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Chemical composition and insecticidal activity of *Glycyrrhiza glabra L.*, root extract against *Bactrocera zonata* (Saunders, 1841) (Diptera: Tephritidae)

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Abstract

All horticulture fruits and some vegetables in Egypt are infested by the damaging polyphagous insect known as the peach fruit fly, *Bactrocera zonata* (Saunders, 1841). This study attends to design an alternative way to control *B. zonata* using licorice, *Glycyrrhiza glabra* L., roots aqueous extract (LRAE). The insecticidal activity of three different concentrations of *G. glabra* roots (20000, 25000, and 30000 ppm) were evaluated against *B. zonata* flies under laboratory conditions. Furthermore, we use Gas Chromatography/Mass Spectrometry analysis (GC/MS) to analyze and identify secondary metabolites of the methanolic root extract of *G. glabra*. The results showed that the *B. zonata* fly population reduced by 93.33% after 72 h of treatment with the highest concentration of 30000 ppm of LRAE. Based on toxicity values, three days (72 h) was the most potent against *B. zonata* flies with LC50 (1970.37 ppm) and LC90 (21996.93 ppm). The insecticidal effect of the (LRAE) was concentration and time-dependent. The GC/MS analysis of the extract revealed the presence of 42 different types of secondary metabolites with various potential bioactive compounds beneficial for insecticidal purposes. The major bioactive compounds identified were Benzaldehyde-4-(1-methylethyl)-, Triacetin (Glycerol triacetate), phenol-2, 4-bis (1, 1-dimethylethyl), and some essential fatty acids and their esters. This study identified bioactive phytochemicals from the roots of *G. glabra* and shed light on its potential utilization as insecticides that contribute to designing alternative ways as part of integrated pest management plans for controlling *B. zonata*.

Keywords: *Bactrocera zonata,* botanical insecticides, insecticidal activity, GC-MS analysis

Introduction

Licorice, *Glycyrrhiza glabra* (Linnaeus, 1753), is an important plant belonging to the family Leguminosae, which grows in Egypt and other countries of the world (Mediterranean, Africa, and some areas of Asia) (Shah *et al*. 2018) [30]. Glycyrrhiza is derived from the ancient Greek term glykos meaning sweet, and rhiza, meaning root (Chopra *et al* 2002) [9]. The Glycyrrhiza genus is widely distributed worldwide and consists of more than 30 species. Triterpenoid saponins such as glycyrrhizin, glycyrrhetinic acid, and liquirtic acid were found in *G. glabra* root extract after a phytochemical investigation (Seki *et al* 2011 and Shah *et al*. 2018) [29, 30], flavonoids (liquirtin, isoflavonoids, and formononetin) and other constituents such as coumarins, sugars, fatty acids, amino acids, tannins, starch and phytosterols (Fukai *et al*., 1998 and Dirican and Turkez, 2014) [12, 17]. Its root extracts not only possess medicinal benefits but also, have insecticidal activities (Pavela, 2016 and Soliman and Genaidy, 2021) [14, 24, 33].

The destructive, polyphagous peach fruit fly, *Bactrocera zonata* Saunders, 1842 (Diptera: Tephritidae), is one of the most important insect pests that cause economic loss by induction severe damage to over 50 species of fruit crops and some vegetables (Allwood *et al*. 1999 and Shehata *et al*., 2008) [4, 31]. In Egypt, it has been established since the late 1990 and the favorable host fruits are peach, guava, mango, and apricot (Awad *et al*., 2014) [6]. Application of synthetic insecticides is not preferred due to its-related dangerous residues in fruit and negative environmental effects. It has become imperative to develop a technique that can keep the *B. zonata* population below the critical economic barrier. Researchers studying insect pest control are now interested in the insecticidal properties of plant extracts alone or combined with appropriate additives since they are more affordable, biodegradable, and practical than other pest control treatments (Campos *et al*. 2019) [8]. In the IPM of fruit fly populations, plant extracts may offer a more environmentally friendly alternative to synthetic insecticides. This study's primary goal was to assess the insecticidal activity of licorice roots aqueous extract (LRAE) against *B. zonata* under laboratory conditions and also, determine and identification of secondary metabolites of the methanolic extract of *G. glabra* roots by Gas Chromatography/Mass Spectrometry analysis (GC/MS).

Materials and methods

1. Culture of insects

In this experiment, *B. zonata* flies were reared at the Plant Protection Research Institute in Giza, Egypt. The cages for rearing adult flies (80 cm, 50 cm, and 40 cm) were maintained in a controlled environment at 27 °C, 70 % RH, and 12:12 L:D photoperiod. In addition to providing the flies with a water source, the enzymatic protein hydrolysate and sugar were administered to them in a ratio of 1:3.

2. Plant material

Glycyrrhiza glabra roots were purchased from a local market in Cairo, Egypt. The plant was identified and authenticated by Botany Department Herbarium, Faculty of Science, Cairo University.

2.1 Extraction of *licorice* roots for bioassay preparation
Under laboratory conditions, the licorice roots aqueous extract (LRAE) was prepared according to Siam and El-Genaidy's (2021) [32], with a few modifications. The original concentration of LRAE was 100000 ppm (100 g root powder/liter). A series of dilutions were done to obtain 20000, 25000, and 30000 ppm. The three concentrations were tested for their toxicity against *B. zonata* flies.

2.2 Preparation of, *G. glabra* roots extract for GC-MS analysis
Roots of licorice were cleaned by washing with water and the dried plant material was grinded and milled with a Retsch-Mühle (type SM 100; cartridge size 1) to obtain coarse powder after drying in the shade for three days, then sieved to collect the fine powder. The powdered roots were extracted with methanol (50 g/ 250 ml methanol) for 24 h. The filter paper was used to purify the extract (Whattman No.1). The filtrate was collected in a new sterile flask. The extract was subjected to a rotary evaporator to remove the solvent and the crude extract (Viscous residue) was stored in a refrigerator for further experiments. The viscous residue was dissolved in analytical-grade methanol for GC-MS analysis.

3. GC-MS analysis
The gas chromatography and mass spectrometry (GC-MS) analysis of the methanolic roots extract of *the G. glabra* plant was accomplished using a GC-MS (Acquisition Parameters, Inst (Perkin Elmer model: Clarus 580/560 S). The sample (1µl) was injected into the column (Elite-5 Capillary Column - 30 m x 0.25 mm I.D. x 0.25 µm) and separation was done using helium as a carrier gas at a constant column flow of 1.20 ml/min at 85.4 kpa inlet pressure and 280 °C temperature. The temperature was programmed to rise steadily by 5°C/minute from 50 °C to 280 °C. A 1:20 split ratio was used to inject the sample. At 70 eV, mass spectra were captured with a 0.5-second scan interval.

3.1 Identification of *G. glabra* compounds
The National Institute of Standards and Technology's (NIST's) database, which has more than 62,000 patterns, and WILEY 8 were used to interpret the mass spectrum of the GC-MS. By using library reference spectra, the compounds were identified, and the mass spectra of unknown components were compared to the spectra of the known components kept in these libraries.

4. Effect of aqueous licorice root extract on peach fly (*B. zonata*)
The experiment was carried out by spraying the fruits of peach with the prepared three different concentrations (20000, 25000 and 30000ppm) of the aqueous extract of licorice root (LRAE). The previous concentrations were sprayed and exposed to *B. zonata* flies after the extract dried on the fruits in the cage prepared for the experiment. *B. zonata* (100 peach fly flies) was feeding on fruits spraying with each concentration of LRAE. Control test was carried out with water and experiment was replicated five times. The mortality data was observed and recorded after 24, 48 and 72 hours.

5. Statistical analysis
Three replicates of each treatment were used in the experiment, which was run three times. To analyze the data, SPSS version 16.0 was used (SPSS Inc., Chicago USA). Duncan's test was used to determine the significance of the difference between means at the 5 % level. Results were presented as mean standard error (mean ± SE).

Results
1. Phytochemical investigation of *G. glabra* roots
1.1 GC-MS analysis
Our results of the GC-MS profile from the methanolic root extract of *G. glabra* showed the presence of different Phyto-compounds in the methanolic root extract of *G. glabra* and categorized under different classes of compounds (Aldehydes, benzene derivatives, alcohols, and fatty acids and their ester) (Table 1). The GC-MS chromatogram of the methanolic extract of *G. glabra* roots revealed the presence of various compounds, belonging to different categories (Figure, 1). A total of 42 compounds were identified in the chromatogram and the major compounds identified were Phenol, 2, 4 bis (1, 1-dimethylethyl) - (20.79 %), Benzaldehyde, 4-(1-methylethyl) - (12.65 %), Triacetin (Glycerol triacetate) (10.74 %), 1, 2-Benzene dicarboxylic acid (1.20 %), fatty acids and their esters (21.47 %) and eleven benzene derivatives (12.86 %). Fatty acids and their esters have also been presented by GC-MS and 9 fatty acids are reported, Oleic acid, methyl ester (4.35 %), Octadecenoic acid-methyl ester (Methyl stearate) (3.68 %), Linolenic acid ethyl ester (1.345%), Stearic acid (3.652 %), Linoleic acid (1.853 %), Palmitic acid (2.36 %), Cis-Vaccenic acid (1.327 %), Eicosanoic acid (1.678 %) and Cis-13-Eicosenoic acid (1.211 %). Also, GC-MS analysis showed the presence of some benzene derivatives; like Benzene, (1-pentyloctyl) (2.263 %), Benzene, (1-butylnonyl) - (1.47 %), Benzene and (1-methyl undecyl) – (1.28 %). The list of the bioactive compounds obtained from the methanolic roots extract of G. glabra by GC-MS analysis is represented in Table (2).

Table 1: GC-MS analysis of the methanolic extract of *Glycyrrhiza glabra* root.

No.	RT	Compound Name	MW	Area (%)	MF
1	11.91	Benzaldehyde, 4-(1-methylethyl)- (Cumic aldehyde)	148	12.65	$C_{10}H_{12}O$
2	12.21	Propanal, 2-methyl-3-phenyl-	148	0.575	$C_{10}H_{12}O$
3	13.68	Triacetin Glycerol triacetate	218	10.74	$C_9H_{14}O_6$
4	16.05	4-Octadecenal	266	0.470	$C_{18}H_{34}O$
5	16.58	Phenol, 2,4-bis(1,1-dimethylethyl)-	206	20.79	C14H22O
6	16.71	Indan-1,3-diol monopropionate	206	0.619	$C_{12}H_{14}O_3$
7	16.84	Lilial (4-tert-Butyl-α-methyl-phenyl benzenepropanal)	204	2.434	$C_{14}H_{20}O$
8	17.06	2-Monolinolenin, 2TMS derivative	497	1.345	$C_{27}H_{52}O_4Si_2$
9	17.79	Tetratetracontane	619	0.975	C44H90
10	18.22	Benzene, (1-butylheptyl)-	232	0.486	$C_{17}H_{28}$

11	18.36	Benzene, (1-propyloctyl)-	232	0.495	$C_{17}H_{28}$
12	18.67	1-Penten-3-one, 1-(2,6,6-trimethyl-1-cyclohexen-1-yl)-	206	1.679	$C_{14}H_{22}O$
13	19.07	Eicosane, 2-methyl-	296	0.945	$C_{21}H_{44}$
14	19.12	Benzene, (1-methyldecyl)-	232	0.639	$C_{17}H_{28}$
15	19.39	Benzene, (1-pentylheptyl)-	246	1.066	$C_{18}H_{30}$
16	19.45	Benzene, (1-butyloctyl)-	246	0.957	$C_{18}H_{30}$
17	19.60	Benzene, (1-propylnonyl)-	246	0.958	$C_{18}H_{30}$
18	19.71	Octanal, 2-(phenylmethylene)- (α hexylcinnamaldehyde)	216	0.741	$C_{15}H_{20}O$
19	19.87	Benzene, (1-ethyldecyl)-	246	0.949	$C_{18}H_{30}$
20	20.24	8-Octadecenal	266	1.235	$C_{18}H_{34}O$
21	20.34	Benzene, (1-methylundecyl)-	246	1.279	$C_{18}H_{30}$
22	20.56	Benzene, (1-pentyloctyl)-	260	2.263	$C_{19}H_{32}$
23	20.64	Benzene, (1-butylnonyl)-	218	1.474	$C_{16}H_{26}$
24	20.82	Benzene, (1-propyldecyl)-	260	1.166	$C_{19}H_{32}$
25	21.16	Benzene, (1-ethylundecyl)-	246	1.133	$C_{18}H_{30}$
26	21.35	Stearylvinyl ether	296	1.342	$C_{20}H_{40}O$
27	21.57	Octadecane, 3-ethyl-5-(2-ethylbutyl)-	366	0.567	$C_{26}H_{54}$
28	21.76	Benzene, (1-methyldodecyl)-	260	3.651	$C_{19}H_{32}$
29	21.98	Palmitic acid (Hexadecanoic acid, methyl ester)	270	2.363	$C_{17}H_{34}O_2$
30	23.07	Eicosanoic acid	312	1.678	$C_{20}H_{40}O_2$
31	24.83	Oleic acid, methyl ester	296	4.355	$C_{19}H_{36}O_2$
32	24.91	Linoleic acid	280	1.853	$C_{18}H_{32}O_2$
33	25.27	Stearic acid	284	3.652	$C_{18}H_{36}O_2$
34	25.93	Octadecanoic acid, methyl ester (Methyl stearate)	296	3.684	$C_{19}H_{38}O_2$
35	26.49	Octadecanal,2-bromo-	347	1.234	$C_{18}H_{35}BrO$
36	26.64	Cis-Vaccenic acid	282	1.327	C18H34O2
37	27.97	Linolenic acid ethyl ester	306	1.345	C20H34O2
38	29.73	Cis-13-Eicosenoic acid	310	1.211	$C_{20}H_{38}O_2$
39	31.29	2-Hexadecanol	242	0.493	$C_{16}H_{34}O$
40	31.77	1,2-Benzenedicarboxylic acid,	390	1.200	$C_{24}H_{38}O_4$
41	34.27	Octadecane, 3-ethyl-5-(2-ethylbutyl)-	366	0.551	$C_{26}H_{54}$
42	35.71	2,4,6-Cycloheptatrien-1-one, 3,5-bis-trimethylsilyl-	250	0.532	$C_{13}H_{22}OSi_2$

RT= Retention time MW=Molecular weight MF= Molecular formula

Table 2: GC-MS analysis of bioactive compounds of *Glycyrrhiza glabra* roots.

NO.	Compound Name	MW	MF	Area (%)	Biological activity
1	Benzaldehyde, 4-(1-methylethyl)-	148	$C_{10}H_{12}O$	12.65	Insecticidal effect (Mahran, 2022 and Abdelaal *et al* 2021) [1]
2	Triacetin (Glycerol triacetate)	218	$C_9H_{14}O_6$	10.74	Insecticidal activity (Jeyasankar and Chinnamani 2017 and Akami, *et al* 2016) [2, 19]
3	Phenol, 2,4-bis(1,1-dimethylethyl)-	206	$C_{14}H_{22}O$	20.79	Insecticidal activity (Zhao, *et al* 2020) [37].
4	Lilial (4-tert-Butyl-α-methyl-phenyl benzenepropanal)	204	$C_{14}H_{20}O$	2.434	Repellent effect (Zeng, *et al* 2018) [36].
5	Palmitic acid (Hexadecanoic acid)	270	$C_{17}H_{34}O_2$	2.363	Insecticidal effect (Figueroa-Brito *et al*. 2002 and Pérez-Gutiérrez, *et al* 2011) [16, 25]
6	Linoleic acid	280	$C_{18}H_{32}O_2$	1.853	Insecticidal effect (Rahuman *et al*., 2008 and Ramos-López, *et al* 2012) [26, 27]
7	Oleic acid, methyl ester	296	$C_{19}H_{36}O_2$	4.355	Insecticidal activity (Kannathansan *et al*., 2008 and Farag, *et al* 2011) [15]
8	Stearic acid	284	$C_{18}H_{36}O_2$	3.652	Insecticidal effect (Figueroa-Brito *et al*. 2002, Pérez-Gutiérrez *et al* 2011 (Farag, *et al* 2011) [15, 16, 25]
9	Octadecanoic acid, methyl ester	296	$C_{19}H_{38}O_2$	3.684	Insecticidal activities (Farag, *et al* 2011) [15]
10	Cis-Vaccenic acid	282	$C_{18}H_{34}O_2$	1.327	Insecticidal compound (Farag, *et al* 2021)
11	Linolenic acid ethyl ester	306	$C_{20}H_{34}O_2$	1.345	Insecticidal activity (Kannathansan *et al*., 2008 and Farag, *et al* 2011) [15]
12	1,2-Benzenedicarboxylic acid	390	$C_{24}H_{38}O_4$	1.200	Insecticidal activity (Khalil, *et al* 2014) [21]

RT= Retention time MW=Molecular weight MF= Molecular formula

2. Insecticidal activity of *licorice* roots aqueous extract

The insecticidal activity of aqueous extract obtained from licorice (*G. glabra* L.) roots was tested against *B. zonata* flies. The mortality level of *B. zonata* flies' population to different concentrations of *G. glabra* is described in Table (3). The results showed that *G. glabra* aqueous extract exhibited insecticidal activity against *B. zonata* flies after 24, 48, and 72 h The toxicity effect of *G. glabra* against *B. zonata* flies was expressed by the mortality. The three concentrations (20000, 25000, and 30000 ppm) of the *G. glabra* extract caused mortality of around 80 % after 24 h The highest mortality of flies (93.30 %) was recorded with the highest concentration of 30000 after 72 h. In general, after 24 h the extract showed an efficacy higher than 75 %; while 48 and 72 h caused a reduction of more than 85 % compared to the control. A significant ($p<0.001$) insecticidal activity with a dose-response relationship was revealed by the data's analysis of variance.

The effect of licorice roots aqueous extract (LRAE) on *B. zonata* flies in this study varied significantly along the tested period (three days) and the three concentrations used. After 72 h of treatment, the highest reduction of *B. zonata* flies' population was caused, while the lowest was recorded after 24 h Concentrations of 20000, 25000, and 30000 ppm extract of *G. glabra* recorded 77.50±0.153, 79.64±0.281and 80.80±0.263 % mortality after 24h, respectively. The percentage mortality increased after 48 h (87.78±0.234, 84.64±0.161 and 86.54±0.586 %), while the highest mortalities (93.30±0.058, 89.90±0.264 and 89.70±0.088) were recorded with the same three concentrations after 72 h, respectively. Also, results in Table (3) showed that *G. glabra* extract (LC_{50}= 1970.37 ppm) was found to be more effective against *B. zonata* flies after 72 h as compared to 24 h and 48 h (LC_{50}=6428.21 and 3120.75 ppm, respectively). Similarly, after 72 h of treatment, *G. glabra* extract was found to be more effective (LC_{90}=21996.93 ppm) followed by 48hrs (LC_{90}= 40261.69ppm, respectively), then the time 24hrs was least effective (LC_{90} = 53982.81ppm).

Table 3: Insecticidal effect of licorice roots aqueous extract (LRAE) at three concentrations against *B. zonata* flies.

Conc. (ppm)	Mortality (Mean%±SE)		
	24 hours	**48 hours**	**72 hours**
20000	77.50±0.153	87.78±0.234	89.70±0.088
25000	79.64±0.281	85.64±0.161	89.90±0.264
30000	80.80±0.263	86.54±0.586	93.30±0.058
LC_{50}	6428.21	3120.75	1970.37
LC_{90}	53982.81	40261.69	21996.93
X^2	0.1129	0.0440	0.0305
Slope	0.2454	1.1539	1.2331
r	0.9869	0.9787	0.8577

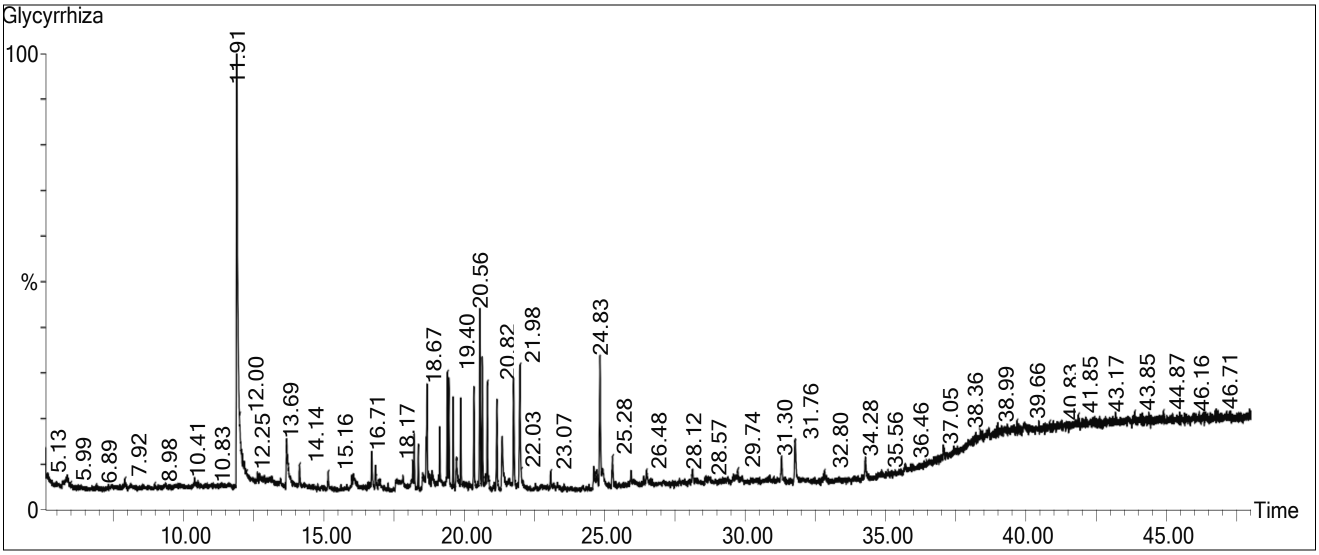

Fig 1: The GC-MS chromatogram of methanolic extract of *Glycyrrhiza glabra* roots.

Discussion

Fruit fly management is challenging because fully developed larvae infest the fruits and drop to the soil to pupate, so, protecting the larvae and the pupae from foliar insecticides (Heve *et al*., 2017) [18]. The present study aimed to introduce an alternative way of insect control through biodegradable plant materials.

Generally, alkaloids, glycosides, starches, flavonoids, phenolic compounds, carbohydrates, proteins, pectin, saponins, lipids, tannins, sterols, and steroids were found in the *G. glabra* root during the phytochemical screening process (Al-Snafi, 2018) [5]. GC-MS analysis of a methanolic extract of *G. glabra* roots was investigated and determined by several studies and the chemical constituents obtained were categorized under different classes of phytochemical compounds (Denisova, *et al* 2006, Çakmak, 2011, Akhtar and Shahzad, 2017 and Vijayalakshmi and Shourie, 2019) [3, 7, 11, 44]. Our findings of GC-MS analysis of *G. glabra* roots showed that forty-two compounds belonged to different phytochemical compounds categories (Aldehydes, benzene derivatives, alcohols, and fatty acids and their ester) were identified in the methanolic extract of *G. glabra*. The results of GC-MS analysis of *G. glabra* are consistent with study of Akhtar and Shahzad, (2017) [3], who reported that, the chemical constituents obtained were categorized under different classes of compounds *viz*. polysaccharides, fatty acids and their ester forms, phytosterols, vitamins etc. Additionally, the methanolic extract of dried-powdered roots of *G. glabra* showed the presence of 47 phyto-compounds including Phenol, 2,4-bis (1,1-dimethylethyl)-, Benzoic acid, 4-ethoxy-ethyl ester, Mome inositol, 3-heptadecanol and fatty acids and their ester such as 9,12-octadecadienoic acid (z,z), Octadec-9-enoic acid, Octadecanoic acid, 9,12-Hexadecanoic acid, methyl ester, 9,12-octadecadienoic acid (z,z)-, methyl ester and octadecadienoic acid (z,z)-, methyl ester. In another assay, Näf and Jaquier (2006) [23], reported that the roots of *G. glabra* contain secondary metabolites specifically, fatty acids, phenol, guaiacol, asparagines, glucose, sucrose, polysaccharides, and sterols. Twelve bioactive compounds were identified as the major compounds and have insecticidal and repellent activities against a variety of insects (Table 2). The activity of major bioactive compounds depending upon percent of the area screened in the roots of *G. glabra*. The major bioactive compounds identified are Phenol, 2, 4-bis (1, 1-dimethylethyl) - (20.79 percent), Benzaldehyde, 4-(1-methylethyl) - (12.56 percent), Triacetin (Glycerol triacetate) (10.74 percent). The obtained results also revealed the presence of three fatty acids namely, palmitic acid (Figueroa-Brito *et al*. 2002 and Pérez-Gutiérrez, *et al* 2011) [16, 25], linoleic acid (Rahuman *et al*., 2008 and Ramos-López, *et al* 2012) [26, 27], stearic acid (Figueroa-Brito *et al*. 2002 and Farag, *et al* 2011) [15, 16] and two fatty acids ester, oleic acid, methyl ester, octadecanoic acid, methyl ester and linolenic acid ethyl ester (Kannathansan *et al*., 2008 and Farag, *et al* 2011) [15], which considered various potential bioactive compounds and can be useful for insecticidal purposes.

Although roots of *G. glabra* contain phenolics, tannins, and flavonoids, saponins are the main component and have insecticidal activity against a variety of pests insects (De Geyter *et al*. 2007) [10]. The insecticidal effects of Licorice were evaluated by El-Genaidy *et al* (2021) [14] who studied the effect of *G. glabra* extract on *B. zonata* by contact toxicity test in sandy and clay soils. Aqueous extract from licorice roots decreased the number of *B. zonata* pupae in sandy soil by 74.44 percent, but it had a stronger effect (87.5 percent) in clay soil. Also, Soliman and El-Genaidy, (2021) [33], tested licorice, *G. glabra* L. roots aqueous extract (LRAE) on *Ceratitis capitata* (Wiedemann, 1824) and reported that LRAE has an insecticidal potential against *C. capitata* larvae and pupae. Licorice roots aqueous extract (LRAE) is an effective green insecticide that can control the Mediterranean fruit fly, *C. capitata* (Wiedemann). Also, *G. glabra* roots have acaricidal activity (Pavela, 2016) [24] and a repellent effect (Hasan, *et al* 2014). Although the major flavonoids of *G. glabra* extract (Furfural, herniarin, and glabridin) and the principal bioactive compound glycyrrhizin, were not detected in the GC-MS profile of roots in the present study. The possibility that this is due to the presence or absence of glycyrrhizin and some other compounds of commercial value depends on the time of harvesting, climatic condition, age of the plant, etc. (Karkanis, *et al* 2016). In the present study, the insecticidal activity of *G. glabra* extract in the absence of these compounds may be attributed to the presence of some bioactive compounds such as phenol-2,4-bis (1,1-dimethylethyl)-, benzaldehyde-4-(1-methylethyl)- and fatty acids and their esters which have insecticidal activities (Pérez-Gutiérrez *et al* 2011, Ramos-López, *et al* 2012, Zhao, *et al* 2020 and Mahran, 2022) [25, 27, 37].

Conclusion

In conclusion, the insecticidal potential of licorice, *G. glabra* roots, and their aqueous extract (LRAE) against *B. zonata* was demonstrated, and the mortality results showed a notable difference between the control and other treatments. These findings point to *G. glabra* potential as a *B. zonata* control agent; therefore, it can be used as an effective natural alternative to the chemical pesticides for controlling *B. Zonata* after semi-field and field experiments.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Contributions

The manuscript's preparation and editing were a collaborative effort by all the authors.

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