Population dynamics of safflower capsule flies (Diptera: Tephritidae) in Kohgiluyeh safflower farms of Iran

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Abstract

Oilseeds such as flax, canola, safflower, soybean and sunflower, which are annual plants, provide the world's major source of vegetable oils, although the highest oil yield comes from oil-bearing tree fruits. One of the most popular oil seeds is safflower (*Carthamus tinctorius* L.), which belongs to the Asteraceae family. Due to the ability of this plant to grow in dry and semi-dry conditions, safflower oil has the potential to be a commercially profitable product in Iran. Seasonal populations of safflower capsule flies were studied in Kohgiluyeh safflower farms, Iran, from March to May in 2008 and 2009. Four yellow sticky traps were used to monitor populations of fruit flies in the safflower farms. Traps were checked once a week during the sampling period. The traps were emptied weekly into insect collection vials containing 70% ethanol. Data were analysed with a two-way ANOVA. The relation between abiotic factors and species abundance was analysed with multiple linear regression. The results emphasized that *Acanthiophilus helianthi* was the most serious pest of safflower under the ecological conditions found in Gachsaran, being present in the field throughout three months of the year (March to May). *Chaetorellia carthami* was present in safflower fields from March to May, but in significant numbers only during April and May. *Terellia luteola* was present in safflower fields from March to May and in significant numbers only in late April, it does not seem to be a serious pest in safflower farms under Gachsaran's ecological conditions.

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Introduction

Safflower (*Carthamus tinctorius* L.) is a member of the Compositae or Asteraceae family (Emongor, 2010). It is a multi-purpose oilseed crop grown mainly for its high quality edible oil, as well as for bird seed (Karimi, 2000). Initially, safflower oil was used as a source of oil in the manufacture of paint, but today it is widely used as edible oil for cooking, and in the production of margarine and salad oil (Tinay, 2001). Safflower is also grown for its flowers, which are used as; cut flowers, in colouring and food flavouring, for the manufacture of dyes for the textile industry, livestock forage, as vegetable, herbal teas and for medicinal purposes (Karegar *et al*., 2004). In China, safflower is grown as a medicinal plant for the treatment of cardiovascular diseases, male and female fertility, lowering blood cholesterol, as well as various types of rheumatism and respiratory diseases (Rennie *et al.,* 2003).

Safflower, is now cultivated on approximately one million hectares of land and annually about 700,000 tons of seed are produced (Zeynali, 2001). Iran, once known as Persia, used to be a centre for the commercial cultivation of safflower in the ancient world and it continues to cultivate this oil seed to this day (Golkar *et al*., 2010). At present, approximately 1000 hectares of land are under safflower cultivation in Iran, which produces approximately 700 tons of seed annually (Karegar *et al*., 2004). Due to the ability of the plant to thrive in arid and semi-arid lands, safflower has the potential to become a commercially profitable product in Iran (Karimi, 2000).

Like other crops, safflower is susceptible to various diseases and insect attacks (Majidi *et al*., 2011). Due to water restrictions and the amount of arable land, one of the methods used to increase production is to reduce the damage caused by pests and plant diseases.

In nature, insect populations fluctuate depending on environmental factors. Broadly speaking, these environmental factors can be divided into biotic factors, such as natural enemies and plants, and abiotic factors, such as temperature, relative humidity and precipitation. From ecological studies, vital information can be obtained by monitoring changes in insect population numbers that result from changes in environmental factors. Studies of potential pests are necessary in order to meet the challenges of providing protection for both crops and livestock (Den & Walton, 1997).

Fruit flies of the family Tephritidae (Order: Diptera) are one of the most serious pests of fruits and vegetables. They cause enormous economic losses in the production of fruits and vegetables throughout the world (Korneyev & Konovalov, 2010). In the Iranian province of

Kohgiluyeh va Boyerahmad, there are 18 known species of fruit flies, however, the species considered to be the most serious pests of fruits and vegetables number less than ten (Gilasian & Merz, 2008). The majority of these species are polyphagous, with high fecundity and the ability to spread quickly over a wide area, thus making them serious pests for the growers of fruits and vegetables.

Effective management of this fly on safflower crops requires a better understanding of the species' seasonal dynamics in a particular locality. To achieve effective pest control measures, actions need to be targeted at periods of maximum population build-up and at the most vulnerable stage of the crop (Saeidi, 2006). The present study was carried out to monitor population fluctuations of fly species associated with safflower damage in the Gachsaran region of Iran.

Despite the fact that the threat of pest infestation is a serious problem that hinders the cultivation of safflower on a commercial scale, no comprehensive or useful information about safflower pests in Kohgiluyeh va Boyerahmad Province and other parts of the country could be found.

Materials and methods

Study site

Kohgiluyeh-va-Boyerahmad is a mountainous province situated in South West of Iran. About 3/4 of the area is rugged and plains comprise only 1/4 of the province area (Figure 1). The study was performed from March to May in 2008 and 2009 at the safflower farm in the Agricultural Research Station, Gachsaran. This site has a warm climate (mean minimum temperature of 15°C and a mean maximum temperature of 46°C), and it is characterized by annual precipitation of about 250-300 mm. The total land area of the safflower farm surveyed covered an area of 0.5 ha. The site was selected because it represented a large area of cultivated safflower that is commonly infested by fruit flies.

Fly trapping

Four yellow sticky traps were used to monitor the populations of fruit flies in the safflower farm. The traps were composed of polyethylene plates with dimensions 20×20 cm produced by the Agro science British Company. The traps were installed at a height of 80 cm from the ground, 200 m away from the field edge and 800 m apart from each other. Traps were checked once a week during the sampling period. The sticky traps were completely cleaned after each survey and re-glued if necessary.

Collection and identification of traps catches

The traps were emptied weekly into insect collection vials containing 70% ethanol. The insects collected were sent to a laboratory for identification and counting. Identification was based on the morphological characteristics of the collected specimens using a taxonomic key developed by the Iranian Fruit Fly Initiative (Mohamadzade Namin *et al.*, 2010). Samples of the identified insects have been deposited at the Department of Plant Protection, Agricultural and Natural Resources Research Center of Yasouj, Iran.

Incubation of flower heads

Each week 50-safflower flower heads were collected and placed into plastic vessels. The mean room temperature during the incubation period was 23°C, while the relative humidity for the same period varied between 55% and 60%. The flower heads were inspected every other day to remove fruit flies pupae, until there no were pupae present in the flower heads. The pupae were then placed in plastic bottles (diameter 8 cm and height 15 cm) lined at the bottom with moist tissue paper for emergence. Emerged flies were collected by aspirator and then counted.

Climatic data

Data on temperature, precipitation and relative humidity of the study area were obtained from the local weather station at the Gachsaran Agricultural Research Station.

Data analysis

Data was subjected to two-way ANOVA. The correlation between abiotic factors and species abundance was analyzed with SPSS multiple linear regression.

Results and discussion

Relationship of safflower capsule flies and abiotic factors

A total of 7633 fruit flies were captured in the yellow sticky traps during both years, and consisted of 88.8% (6780) *A. helianthi*, 7.6% (585) *C. carthami* and 3.5% (268) *T. luteola*. In addition, 854 fruit flies emerged from the incubated flower heads of which 70.8% (605) were *A. helianthi,* 20.0% (171) *C. carthami* and 9.1% (78) *T. luteola*.

A total of 3446 fruit flies were captured in the yellow sticky traps from March to May 2008. There was a significant difference among months in 2008 [degree of freedom (df)=2; F=3.59; P=0.041]. The highest

Figure 1. The geographical position of Kohgiluyeh va Boyerahmad province on map of Iran (Saeidi *et al.*, 2015).

number of individuals was obtained in May (Figure 2), and the number of flies captured of each species was also significantly different (df=2; F=133.72; P=0.000). The highest number of specimens came from *A. helianthi* (3780), followed by *C. carthami* (296) and *T. luteola* (111) (Figure 3). *Acanthiophilus helianthi* was the species with the highest number of individuals (P<0.05) emerging from incubated flower heads with 225 (63.2%) individuals, followed by *C. carthami* and *T. luteola* with 101 (28.3%) and 30 (8%) specimens, respectively (Table 1).

Similar results were obtained in 2009. A total of 4187 fruit flies were captured in the yellow sticky traps from March to May 2009. There was a significant difference found in the various months in 2009 (df=2; F=6.46; P=0.005). The highest number of specimens was obtained in May (Figure 4), and the number of flies captured was also significantly different between species (df=2; F=133.72; P=0.000). The highest number of individuals belonged to *A. helianthi* (3000), followed by *C. carthami* (289) and *T. luteola* (157) (Figure 5). *Acanthiophilus helianthi* was still the most significant species (P<0.05) with the highest number of individuals emerging from incubated flower heads at 380 (76.3%) individuals, followed by *C. carthami* and *T. luteola* with 70 (14%) and 48 (9.6%) specimens, respectively (Table 2).

Examining damaged safflower's flower heads across the semi-arid areas in Kohgiluyeh va Boyerahmad Province, in the south-west of Iran, it was observed that the safflower capsule fly and two other flies, namely *Terellia luteola* and *Chaetorellia carthami,* were infecting the flower heads of this crop. Overall, *A. helianthi* was the most abundant insect species.

Figure 6 gives population dynamics of the different fruit fly species during the study period (2008). The number of flies per trap per week for *A. helianthi* was significantly higher (P<0.05) in the three months from March to May than those for *C. carthami* and *T. luteola*. Actually, there was no significant difference found between *C. carthami* and *T. luteola* numbers. The highest number of flies per trap per week for *A. helianthi* was recorded in mid-May, while the highest catch for *C. carthami* was recorded in early May. Whereas, the highest trap catch for *T. luteola* was recorded at the end of March and April.

Table 2 shows the number of fruit fly species coming from incubated flower heads during the study period (2009). The trapped numbers for the three fruit fly species were not significantly different (P<0.05). The mean number of *A. helianthi* captured during the study was significantly higher than those of *C. carthami* and *T. luteola*. *A. helianthi* was the most dominant (P<0.05) fruit fly species that emerged from the incubated fruits during the peak safflower months from March to May.

Table 3 shows the correlations matrix for the three fruit fly species. The occurrence of *A. helianthi* was negatively correlated with that of *C. carthami*. The occurrence of *A. helianthi* was also negatively correlated with temperature, but positively correlated with relative humidity. However, populations of *C. carthami* were positively correlated with temperature, but negatively correlated with both relative humidity and rainfall. Populations of *T. luteola* did not show any significant correlations in these measures.

Relationship of safflower capsule flies and abiotic factors (2009)

A total of 4187 fruit flies were captured in the yellow sticky traps from March to May 2009. Out of these 90.2% (3780) were *A. helianthi*, 7.1% (296) *C. carthami* and 2.6% (111) *T. luteola*. In addition, 498 fruit flies emerged from the incubated flower heads of which 76.3% (380) were *A. helianthi,* 14% (70) *C. carthami* and 9.6% (48) *T. luteola* (Table 2).

Figure 7 shows population dynamics of the different fruit fly species during the study period (2009). The number of flies per trap per week for *A. helianthi* was significantly higher (P 0.05) in the three months from March to May, than those for *C. carthami* and *T. luteola*. In fact,

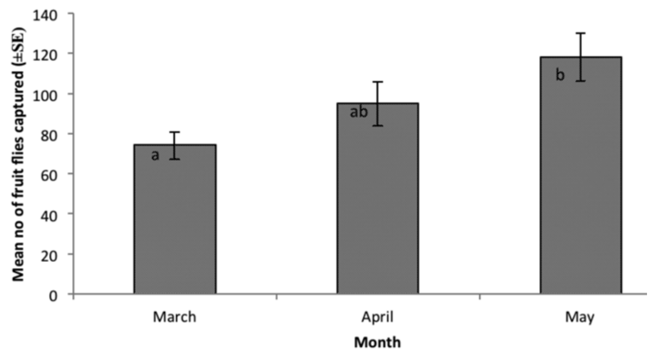

Figure 2. Number of safflower capsule flies found in different months 2008.

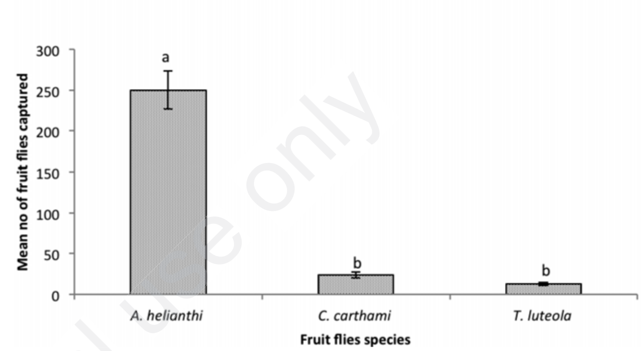

Figure 3. Number of safflower capsule flies for each species in 2008.

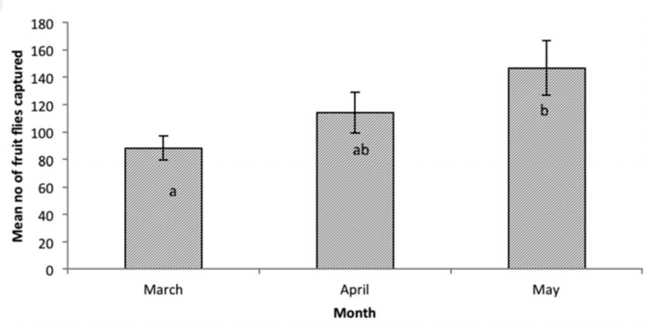

Figure 4. Number of safflower capsule flies in the months of 2009.

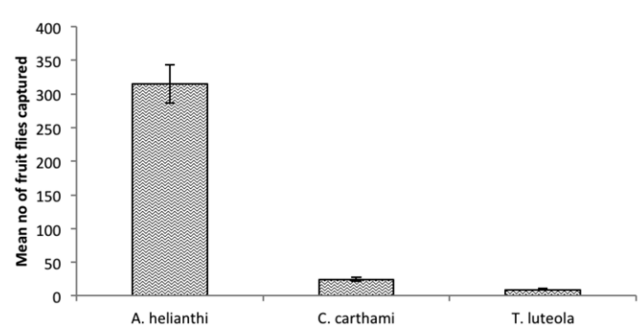

Figure 5. Number of safflower capsule flies for each species in 2009.

there was no significant difference found between *C. carthami* and *T. luteola*. The highest number of flies per trap per week for *A. helianthi* was recorded in late May, while the highest catch for *C. carthami* was recorded in early May. The highest trap number for *T. luteola* was recorded in the first week of April.

Figure 8 shows the percentage of fruit fly species extracted from the incubated flower heads during the study period (2009). The trap catch numbers for the three fruit fly species were not significantly different ($P<0.05$). However, the mean number of *A. helianthi* captured during the study was significantly higher than those of *C. carthami* and *T. luteola*. *A. helianthi* was the most dominant ($P<0.05$) fruit fly species that emerged from the incubated fruits in the peak safflower season months from March to May.

Table 4 shows the correlations matrix for the three fruit fly species. The occurrence of *A. helianthi* was negatively correlated with that of *C. carthami*. Furthermore, the occurrence of *A. helianthi* was also negatively correlated with temperature, but positively correlated with relative humidity. In addition, populations of *C. carthami* were positively correlated with temperature, but negatively correlated with both relative humidity and rainfall. Populations of *T. luteola* did not show any significant correlations with abiotic factors.

The production of safflower in Asia is threatened by three major insect pests, namely; aphids (Homoptera: Aphididae), stem borers (Lepidoptera: Noctuidae) and fruit flies (Diptera: Tephritidae). However, only the latter cause large-scale economic damage to the safflower flower heads (Kutuk and Ozgur, 2003). For example, yield losses due to fruit flies of more than 45% have been reported in West Asia (Khouzama *et al*., 2002) and between 28% to 85% in Iran (Keyhanian, 2008; Hasanshahi and Askarianzadeh, 2012).

Studies on the species of fruit flies associated with safflower in the Gachsaran Agricultural Research Station showed that *A. helianthi*, *C. carthami* and *T. luteola* were the most important fruit fly species. The results from the present study demonstrated that *A. helianthi* was the dominant species from March to May. It was also the dominant fruit fly species that emerged from incubated safflower flower heads.

The dominance of this fruit fly species coincided with the production of flower heads in both early and late maturing safflower varieties. This could be due to the absence of flower heads on the alternative host plants such as weeds. In addition, the study period represents the arid period at the Gachsaran station, which is conducive to the population growth of *A. helianthi* (Jakhmola and Yadav, 1980). As a consequence, *A. helianthi* causes an enormous amount of damage to safflower flower heads, resulting in complete seed loss if appropriate control measures are not taken (Merz, 2008; Gharajerdaghi *et al*., 2012).

The results showed that the patterns of fruit fly population fluctuations in the safflower farm and during the study were similar (Figures 2 and 4). The population appeared in March, started increasing in April and reached its maximum in May of both years (2008 and 2009). Hasanshahi and Askarianzade (2012) reported similar results from the Tehran Province (Iran). They stated that the peak population of *A. helianthi* was observed in May. This peak period of safflower capsule fly population coincides with the ripening of the safflowers.

Keyhanian (2008) reported different results from Ghom Province in Iran. He carried out an experiment to determine the seasonal abundance and loss assessment of the safflower capsule fly on safflowers. The results showed that the adults of *A. helianthi* appeared on the safflower crop between the 1st week of April up to 4th week of June, and an infestation of capsules by *A. helianthi* larvae was observed from the 1st of April to the end of June. Thereafter it declined, which was attributed to the maturity of the crop. Its maximum population in the 1st and 2nd

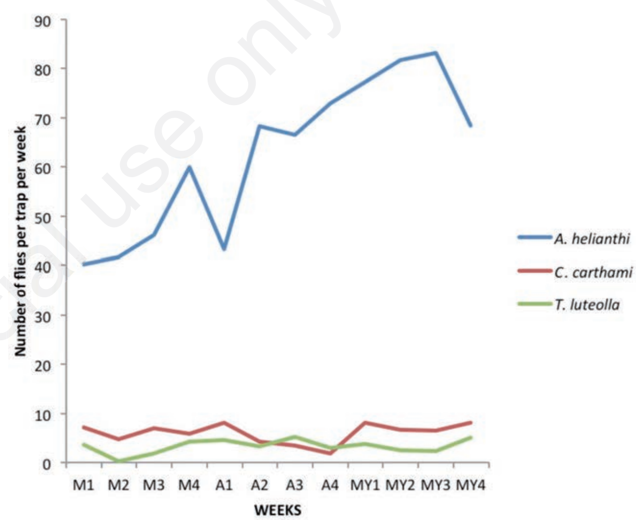

Figure 6. Mean number of fruit flies per trap per week of the three fruit fly species from March to May 2008.

Table 1. Fruit fly species recovered from incubated safflower flower heads in 2008.

Month	Number of flower heads incubated	Number of fruit fly species emerged		
		Acanthiophilus helianthi	*Chaetorellia carthami*	*Terellia luteola*
March	200	25	11	5
April	200	85	40	9
May	200	115	50	16

Table. 2 Fruit fly species recovered from incubated safflower flower heads in 2009.

Month	Number of flower heads incubated	Number of fruit fly species emerged		
		Acanthiophilus helianthi	*Chaetorellia carthami*	*Terellia luteola*
March	200	90	10	5
April	200	120	20	12
May	200	170	40	31

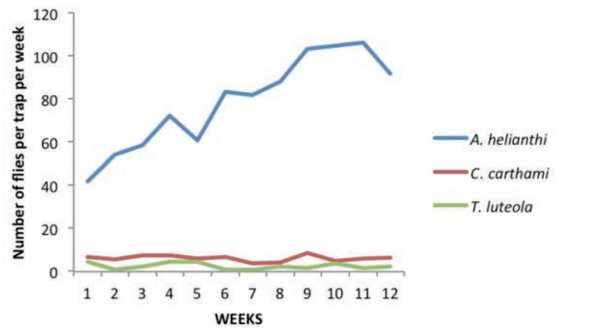

Figure 7. Mean number of fruit flies per trap per week of the three fruit fly species from March to May 2009.

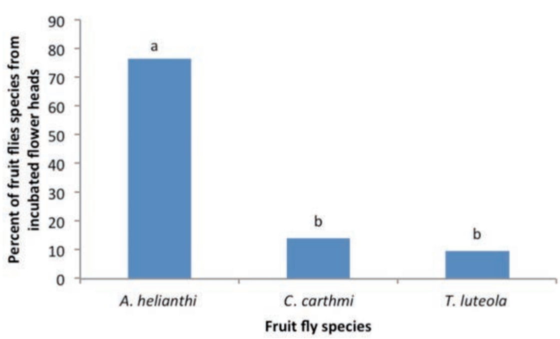

Figure 8. Percentage of fruit fly species from incubated flower heads from March to May 2009. Means with different letters are significantly different at P<0.05.

generation was seen at the last week of May and the 1st week of June, respectively. One of the most important reasons for the different results obtained in Gachsaran and Ghom are due to the different climatic conditions and vegetation types present in these two areas.

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Table 3. Correlation coefficients (*r*) between the occurrence of fruit flies and climatic parameters in 2008.

	A	B	C	D	E	F
Acanthiophilus helianthi (A)	1					
Chaetorellia carthami (B)	0.442*	1				
Terellia luteola (C)	0.365	0.210	1			
Precipitation (D)	0.292	0.345	0.128	1		
Relative humidity (E)	0.678*	0.535*	0.008	0.731*	1	
Temperature (F)	0.410*	0.176*	0.205	0.556	0.660*	1

Numbers with asterisks are significant (P<0.05).

Table 4. Correlation coefficients (*r*) between the occurrence of fruit flies and climatic parameters in 2009.

	A	B	C	D	E	F
Acanthiophilus helianthi (A)	1					
Chaetorellia carthami (B)	0.453*	1				
Terellia luteola (C)	0.389	0.230	1			
Precipitation (D)	0.299	0.369	0.136	1		
Relative humidity (E)	0.692*	0.565*	0.009	0.767*	1	
Temperature (F)	0.450*	0.182*	0.215	0.585	0.689*	1

Numbers with asterisks are significant (P<0.05).

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