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Evaluating the efficacy of pesticides spraying programme based on threshold levels in controlling *Tuta absoluta* on tomato in high tunnels

By

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Introduction

- Tomato is the most cultivated under protected structures in Lesotho (Sebitia *et al*., 2021).
- However, vegetable crops grown under protected structures are vulnerable to various diseases and pest attacks (Sood, 2010).
- Presence of warm, humid conditions and abundant food supply provide a stable environment and habitat for pests
- The tomato leaf miner (*Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae)) is one of the pests of tomato, causing a 90–100% yield loss
- This pest was introduced in Lesotho in 2016 (Sebitia *et al*., 2021).

Introduction (cont.)

- The control strategies for *T. absoluta* still largely rely on chemical applications (Tropea Garzia *et al*., 2012) on a calendar based programmes (Braham and Bensalem, 2017).
- Calendar sprays are applied at specific days after planting without taking into account continued presence or absence of the pest (Afun *et al*., 1991).
- However repeated pesticide applications, could have unwanted effects, such as toxicity toward non-target organisms and the environment in general (Biondi *et al*., 2012)
- Could also lead to resistance of the pest against the insecticides(Reyes *et al*., 2012).

Introduction (cont.)

- IPM is an effective and environmentally friendly approach to pest management that relies on a combination of several practices (El-Bouhssini and Trissi, 2018).
- IPM uses ET and EIL as the main indices used in decision-making systems for pest management programs (Picanço Filho *et al.*, 2024)
- ET as the density of the pest at which control measures must be taken so that the population does not reach the EIL.
- EIL is the lowest density of the pest at which economic damages match the costs of control measures.

Introduction (cont.)

- However, In Lesotho, there are no threshold levels for tomato leafminer being used
- Farmers rely on insecticide spraying programs usually at 7 or 14 days interval without regards to the threshold levels (Masupha, unpublished data).

Introduction (cont.)

Problem statement

- Farmers in Lesotho rely on the use of traditional calendar based application of pesticides without regard to the threshold levels of this pest.
- Some of the farmers, due to financial constraints rely heavily on a single insecticide for the control of this pest and very few afford to incorporate the pheromone-based traps.
- Just like with other pests, farmers fail to adopt the IPM for the control of *T. absoluta*.

Introduction (cont.)

- Therefore, tomato yields continue to decline, and at some point, some farmers were forced to halt their production due to severity of damage by *T. absoluta* (Sebitia *et al*., 2022).

Introduction (cont.)

General objective

- To evaluating the efficacy of pesticides spraying programme based on threshold levels in controlling *T. absoluta* on tomato in high tunnels

Specific Objectives

- To determine the farming and management history of the experimental sites
- To determine the population built-up of *T. absoluta* under different management practices.

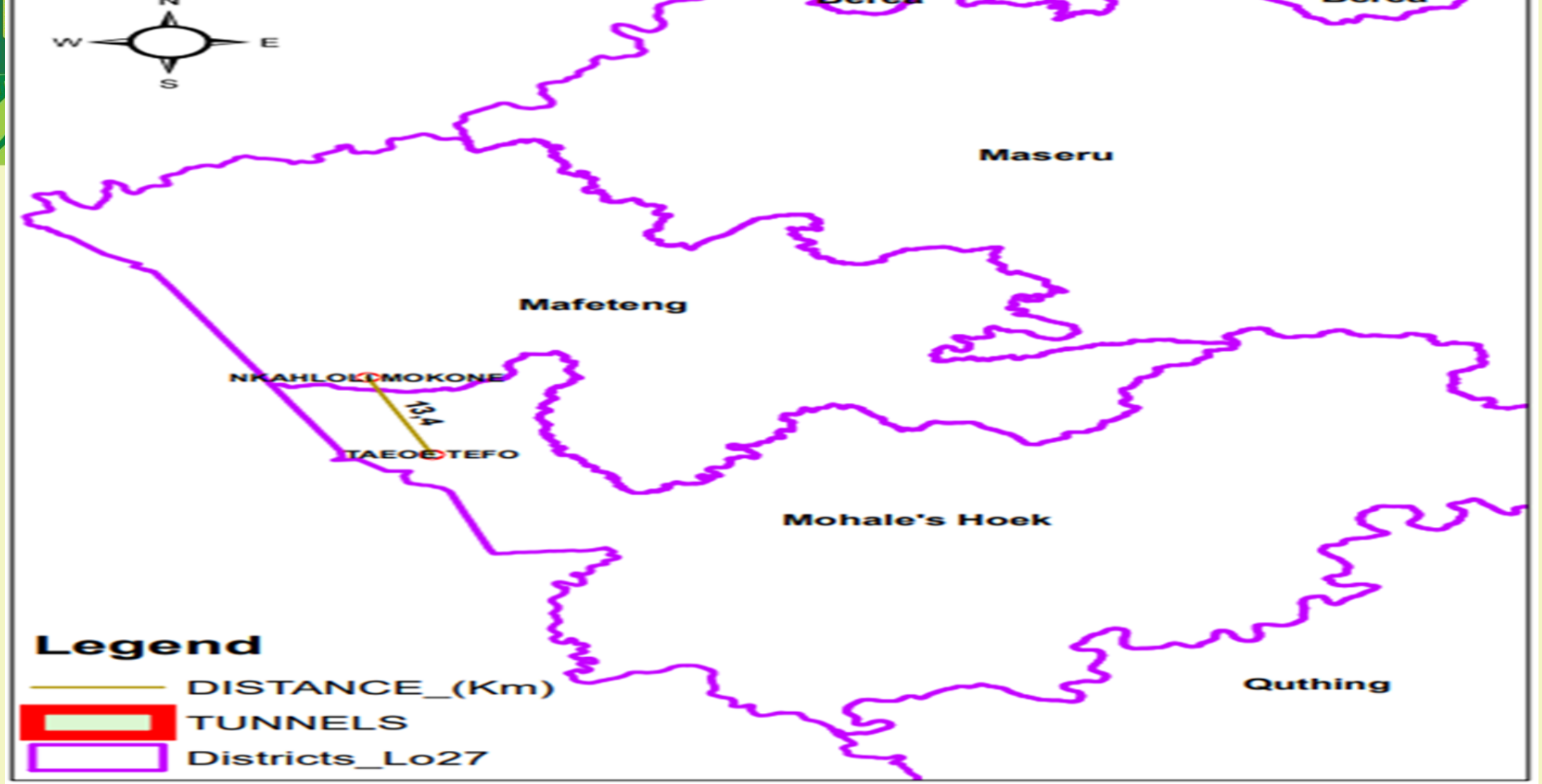
Introduction (cont.)

- To determine the most effective threshold level that can be used by the farmers in Lesotho for the control of *T. absoluta*
- To evaluate the effectiveness of different synthetic insecticides applied singly and in rotations based on threshold levels in reducing *T. absoluta* invasion and damage.

Materials and methods

Study areas

- The study (on-farm experiment) was conducted in two of the southern districts of Lesotho namely, Mafeteng and Mohale's Hoek under high tunnels.



- Fig 1. A map showing location of tunnels in both districts.

Materials and methods (cont.)

Preliminary study was conducted with the selected farmers to establish the following attributes;

- cropping history of tunnels,
- horticultural practices implemented,
- type of pests encountered,
- their management particularly *T. absoluta*,
- trainings received on IPM with emphasis on *T. absoluta* etc.
- The observations (own) in and around tunnels were noted, focusing on sanitation in general.

Materials and methods (cont.)

Experimental Plots and Design

Ten treatments were evaluated in a split-plot experimental design replicated thrice within a 30m by 10m high tunnel.

- Transplants were spaced at 0.60m (inter-row) by 0.45 m (in-row).
- Each plot of 1.4m x 0.6m (0.84m2) consisted of six (6) tomato transplants.
- A 0.9 m spacing was left between thresholds to minimize the effect of insecticide drifts during application.

Materials and methods (cont.)

The treatments consisted of four threshold levels as the main plots

- TH1: moth detection in the trap,
- TH2: obtaining > 20 moth counts in the trap,
- TH3: density of 1- 4 galleries
- TH4: >4 galleries)

Materials and methods (cont.)

Treatment ‘insecticides’ as subplots included;

- TP1: *Indoxacarb*,
- TP2: *Cypermethrin*,
- TP3: *Flubendiamide*,
- TP4: *Cypermethrin* + *Indoxacarb* rotations,
- TP5: *Cypermethrin* + *Flubendiamide* rotations
- TP6: Control
- applied only when thresholds were reached.
- All the main plots were 12 and there were 72 sub-plots.

Materials and methods (cont.)

- *Indoxacarb* and *Flubendiamide* are specifically recommended to use by farmers by the government of Lesotho for management of *T. absoluta*.
- The choice of these insecticides was influenced by their popularity and diverse use among the farming communities (15%, 13%, and 3.3% of farmers used *Cypermethrin*, *Indoxacarb* and *Flubendiamide*) (Sebitia *et al*., 2021).
- *Indoxicarb* is also one of the insecticides recommended by IRAC for tomato leaf miner (Moeini-Naghade *et al*., 2020)
- *Flubendiamide* insecticides have been recommended for a 120day term in Spain (Bloem and Spaltenstein, 2011).
- The chemical sprays were also applied at recommended rates by the supplier

Data collection

Detection and monitoring of *T. absoluta*

- Yellow Delta traps equipped with pheromone lures and sticky pads were set up in each tunnel to trap the leafminer moths.
- The moth catches were identified, counted, and recorded fortnightly throughout the study period.
- A formal scouting was conducted to establish if other thresholds were reached.
- Within 48 hours of reaching the threshold, the insecticides were applied accordingly using manually operated and pressure sprayers, then followed by regular spraying at a 14-day interval.

Data collection (cont.)

Determination of the degree of leaf/fruit damage by *T. absoluta*

- Assessment was done twice for Mafeteng and thrice for Mohale's hoek
- Four plants were randomly selected and degree of damage was established by counting the total number of plant leaves per plot, and the number of affected leaves /plot.
- Once sampling was done the infected leaves were pruned and eliminated.

Data collection (cont.)

Determining the tomato yield response to insecticides treatment interaction

- The tomato fruits were harvested three times at the breaker stage, and number of fruits per plant and per plot recorded (kg).
- Fruits were then classified as marketable and non-marketable (having holes associated with the larvae).

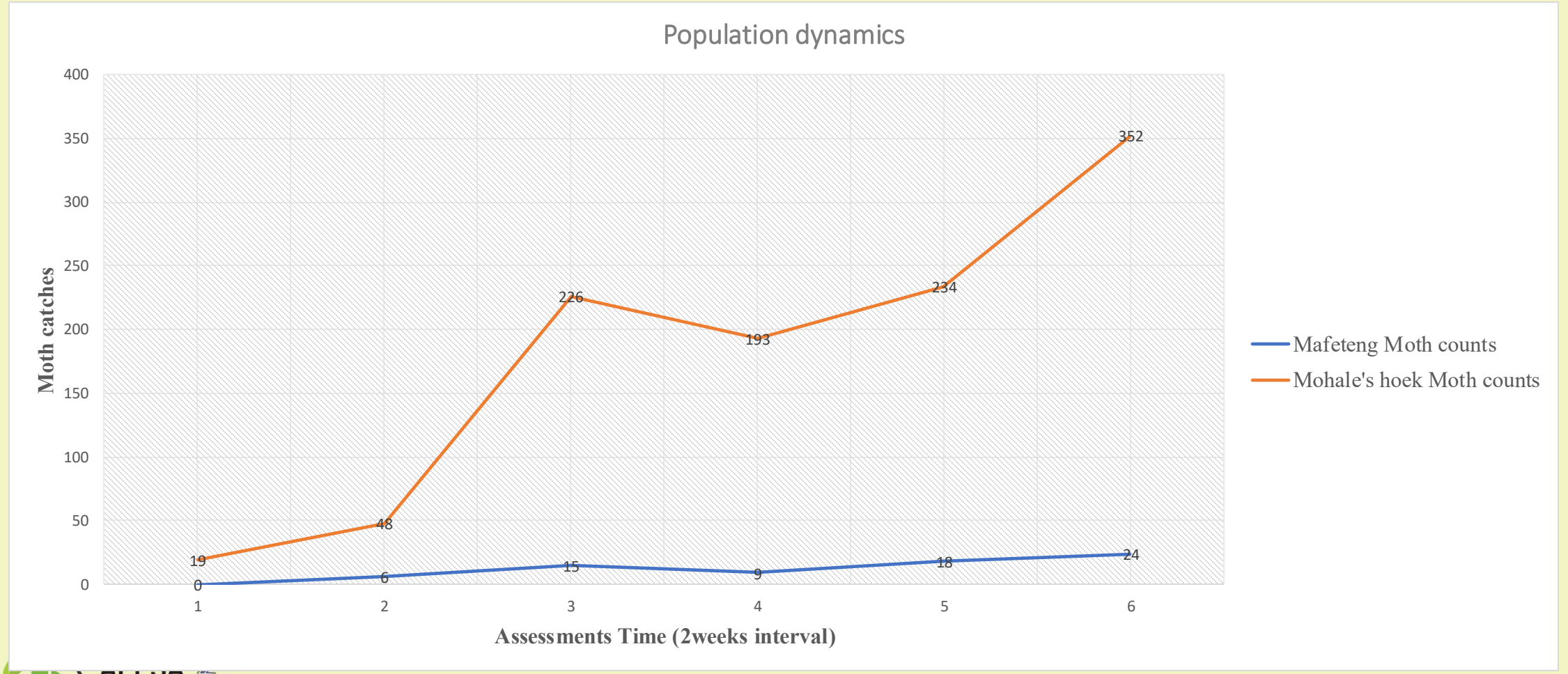
Data analysis

- Data was analysed using GenStat statistical tool to determine the ANOVA table and to determine if there was a any statistical difference among the treatment means at LSD of 5%

Results, Interpretation and Discussion

Attributes	Mohale's hoek Farmer	Mafeteng farmer
Tunnels establishment	2020	2021
Crops produced	Tomatoes, cabbage, seedling production	Tomatoes, cabbage
Insects pests	Tomato leafminer, red spider mites, aphids, locusts, cutworms	Tomato leafminer, bollworms, ladybird beetles, cutworms, aphids
Awareness and adoption of IPM	Attended trainings	Attended trainings
	Fully aware of IPM strategies but not practising	Fully aware of IPM strategies and practicing
IPM	Rotation of cabbage with tomatoes	Rotation of cabbage with tomatoes
	Synthetic pesticides application	Concoction of basil, comfrey and wild garlic, and synthetic pesticides application
	Poor sanitation practices	Good sanitation practices
Own observations		
Sanitation	Tunnels and the surroundings not cleaned; infested plant debris discarded around the tunnels	Tunnels and surroundings clean and free from plant debris

Results, Interpretation and Discussion (cont.)



Results, Interpretation and Discussion (cont.)

- The sharp increase in Mohale's hoek occurred during application of the insecticides.
- In a study by Moeini-Naghade *et al*., 2020 *indoxacarb* and *cypermethrin* were among the insecticides tested that did not have a satisfactory effect on the adult stage.

Results, Interpretation and Discussion (cont.)

- Table of means for the degree of leaf damage in Mafeteng

Means	Thresholds				Insecticides					
	TH1	TH2	TH3	TH4	TP1	TP2	TP3	TP4	TP5	TP6
Ass 1	1.333	1.111	1.444	1.278	1.083	1.083	1.417	1.333	1.500	1.333
F pr.	0.086				0.093					
lsd	-				-					
Ass 2	1.333	1.111	1.444	1.278	1.083	1.083	1.417	1.333	1.500	1.333
F pr.	0.086				0.093					
lsd	-				-					

Results, Interpretation and Discussion (cont.)

- Table of means for Degree of fruit damage in mafeteng

Means	Thresholds				Insecticides					
	TH1	TH2	TH3	TH4	TP1	TP2	TP3	TP4	TP5	TP6
Harv 1	1.000	1.111	1.056	1.000	1.000	1.000	1.083	1.000	1.167	1.000
F pr.				0.189						0.278
lsd				-						-
Harv 2	1.000	1.056	1.167	1.000	1.000	1.000	1.167	1.083	1.000	1.083
F pr.				0.455						0.235
lsd				-						-
Harv 3	1.389	1.167	1.222	1.222	1.167	1.250	1.333	1.083	1.417	1.250
F pr.				0.485						0.270
lsd				-						-

Results, Interpretation and Discussion (cont.)

- Table of means for the degree of leaf damage in Mohale's hoek

Means	Thresholds				Insecticides					
	TH1	TH2	TH3	TH4	TP1	TP2	TP3	TP4	TP5	TP6
Ass 1	1.50	1.56	1.56	1.28	1.42	1.67	1.42	1.50	1.67	1.17
F pr.	0.273				0.063					
lsd	-				-					
Ass 2	2.50^{bc}	1.89^{a}	2.17^{ab}	2.33^{abc}	2.33	2.25	2.25	2.25	2.00	2.25
F pr.	0.037				0.812					
lsd	0.384				-					
Ass 3	4.33	4.17	4.33	4.00	4.14	4.25	4.25	4.25	4.17	4.17
LSD	0.552				0.130					
F pr.	-				-					

Results, Interpretation and Discussion (cont.)

- Table of means for the degree of fruit damage in Mohale's hoek

Means	Thresholds				Insecticides					
	TH1	TH2	TH3	TH4	TP1	TP2	TP3	TP4	TP5	TP6
Hav 1	2.167	2.000	2.000	1.889	1.833^{a}	1.833^{a}	1.917^{ab}	2.000^{abc}	2.417^{d}	2.083^{abcd}
F pr.				0.496						0.033
lsd				-						0.3816
Hav 2	2.722^{c}	1.611^{a}	1.833^{abc}	1.667^{ab}	1.833	1.750	1.833	2.083	2.167	2.083
F pr.				0.012						0.350
lsd				0.5977						-
Hav 3	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
F pr.				-						-
lsd				-						-

Table 6: The effect of treatment interaction on tomato yields in Mohale's hoek

Treatment Interaction (Thresholds*Insecticides)	Total yields (kg/plot)				Non-marketable yields (kg/plot)				
	1st harvest	2nd harvest	3rd harvest	yield gain	1st harvest	2nd harvest	3rd harvest	yield loss	% yield loss
Detection + *Indoxacarb*	2,683	2,967	7,317^{a-d}	13,0	0.450^{cd}	1.050	3.167^{cd}	4.67	35.9
Detection + *Cypermethrin*	2,450	3,567	4,133^{ef}	10,2	0.650^{b-d}	0.417	5.267^{ab}	6.33	62.1
Detection + *Flubendiamide*	3,183	2,267	7,650^{a-c}	13,1	0.417^{cd}	0.617	5.600^{ab}	6.63	50.6
Detection + *Indoxacarb* & *Cypermethrin*	4,233	5,317	6,450^{a-d}	16,0	0.933^{a-c}	1.367	4.133^{b-d}	6.43	40.2
Detection + *Cypermethrin* & *Flubendiamide*	2,283	6,350	3,817^{f}	12,5	0.650^{b-d}	2.383	2.700^{d}	5.73	45.8
Detection + Control	4,900	4,500	6,217^{a-e}	15,6	1.617^{a}	3.783	5.767^{ab}	11.17	71.6
>20 moth catches + *Indoxacarb*	4,300	4,600	7,200^{a-d}	16,1	0.500^{cd}	1.183	5.283^{ab}	6.97	43.3
>20 moth catches + *Cypermethrin*	2,300	6,117	6,25 $^{a-e}$	14,7	0.550^{b-d}	1.567	5.467^{ab}	7.58	51.6
>20 moth catches + *Flubendiamide*	4,117	4,350	6,317^{a-d}	14,8	1.233^{ab}	1.083	5.283^{ab}	7.6	51.4
>20 moth catches + *Indoxacarb* & *Cypermethrin*	3,567	2,233	8,183^{a}	14,0	0.483^{cd}	0.467	5.500^{ab}	6.45	46.1
>20 moth catches + *Cypermethrin* & *Flubendiamide*	2,583	2,433	7,617^{a-c}	12,6	0.550^{b-d}	0.517	5.333^{ab}	6.4	50.8
≥20 moth catches + control	3,900	4,967	7,250^{a-d}	16,1	0.233^{cd}	2.483	5.917^{ab}	8.63	53.6

1-4 galleries + *Indoxacarb*	1,850	5,283	5,850^{b-f}	13,0	0.550^{b-d}	0.900	4.817^{a-c}	6.27	48.2
1-4 galleries + *Cypermethrin*	3,367	2,317	6,767^{a-d}	12,5	0.183^{d}	2.250	4.867^{a-c}	7.3	58.4
1-4 galleries + *Flubendiamide*	2,633	5,583	6,317^{a-d}	14,5	0.383^{cd}	2.117	4.383^{b-d}	6.88	47.5
1-4 galleries + *Indoxacarb* & *Cypermethrin*	4,117	3,933	5,617^{c-f}	13,7	0.683^{b-d}	1.833	4.500^{b-d}	7.02	51.2
1-4 galleries + *Cypermethrin* & *Flubendiamide*	2,200	1,583	5,533 $^{c-f}$	9,3	0.533^{b-d}	0.333	4.350^{b-d}	5.22	56.1
1-4 galleries + control	3,717	4,183	6,117^{a-e}	14,0	0.567^{b-d}	1.483	5.083^{a-c}	7.13	50.9
>4 galleries + *Indoxacarb*	2,750	3,467	6,417^{a-d}	12,6	0.450^{cd}	0.917	4.433^{b-}	5.8	46.0
>4 galleries + *Cypermethrin*	5,067	3,533	7,833^{ab}	16,4	0.500^{cd}	0.767	6.633$^{a\ d}$	7.9	48.2
>4 galleries + *Flubendiamide*	3,200	3,883	7,667^{a-c}	14.8	0.600^{b-d}	1.050	5.167^{ab}	6.82	46.2
>4 galleries + *Indoxacarb* & *Cypermethrin*	2,400	4,883	7,033 $^{a-d}$	14,3	0.633^{b-d}	0.617	5.700^{ab}	6.95	48.6
>4 galleries + Cypermethrin & Flubendiamide	3,883	4,217	5,467^{d-f}	13,6	0.183^{d}	1.133	4.617^{b-d}	5.93	43.6
>4 galleries + control	4,367	2,633	8,217^{a}	15,2	0.650^{b-d}	2.000	5.633^{ab}	6.28	41.3
Grand mean	3.335	3.969	6.551		0.586	1.347	4.983		
LSD (P≤0.05)	N/S	N/S	2.138		0.723	N/S	1.951		
GRAND TOTAL YIELDS				**332.5**				**171.42**	**51.6**

Key – LSD: least significant difference at 5%, N/S: non-significant,

The effect of treatment interaction on tomato yields in Mohale's hoek

- Threshold Detection + *Indoxacarb* recorded the lowest fruit loss.
- This results are similar to those obtained by Bhat *et al*., 2017 who reported that the *indoxacarb* was among the insecticides that recorded the least fruit damage
- Braham and Hajji, 2012 found the use of *indoxicarb* very effective against *T. absoluta*.

Table 7: The effect of treatment interaction on tomato yields in Mafeteng

Treatment Interaction (Thresholds*Insecticides)	Total Tomato Yield (kg/plot)				Non-Marketable Tomato Yields				
	1st harvest	2nd harvest	3rd harvest	Cumulative yield	1st harvest	2nd harvest	3rd harvest	Cumulative yield loss	% yield loss
Detection + *Indoxacarb*	2.250^{a}	3.267	4.400	9.92	0.000^{b}	0.000^{b}	0.133^{ab}	0.13	3.0
Detection + *Cypermethrin*	2.267^{a}	4.467	3.833	10.57	0.000^{b}	0.000^{b}	0.000^{b}	0	0
Detection + *Flubendiamide*	1.933^{a-c}	4.083	3.217	9.23	0.000^{b}	0.000^{b}	0.017^{ab}	0.02	0.2
Detection + *Indoxacarb* & *Cypermethrin*	1.367^{a-f}	3.283	2.467	7.12	0.000^{b}	0.000^{b}	0.000^{b}	0	0
Detection + *Cypermethrin* & *Flubendiamide*	1.967^{ab}	3.400	4.400	9.77	0.000^{b}	0.000^{b}	0.000^{b}	0	0
Detection + Control	1.833^{a-c}	4.200	4.133	10.12	0.000^{b}	0.000^{b}	0.067^{ab}	0.067	0.7
≥20 moth catches + *Indoxacarb*	0.383^{f}	4.000	3.600	7.98	0.000^{b}	0.000^{b}	0.017^{ab}	0.017	0.2
≥20 moth catches + *Cypermethrin*	0.550^{ef}	2.817	3.950	7.32	0.000^{b}	0.000^{b}	0.000^{b}	0	0
≥20 moth catches + *Flubendiamide*	1.783^{b-f}	3.750	2.067	7.6	0.017^{ab}	0.017^{b}	0.083^{ab}	0.1	1.3
≥20 moth catches + *Indoxacarb* & *Cypermethrin*	1.333^{a-f}	3.950	3.133	8.42	0.000^{b}	0.000^{b}	0.000^{b}	0	0
≥20 moth catches + *Cypermethrin* & *Flubendiamide*	2.267^{a}	4.800	3.700	10.77	0.067^{a}	0.000^{b}	0.117^{ab}	0.184	1.7
≥20 moth catches + control	1.900^{a-c}	3.500	3.600	9	0.000^{b}	0.000^{b}	0.000^{b}	0	0

1-4 galleries + *Indoxacarb*	0.817^{c-f}	4.167	3.517	8.5	0.000^{b}	0.000^{b}	0.000^{b}	0	0
1-4 galleries + *Cypermethrin*	0.700^{d-f}	3.517	2.683	6.9	0.000^{b}	0.000^{b}	0.100^{ab}	0.1	1.5
1-4 galleries + *Flubendiamide*	1.467^{a-f}	3.883	4.217	9.57	0.000^{b}	0.017^{b}	0.233^{a}	0.25	2.6
1-4 galleries + *Indoxacarb* & *Cypermethrin*	0.883^{b-f}	3.900	3.867	8.65	0.000^{b}	0.267^{a}	0.100^{ab}	0.367	4.2
1-4 galleries + *Cypermethrin* & *Flubendiamide*	1.150^{a-f}	3.883	3.467	8.5	0.000^{b}	0.000^{b}	0.000^{b}	0	0
1-4 galleries + control	1.033^{b-f}	3.400	2.433	6.87	0.000^{b}	0.067^{b}	0.000^{b}	0.067	1
>4 galleries + *Indoxacarb*	1.550^{a-e}	3.417	3.383	8.35	0.000^{b}	0.000^{b}	0.000^{b}	0	0
>4 galleries + *Cypermethrin*	0.683^{ef}	4.033	4.033	8.75	0.000^{b}	0.000^{b}	0.033^{ab}	0.033	0.4
>4 galleries + *Flubendiamide*	1.317^{a-f}	3.033	4.000	8.32	0.000^{b}	0.000^{b}	0.000^{b}	0	0
>4 galleries + *Indoxacarb* & *Cypermethrin*	1.117^{b-f}	1.750	3.567	6.43	0.000^{b}	0.000^{b}	0.000^{b}	0	0
>4 galleries + *Cypermethrin* & *Flubendiamide*	1.617^{a-e}	4.067	1.817	7.5	0.000^{b}	0.000^{b}	0.000^{b}	0	0
>4 galleries + control	1.033^{b-f}	2.650	4.583	8.27	0.000^{b}	0.000^{b}	0.000^{b}	0	0
Grand mean		1.358	3.643	3.499		0.586	1.347	4.983	
LSD (P≤0.05)		1.127	N/S	N/S		0.723	0.169	0.218	
Grand Total Yields					**204.43**			**1.515**	**15.8**

Key – LSD: least significant difference at 5%, N/S: non-significant,

Results, Interpretation and Discussion (cont.)

- Mafeteng showed the lowest infestation and damage to both the leaves and the fruits due to implementation of integrated pest management

Conclusion/Recommendation

- The results have since shown that the *Cypermethin* was not highly effective in the control of *T. absoluta*.
- Salazar and Araya (2001) reported that tomato leaf miner shows resistance to phosphorous and pyrethroid insecticides.

- Recommend a study to determine the resistance of *T. absoluta* against *Cypermethrin* in Lesotho
- This study is based on one cropping season;

Conclusion/Recommendation

- There was a very low infestation of *T. absoluta* with the farmer from Mafeteng that was using IPM for control of this pest therefore, recommend the adoption of this control strategy.
- In this study, most of the damage was recorded closer to the openings of the high tunnels.
- Biondi *et al*., 2015 also indicated that there is a higher infestation of tomato plants closer to openings in greenhouses.
- Insect-proof screens (agronets) are a physical means of crop protection that can prevent or limit the entrance of insects into the greenhouse, (Fatnassi *et al*. 2002)

Conclusion/Recommendation

- Closure of the high tunnels at night
- Good sanitation practices; decomposition of the plant debris

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