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Distribution and infestation rate of Carpomya incompleta on Sider fruit (Ziziphus spina-christi L.) in Jazan Province Saudia Arabia

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ABSTRACT In the Middle East, people used the fruit and leaves of Sider or Ber (*Ziziphus spina-christi* L.) as food and in traditional medicine. Out of 26 sites surveyed, it was found that *Carpomya incompleta* was the dominant insect in all surveyed sites that separated from fruits in trees and fallen. In only two locations, a type of weevil was recorded on fallen fruits in a minimal number (in Khawarah, Sabia), and a different kind of Lepidoptera was recorded in (Mokhtara, Samtah) in a limited number. However, the various sites recorded Braconid wasps (parasitoids used in biological control) at the end of the fruiting season. The results pointed to no more than one larva of *C. incompleta* recorded inside the infested fruit, and no cocoons were detected inside the examined fruits. The infested fruits varied from 5 to 32% in the fruits in the investigated trees; meanwhile, it reached 4 to 80% in the fallen fruits. While the seasonal abundance was represented, a single peak of infestation occurred at the end of the fruiting season with late spring. The study introduced the surveyed sider plantations to investigate the distribution and fluctuations of the most dominant insects. It also evaluated insect infestations and their causes to determine the causes of economic losses in their fruiting yield in Jazan Province, Saudi Arabia**.**

INDEX TERMS Carpomya Incompleta, Jazan, Pest Infestation, Zizyphus Jujube.

I. INTRODUCTION

The Jazan Area is located between latitudes 16º 22´ and 17º 46´N and longitudes 41º 33´ and 43º 09´E in the southwest corner of Saudi Arabia. Jazan is considered to belong to the Afrotropical realm based on [1-3]. It is characterized by its tropical climate of high temperature (sometimes more than 50º in summer), high evaporation (with RH exceeding 60% in most months of the year), and scarce water [4]. Despite this harsh climate, it is considered one of the wealthiest areas of floral diversity in Saudi Arabia, with most species of African origin [5-6].

The genus Ziziphus belongs to the family Rhamnaceae, about 85 species. *Ziziphus spina-christi* willd. (sidr) is one of the species of *Ziziphus* found in Saudi Arabia [7]. *Ziziphus spina-christi* is one of the true native species and is very adapted to the environmental conditions of Saudia Arabia. It is locally known as ber or sider and is a multipurpose tree used for fodder, food, medicine, and desertification control in arid lands. It represents the primary source of income for a wide sector of growers and beekeepers where sider honey is produced [8-9]. Jujube fruit fly has been a limiting factor for the production of decent quality and causing crop losses [10-11-]. Tephritidae (Diptera), or the jujube fruit fly, are and economically significant [12-13]. This species is a serious pest of the fruit of Ziziphus species, including common jujube (*Z. jujuba*), distributed in Italy, Egypt, Sudan, Eritrea, and Iraq [13- 14]. A new report about the presence of the zizyphus fruit fly in Spain for the first time. This presence has been reported to the Early Warning Systems on Alien Invasive Species of the Andalusian Government (Spain)[15]. *Carpomya incompleta* causes economic losses to the crop that require management to decline their population and enhance fruit quality [16].

Balikai recorded 22 non-insect and insect species feeding on cultivated ber in Karnataka [17]. A total of 23 insect species on ber from India were observed. The species *C. incompleta* is known from Africa (Burkina Faso, Egypt, Eritrea, Ethiopia, Libya, Niger, Sudan), western Asia (Iraq, Saudi Arabia, Oman, United Arab, Emirates, Yemen) and Europe (France, Italy [including Sicily]) [16-18]. Larva Fruit fly *C. incompleta*, after hatching, enters into fruit and feeds there till larval metamorphoses is complete; the infested fruits drop down and dry off [19]. While information regarding the distribution and fluctuation of fruit flies (*Carpomya incompleta* Becker, 1903) in the Jazan region is scarce. Insect pests are a significant factor in limiting the distribution of wild and cultivated plants. One of the justifications for this study is the continuous complaints from

consumers about the presence of larvae in the jujube fruits and their unfitness for eating. Therefore, we aimed to document information about *C. incompleta* insect distribution and fluctuations in Ber fruit (*Z. spina-christi* L.) in Jazan Province. Also, seeking to help in the future in designing a successful insect management program for the pest of *Z. spina* in Saudi Arabia.

II. MATERIALS AND METHODS

Field trials were conducted in the spring months (From the beginning of February until the end of April) of 2020 and 2021 to collect samples of Sider (*Ziziphus spina-christi*) from 26 different locations in six governorates, representing most of the regions in the plain of the Jazan region (Table 1).

1-Description of study sites:

TABLE 1. shows the geographical location of the study sites and their most important features

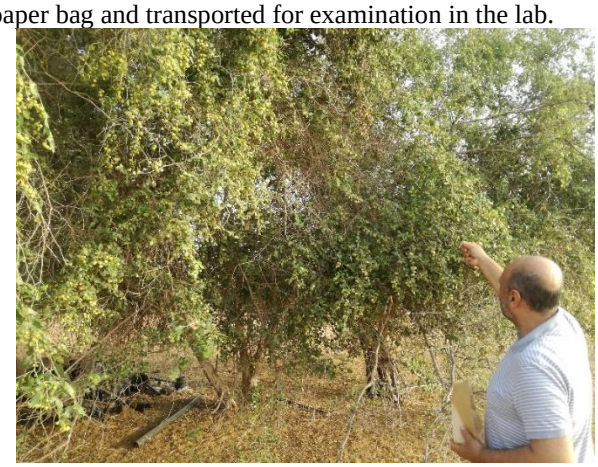
Sampling stations	Local name	Latitude, Longitude	Remarks
Baish	Alsilaa (F)	17°14'27.9"N 42°37'25.2"E	Large and old trees, their numbers are limited
	Al Haqu (T and F)	17°27'56.5"N 42°40'38.6"E	Small, scattered trees in the valley
	Baish Alolia (F)	17°23'28.8"N 42°34'00.5"E	Large and old trees, their numbers are limited
Sabia	Aldhabyah (T)	17°07'05.5"N 42° 39'13.5"E	Small, scattered trees in the home border
	Khawarah (T and F)	17°07'24.0"N 42° 38'03.8"E	Many numbers of old and large trees
	King Abdullah Rd (T and F)	17°09'00.5"N 42° 39'11.3"E	Large, scattered trees in the valley
	East (T and F)	17°09'32.9"N 42°40'29.1"E	Small, scattered trees in the home border
	Al Husayni (T)	17°08'57.7"N 42°40'58.4"E	Small, scattered trees in the home border
	Damad Road (T and F)	17°10'40.4"N 42°45'23.5"E	Large, scattered trees in the valley
	Harub (T)	17°26'01.1"N 42°53'09.4"E	Small, scattered trees in the home border
	Hafadia (Sanba) (T and F)	17°25'56.04"N 42° 39'03.83"E	Limited numbers of trees in the middle of cultivated lands
Damad	East1 (T)	17°07'06.27"N 42° 47'51.86"E	Large, scattered trees in the valley
	East2 (T and F)	17°07'46.2"N 42° 47'10.6"E	Large, scattered trees in the valley
	East3 (T)	17°07'10.3"N 42° 48'39.0"E	Small, scattered trees in the home border
	Shokariy (T and F)	17°07'32.7"N 42° 48'52.0"E	Large, scattered trees in the valley
Abu Arish	Abo Al Nurah (F)	17°02'56.7"N 42° 52'49.7"E	Large, scattered trees in the valley
	AL Mijasas1 (T)	17°02'36.0"N 42° 52'23.9"E	Large, scattered trees in the valley
	AL Mijasas2 (T)	17°02'18.4"N 42° 52'38.7"E	Small, scattered trees in the home border
	ALkanwat Road (T and F)	17°01'20.6"N 42° 51'54.6"E	Large, scattered trees in the valley
	East (F)	17°59'36.5"N 42° 50'22.8"E	Large, scattered trees in the valley
Ahad al Masarihah	North (T)	16°43'16.0"N 42°56'08.8"E	Large, scattered trees in the valley
	West (T)	16°42'36.5"N 42°56'03.1"E	Small, scattered trees in the home border
	AL Dagharir (T and F)	16°40'59.3"N 42°57'45.7"E	Large, scattered trees in the valley
Samtah	Mokhtara (F)	16°40'14.5"N 42°56'24.4"E	Small, scattered trees in the home border
	Mokhtara (T)	16°39'44.7"N 42°56'14.5"E	Small, scattered trees in the home border
	North (T)	16°37'37.6"N 42°56'48.7"E	Large, scattered trees in the valley

- T Refers to fruits collected from trees.
- F Refers to fallen fruits collected at the bottom of the tree.
- T and F It indicates the availability of fruits above and below the tree..

2- Fruit sampling:

a. Samples of fruits from trees

Fruit ripening season begins from February to the end of April. The fruits (100 samples) were collected from each site randomly from five trees (replications) representing the site. As shown in Figure 1 (a-c), the height of the trees ranges from 3 to 4 meters. Ripe fruits were collected from the level of 1.5 meters to 2.5 meters, every 20 fruits were placed in a paper bag and transported for examination in the lab.



a

b

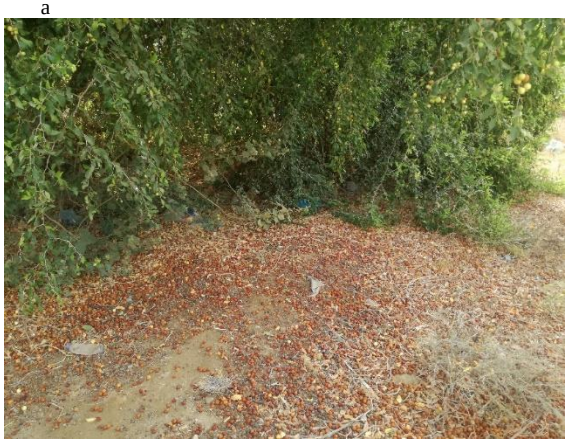
c

FIGURE 1 (A-C). Sider Trees from during sample collection in different sites (a – Fruit collection - b- High yielding trees c-Ripe fruits)

b. Samples of fallen fruits

Fallen fruits were collected from 15 sites. One hundred samples of fallen fruits were collected from each site in 5 replicates (20 * 5) to identify the pests associated with Ber fruit and compare the infestation by fruit fly in trees and fallen fruits.

a



b

FIGURE 2 (A-B). The places of fruits were collected a fruit samples from tree b- fruit samples under the tree (fallen).

3- Rearing of collected larvae

As shown in Figure 3, the collected samples were transported to the lab and incubated over two weeks under laboratory conditions. Then, the emergence of adult stages was monitored, separated, and preserved in 70% alcohol until they were fully prepared and sent for identification.

4-Insect identification:

Collected insects were identified using different taxonomic keys with the help of experts Prof. Magdi El-Hawagry, Department of Entomology, Faculty of Science, Cairo University, and Giza, Egypt.

5- Statistical analysis

Data from infected trees and fallen fruit were analyzed descriptively among sites and main locations by ANOVA

followed by Tukey's HSD test ($P < 0.05$) to determine the variation in the infection across different study sites and between infection % and parasites % by SPSS (21.0 Version).

a b

FIGURE 3. Samples of *Z. spina-christi* L fruits incubated to identify the associated pests. a- Collected fruits b- Breeding containers.

III. RESULTS

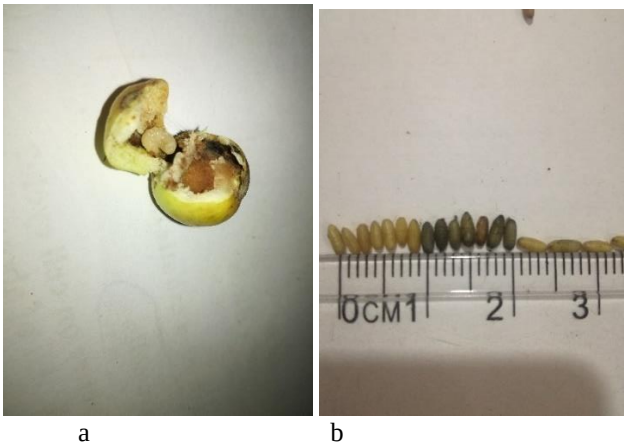
The fruit of *Z. spina-christi* L roughly reached about 1.5 cm in diameter (Fig. 4a-b). Meanwhile, mature fruit falls from trees in spring and early summer. The survey collected samples from 26 sites in 6 governorates where fruitful *Z. spina-christi* trees grow.

a b

FIGURE 4. *Z. spina-christi* fruit, a- different developmental stages b-symptoms of infestation externally.

1. *Examination of Z. spina-christi fruits*

The present examination of *Z. spina-christi* fruits revealed larvae of one species namely *Carpomya incompleta* (Becker, 1903): Tephritidae as common herbivores on *Z. spina-christi* fruits in tropical and subtropical regions. The female of *C. incompleta* deposits her egg (usually one) inside the fruit while still on the tree. After hatching, the larva bores into the fruit and feeds exclusively on the contents of the fruit except the seed. The larva develops through different instars to reach the full-grown larva (5-7 mm in length). Reaching the full-grown larva, it tunnels the surface of the fruit and makes a round hole in the surface and the pericarp for emergence (Figure 5). Under the laboratory conditions (25±2 °C & 60%R.H.), the larval development within the fruit takes about 7-9 days; meanwhile, the pupal stage takes about one week. Fruits were examined internally to determine the damage caused to the fruits. Accordingly, the inspected fruits were segregated into healthy and infested ones. Throughout the study period, insect *C. incompleta* was dominant in all sites and separated from fruits in trees and fallen fruits. In only two locations, a type of weevil was recorded on fallen fruits in a minimal number (in Khawarah, Sabia). Also, another type of Lepidoptera was recorded in (Mokhtara, Samtah) in a limited number (Fig. 6a-b). During the sample's examination, important notes were observed on the 1st. More than one larva was recorded inside the infested fruit. 2nd. Also, no cocoons inside any of the examined fruits. Most of the recorded infections were in ripe fruits or those that began to ripen, characterized by a color change.



a b

FIGURE 5 (A-B). Larva of *C. incompleta* a pest on *Z. spina-christi* fruits. a- mature larva b- pupa phase.

a b

FIGURE 6. (a-b) Pests recorded in fallen fruits a- weevil recorded on fallen fruits b- cocoons outside fruits

2. *Z. spina-christi L fruit fly infestation rates in different locations in the Jazan region*

The examination during the study period (Table 2) revealed a significant difference in the infested fruit rats, where the percentage of infested fruits varied from 5% to 22.3%. The highest percentage of infestation was recorded in Samtah governorates, which represented (22.3 % infested fruit) while the lowest percentage of infested fruits was 5 % in Harub governorates (Fig. 7).

The results show the clear superiority in infestation rates for the southern governorates (Ahad al Masarihah and Samtah) over the northern governorates (Sabia and Baish). Within the governorates of the study, the lowest number of infested fruits was represented at the Harub site, where the infestation rate was 5%. In comparison, the Mokhtara site in Samtah Governorate was the highest infestation site, recording 30% infested fruit.

1. *A comparison between the rates of C. incompleta fruit fly infestation in tree and fallen fruits*

The examined fruits could be categorized according to their position of presence into two types: the 1st type was the fruit collected from the tree, while the 2nd one was collected under the tree (fallen fruit). During the study period, 15 sites were selected for trees, and fallen fruits were collected (Fig. 8). The percentage of infested fruits varied from 5 to 30 % in fruit trees; meanwhile, the percentage of infested fallen fruits varied from 4 to 80 %.

The results revealed a high percentage of the infested fruits in fallen fruits. As shown in Fig. 8, the infestation rate in fallen fruits was higher than in tree fruits in all locations except Site Aldhabyah, where the infestation rate in tree fruits was higher than in fallen fruits. Khawarah site occupied the forefront, as there was a considerable increase in the number of infested fruits, reaching 80% of the fruits. The highest significance of side effects was ($F=3.23$, $p \leq 0.04$) infected trees and ($F=48.622$, $p \leq 0.00$) fallen fruits, respectively.

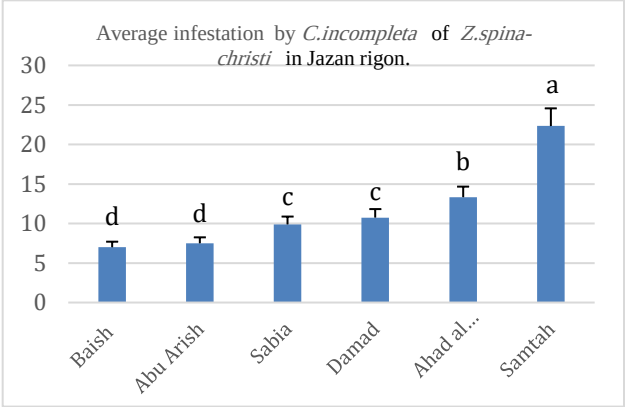


FIGURE 7. Average of Z. *spina-christi* fruit infested by *C. incompleta* in Jazan region during the spring months of 2020.

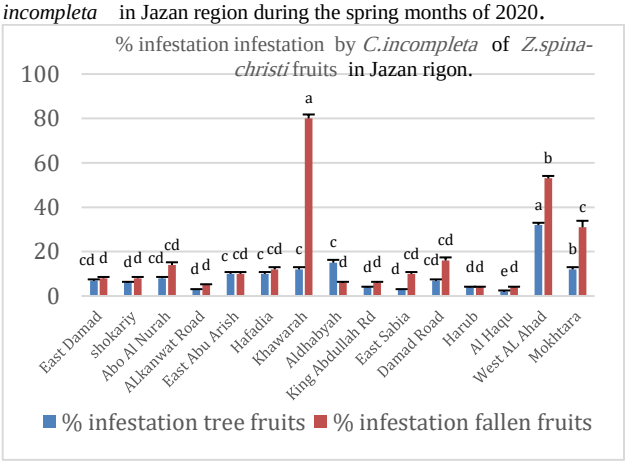


FIGURE 8. Average of Z. *spina-christi* fruit infested by C. *incompleta* (tree and fallen) in the Jazan region during the spring months of 2020

2. *Study of fluctuations of infestation by C. incompleta fruit fly during the fruiting season*

Over two successive years of study, two sites with tree-high density and fruiting rates were selected, one in the north of the Jazan region and the other in the south. The examined fruits were collected weekly to determine the fluctuation in infestation. As shown in Figure (9), the seasonal abundance of infestation was represented as a smooth wavering pattern. A single peak of infestation was observed at both study sites. It occurred at the end of the fruiting season in late spring, where the site West AL Ahad (the peak was recorded (35 % in 1st year) and (36 % in 2nd year) in the second week of April. Meanwhile, Khawarah–Sabia) site the peak was recorded (15 % in 1st year) and (20 % in 2nd year) in last week of March (Figure 10).

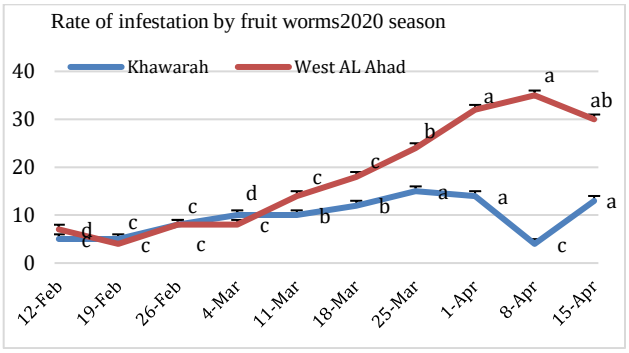


FIGURE 9. Weekly infestation for *Ziziphus spina-christi* fruits by *C. incompleta* during the period from 12 Feb. to 15 Apr. 2020.

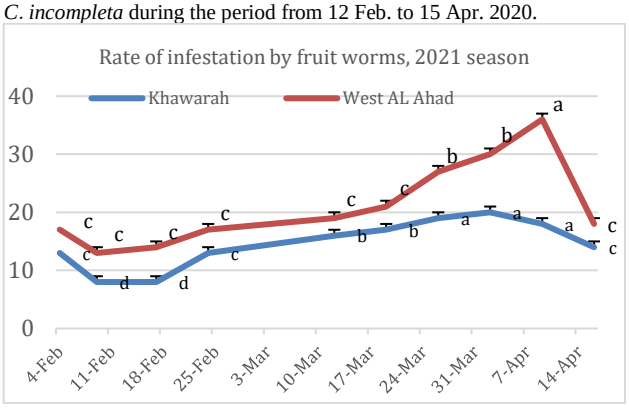


FIGURE 10. Weekly Infestation for *Ziziphus spina-christi* fruits by *C. incompleta* during the period from 9 Feb. to 16 Apr. 2021.

5- The spread of parasitoids associated with the Sidr fruit blight in the Jazan region

Table 2 and Figure 11 show insect parasitoids Braconid wasps from the order Hymenoptera were observed in the study's eight sites. Whereas, from five locations, larval parasitoids were collected from tree fruits from four locations and obtained from larvae of fallen fruits, and in one area (Samtah Mokhtara), the parasitoids were collected from both tree and fallen fruits. It could be concluded that the Sanba Hafadia site is the richest in parasite numbers, as 10 individuals were collected from the examined samples. It was noted that the largest number of parasitoids, Braconid wasps, was recorded at the end of the fruiting season at various study sites, especially in the study sites in the south of the Jazan region.

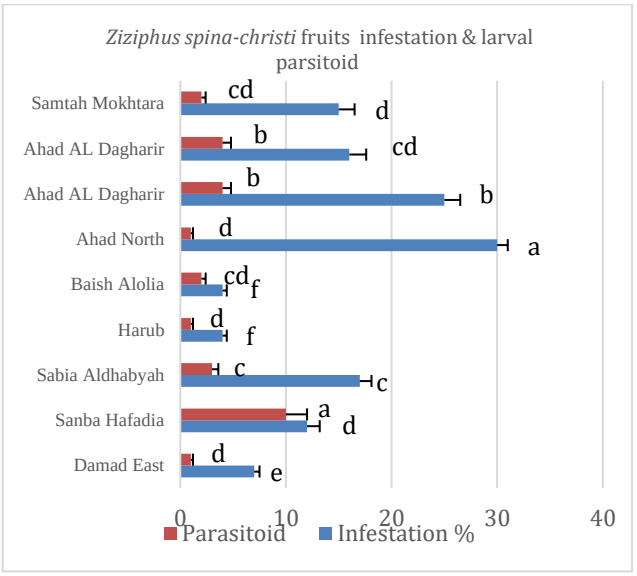


FIGURE 11. Density and spread of larval parasitoid-associated *Z.spina-christi* fruit in the Jazan region during the spring of 2020.

TABLE 2. Insect parasitoids and pest infestation percentage in the Jazan region sites.

Date	location	site	Fruits Place	Infestation %	Parasitoid
29. 2. 2020	Damad	Damad East	On tree	7	1
12. 2. 2020	Sabia	Sanba Hafadia	Fallen	12	10
21. 3. 2020	Sabia	Sabia Aldhabyah	On tree	17	3
14. 3. 2020	Harub	Harub	On tree	4	1
	Baish;	Baish Alolia	Fallen	4	2
11. 4. 2020	Ahad al Masarihah	Ahad North	On tree	30	1
	Samtah	Ahad AL Dagharir	Fallen	25	4
	Samtah	Ahad AL Dagharir	On tree	16	4
F (p value)				1.025(0.058)	

IV. DISCUSSION

Sidr is one of the most important plants in Jizan province, Saudi Arabia, as a pasture for bees to obtain the best types of honey and a basic component of balanced ecosystems in desert areas. Therefore, the study deals with sider insects and the distribution and fluctuations in Jazan. The results obtained from 26 sites representing different regions of Jazan during the study period showed one species: *Carpomya incompleta* (Becker, 1903)**:** Tephritidae as common herbivores on *Z. spina-christi* fruits. One of the critical notes we observed on the 1st. No more than one larva was recorded inside the infested fruit, and the2nd one also no cocoons were detected inside all examined fruits. Most of the recorded infestations were in ripe fruits or those that began to ripen, which are characterized by a color change. The results obtained are consistent with those **[18-21]** who reported the activity of fruit flies was very high during fruit maturity. Early harvesting of fruits at the color change stage avoids,s the over-ripening of fruits on trees and promotes fewer fruit flies' survival. Also, the study revealed a great vary from 5% to 22.3of the infested fruit rats with superiority in infestation rates in the southern governorates (Ahad al Masarihah and Samtah) over the northern governorates (Sabia and Baish); this may be due to the condition around plants and the rich fruits, as well as the accumulated and neglected fruits from the previous season. These results are consistent with the previous studies in different regions; for example, The *zizyphus* fruit fly (*C. incompleta*) is a monophagous pest of jujube (*Ziziphus* spp., Rhamnaceae), with two to five annual generations between spring and autumn [**21-24]**. Adult flies lay the eggs on fruit at the onset of ripening, and the carpophagous larvae, which go through three instars, dig a tunnel inside the fruit. They subsequently develop, with pre-pupariating third instars dropping to the soil to pupate, where enter diapause by the end of April [**22**]. Larval feeding promotes plant tissue decomposition and leads to bitter fruits, fruit rot, and drop, but sometimes, both eggs and larvae disappear inside the fruit [**12-25**]. *C. incompleta* may produce a low yield and poor quality fruits, which can often exceed 60% of infested trees **[24].** The variations among sites of collected trees and fallen fruits in infested fruits varied from 5 to 32 % in fruits in trees; meanwhile, the percent of infested fallen fruits varied from 4 to 80 %. This can be explained by several reasons, including that the pest prefers fruits in the ripening stage, and thus, they fall after that. Infested fruits are weaker in connection to the mother tree, so they fall more easily. The interaction effect of people or weather factors can increase the presence of infected fruits under the tree. In contrast, farmers collect only healthy fruits and leave the damaged fruits under the trees. As for the effect of season on inset abundance, a smooth wavering pattern of infestation was found. A single peak of infestation was observed at sites that occurred at the end of the fruiting season with late spring. It can be concluded that insects prefer ripe fruits, which is evident as the infestation rate increases with the completion of the ripening of most fruits and the forthcoming end of the season.

From eight sites, insect parasitoids Braconid wasps and order Hymenoptera were collected from trees and fallen fruits. Meanwhile, the highest rate of parasitism reached 10%, while the most significant number of parasitoids, Braconid wasps, was recorded at the end of the fruiting season, especially in the south of Jazan. The larvae bore down into the soil to a depth of 2 to 12 cm, where it pupates **[18-26]** and destroy the hibernating pupae by exposing them to bright sunlight and birds, considerably reducing the infestation. Heating of soil by burning grass and irrigation during summer also kills the pupae **[27].**

Finally, it could be concluded that *C. incompleta* is the key pest in the sider tree, and its parasitoids (Braconid wasps) are high due to the rich biodiversity in the Jazan region. However, there are no significant relationships between insect infestation and parasites ($P > 0.058$). So, this infestation needs more action to be less than the economic level to preserve this important type of plant and environment. While these results may contribute to developing suitable integrated pest control programs that meet the Jazan region's conditions, it should activate the prevention action before applying integrated pest management to protect *Z. spina-christi* trees.

V. CONCLUSION

The present study demonstrates that *C. incompleta* was the dominant insect in all surveyed sites. Braconid wasps

(parasitoids used in biological control) were recorded at various sites. In contrast, the seasonal abundance represented a single peak of infestation that occurs at the end of the fruiting season with late spring. All this data helps in designing an integrated control program for this pest, the times of activity and spread of this pest, taking advantage of the natural enemy, and considering the possibility of including it in the control program to preserve the environment.

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Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon necessary request.

DECLARATIONS

Conflict of interest

The authors declare no conflict of interest regarding this publication.

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