EFFECTS OF SOME PLANT EXTRACTS ON *TUTA ABSOLUTA* (MEYRICK, 1917) (LEPIDOPTERA: GELECHIIDAE) UNDER LABORATORY CONDITIONS

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ABSTRACT

Tomato is one of the most important vegetables grown in Turkey. Tomato leaf-miner, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) has caused serious losses in tomato production since 2009. This pest can feed on all green parts of tomato plants and can cause crop losses up to 100%, if not controlled. Growers use insecticides two times a week in order to control the pest. Intensive use of pesticides causes environmental pollution and threatens human health. In order to prevent such harmful effects of pesticides, alternative chemicals gain importance.

In this study, Gamma-T-Ol, Fungatol, Fungatol+Neem Spray (50.0-001) and Fungatol+Neem Spray (50.0-002) plant extracts were tested against third or fourth stages of Tomato leaf-miner using the dipping method. Assessments were done according to live individual counts at the 1, 24, 48 and 72 HAA. Fungatol+Neem Spray (50.0-001) was found to be the most effective extract while Fungatol was moderately effective at the 72 HAA.

KEYWORDS:
Plant extract, tomato, tomato leaf-miner, *Tuta absoluta*

1. INTRODUCTION

Tomatoes (*Solanumlycopersicum* L.) (Solanaceae), one of the major agricultural products in terms of both production and export volume, for the first time in Turkey, were started to be grown in Adana. Consumption of tomatoes is quite common because it is cheap and has high nutritional value. Turkey is ranked as the fourth after China, USA and India, with regards to the amount of tomato production [1]. The amount of tomatoes produced in Turkey in 2013 amounted to about 11.8 million tons [2]. Also, tomato exports of Turkey are approximately 400 million US$, which is 57% of total vegetable exports [3].

The main pest on tomato is the tomato leaf-miner *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) originating from South America [4]. This pest entered Europe from the east part of Spain, in the end of 2006 [5], and spread to other Mediterranean and European countries [6].

This pest that begun to be seen in Turkey since 2009 [7, 8] causes significant economic losses in product quality and quantity, after it was spread rapidly in tomato fields, in the recent years.

T. absoluta lays eggs on leaves by 73%, on veins and stems by 21%, on sepals by 5%, and on fruits by 1% [9]. Larvae of this pest have the high potential for harm in tomato fields, and do not enter diapause as long as sufficient food is available, and the pest can give 10-12 generations per year under appropriate climatic conditions [10].The pest can over-winter as eggs, pupae and adults. This olygophagous pest cannot only feed on tomatoes, but also other crops and weeds from Solanaceae family [10, 11], and larvae of this pest feed on leaves, shoots, stems, flowers and fruits of tomatoes, but only on leaves and stems or tubers of other hosts [12]. Larvae of this pest build transparent galleries between the lower and upper epidermises in tomato leaves by feeding on mesophyll tissues, and then, the transparent gaps necrotic change to brown. It is suggested that this pest destroyed the market value of tomatoes largely, and can even cause crop losses up to 100%, if not controlled [10, 13]. In addition to this, it is reported that the pest can cause economic losses in the rate of 1-5%, even when applying specific control against it [13].

At the present time, the most effective method of pest control is usage of chemical substances. However, the excessive and unconscious usage of chemicals leads to environmental pollution and depredation. It is clearly known that many chemicals using for the pest control have adverse effects on non-target organisms in agro-ecosystem. Nevertheless, intensive usage of synthetic chemicals brings about residual problems on products and development of pest resistance [14]. It is pointed out that the pest has resistance against abamectin, cartap, methamidophos, permethrin and deltamethrin active ingredients [15-17]. Also, usage of the control methods that can be applied within the scope of integrated pest management, such as biological control, is not possible because of intensive chemical applications. There is an urgent need for the studies on alternative control methods for this pest, which has a high damage potential [18].

As an alternative control method to pests, performing the studies on the effect of plant extracts, which has low risk of pest resistance development, is important in the sense of environmental and human health as well as the national economy. The number of studies on effects of plant extracts on pests has been started to increase, recently [19-24]. Moreover, it is stated that the number of plants, extracts of which have an impact on pests, is approximately 2000 [19].

For the reasons aforementioned, the study claimed to find out the effect of Gamma-T-Ol, Fungatol, Fungatol+Neem Spray (50.0-001) and Fungatol+Neem Spray (50.0-002) on larvae of *T. absoluta*. Hereby, increasing the use of plant extracts, which has low risk of pest resistance development, will contribute to the reduction of negative effects on environmental and human health, and as a result of this, a more economical agricultural production will be carried out.

2. MATERIALS AND METHODS

The main material of the study consisted of tomato plant (*Solanumlycopersicum* L.) (Solanaceae), the third and fourth instar larvae of *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae), Gamma-T-Ol, Fungatol, Fungatol+Neem Sprey (50.0-001), and Fungatol+Neem Sprey (50.0-002) plant extracts.

The third and fourth instar larvae of *Tuta absoluta* used in the experiment were provided from the stock insect culture generated under controlled climate room conditions at 26±1 ºC, relative humidity 60±5%, and a photo-period of 16:8 h, from larvae of *T. absoluta* collected in tomato greenhouses in Antalya. Five different concentrations of the extracts were used in the experiment, including 0.25, 0.50, 0.75, 1.00 and 1.25% in proportions. Also, distilled water was used as a control to compare with the different concentrations of the extracts. All concentrations of the extracts were applied by the dipping method. For this purpose, 5 larvae placed into a small piece of net, were submerged in the solution of plant extract for 5 seconds. After applications, larvae with two small tomato leaves were transferred into petri dishes (5 cm diameter x 8 cm height, at the base of which blotting paper was located, and the petri dishes in plastic trays were kept in a climate chamber set to 26 ºC, relative humidity of 60%, and a photo-period of 16:8 h. Assessments were done according to live individual counts at the 1, 24, 48 and 72 HAA (Hours After Application).

The experiment was arranged in a completely randomized pot design with 10 replicates for each concentration of plant extracts. Also, the percentage effects of different concentrations of plant extracts were calculated by Abbott's formula [25, 26]. The percentage values were then transformed into $\sqrt{x+5}$ values, according to Bartlett's Homogeneity Variance Test of statistical analysis. Afterwards, transformed values were submitted to One-Way ANOVA, and then, means were separated by Tukey's test (P = 0.05), using statistical software SPSS® (Version 15.00, November 2006, SPSS Inc., Chicago, IL, USA.). The means given in the tables were transformed values of percentage data calculated by Abbott's formula.

3. RESULTS

The study investigated the effects of Gamma-T-Ol, Fungatol, Fungatol+Neem Spray (50.0-001) and Fungatol+NeemSpray (50.0-002) plant extracts at 5 different concentrations on *Tuta absoluta* under laboratory conditions. The results of the study were examined separately for each plant extract. The study, in which the effect of the time was also assessed as well as the effect of different concentrations, demonstrated that the activities of plant extracts increased depending on time (Tables 1-4).

The highest effect of Gamma-T-Ol on larvae of *T. absoluta* at the 1 HAA was determined at 0.25% concentration. Effects of 1.00 and 1.25% concentrations were in the same statistical group. The control was included in the different statistical groups from these concentrations. The extract concentrations of 0.50 and 0.75% were involved in the same statistical group with the control. Also Gamma-T-Ol extract reached the highest effect at the concentration of 0.75% after 72 h of applications (Table 1).

TABLE 1 – Effects of Gamma-T-Ol on larvae of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) at the 1, 24, 48 and 72 HAA*

Concentrations	1 HAA	24 HAA	48 HAA	72 HAA
0.25%	0.28±0.03 cA	0.48±0.06 bcA	0.66±0.06 aAB	0.72±0.04 a AB
0.50%	0.06±0.03 cBC	0.38±0.06 bAB	0.58±0.06 a A	0.72±0.06 a AB
0.75%	0.08±0.03 cBC	0.56±0.04 bA	0.66±0.04 a AB	0.82±0.03 a A
1.00%	0.20±0.07 cAB	0.40±0.11 bAB	0.52±0.07 a AB	0.55±0.08 a B
1.25%	0.14±0.03 bAB	0.24±0.04 bB	0.50±0.03 a A	0.70±0.03 a AB
Control	0.00±0.00 bC	0.16±0.16 abC	0.20±0.15 ab B	0.24±0.14 a C

*Means (± standard error) in the same row followed by the same lowercase letter, and in the same column followed by the same uppercase letter do not differ significantly (p>0.05; n=10, total 50 larvae for each application), according to Tukey's test. The means given in the table are transformed values of percentage data calculated by Abbott's formula. All data were analyzed using SPSS® (Version 15.00, November 2006, SPSS Inc., Chicago, IL., USA).

The highest effect of Fungatol on larvae of *T. absoluta* at the 1 HAA was seen at 1.00% concentration. This concentration was followed by 0.25% concentration of the extract, and the difference between the concentrations of 0.25 and 1.00% was not statistically very significant. After these concentrations, the highest effect was shown by 0.50% concentration. The effect of this concentration at the 1 HAA was not found to be significantly different from the effect of 0.25% concentration. However, the concentration of 0.50% was statistically different from 1.00% concentration of Fungatol. The effects of the concentrations of 0.75 and 1.25% were in the different statistical groups from other concentrations of Fungatol and the control. When the highest effects at 24 and 48 HAA were obtained from 0.25% concentration of Fungatol, the highest effect at 72 HAA was seen at 1.00% concentration of the extract. The effects of all concentrations of Fungatol were located in the different statistical groups from the control at all assessments made after the application (Table 2).

At all assessments made after the application, the mixture of Fungatol+Neem Sprey (50.0-001) plant extracts showed the highest effects at 0.75 and 1.00% concentrations. The highest effect of the extract mixture after these concentrations is seen at the mixture concentration of 0.25%, followed by that of 0.50%. All concentrations of the extract mixture at all assessments made after the application were involved in a different statistical group from the control. The mixture concentrations of 0.75 and 1.00% were in the same statistical group, in all assessments made at the 1, 24, 48 and 72 HAA. All concentrations of the extract mixture, except 1.25%, took part in the same statistical group at the 72 HAA (Table 3).

The differences between the control and all concentrations of the mixture of Fungatol+Neem Sprey (50.0-002) plant extracts were found to be statistically significant at all assessments made after the application. The largest effect of the mixture at the 1 HAA was determined at 0.25% concentration, followed by 0.75% of the extract mixture. The difference between these concentrations was not highly statistically significant. The highest effect at the 24 and 48 HAA was seen at the concentration of 0.75%. However, the effect of this concentration was moderately significant compared to those of 0.25 and 0.50% concentrations of Fungatol+Neem Sprey (50.0-002). All concentrations of the extract mixture were in the same statistical group at the 72 HAA (Table 4).

The highest effects of plant extracts used in the experiment were obtained at the concentrations of 0.75 and 1.00% (Tables 1-4). Therefore, these concentrations of the extracts were thought to be useful to compare. Table 5 shows the efficacy of the extract concentration of 0.75% at the 1, 24, 48 and 72 HAA. Fungatol+Neem Sprey (50.0-001), among all extracts, was the most active one at 0.75% concentration. This extract was followed by Fungatol+ Neem Sprey (50.0-002). Gamma-T-Ol and Fungatol extracts being in the same statistical group at the 1 HAA.

TABLE 2 – Effects of Fungatol on larvae of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) at the 1, 24, 48 and 72 HAA*

Concentrations	1 HAA	24 HAA	48 HAA	72 HAA
0.25%	0.52±0.03 b AB	0.70±0.04 b A	0.87±0.04 a A	0.89±0.04 a AB
0.50%	0.40±0.06 c B	0.54±0.05 c A	0.78±0.03 b AB	0.92±0.03 a AB
0.75%	0.16±0.07 c C	0.35±0.11 b B	0.71±0.07 A B	0.70±0.09 a B
1.00%	0.61±0.07 b A	0.64±0.08 b A	0.77±0.04 b AB	0.95±0.03 a A
1.25%	0.14±0.04 c C	0.18±0.04 c Bc	0.38±0.06 b C	0.60±0.05 a C
Control	0.00±0.00 b D	0.08±0.04 a C	0.10±0.06 a D	0.10±0.06 a D

*Means (± standard error) in the same row, followed by the same lowercase letter, and in the same column followed by the same uppercase letter, do not differ significantly (p>0.05; n=10, total 50 larvae for each application), according to Tukey's test. The means given in the table are transformed values of percentage data calculated by Abbott's formula. All data were analyzed using SPSS® (Version 15.00, November 2006, SPSS Inc., Chicago, IL., USA).

TABLE 3 – Effects of Fungatol+Neem Sprey (50.0-001) on larvae of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) at the 1, 24, 48 and 72 HAA*

Concentrations	1 HAA	24 HAA	48 HAA	72 HAA
0.25%	0.61±0.03 c A	0.73±0.03 bc AB	0.81±0.03 b B	0.93±0.03 a A
0.50%	0.20±0.04 c B	0.58±0.07 b B	0.88±0.03 a B	0.90±0.03 a A
0.75%	0.64±0.04 c A	0.84±0.04 b A	1.00±0.00 a A	1.00±0.00 a A
1.00%	0.70±0.06 c A	0.80±0.07 bc A	0.92±0.04 ab AB	0.96±0.02 a A
1.25%	0.20±0.04 c B	0.32±0.05 bc C	0.44±0.05 ab C	0.62±0.06 a B
Control	0.00±0.00 a C	0.04±0.03 a D	0.04±0.04 a D	0.04±0.04 a C

*Means (± standard error) in the same row, followed by the same lowercase letter, and in the same column followed by the same uppercase letter, do not differ significantly (p>0.05; n=10, total 50 larvae for each application), according to Tukey's test. The means given in the table are transformed values of percentage data calculated by Abbott's formula. All data were analyzed using SPSS® (Version 15.00, November 2006, SPSS Inc., Chicago, IL., USA).

TABLE 4 – Effects of Fungatol+Neem Sprey (50.0-002) on larvae of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) at the 1, 24, 48 and 72 HAA*

Concentrations	1 HAA	24 HAA	48 HAA	72 HAA
0.25%	0.37±0.07 c A	0.46±0.07 bc AB	0.60±0.07 ab AB	0.73±0.07 a A
0.50%	0.18±0.05 c BC	0.38±0.06 b AB	0.58±0.06 a AB	0.70±0.07 a A
0.75%	0.34±0.07 b AB	0.58±0.08 a A	0.68±0.06 a A	0.76±0.05 a A
1.00%	0.13±0.04 c C	0.28±0.07 bc B	0.45±0.07 b B	0.75±0.06 a A
1.25%	0.14±0.04 c C	0.32±0.06 b B	0.42±0.06 ab B	0.62±0.04 a A
Control	0.00±0.00 a D	0.08±0.04 a C	0.08±0.04 a C	0.08±0.04 a B

*Means (± standard error) in the same row, followed by the same lowercase letter, and in the same column, followed by the same uppercase letter, do not differ significantly (p>0.05; n=10, total 50 larvae for each application), according to Tukey's test. The means given in the table are transformed values of percentage data calculated by Abbott's formula. All data were analyzed using SPSS® (Version 15.00, November 2006, SPSS Inc., Chicago, IL., USA).

TABLE 5 – Effects of plant extracts used at a concentration of 0.75% in the experiment on larvae of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) at the 1, 24, 48 and 72 HAA*.

Plant extracts	1 HAA	24 HAA	48 HAA	72 HAA
Gamma-T-Ol	0.08±0.03 C	0.56±0.04 B	0.66±0.04 B	0.82±0.03 B
Fungatol	0.16±0.07 C	0.35±0.11 C	0.71±0.07 B	0.70±0.09 B
Fungatol+NeemSprey (50.0-001)	0.64±0.04 A	0.84±0.04 A	1.00±0.00 A	1.00±0.00 A
Fungatol+NeemSprey (50.0-002)	0.34±0.07 B	0.58±0.08 B	0.68±0.06 B	0.76±0.05 B

*Means (± standard error) in the same column, followed by the same letter, do not differ significantly (p>0.05; n=10, total 50 larvae for each application), according to Tukey's test. The means given in the table are transformed values of percentage data calculated by Abbott's formula. All data were analyzed using SPSS® (Version 15.00, November 2006, SPSS Inc., Chicago, IL., USA).

TABLE 6 – Effects of plant extracts used at a concentration of 1.00% in thee xperiment on larvae of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) at the 1, 24, 48 and 72 HAA*.

Plant extracts	1 HAA	24 HAA	48 HAA	72 HAA
Gamma-T-Ol	0.20±0.07 B	0.40±0.11 C	0.52±0.07 C	0.55±0.08 C
Fungatol	0.61±0.07 A	0.64±0.08 B	0.77±0.04 B	0.95±0.03 A
Fungatol+NeemSprey (50.0-001)	0.70±0.06 A	0.80±0.07 A	0.92±0.04 A	0.96±0.02 A
Fungatol+NeemSprey (50.0-002)	0.13±0.04 B	0.28±0.07 C	0.45±0.07 C	0.75±0.06 B

*Means (± standard error) in the same column, followed by the same letter, do not differ significantly (p>0.05; n=10, total 50 larvae for each application), according to Tukey's test. The means given in the table are transformed values of percentage data calculated by Abbott's formula. All data were analyzed using SPSS® (Version 15.00, November 2006, SPSS Inc., Chicago, IL., USA).

Fungatol+Neem Sprey (50.0-001) was followed by Gamma-T-Ol and Fungatol+Neem Sprey (50.0-002) at the 24 HAA. Gamma-T-Ol and Fungatol+Neem Sprey (50.0-002) were involved in the same statistical group at the 24 HAA. The differences between Gamma-T-Ol, Fungatol and Fungatol+Neem Sprey (50.0-002) were not found to be statistically significant while Fungatol+Neem Sprey (50.0-001), which was seen as the most effective extract at all assessments made after the application, was in a separate statistical group (Table 5).

The efficacies of the extract concentration of 1.00% at the 1, 24, 48 and 72 HAA are seen in Table 6. Fungatol and Fungatol+Neem Sprey (50.0-001) took part in the different statistical groups from Gamma-T-Ol and Fungatol+Neem Sprey at the 1 HAA. Fungatol+Neem Sprey (50.0-001) was the most effective extract in assessments made at the 24 and 48 HAA, and the extract was followed by Fungatol. Also, Fungatol and Fungatol+Neem Sprey (50.0-001) were located in the same statistical group at the 72 HAA. Fungatol+Neem Sprey (50.0-002) followed these extracts, and is involved in a different statistical group (Table 6).

4. DISCUSSION

The study investigated the efficacies of 0.25, 0.50, 0.75, 1.00 and 1.25% concentrations of Gamma-T-Ol, Fungatol, Fungatol+Neem Spray (50.0-001) and Fungatol+Neem Spray (50.0-002) plant extracts on larvae of *Tutaabsoluta*under laboratory conditions. The results of the study indicated that the efficacies of plant extracts increased depending on the time.

A study by Iramu (2012) [23] reported that Fungatol, Gamma-T-Ol, Fungatol+Neem and Gamma-T-Ol+Neem extracts were highly effective on *Aphis gossypii*. In the same study, it is noticed that LC_{50} values of Fungatol+Neem and Gamma-T-Ol+Neem were, respectively, 2.78 and 0.76%, if applied by the dipping method, and also LC_{50} values of Fungatol, Gamma-T-Ol, Fungatol+Neem and Gamma-T-Ol+Neem, when applied by the spraying method, were 0.37, 0.27, 0.18 and 0.52% under laboratory conditions, and 0.17, 0.18, 0.45 and 0.75% in greenhouse conditions. In addition to this, it is reported that these extracts have different impact mechanisms on *A. gossypii* and low effects on the parasitoid of *A. gossypii* (Hymenoptera: Aphidiinae). For these reasons, the use of these extracts against *A. gossypii* as part of integrated pest management was reported to be appropriate.

Durmuşoğlu*et al.* (2011) [22] investigated the effect of Anonin, Azadirachtin, Karanjin and their mixtures on larvae of *T. absoluta*. The results of this study demonstrated that Anonin, Azadirachtin and their mixtures can be a good alternative to currently used chemicals against this pest in greenhouse and field conditions. The study on the impacts of neem oil on *T. absoluta*, as an alternative to synthetic chemicals was conducted by Coelho Junior and Deschamps (2014) [27], they noticed that neem oil has anti-feedant and insecticidal effects on *T. absoluta*. Şenel (2013) [24] examined the effects of different concentrations of ethanol and hexane extracts of *Laurusnobilis* L. and *Rosmarinus officinalis* L. on different biological stages of *T. absoluta*. The study showed that extracts of both plants affect egg-laying behaviour of the pest at rates up to 100%, and besides, it was expressed in the study that efficacies of plant extracts also increased up to 100% with rising concentration at the applications made in both egg and larvae stages of the pest. The study of Gonçalves-Gervásio and Vendramim (2004) [20] stated that water and chloroform extracts of leaves of *Trichilia pallida* have a trans-laminar effect on *T. absoluta* and affected the development of the pest.

The results of statistical analyses of the present study demonstrated that the highest effects of plant extracts used in the experiment were seen at 0.75 and 1.00% concentrations. Fungatol+Neem Spray (50.0-001), among all extracts, was the most active extract in all assessments made at the 1, 24, 48 and 72 HAA at 0.75% level. This extract was followed by Fungatol+Neem Spray (50.0-002) at the 1 HAA while Fungatol+NeemSprey (50.0-001) became the most effective extract at the 24 HAA as well as Gamma-T-Ol and Fungatol+Neem Spray (50.0-002) following this extract.

Considering the effects of extracts at 1.00% concentrations at the 1 HAA, Fungatol and Fungatol+Neem Spray (50.0-001) were the most effective extracts, followed by Gamma-T-OlveFungatol+Neem Spray (50.0-002). In the assessments made at the 24 and 48 HAA, the most active extract was Fungatol+Neem Spray (50.0-001). Effects of Fungatol and Fungatol+Neem Spray (50.0-001) were similar at the 72 HAA. These two extracts were followed by Fungatol+Neem Spray (50.0-002).

Consequently, the study demonstrated that the highest effects of plant extracts on larvae of *T. absoluta* were at the concentrations of 0.75 and 1.00%, and it is also seen that Fungatol has a moderately impact on larvae of *T. absoluta*at the 72 HAA. In addition, Fungatol+Neem Spray (50.0-001) in these plant extracts was determined to be the most effective one. As a result of this study, it is concluded that effects of these plant extracts on *T. absoluta* should be investigated in greenhouse conditions and large areas.

In case of the application of chemical control against the concerned pest, the use of plant-originating extracts with a low risk of pest resistance development will contribute to a more economical agricultural production, as well as the reduction of negative effects on environmental and human health.

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