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Research Article
Controlling the 2nd Instar Larvae of *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) by Simmondsin Extracted from Jojoba Seeds in KSA

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Abstract
Background and Objective: Tomato leaf miner, *Tuta absoluta* (Gelichiidae: Lepidoptera) is a destructive pest of tomato crops worldwide. So, the main objective was to evaluate simmondsin extracted from Jojoba seeds against *T. absoluta* larvae, which are considered to be the most dangerous pests of the family, especially tomato. **Materials and Methods:** Individuals of the tomato leaf larvae, pupa and adults were collected from green houses and tomato leaves were infested and incubated under lab condition until the emerging of adults. Newly laid eggs (24 h old) were carefully collected from tomato plants that had previously been exposed to *T. absoluta* adults (both sexes). The effects of simmondsin extracts on mortality were tested using one-way ANOVA and corrected by using Abbott's formula. **Results:** Several simmondsin extracts were used (by ammonium hydrogine peroxide, isopropanol, acetone, or water at concentrations of 25, 50, 75 or 100%. The result obtained showed that simmondsin extracts by acetone and water significantly reduced (at 5%) *T. abslouata* populations in comparison with data oblations from simmondsin extracted by ammonium hydrogen peroxide and by isopropanol. A strong correlation between the susceptibilities of *T. absoluta* populations to extraction methods and concentrations were observed. **Conclusion:** Simmondsin extractions were more effective in controlling the 2nd instar larvae of *T. absoluta*. It may be concluded that use of simmondsin extracts could be useful within IPM programs. This finding indicates that biorational insecticides are a good alternative than synthetic ones particularly with fresh vegetables. Possible use of biorational insecticides in the management of *T. absoluta* in organic farming system is being discussed. Poor-resource farmers of tomato could therefore adopt jojoba extracts as alternatives to synthetic insecticide.

Key words: Tomato leaf-miner, *Tuta absoluta*, jojoba, simmondsin, biorational control, botanical extracts, IPM

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Tomato leaf-miner (TLM) has been attracting the attentions of both entomologists and tomato growers in the tomato production areas as it causes serious problems that may impede the tomato production in the future[1]. *Tuta absoluta* is a destructive insect pest of tomato and other Solanaceae plants world-wide TLM introduced from Latin America, where the pest changed its status in dramatic fashion to be a global key pest for tomatoes[1,2]. The TLM is considered the cross-borders pest, which infests and devastates tomato-production whether cultivated under the greenhouses and/or in the open fields around the world particularly in Mediterranean regions[1-3]. Additionally, this pest is considered a model for the invasive species in the world, because of its capacity to rapid development and its ability to rapid spread in new areas causing economically relevant damage[4,5]. Since the first time of detection, TLM has caused serious damages to tomato in its invaded areas[6,7] and it is currently considered a key agricultural pest threat to European, Middle East, North African Tomato production and part of Asia[7].

The Mediterranean basin formed a comfortable and appropriate new habitat for reproduction and spreading of the insect, therefore, TLM attacks new Solanaceae plants[2,3]. Accordingly, *T. abslouta* has 10-12 generations yearly and a higher fecundity rates which a single female can lay about 250-300 eggs per female[8,9]. Consequently, these constraints require an activation of the role of agricultural quarantine against TLM.

The TLM is a holometabolous insect (complete metamorphosis), which larvae are considered the harmful stage in insect life cycle[1-4, 8]. Larva attacks the leaves causing leaf-mines, the main and lateral stems and, fruits causing significantly reduction(at 5%) in tomato fruits quality and quantities. Accordingly, dramatic loss of the commercial value of tomatoes production world-wide occurred (more than 50%), whereby the tomatoes fruits become unsellable[10].

The main control method of TLM is mainly based on the chemical pesticides. Nevertheless, this procedure is environmentally unsustainable and led to continuous exposure to a broad spectrum of pesticides that resulted in the prevalence resistance in *T. absoluta* rendering current conventional methods to control this pest ineffective. Chemical pesticides have limited effectiveness due to the nature of insect damage, beside its rapid development of a resistant against the pesticides used. Contrariwise, a scarcity of information about the importance of this pest in open-field cultivation is currently present, which may lead to ineffective control strategies[10].

The IPM strategies are being developed to control TLM. So, plenty of active substances can be applied in combination with bio-rational control tactics. The IPM aiming at the sustainability of production systems has been investigated with a formulation of botanical insecticides[11]. Various derivatives of vegetable origin, especially in the form of extracts or essential oils, have been recommended as alternatives to synthetic pesticides[12,13]. One of the most studied species in recent decades is neem (*Azadirachta indica*) (Meliaceae)[14-16] and several commercial formulations with it are now available worldwide.

Botanical pesticides are naturally occurring chemicals extracted from plants. Natural pesticidal products are available as an alternative to synthetic chemical formulations but they are not necessarily less toxic to humans. Some of the most deadly, fast acting toxins and potent carcinogens occur naturally[17].

In view of the effects of synthetic pesticides on human health, biodiversity and the environment, it is essential therefore to intensify research trials on the use of alternatives for synthetic insecticides that are adoptable, affordable and with relative ease of application. The objective of this study was to evaluate the potentials of Simmondsin extracted from Jojoba against tomato leaf miner and untreated control against 2nd instar larval population of *T. absoluta*.

MATERIALS AND METHODS

The experiment was conducted in the greenhouse and Entomology Laboratory in the Department of Plant Production and Protection, Collage of Agriculture and Veterinary Medicine, Qassim University, KSA in 2013.

Insect rearing: Individuals of the tomato leaf miner, *Tuta absoluta* (Gelichiidae: Lepidoptera) larvae, pupa and adults were collected from infested tomatoes in greenhouses from different Qassim regions to establish colonies to be used in the laboratory bioassays. Infested leaves were incubated under lab condition until the emerging of adults. The larvae were put in a large breading cage (1.0×1.0×1.20 m and coated with anti-aphids mash) with tomato seedlings under controlled conditions at 27±2°C and 55% RH. Tomato plants were placed in the chamber weekly for feeding and egg lying. Adults were collected using an aspirator. Adults were then inserted in glass jars lined with filter paper. Jars were covered with muslin fixed with a rubber band. Using a fine paintbrush and a stereoscopic binocular microscope, newly laid eggs (24 h old) were carefully collected from tomato plants that had previously been exposed to *T. absoluta* adults

Table 1: Treatments, extracting methods and concentrations

Treatments	Extracted methods	Symbols	Concentrations used
1	Simmondsin extracted by ammonium hydrogine peroxide	AW	25, 50, 75 and 100%
2	Simmondsin extracted by isopropanol	I	25, 50, 75 and 100%
3	Simmondsin extracted by acetone	AC	25, 50, 75 and 100%
4	Simmondsin extracted by water	W	25, 50, 75 and 100%
5	Check treatment (water only)	-	-

(both sexes). Emerged moths were feed on a piece of cotton wool soaked with 10% honey bee solution as a source of food for the moths in addition to new seedlings for egg laying. Newly deposited eggs were collected daily with its seedlings and maintained until reaching the 2nd instar larvae.

Evaluation of simmondsin extracts: The evaluation was performed with second-instar larvae of *T. absoluta*. The TLM was obtained from a laboratory rearing colonies located at the campus of Qassim University, KSA. Evaluation tests were performed with 2nd instar larvae of *T. absoluta* as in Table 1.

The second instar larvae were carefully taken out from their mines by using zero brush and then transferred to newly un-infested tomato leaves in Petri-dishes (15 cm in diameter). Twenty larvae were put in each Petri-dish. Tomato leaves and *T. absoluta* larvae were sprayed with a tested treatment (3 mL/Petri-dish). Petri-dishes were provided with filter paper to protect larvae from excessive humidity. Petri-dishes were maintained at the previously mentioned laboratory conditions. Each treatment was replicated five times. Control experiment was performed using distilled water. Number of live and dead larvae of each treatment as well as control was recorded after 1, 3, 5 and 7 days of treatment. At every day, leaves were removed and replaced with fresh untreated leaves for control and treated leaves for treatments. Mortality percentages were calculated.

Statistical analysis: The effect of simmondsin extracts and concentrations on mortality of the 2nd instar larvae of *T. absoluta* were tested using one-way ANOVA. Significantly different means of treatments were determined using Duncan's multiple range test at p = 0.05. Means comparison was conducted according to Duncan's Multiple Range Test (DMRT) at the probability of 5%[18]. Standard deviation among different treatments has been calculated according to Costat Software[18].

Abbott's formula[19] was used to correct bioassay data for control response and has become a standard in bioassay evaluation and for to determine insecticide efficacy (EA) measures the mortality caused by the insecticide in the pest population with a correction for natural mortality in the untreated pest population:

$$EA = 100\frac{Nc - Nt}{Nt} \quad (1)$$

where, Nc is live individuals in the control after the treatment and Nt is live individuals in the treatment after the treatment.

RESULTS

Efficiency of simmondsin against the 2nd instar larvae of *Tuta absoluta*

Treat of larvae inside the plant leaf tunnels: Four extraction methods efficacy of Jojoba seeds against the 2nd larval instar of *T. absoluta* was evaluated in this study. This study data demonstrated that the insecticidal potency of extracted Jojoba seeds on the 2nd instar of *T. absoluta*. Table 2 shows that all extraction methods of jojoba seeds had a great impact and efficiency as botanical insecticides against the 2nd instar *T. absoluta* at different concentrations. However, it could be noted that the mortality rates varied based on extraction method and the concentration used. The highest initial kill (1st day after application) against the 2nd instar larvae was obtained when treated with simmondsin extracted by water (W). Simmondsin extracted by isopropanol (I) caused slightly higher mortality rates than the previous extraction method. However, extraction by ammonium hydrogen peroxide (AW) and acetone (AC) were in similar in regard of the initial kill. Significant differences were observed among the concentrations within the 1st day of treatment at $p \leq 0.0001$; F=12.33 and df = 16 and 34 (Table 2).

In the 3rd day of treatment, the mortality percentage increased sharply and dramatically to achieve about 50% of mortality for all extraction methods (Table 2). The mortality percentage by simmondsin extracted with ammonium hydrogen peroxide (AW) recorded different rates based on the concentrations of the extract. Meanwhile, the average mortality percentage of the extraction by ammonium hydrogen peroxide (AW) in the 3rd day lasted about 50% of the total.

In same context, the mortality percentage as a result of using the simmondsin extracted by isopropanol (I) ranged from 33.33±3.33 to 66.66±3.33% according to the concentrations used. Additionally, the average mortality

Table 2: Toxicity of four extracting methods of jojoba extracts tested against *Tuta absoluta* inside tomato leaf tunnel after topical application

	Mortality percentage based on days after treatment (Average±SD)					
Treatment and concentrations	1	3	5	7	Residual effects (Average±SD)	Total activity (Average±SD)
Simmondsin extract by ammonium hydrogen peroxide (AW)						
25%	5.00 ± 2.89^{fg}	35.00 ± 2.89^{e}	43.33 ± 4.41^{fgh}	43.33 ± 4.41^{f}	40.55 ± 3.90	22.77 ± 3.65
50%	$8.33\pm1.66e^{fg}$	50.00 ± 5.78^{cd}	53.33 ± 6.67^{ef}	53.33 ± 6.67^{ef}	52.22 ± 6.37	30.27 ± 4.01
75%	18.33 ± 1.66^{cd}	58.33 ± 4.41^{bc}	68.33 ± 1.66^{bcd}	68.33 ± 1.66^{cd}	64.40 ± 2.57	41.66 ± 2.11
100%	$20.00\pm2.89b^{cd}$	60.00 ± 2.89^{bc}	63.33 ± 3.33^{de}	76.66 ± 3.33^{bc}	66.66 ± 3.18	43.33 ± 3.03
Average	12.91 ± 2.27	50.75 ± 3.99	57.08 ± 4.01	60.40 ± 4.01	56.07 ± 4.01	43.49 ± 3.13
Simmondsin extract by isopropanol (I)						
I 25%	16.66 ± 3.33^{de}	33.33 ± 3.33^{e}	33.33 ± 3.33^{h}	46.66 ± 3.33^{ef}	37.77 ± 3.13	27.21 ± 3.13
I 50%	18.33 ± 4.41^{cd}	45.00 ± 5.00^{de}	45.00 ± 5.00^{fgh}	51.66 ± 4.41^{ef}	47.22 ± 4.80	65.55 ± 4.60
I 75%	23.33 ± 3.33^{bcd}	50.00 ± 5.78^{cd}	$50.00\pm5.78\ ^{fg}$	73.33 ± 3.33^{c}	57.77 ± 4.96	40.55 ± 4.41
I 100%	38.33 ± 4.41^{a}	66.66 ± 3.33^{b}	68.33 ± 1.66^{bcd}	76.66 ± 3.33^{bc}	47.55 ± 2.77	42.94 ± 3.59
Average	24.15 ± 3.87	48.74 ± 4.36	49.16 ± 3.94	62.07 ± 3.60	53.33 ± 3.90	38.73 ± 3.88
Simmondsin extract by acetone (AC)						
25%	15.00 ± 2.89^{de}	33.33 ± 3.33^{e}	40.00 ± 5.78^{gh}	56.66 ± 3.33^{de}	43.33 ± 4.14	29.16 ± 3.51
50%	20.00 ± 2.89^{bcd}	60.00 ± 5.78^{bc}	66.66 ± 3.33^{d}	66.66 ± 3.33^{cd}	64.66 ± 4.1	42.22 ± 3.51
75%	23.33 ± 3.33^{bcd}	80.00 ± 5.78^{a}	80.00 ± 2.89^{bc}	93.33 ± 6.67^{a}	84.44 ± 5.11	53.85 ± 4.22
100%	28.33 ± 1.66^{b}	85.00 ± 2.89^{a}	88.33 ± 1.66^{ab}	96.66 ± 3.33^{a}	98.99 ± 2.62	59.16 ± 2.14
Average	21.66 ± 2.68	64.58 ± 4.44	68.73 ± 3.41	78.31 ± 4.16	70.54 ± 4.00	46.10 ± 3.34
Simmondsin extract by water (W)						
25%	5.00 ± 2.89^{fg}	33.33 ± 3.33^{e}	36.66 ± 3.33^{h}	70.00 ± 5.78^{c}	46.66 ± 12.4	25.83 ± 7.66
50%	13.33 ± 3.33^{def}	55.00 ± 2.89^{bcd}	71.66 ± 6.01^{bc}	86.66 ± 3.33^{ab}	71.10 ± 4.07	42.20 ± 3.70
75%	26.66 ± 3.33^{bc}	80.00 ± 2.59^{a}	93.33 ± 3.33^{a}	98.33 ± 1.66^{a}	90.54 ± 5.83	58.55 ± 4.59
100%	40.00 ± 2.89^{a}	86.66 ± 3.33^{a}	95.00 ± 2.89^{a}	95.00 ± 2.89^{a}	92.20 ± 3.03	66.10 ± 2.96
Average	21.24 ± 3.11	63.73 ± 3.03	74.16 ± 3.89	87.48 ± 13.66	75.12 ± 6.70	48.16 ± 4.90
Check treatment	2.88 ± 2.89^{g}	5.00 ± 00^{f}	$6.66\pm1.66g^{i}$	8.33 ± 1.66^{g}		
LSD (p = 0.05)	8.69	11.55	14.78	11.38		
df	16.34	16.34	16.34	16.34		
F	12.33	30.09	34.77	35.37		
p	0.000	0.000	0.000	0.000		

*Means±SE followed by the same capital letters in columns and the same lower letter in rows do not differ significantly at p<0.05 (Tukey's test)

percentage of the extraction by isopropanol (I) in the 3rd day is approaching to 50%. Whilst, applied the Jojoba extracted by acetone (A) caused higher mortality rates after three days of treatment. Similar results were obtained when extracting method occurred using ammonium hydrogen peroxide.

It is worth mentioning the four treatments differed significantly among in-between and also based on concentrations within a treatment in regard of the mortality percentage after three days of the treatment ($p\leq0.0001$; F = 30.09; df = 16; 34).

Five days after treatment, the mortality percentage among *T. absoluta* 2nd instar larvae increased slowly and gradually to achieve approximately 3 quarters of mortalities as a mean of mortality percentage of AW, I, AC and W the four extraction methods, respectively (Table 2). Concentrations of the extraction method varied significantly in causing the mortality percentage among *T. abslouta* population. Notably, the significant differences between the treatments at the 5th day of treatment were observed at $p\leq0.0001$; F = 34.77 and df = 16 and 34 (Table 2).

The highest mortality rates were noticed after 7 days after treatment (Table 2). The mortality percentage increased slowly and gradually and sometimes very slowly. Concentrations of the extraction method varied significantly in causing the mortality percentage among *T. abslouta* population (Table 2). Notably, the significant differences between the four treatments were observed at $p\leq0.0001$; F = 35.37 and df = 16 and 34 (Table 2).

Treat of larvae alone without plant leaf tunnels: Topical application of *T. abslouta* larvae free of plant leaf tunnel showed that the efficiency of the extract of four extraction methods of Jojoba seeds active ingredients was low compared with the larvae bioassay within the plant tunnel (Table 2, 3). Additionally, four extraction methods of jojoba seeds also caused a mortality percentage among *T. absoluta* 2nd instar larvae (Table 3), in which the initial kill was also low, in spite of, that the residual activity of the isolates were somewhat high (Table 3). Data showed that toxicity of extracted active ingredients of jojoba seeds was differed in

Table 3: Toxicity of four extracting methods of Jojoba extracts tested against *Tuta absoluta* without tomato leaf after topical application

	Mortality percentage based on days after treatment (Average±SD)				Residual effects	Total activity
Treatment and concentrations	1	3	5	7	(Average±SD)	(Average±SD)
Simmondsin extract by ammonium hydrogen peroxide (AW)						
25%	18.33±1.66^{def*}	33.33±3.33^{def}	40.00±2.89^{cd}	46.66±3.33^{gh}	39.99±3.18	29.16±2.42
50%	21.66±1.66^{de}	43.33±4.41^{d}	46.66±3.33^{c}	50.00±2.89^{fgh}	46.65±3.54	34.15±2.60
75%	26.66±3.33^{cd}	50.00±5.78^{cd}	68.33±8.34^{ab}	73.33±3.33^{bcde}	63.88±5.81	45.27±9.14
100%	36.66±3.33^{bc}	66.66±1.66^{b}	75.00±2.89^{a}	76.66±3.33^{bcd}	72.77±2.62	54.71±2.97
Average	25.82±2.49	48.33±3.79	57.49±4.36	61.66±3.22	55.82±3.79	40.82±3.14
Simmondsin extract by isopropanol						
25%	8.33±4.41f^{g}	26.66±6.67^{efg}	33.33±3.33^{cd}	40.00±2.89^{h}	33.33±4.29	20.83±4.34
50%	13.33±3.33^{ef}	33.33±6.01^{def}	41.66±3.33^{cd}	53.33±3.33^{fgh}	42.76±4.22	28.04±3.77
75%	15.00±5.00^{ef}	46.66±6.67^{d}	53.33±8.82^{bc}	56.66±3.33^{efgh}	52.18±6.23	33.59±5.61
100%	36.66±3.33^{bc}	76.66±3.33^{ab}	73.33±3.33^{a}	75.00±2.89^{bcd}	74.96±3.18	55.70±3.75
Average	18.33±4.01	45.82±5.66	50.41±4.70	56.24±3.11	50.80±4.46	34.55±4.23
Simmondsin extract by acetone						
25%	13.33±3.33^{ef}	36.66±3.33^{def}	43.33±3.33^{cd}	65.00±10.41^{cdef}	48.30±5.67	30.81±4.48
50%	38.33±4.41^{b}	63.33±3.33^{bc}	63.33±3.33^{ab}	63.33±3.33^{defg}	63.33±3.33	51.00±3.86
75%	50.00±2.89^{a}	73.33±3.33^{ab}	76.66±3.33^{a}	81.66±4.41^{abc}	77.16±3.68	63.58±3.28
100%	53.33±3.33^{a}	83.33±3.33^{a}	83.33±3.33^{a}	96.66±1.66^{a}	87.73±2.73	70.51±3.01
Average	38.74±3.49	64.15±3.33	66.66±3.33	76.41±4.95	69.03±3.83	53.86±3.61
Simmondsin extract by water						
25%	11.66±4.41^{efg}	13.33±3.33^{gh}	23.33±3.33^{de}	55.00±12.13^{fgh}	30.53±6.23	21.06±5.31
50%	13.33±1.66^{ef}	23.33±8.82^{fg}	33.33±14.54^{cd}	73.33±3.33^{bcde}	43.30±8.87	28.30±5.26
75%	16.66±3.33^{def}	40.00±10.01^{de}	50.00±10.00^{bc}	86.66±8.82^{ab}	58.86±9.61	37.73±6.45
100%	26.66±3.33^{cd}	66.66±3.3^{b}	73.33±8.82^{a}	96.66±3.33^{a}	78.83±5.13	52.71±4.21
Average	17.07±3.18	35.83±6.36	44.98±9.17	77.91±6.90	52.86±7.47	34.93±5.32
Check treatment	2.88±2.89^{g}	3.33±1.66^{h}	6.66±1.66^{e}	10.00±00^{i}		
LSD (p = 0.05)	9.65	14.78	17.84	15.80		
df	16.34	16.34	16.34	16.34		
F	19.31	20.01	12.06	15.80		
p	0.000	0.000	0.000	0.000		

*Means±SE followed by the same capital letter in columns and the same lower letter in rows do not differ significantly at p<0.05 (Tukey's test)

terms of the initial kill, days after treatment, residual activity and total activity (Table 3). From Table 3, it could be noticed that all extraction methods of Jojoba seeds had a toxicological impact as botanical insecticides on the 2nd instar larvae *T. absoluta* at the four concentrations used. Additionally, it can be concluded that the mortality percentage varied based upon the extraction method and the concentration used.

Concentrations of the extraction method varied significantly in causing the mortality percentage among *T. abslouta* population at 5% (Table 3). Notably, the significant differences between the two treatment days were observed when $p \leq 0.0001$; F = 20.01 and df = 16 and 34 during the 3rd day and $p \leq 0.0001$; F = 12.06 and df = 16 and 34 in the 5th day of treatment (Table 3).

In the 7th day of treatment, the mortality percentage was increased slowly and slightly and the concentrations of the extraction method also varied significantly in respect of the mortality percentage among *T. abslouta* population (Table 3). Notably, the significant differences at 5% between the four treatments were observed which LSD was 15.80 and $p \leq 0.0001$; F = 15.80 and df = 16 and 34 (Table 3).

Finally, the Statistical analysis indicated that the average mortality percentage of investigated *T. abslouta* larvae varied significantly at 5% (Table 3) among treatments and concentrations used. Consequently, it could be concluded from the results that the simmondsin that was extracted by Water (W) is the most suitable ingredient to suppress *T. abslouta* larvae followed by the simmondsin that was extracted by acetone (AC) and then the simmondsin that was extracted by isopropanol (I), while the simmondsin that was extracted by ammonum hyderogen peroxide (AW) had the lowest toxicity effects against the larvae of this pest (Table 3).

DISCUSSION

Organic farming in Saudi Arabia represents a top priority in the governmental agricultural programs, with the aim of implementing the of Good Agricultural Practice (GAP) to provide high quality production that is free of chemical pesticides, maintain the environment clean and a natural balance relationship between organisms. Subsequently, large scale of both governmental and private sectors started to recognize the importance of maintaining of our environment clean as possible. The only way to achieve this goal is to return back to the organic agriculture. Accordingly, it is extremely important to find out effective alternatives to the synthetic chemical pesticide in insect pest control.

Recently in KSA, organic farming concept has been proliferated among the farmers due to the side effects of chemicals in agricultural production on the human health and environmental contamination. Consequently, the switching from traditional farming to organic farming has increased all over agricultural areas in KSA, towards the pursuit of sustainable food production and environmental conservation[20]. A better way to control the harmful insects in vegetable crops is performed through use of the botanical insecticides, which are natural products of plant origin. Some advantages of the botanical insecticides are the fast degradation mostly under conditions of high luminosity, temperature and humidity[20,21]. Due to their lower persistence in the environment, the impact of the botanical products as an insecticide on beneficial organisms, humans and the environment can be reduced to the lowest levels[20,21]. Botanicals have been in use for a long time for pest control. The compounds offer many environmental advantages.

Nevertheless, before insecticide application, even for those of natural origin, the safety margin on the non-target organisms, such as social insects (bees), should be known and be determined. Garlic extract, neem oil, andiroba oil, citronella oil, eucalyptus oil and rotenone are among the main botanical insecticides used by farmers for pest control[22,23].

Searching on and applying a novel insecticide, originated from natural and secure products that interrupt the physiological processes of a target pest, could be valuable alternatives in IPM approach[24]. For Example, The botanical products for pest control have number of advantages that make them desirable in modern agriculture. They are safe both for environment and for human health. The phytopesticide properties of many plants are known from the remote past. These properties are due to the natural chemical compounds-alkaloids, esters, glycosides etc. that are part of plant composition[25,26].

Globally, the production of tomato has been seriously affected by *T. absoluta* populations that have developed resistance to a wide range of chemical insecticides[27]. Reference reported that tomato leafminer is the single most destructive pest of tomato and other Solanaceae worldwide. Insect damage is caused by larval feeding[28,29]. Larva feed most on the leaf tissues by making tunnels, holes in tomato branches and its fruits. The natural plant extracts may play a key role as alternatives to synthetic pesticides, in *T. absoluata* control, due to the increasing concerns on health hazards, environmental pollution and negative effects on non-target organisms[30,31]. There are more than 2400 plant species belonging to 189 plant families, which are rich sources of bioactive organic compounds[32]. Species from over 60 plant families have been identified as possessing insecticidal[22,33]. Jojoba plants, *Simmondsia chinensis* L., are showing the highest insecticidal activity in the present study. Furthermore, the activity was higher in the hexane extract than in the ethanol extract. The insecticide activity of *S. chinensis* extracts has been reported for several agricultural insect pests. However, there is no thorough study on the effect of this plant on insect pests of agricultural crops. The percentage of larval mortality of *Spodoptera littoralis* had increased by increase of concentration and tested compound[34]. They also indicated that the jojoba oil caused about 73% mortality among *S. littoralis* larvae as botanical insecticides.

Results showed a significant difference (at 5%) in infestation percentages of *T. absoluta* and *H. armigera* as affected by the different control treatments under field conditions. The differences can be attributed to different modes of action of the products and the number of sprays. The results show good efficacy of bio-insecticides against *T. absoluta*, *H. armigera* and *Lutzomyia longipalpis*. On the other hand, prevention of ecdysis and subsequently death, could be attributed to the reduction in ecdysteroid peak or interference with the release of eclosion hormone[35]. For jojoba only, entomologists suggested a possible action of the vegetable oils that penetrate the integument of the insect to affect presumably the nervous or respiratory system to exert the lethal effect[36]. In addition, the present work may provide another factor and possibility to explain the lethal action of jojoba extraction, particularly the increasing dose-level and increasing mortality percentage. Such adverse process resulted in a degree of desiccation and subsequently impaired some vital physiological events leading to death of pupae, in particular.

CONCLUSION

The present study indicated that all extracts of jojoba or *Simmondsia chinensis* were effective in controlling *Tuta abslouata*. *S. chinensis* has an insecticidal mode of actions and had responsible for the reduction of the *T. absoluata* population. The application of these botanical extracts as insecticides at 100% concentration increased the insect mortality followed by 75, 50 and 25% during the study period, respectively. Additionally, Simmondons that extracts by acetone and water had insecticidal effects more than two other extraction methods. It is recommended that other indigenous plant materials should be evaluated in order to get more alternative indigenous materials for *T. absoluata* control in the study area.

SIGNIFICANCE STATEMENT

The importance of this study is due to the fact that it is the first study in which use the simmondsin extracts as a tool to control *T. absoluta*, which consider the most important insect pests in the present time. This botanical extract is harmless to the environment and non-target organisms and can be implemented into integrated control programs to increase its effectiveness.

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REFERENCES

1. Desneux, N., E. Wajnberg, K.A.G. Wyckhuys, G. Burgio and S. Arpaia *et al*., 2010. Biological invasion of European tomato crops by *Tuta absoluta*: Ecology, geographic expansion and prospects for biological control. J. Pest Sci., 83: 197-215.
2. CABI., 2017. *Tuta absoluta* (tomato leafminer). http://www.cabi.org/isc/datasheet/49260.
3. Desneux, N., M.G. Luna, T. Guillemaud and A. Urbaneja, 2011. The invasive South American tomato pinworm, *Tuta absoluta*, continues to spread in Afro-Eurasia and beyond: The new threat to tomato world production. J. Pest Sci., 84: 403-408.
4. Pereyra, P.C. and N.E. Sanchez, 2006. Effect of two solanaceous plants on developmental and population parameters of the tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Neotrop. Entomol., 35: 671-676.
5. Megido, R.C., Y. Brostaux, E. Haubruge and F.J. Verheggen, 2013. Propensity of the tomato leafminer, *Tuta absoluta* (Lepidoptera: Gelechiidae), to develop on four potato plant varieties. Am. J. Potato Res., 90: 255-260.
6. Megido, R.C., E. Haubruge and F.J. Verheggen, 2012. First evidence of deuterotokous parthenogenesis in the tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). J. Pest Sci., 85: 409-412.
7. Guedes, R.N.C. and M.C. Picanco, 2012. The tomato borer *Tuta absoluta* in South America: Pest status, management and insecticide resistance. EPPO Bull., 42: 211-216.
8. Gontijo, P.C., M.C. Picanco, E.J.G. Pereira, J.C. Martins, M. Chediak and R.N.C. Guedes, 2013. Spatial and temporal variation in the control failure likelihood of the tomato leaf miner, *Tuta absoluta*. Ann. Applied Biol., 162: 50-59.
9. Duarte, L., M. Angeles and V.H.P. Bueno, 2015. Biology and population parameters of *Tuta absoluta* (Meyrick) under laboratory conditions. Rev. Proteccion Veg., 30: 19-29.
10. Gebremariamd, G., 2015. *Tuta absoluta*: A global looming challenge in tomato production, review paper. J. Biol. Agric. Healthcare, 5: 57-62.
11. Cantrell, C.L., F.E. Dayan and S.O. Duke, 2012. Natural products as sources for new pesticides. J. Nat. Prod., 75: 1231-1242.
12. De Brito, E.F., E.L.L. Baldin, R.D.C.M. Silva, L.D.P. Ribeiro and J.D. Vendramim, 2015. Bioactivity of piper extracts on *Tuta absoluta* (Lepidoptera: Gelechiidae) in tomato. Pesq. Agropec. Bras., 50: 196-202.
13. Campos, M.R., A.R.S. Rodrigues, W.M. Silva, T.B.M. Silva, V.R.F. Silva, R.N.C. Guedes and H.A.A. Siqueira, 2014. Spinosad and the tomato borer *Tuta absoluta*: A bioinsecticide, an invasive pest threat, and high insecticide resistance. PloS One, Vol. 9. 10.1371/journal.pone.0103235.
14. Mordue, A., 2004. Present Concepts of the Mode of Action of Azadiractin from Neem. In: Neem: Today and in the New Millennium, Opender, K.W. (Ed.). Kluwer Academic Publishers, Dordrecht.
15. Regnault-Roger, C. and B.J.R. Philogene, 2008. Past and current prospects for the use of botanicals and plant allelochemicals in integrated pest management. Pharm. Biol., 46: 41-52.
16. Morgan, E.D., 2004. The Place of Neem Among Modern Natural Pesticides. In: Neem: Today and in the New Millennium, Koul, O. and S. Wahab (Eds.). Kluwer Academic, Dordrecht, pp: 21-32.
17. El-Wakeil, N.E., 2013. Botanical pesticides and their mode of action. Gesunde Pflanzen, 65: 125-149.
18. Costat Software, 2004. Microcomputer Program Analysis. Version 4.20, CoHort Software, Berkeley, CA.
19. Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol., 18: 265-267.
20. Hartmann, M., S. Khalil, T. Bernet, F. Ruhland and A. Al Ghamdi, 2012. Organic agriculture in Saudi Arabia. https://www.giz.de/en/downloads/giz2012-organic-agriculture-saudi-arabia-en.pdf.
21. Terzidis, A.N., S. Wilcockson and C. Leifert, 2014. The tomato leaf miner (*Tuta absoluta*): Conventional pest problem, organic management solutions? Organic Agric., 4: 43-61.
22. Philogene, B.J.R. and C. Vincent, 2005. Botanicals: Yesterday's and Today's Promises. In: Biopesticides of Plant Origin, Regnault-Roger, C., B.J.R. Philogene and C. Vincent (Eds.). Lavoisier Publishing, Paris, pp: 1-15.

23. Labinas, A.M. and W.B. Crocomo, 2002. Effect of Java grass (*Cymbopogon winterianus* Jowitt) essential oil on fall armyworm *Spodoptera frugiperda* (JE Smith, 1797) (Lepidoptera, Noctuidae). Maringa, 24: 1401-1405.
24. Mwanauta, R.W., K.M. Mtei and P.A. Ndakidemi, 2015. Potential of controlling common bean insect pests (Bean Stem Maggot (*Ophiomyia phaseoli*), ootheca (*Ootheca bennigseni*) and aphids (*Aphis fabae*) using agronomic, biological and botanical practices in field. Agric. Sci., 6: 489-497.
25. Balzan, M.V. and A.C. Moonen, 2012. Management strategies for the control of *Tuta absoluta* (Lepidoptera: Gelechiidae) damage in open field cultivations of processing tomato in Tuscany (Italy). EPPO Bull., 42: 217-225.
26. Mateeva, A., 2000. Alternative plant protection means. Zemedelie Plus, pp: 11-12.
27. EPPO., 2005. *Tuta absoluta*. EPPO Bull., 35: 434-435.
28. Sharma, A., P. Kaushal, K.C. Sharma and R. Kumar, 2006. Bioefficacy of some plant products against diamond back moth *Plutella xylostella* L. (Lepidoptera: Yponomeutidae). J. Entomol. Res., 30: 213-217.
29. Souguir, S., I. Chaieb, Z.B. Cheikh and A. Laarif, 2013. Insecticidal activities of essential oils from some cultivated aromatic plants against *Spodoptera littoralis* (Boisd). J. Plant Protect. Res., 53: 388-391.
30. Cloyd, R., 2004. Natural indeed: Are natural insecticides safer and better than conventional insecticides? Illinois Pesticide Rev., 17: 1-7.
31. Rao, N.V., T.U. Maheswari and K. Manjula, 2005. Review on Botanical Pesticides as Tools of Pest Management. Narosa Publishing House Pvt. Ltd., USA., pp: 1-16.
32. Hatem, A.E., H.B. Homam, R.A. Amer, S.A. Samad, H.A. Saleh and A.I. Hussien, 2009. Synergistic activity of several acids in binary mixtures with synthetic insecticides on *Spodoptera littoralis* (Boisduval). Bol. San. Veg. Plagas, 35: 533-542.
33. Gaaboub, I., S. Halawa and A. Rabiha, 2012. Toxicity and biological effects of some insecticides, IGRs and Jojoba oil on cotton leafworm *Spodoptera littoralis* (Boisd.). J. Applied Sci. Res., 8: 5161-5168.
34. Sieber, K.P. and H. Rembold, 1983. The effects of azadirachtin on the endocrine control of moulting in *Locusta migratoria*. J. Insect Physiol., 29: 523-527.
35. Singh, D. and S.S. Bhathal, 1994. Role of insect growth regulators in integrated pest management. J. Insect Sci., 7: 1-9.
36. Marei, S.S., E.M. Amr and N.Y. Salem, 2009. Effect of some plant oils on biological, physiological and biochemical aspects of *Spodoptera littoralis* (Boisd). Res. J. Agric. Biol. Sci., 5: 103-107.