organic and off-season vegetable production technology (Nepali). Shrimati Basanti Budhathoki, Lalitpur, Nepal.

Damalas, C.A. and S.M. Hashemi. 2010. Pesticide risk perception and use of personal protective equipment amongyoung and old cotton growers in northern Greece. Agrociencia. 44: 363–371.

Desneux, N., E. Wajnberg, K.A. Wyckhuys, G. Burgio, S. Arpaia, C.A. Narváez-Vasquez, and J. Frandon. 2010. Biological invasion of European tomato crops by *Tuta absoluta*: ecology, geographic expansion and prospects for biological control. Journal of Pest Science. 83(3): 197-215.

Ellen, S. 2012. Slovin's formula sampling techniques. URL: https://sciencing. com/slovins-formula-sampling-techniques-5475547. html.

Feder, G. 1979. Pesticides, information, and pest management under uncertainty. American Journal of Agricultural Economics. 61(1): 97–103. https://doi.org/10.2307/1239507.

Hashemi, S. M., R. Rostami, M.K. Hashemi and C.A. Damalas. 2012. Pesticide use and risk perceptions among farmers in southwest Iran. Human and Ecological Risk Assessment: An International Journal. 18(2):456-470.

iDE, N., VirginiaTech and CEAPRED. 2017. An overview on Tuta absoluta, identification, origin, distribution, damage and economic impact. An overview on *Tuta absoluta*, identification, origin, distribution, damage and economic impact.

Israel, G. D.1992. Determining sample size (Fact sheet PEOD-6). Gainesville, FL: University of Florida. pp.1-5.

Johnson, P. and J. Gill. 2010. Research methods for managers. Research Methods for Managers. pp.1-288.

Khan, M., H.Z. Mahmood and C.A. Damalas. 2015. Pesticide use and risk perceptions among farmers in the cotton belt of Punjab, Pakistan. Crop Protection. 67:184-190.

Khanal, D., S.K. Neupane, S. Poudel and M. Shrestha. 2021. An overview of chemical pesticide import in Nepal. Naya sonch ra srijana, prakrtitik pranali ko punarsthapana (in Nepali).121p.

Koirala, P., A.S. Tamrakar, B.P. Bhattarai, B.K Yadav, S. Humagain and Y.D. GC. 2010. Use and handling practice of pesticides in vegetables: A case study on some selected districts of Nepal. Journal of Food Science and Technology Nepal. 6:105-109.

Mainali, R. P., R.B. Thapa, S. Tiwari, P. Pokhrel and A.R. Ansari. 2014. Knowledge and practices on eggplant fruit and shoot borer, *Leucinodes orbonalis* Guenee Management in Dhading and Bara Districts of Nepal. Albanian Journal of Agricultural Sciences. 13(4).

McGowan, A.L. 2022. Adoption determinants and economic benefits of integrated pest management for Nepali vegetable farmers. Doctoral dissertation, Virginia Tech, USA.

Pereyra, P.C. and N.E. Sánchez. 2006. Effect of two solanaceous plants on developmental and population parameters of the tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Neotropical Entomology. 35(5): 671-676.

Regmi, H.N. 2005. Vegetable production in plastic house (Nepali). Siddhartha Printing Press, Lalitpur, Nepal.

Rijal, J. P., R. Regmi, R. Ghimire, K.D. Puri, S. Gyawaly and S. Poudel. (2018). Farmers' knowledge on pesticide safety and pest management practices: A case study of vegetable growers in Chitwan, Nepal. Agriculture. 8(1):16.

Sah, L. 201). *Tuta absoluta*: A serious and immediate threat to tomato production in Nepal. Retrieved Feb, 18, 2018 from IDE Nepal: http://www. idenepal. org/what/tuta. Html.

Shashank, P., K. Chandrashekar, N. Meshram and K. Sreedevi. 2015. Occurrence of *Tuta absoluta* (Lepidoptera: Gelechiidae) an invasive pest from India. Indian Journal of Entomology. 77(4): 323-329.

Urbaneja, A., J. González-Cabrera, J. Arnoand R. Gabarra. 2012. Prospects for the biological control of *Tuta absoluta* in tomatoes of the Mediterranean Basin. Pest Management Science. 68(9): 1215-1222.

Vargas, H. 1970. Observations on the biology and natural enemies of the tomato moth, *Gnorimoschema absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Idesia. 1: 75-110.

Zekeya, N., M. Chacha, P.A. Ndakidemi, C. Materu, M. Chidege and E. Mbega,. 2016. Tomato leafminer (*Tuta absoluta* Meyrick 1917): A threat to tomato production in Africa.