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Full Length Research Paper

Development of integrated pest management techniques: Insect pest management on Safflower

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***Acanthiophilus helianthi* Rossi (Diptera: Tephritidae) is a pest of safflower and its management is of great challenge because of its fecundity and concealed larval habitat. Potential components of an integrated pest management program for *A. helianthi* were investigated at the Gachsaran Agricultural Research Station, in southern Iran from November, 2008 to July, 2009. For the life cycle studies, the infected flower heads were collected from an experimental field plot and were developed from egg to adult under laboratory conditions. The results showed that the first adults emerged gradually in mid April, 2009. Female *A.helianthi* had a pre-oviposition period of 5.8 ± 1.0 days and the average fecundity was 27 ± 3.2 eggs. The eggs were laid in the bracts of flower heads singly or in clusters of 3-18. The Incubation period was 3.8 ± 0.6 days under field conditions and 3.4 ± 0.6 days under cage conditions. Three larval instars occurred, and the larval phase was 7-10 days. Males emerged earlier than females, but the longevity of the adult females (12 ± 3.0) was significantly greater than that of males (8 ± 1.0). Analysis of aggregated male and female sampling data showed that the sex ratio was 1:1.28. To evaluate the efficiency of different methods of fruit fly control on Safflower, a field experiment was carried out. Five diverse methods, insecticides, baiting, cultural, integrated management and no treatment were assessed on weight of one thousand seeds, percentage of oil, percentage seed damage and harvest/ha. Integrated management and insecticide control indicated best results with harvest potential of 1850 and 1723 kg/ha with a least damage of 5 and 8%, respectively. Since the use of selective insecticides is one of the most important methods for pest management, we evaluated the efficacy of six insecticides against *A. helianthi* infesting safflower. Among the treatments Endosulfan 35% EC at 0.03% proved more effective followed by Chlorpyriphos and Monochrotophos.**

Key words: Efficacy, insecticides, *Acanthiophilus helianthi*, damage, safflower, integrated management.

INTRODUCTION

The safflower fly is one of the most important pests of safflower in Iran. Losses caused by larval feeding leads to disrupted plant activities, reduction in flower buds, and ultimately, to decreased quality and quantity of crop. Safflower (*Carthamus tinctorius* L.) is an important oilseed crop and an essential component of cropping systems in the dry regions and marginal areas of the world (Sabzalian et al., 2008). Like other crops, safflower suffers from various diseases and insects (Weiss, 2000). The most serious safflower pest in Asia and Europe is the safflower fly *Acanthiophilus helianthi* Rossi (Tephritidae), and it is sometimes known as the shoot fly or capsule fly (Talpur et al., 1995; Zandigiacomo and Iob, 1991). In Asia, the safflower fly devastates most production areas in Iraq (Al-Ali et al., 1977), Pakistan (Talpur et al., 1995), and India (Vaishampayan and Kapoor, 1970; Verma et al., 1974). In Iran, seed-yield loss due to the safflower fly is estimated to be 30-70% for different safflower cultivars (Sabzalian et al., 2010). The safflower fly is a poly-phagous insect belonging to the Tephritidae family (Ashri, 1971). Adult flies lay eggs on the inner side of involucral bracts of safflower green heads (Narayanan, 1961; Ashri and Knowles, 1960). Heavy infestations of safflower fly occur during the reproductive phase of the plant, and the fly prefers to lay its eggs inside developing heads throughout the flowering stage (Talpur et al., 1995). Larvae

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hatch from eggs, penetrate the head bracts, and feed on receptacle tissue or the whole seed (Faure et al., 2004; Jkhmola and Yadav, 1980; Narayanan, 1961; Ricci and Ciriciofolo, 1983). Larval feeding on seeds causes significant losses in seed weight, yield, and seed market-ability (Ashri, 1971). A large number of plants including weeds are alternate hosts of *A. helianthi*, and some are used by this pest for both feeding and reproduction. *Chenopodium virgata*, *Polygonum aviculare*, *Salsola kali*, *Acroptilon repens*, *Carthamus oxyacantha*, *Cuscuta campestris* and *Convolvolus arvensis* serve as alternative host plants for *A. helianthi* (Hegazi and Moursi, 1983; Selim, 1977; Singh et al., 1982). The increasing impact of *A. helianthi* has elicited concern among entomologists who are looking for pest management options. The biology and behavior of *A. helianthi* has been described by some entomologists in various parts of Iraq (Al-Ali et al., 1977), Pakistan (Rahoo et al., 1997), India (Verma et al., 1974), and Egypt (Hegazi and Moursi, 1983). However, little information is available on the biology, ecology and control of this pest in the dry zone of Iran (Bagheri, 2007) and no information is available for Gachsaran, Iran. Therefore, the main objectives of this study were to elucidate the biological and different methods control of *A. helianthi* in the Gachsaran zone of Iran. Results presented here may be helpful for future planning of large-scale safflower cultivation in similar environmental conditions of the tropics, especially for pest management purposes.

MATERIALS AND METHODS

Experimental plot

Studies were conducted on a 50×50 m safflower plot located within the premises of the Agricultural Research Station in Gachsaran (50° 5´ N latitude and 30° 20´ longitudes) in southern Iran during November, 2008 to July, 2009. The seed of the safflower variety “Sina” obtained from the oilseeds division of the research institute were planted within the experimental plot, following standard agricultural practices. Approximately 2500 plants were in the experimental plot. Plants were fertilized with NPK fertilizer once every 3 months, and watering was performed when necessary. No insecticides, herbicides, or fungicides were used .

Experimental insects

A. helianthi began to attack the plants 5 to 6 months after planting (during the formation of flower heads). Field and laboratory experiments were started after *A. helianthi* became available in the experimental plot.

Experimental protocol

Rearing studies

A. helianthi was reared under controlled conditions in cages at the Gachsaran Agricultural Research Station, to determine the oviposition, fecundity, longevity and for developmental experiments. Adult *A. helianthi* were collected from the experimental plot, reared outdoors in wooden framed cages (160 × 160 × 100 cm), and covered with organdy cloth. An opening of 100 ×70 cm was made in the organdy cloth cover on one side of each cage for the safflower plants and the insects. Safflower plants of approximately 130 cm in height and grown in polythene soil containers (80 cm diameter and 60 cm high) were placed separately inside each cage. The egg clusters collected from the safflower plot together with parts of the receptacles on which they were found were stapled on-to flower heads of potted plants without disturbing the eggs. Egg clusters were examined daily until the eggs hatched.

Life stage studies

Upon hatching, the first instar larvae from each egg cluster were transferred to a potted plant placed inside another cage. These larvae were left undisturbed to feed, molt, and metamorphose into pupa and adults. Adults were carefully observed and sexed using morphological features. The pre-oviposition, oviposition, and post-oviposition periods were studied under laboratory conditions. Adult male and female insects were collected from the rearing cages within 24 h of the last molt. Batches of the three males and one female each were placed separately in 20 rearing jars (90 cm internal diameter × 70 cm high). A 20-30 cm long piece of safflower flower head was placed inside each jar, which provided nourishment and surfaces on which the insects could rest and oviposit. A 5 cm thick layer of Plaster of Paris was laid at the bottom of each jar to provide sufficient moisture to prevent the safflower flower head from wilting. The mouth of each jar was covered with muslin cloth to allow aeration. Insects in the rearing jars were monitored daily until they died. Pre-oviposition, oviposition and post-oviposition periods were recorded.

Twenty pairs of newly emerged adults collected from the rearing cages were placed inside a new rearing cage containing a potted safflower plant. The insects were allowed to mate and oviposit. The number of egg clusters produced each day by the 20 females was recorded. In a separate experiment, newly emerged adults males (n = 20) and females (n = 20) were collected from the rearing cage and placed separately, with a 20-30 cm long piece of safflower flower head, in the rearing jars as described above. Insects in the rearing jars were monitored daily to determine adult longevity until all of the insects died. The incubation period and egg viability were studied both in the laboratory and field. Newly laid egg clusters were randomly selected from the rearing cages (n = 20) and the field (n = 20) and observed daily until hatching. The number of eggs in each cluster was recorded. The number of unhatched eggs in each cluster was recorded after the incubation period. The incubation period and egg viability inside the cage and under field conditions were compared using a t-test. Larvae were examined daily and the number of instars was determined by molts and by measuring head capsule size.

Morphological studies

Fifty infected flower heads were collected from the experimental plot and brought into the laboratory. In the laboratory, each flower head was opened, and the eggs were transferred individually to a glass slide. The length and width of 100 randomly selected eggs were measured under a light microscope fitted with a micrometer eyepiece. Then, the length and width of first, second, and third instar larvae were measured in the same manner; the pupae and adults were measured using a pair of dividers and a millimeter scale. The morphological features of the eggs, larvae, pupae, and adults were examined under a stereomicroscope (×25).

Field studies

Sex ratio, mating, and oviposition behavior of *A. helianthi* were

Table 1. List of insecticides used under field conditions.

Name of chemical	Trade name	Source	Concentration used
Endosulfan 35%EC	Sholay	Insecticide India Ltd	0.03
Chlorpyriphos 20%EC	Kohiban	Fungicide India Ltd	0.01
Monochrotophos 28%EC	Kohiban	Insecticide India Ltd	0.03
Deltamethrin 2.8%EC	Decis	Insecticide India Ltd	0.01
Malathion 56% EC	Courage	Fungicide India Ltd	0.03
Supracide 40% EC	Kohiban	Insecticide India Ltd	0.03

studied under field conditions. To determine the sex ratio, adult A. helianthi captured in a sweeping net were sexed and counted once per week. We could distinguish adult males from females using morphological differences in the abdominal tips. The sex ratio of adults was determined using the chi-square test. Preliminary observations of mating and egg laying behavior were conducted in the field. Focal animal sampling (Martin and Bateson, 1986) was chosen (observing one individual until the end of the desired behavior) and duration of the behavior was recorded (n = 50).

Measurement of physical environmental factors

Daily maximum and minimum temperature within the experimental plot were measured using four maximum and minimum thermometers. Relative humidity (RH) was measured using a thermo-hydrograph.

An experiment was conducted on an established safflower genotype namely 'Sina' and four methods of control of capsule fly, including insecticide Danitol (Fenpropathrin @ 100 gm/acre); baiting with Biolure (ammonium acetate), cultural (plant residue burning and collection of fallen flower heads after harvesting), integrated management (insecticide, baiting and cultural) and these four were compared with no treatment. These five treatments were arranged in a randomized complete block design with three replications on fifteen plots. Each plot with a size of 2 × 10 m^2 has ten rows, so that at the time of harvest six rows in the middle from each plot were selected for each treatment. Distance between each plot was kept as 10 m. All other agronomic practices were applied equally in all methods. Information on different factors was recorded and analyzed statistically by Fishers analysis of variance. Seed damage and yield per plot in different methods were compared by using Least Significance Difference (LSD) test at 5% (Bashir et al., 2005).

A research trial was carried out in the experimental farm at Agriculture Research Station Gachsaran, Iran during 2008-2009 to evaluate the efficacy of Chlorpyriphos, Deltamethrin, Endosulfan, Malathion, Monochrotophos, and Supracide on safflower fly and the natural enemies. These insecticides were obtained from the local market and the safflower variety 'Sina' used in this study was obtained from the oilseeds division seed and plant improvement Institute Karaj, Iran. It was sown by hand (1 seed/hill). The experiment was laid out in Randomized Complete Block Design with six treatments in three repeats and the plot size measuring 6 × 6 m^2 row to row and the plant to plant distance was kept 75 × 50 cm. A path of 100 cm was maintained among the treatment. All the agronomic practices were applied as and when needed and kept constant for the whole safflower field. Data were analyzed using F-test and Duncan's multiple rouge test (DMRT) for means separation.

Treatments

Various insecticides as per recommendations of Division of Entomology University of Shiraz were evaluated against safflower fruit fly. The concentrations, their sources, trade names are given in Table 1.

The data on safflower fly infestation was recorded from 10 randomly selected plants by counting sound and damage squares, bolls, and live larvae by dissecting squares and bolls. The insecticides were applied at 100 and 120 days after cultivation, respectively. Control plots were sprayed with water only. The insecticides were used at their recommended doses (Table 1). Before each spray, the volume of spray solution was calibrated by spraying measured volume of water on the check plots. Ten litters hand operated Knapsack sprayer was used for the application of insecticides.

For the larvae of safflower fly population density on each plant, ten flower head were randomly selected and tagged. In each of these flower heads after opened populations of larvae safflower fly were recorded. Percent decrease over control for safflower fly of larvae was calculated by the following formula (Khattak et al., 1987):

$C = A/B \times 100$

Where: A = Population infestation in treated plants; B = Population infestation in control; C = Decrease over control.

Percent decrease = 100 – C

RESULTS AND DISCUSSION

A. helianthi was established throughout the study period, as insecticides, herbicides, or fungicides were not used. Subsequently, *A. helianthi* found in the experimental plot were identified by comparing their morphological characters with voucher specimens from the Insect Taxonomy Research Institute of Iran. The adult *A. helianthi*, found in Gachsaran was a grey or slightly green colored, medium sized fly. Sexes differed in size; the female has an average length of 5.2 ± 0.7 mm, whereas the male was slightly smaller with an average length of 4.7 ± 0.5 mm. The female also had a characteristic spear like ovipositor at abdominal tip. Adults were relatively inactive during the early morning, evening, and night, and typically remained on the lower surface of leaves. During the day (8.0 to 18.0 h) adults became more active and were found on both the upper and lower surfaces of flower head bracts. Newly emerged adult females were ready to mate 2 days after emergence from the pupa. Males and females began to copulate about 1 day after exit from the pupae, and mating occurred usually during

Table 2. Duration of various *A. helianthi* life parameters.

Life history parameter	Duration (in days)		
	Minimum	Maximum	Average (±SE)
Pre-oviposition period	4	8	5.8±1.0
Oviposition period	8	14	11.0±1.2
Post-oviposition period	3	7	6.0±2.0
Male longevity	6	11	8.0±1.0
Female longevity	9	15	12.0±3.0
Incubation period (in field)	2	7	3.8±0.6
Incubation period (in lab)	2	6	3.4±0.6
First instar larvae	2	3	2.5±0.1
Second instar larvae	2	3	2.6±0.1
Third instar larvae	3	4	3.6±0.2
Pupae period	6	9	7.5±0.0

the day. Males and females mated multiple times, usually with different partners, and each mating episode lasted 1 to 2 h. Females typically mated multiple times during a three days period before starting to oviposit. Mating continued throughout the oviposition period.

A female produced 2 to 4 egg clusters during her lifespan with an average of 2.8 ± 1.0. The number of eggs in a cluster obtained from the rearing cage ranged from 4 to 18 with a mean of 10 ± 2.0, whereas egg clusters obtained from the experimental plot ranged from 5 to 20 eggs with mean of 11 ± 2.1. The difference in means between eggs in a cluster laid in rearing cages and in the experimental plot was not statistically significant. The total number of eggs laid by a female during her lifetime ranged from 10 to 37 with a mean of 27 ± 3.2.

Rahoo et al. (1997) stated that the mean number of eggs in an *A. helianthi* egg cluster in Pakistan (in the field) was 10. The mean number of eggs in a cluster at Gachsaran (in the field) was 11.0 ± 2.1. Despite the differences in climatic conditions between Pakistan and Iran, the mean number of eggs in a cluster in both places was approximately the same, indicating that the number of eggs in a cluster is an inherent trait unaffected by climatic differences.

Under laboratory conditions, the incubation period ranged from 2 t0 6 days with a mean of 3.4 ± 0.6 days, whereas under field conditions, it ranged from days with a mean of 3.8 ± 0.6 days (Table 2). The difference between the incubation period under laboratory and field conditions was not significantly different. Egg viability recorded from egg clusters collected from the rearing cages was 81.85%, whereas that of egg clusters collected from the experimental plot was 83.28%. No significant difference between the viability of eggs laid in rearing cages and in the experimental plot was observed.

Longevity of the adult females was significantly greater (t-test; $P<0.01$) than that of the males; females lived for 9-15 days with a mean of 12 ± 3.0 days, whereas the longevity range of the males was 6-11 days with a mean of 8 ± 1.0 days (Table 2). Egg viability appears to be affected by ambient RH, especially when it fluctuates drastically (Bagheri, 2007). These authors reported that egg viability was 56 at 30% (RH) and increased gradually with increasing RH, reaching a maximum of 85 at 87% RH. Meteorological data recorded during the present study showed that the RH at Gachsaran fluctuated between 75 and 83% with a mean of 78 ± 2.3%, and egg viability remained high throughout the study period. The mean egg viability (83.28%) was similar to the maximum percent viability (85%) recorded by Bagheri (2007).

A. helianthi has three larval instars. Larvae are elongate and sub cylindrical with a milky-white colored integument. The main difference between instars is body size and length of the cephalopharyngeal skeleton. The cephalopharyngeal skeleton of first instar larvae ranges in size from 0.5 to 0.10 mm and is shaped differently than that of second and third instars. The mean duration of the first instar larvae was 2.5 ± 0.1 days (Table 2). The shape of the cephalopharyngeal skeleton of second instar larvae was similar to that of the third instar. The cephalopharyngeal skeleton of second instar ranged from 0.20 to 0.35 mm. The mean duration of the second larval period was 2.6 ± 0.1 days (Table 2). The cephalopharyngeal skeleton of third instar larvae ranged from 0.40 to 0.65 mm in length. The mean duration of the third instar larvae was 3.6 ± 0.2 days (Table 2). Larvae at this stage are pale yellow in color and much more active than less developed instars.

Males emerged earlier than females, so that in the first and second week of sampling, the number of males in the sweeping net was 10 times greater than that of females, but over time, the male: female ratio gradually became closer, so that the final sex ratio was 1:1.28.

During the study period, the daily minimum temperature fluctuated from 24.2 to 27.5°C and the daily maximum temperature ranged from 37 to 39.5°C. The daily temperature and RH inside the rearing cages were only marginally higher than those in the experimental plot. However,

Table 3. Comparison of biological parameters records of *A. helianthi* between the present study and results of other studies.

	Bagheri, 2007	Jakhmola and Yadav, 1980	Keyhanian, 2007	Ricci and Ciriciofolo, 1983	Zandigiacomo and Iob, 1991	Present study
Number of generations/year		-	2	-	2	3
Sex ratio	1.1:0.9	-	-	-	1:1	1:1
Longevity of females (days)	-	-	-	-	-	12±3.0
Number of pupae in each flower head	-	-	1-13	-	5.4	1-11
Yield losses (%)	25-70	96-99	10-33	14-79	59	39-78
Duration of larval stage	15	-	11-12	-	-	7-10

Table 4. Means squares of ANOVA for all traits.

ANOVA	Df	Weight of one thousands seeds (g)	Percentage of oil	Percentage of damage	Harvest/ha.
Block	2	0.20	1.61	3.20	1265.40
Treatment	3	33.85	35.80	556.32	254306.56
Error	6	1.43	0.17	0.70	43.317

fecundity, mean oviposition period, and percentage of viable eggs were not significantly different inside the cages compared to the field conditions. Therefore, (using cages) is recommended for biological studies of *A. helianthi*. Studies of *A. helianthi* have shown that the mean duration of pre-oviposition, oviposition and post-oviposition are 5.8 ± 1.0, 11 ± 1.2, and 6 ± 2.0 days, respectively. In the present study, egg incubation time was relatively longer than the value reported by Rahoo et al. (1997), (incubation period of 2-4 days, mean of 2.9 days), which might be attributed to different host varieties,. In our study *A. helianthi* adults survived on a water and- honey diet for 3-17 days, (mean, 10 ± 1.0 days,), which is considerably longer that on a water and sugar diet, which is approximately 2-12 days, with an average of 7.5 ±1.0 days (Bagheri, 2007). Female longevity (12 ± 3.0 days) was longer than males (8 ± 1.0 days), which was consistent with other studies (Bagheri, 2007; Rahoo et al., 1997), as shown in Table 3. We reported a different sex ratio (1:-1.28) for *A. helianthi* than that (1:1) reported by Keyhanian (2007) (Table 3). Genetic heterogeneity of the local *A. helianthi* populations and inherent demographic stochasticity of *A. helianthi* individuals, as well as the use of safflower as a host may account for the minor inconsistencies between our results and those of other studies. *A. helianthi* is normally active for 4 months from April to July, in the Gachsaran region where it has three generations per year. Although, the number of generations per year was quite close to that reported for Iraq (Al-Ali et al., 1977), a study conducted in Italy reported two generations per year (Zandigiacomo and Iob, 1991), (Table 3). *A. helianthi* larvae feed mainly on safflowers, but can also feed on some species of Compositae (Hegazi and Moursi, 1983). Further research is required to clarify the host effect on the biology and feeding behavior of *A. helianthi*.

Analysis of variance in the seed characters revealed that there was significant variation in weight of one thousand seeds, percentage of oil, percentage of damage and harvest/ha among five different methods of control safflower capsule fly, at $P<0.05$ (Table 4). The coefficient of variation (C.V) was recorded for weight of one thousand seeds, percentage of oil, percentage of damage and harvest/ha as 4.5, 1.48, 1.55 and 0.43, respectively.

Percentage damage

Percentage damage of Safflower seed was significantly different among the various methods tested for fruit fly control. The highest seed damage of 39.4% was observed in case of Safflower plants where no treatment was adopted. The lowest damage of 5% of Safflower plants was recorded where integrated management practices were carried out. This method had significant differences with insecticide control method in which

Table 5. Comparison of different methods to control fruit fly (*Acanthiophilus helianthi*) on Safflower.

Method employed	Weight of one thousands seeds (g)	Percentage of oil	Percentage of damage	Harvest (kg/ha)
Control	22.6000[c]	24.5667[c]	39.4333[a]	1103.000[e]
Insecticide	29.2667[a]	28.3000[b]	8.0000[d]	1723.333[b]
Bait	26.3333[b]	25.1500[c]	20.0000$_b$	1405.000$_d$
Cultural	24.000[c]	28.2333[b]	14.0000[c]	1566.667[c]
Integrated management	30.5000[a]	33.2667[a]	5.1667[e]	1850.000[a]
LSD value (0.05)	2.2556	o.7828	0.5076	12.392

[c], [a], [b], [d], [e] Means with at least a common letter significant, in the ANOVAs test at 5% level have significant difference.

8% damage was recorded (Table 5). Ricci and Ciriciofolo (1983) had reported that pest damage levels on small medium and large flower heads are 14, 38 and 79% respectively in no treatment practice. Furthermore, Keyhanian (2007) reported a 10 to 33% damage of the flower head due to feeding of this fly.

Harvest (kg/ha)

Final seed harvest is a function of cumulative effect of various harvest parameters. Seed yield differs significantly among varied methods of fruit fly control. Integrated Management produced a significantly highest harvest of 1850 kg/ha followed by insecticidals control method, which gave a harvest of 1723 kg/ha (Table 5). The lowest harvest of 1103 kg/ha was recorded in case of plants where no treatment was applied. With respect to the most important measure from commercial perspectives -the amount of harvest- the control method (no measure taken) was recognized as the least productive. Therefore, the necessity of adopting the most appropriate method of controlling capsule flies is a need which will determine the profitability of cultivating safflower.

Weight of one thousands seeds (gram)

Weight of one thousands seeds of Safflower was significantly different among the various methods tested for fruit fly control. The minimum weight of one thousands seeds 22.6 g was observed in case of Safflower plants where no control measure was adopted. The maximum weight of one thousands seeds 30.5 g was recorded in the case where integrated management practices were carried out. Integrated management had a non-significant difference with insecticide control method in which 29.2 g were recorded. Among the four methods compared to the control case, the Cultural method was observed to be the least successful method with respect to the measure of one thousands seeds weight (Table 5).

Percentage of oil (%)

Percentage oil of Safflower seed was significantly different among the various methods tested for fruit fly control. The lowest percentage oil seed of 24.56% was observed in case of Safflower plants where no control measure was adopted. The highest percentage of oil seed of 33.26% was recorded in case of Safflower plants in which integrated management practices were carried out. Integrated management had significant differences with insecticide control method in which 28.3% were recorded. In case of the measure of percentage of oil, the cultural methods were found to be as successful as the insecticide method. However, with the exception of the integrated management method, the other methods compared to the control method were found roughly yielding close results, although they are statistically different.

The efficacy of six insecticides, Chlorpyriphos 20 EC; Deltamethrin 2.8 EC; Enudosulfan 35 EC; Malathion 56 EC; Monochrotophos 28 EC and Supracide 40 EC were tested at recommended doses for the control of safflower fly. The insecticides were applied two times. The first application was made on April 10, and the second was on May 6th, 2008. The post spray data, first recorded 24 h after 1st spray and then on a weekly basis.

First spray

The data in Table 6 reveal that all the insecticides were significantly effective in reducing the larvae of safflower fly population as compared to control. The larvae of safflower fly population density after 24 h was 0.46, 1.80, 2.06, 3.4, 4.13 and 4.33 larvae of safflower fly inside of ten flower heads in Endosulfan; Chlorpyriphos; Monochrotophos; Deltamethrin; Malathion and Supracide treated plants, respectively, as compared to control where it was 11.33 larvae of safflower fly in ten flower heads.

The statistical analysis showed that after 1st week of spray, Endosulfan ranked first in reducing the population density followed by Chlorpyriphos, Monochrotophos, Deltamethrin, Malathion and Supracide with population densities of 2.20, 3.46, 4.33, 4.60, 6.00 and 6.73 larvae of safflower fly inside ten flower heads respectively. The highest population density of larvae safflower fly was recorded in check plots where it was 11.73 larvae of safflower fly inside ten flower heads.

Table 6. Mean number of safflower flies larvae for 10 bolls after the first spray of 6 different insecticides.

S/N	Insecticide		Larvae safflower fly in 10 flower heads after first sprayed					
	Common name	Trade name	24 h	1st week	2 nd week	3rd week	4th week	Mean
1	Endosulfan	Thiodan	0.46 F	2.20 E	3.33 E	5.53 F	7.63 D	3.83 E
2	Chlorpyriphos	Lorsban	1.80 E	3.46 DE	4.53 DE	6.53 EF	8.46 CD	4.95 D
3	Monochrotophos	-	2.60 E	4.33 CD	5.26 D	7.86 DE	8.93 C	5.79 D
4	Deltamethrin	Decis	3.4 C	4.60 CD	6.80 C	8.53 CD	10.28 B	6.72 C
5	Malathion	Malathion	4.13 B	6.00 BC	7.33 C	9.73 BC	11.17 B	7.67 BC
6	Supracide	Methidathion	4.33 B	6.73 B	8.50 B	10.53 B	11.47 B	8.31 B
7	Control		11.33 A	11.73 A	12.07 A	13.67 A	14.13 A	12.59 A

Mean followed by the same letter in a column are not significantly different from each other (*P>0.05*), using DMR test.

Table 7. Mean number of safflower flies larvae for 10 bolls after the second spray of 6 different insecticides.

S/N	Insecticides		Larvae safflower fly in 10 flower heads after first sprayed							
	Common name	Trade name	24 h	1st week	2 nd week	3rd week	4th week	5th week	6th week	Mean
1	Endosulfan	Thiodan	0.C	1.13 F	2.33 G	4.46 E	6.13 G	7.40 D	9.13 D	4.36 F
2	Chlorpyriphos	Lorsban	0.93 C	2.66 E	4.53 F	6.20 DE	7.86 F	8.46 D	10.27 C	5.84 E
3	Monochrotophos	-	2.53 B	4.20 D	5.66 E	7.86 CD	8.80 E	10.33 C	13.53 B	7.55 D
4	Deltamethrin	Decis	2.66 B	4.26 CD	6.60 D	9.20 C	9.80 D	11.13 C	13.67 B	8.18 CD
5	Malathion	Malathion	2.93 B	5.73 BC	8.56 C	9.80 BC	10.73 C	11.33 C	13.80 B	8.98 C
6	Supracide	Methidathion	3.80 B	6.73 B	9.60 B	11.40 B	6.13 G	7.40 D	14.20 B	10.33 B
7	Control		14.20	14.26 A	14.28 A	17.47 A	16.87 A	16.60 A	15.80 A	15.64 A

The data recorded two weeks after the spray revealed that Endosulfan proved to be the best treatment followed by Chlorpyriphos, Monochrotophos, Deltamethrin, Malathion and Supracide with a population of 3.33, 4.53, 5.26, 6.80, 7.33 and 8.50 larvae of safflower fly in ten flower heads, respectively.

The observation made on the 3th week of the 1st spray for treatments revealed the lowest population of 5.53 larvae of inside ten flower heads, with Endosulfan followed by Chlorpyriphos; Monochrotophos; Deltamethrin; Malathion and Supracide with a population of 6.53, 7.86, 8.53, 9.73 and 10.53 larvae of safflower fly inside ten flower heads, respectively, as compared to control where it was 13.67 larvae of safflower fly inside ten flower heads. The results revealed that all the insecticides were significantly better than control. Endosulfan proved to be the best of all the treatments.

The data recorded on 4th week of spray revealed that all the insecticides were significantly different from the check plots. Endosulfan proved to be the best treatment by reducing larvae of safflower fly population to 7.63 larvae of inside ten flower heads followed by Chlorpyriphos; Monochrotophos; Deltamethrin; Malathion and Supracide with a population of 8.46, 8.93, 10.28, 11.17 and 11.47 larvae safflower fly inside ten flower heads, respectively, as compared to control where it was 14.13 larvae of safflower fly inside ten flower heads.

The results of Deltamethrin; Malathion and Supracide were non-significant to each other. After application of the 1st spray mean data showed that Endosulfan (3.83 larvae of safflower fly inside ten flower heads) was significantly better than all other treatments.

Second spray

The post spray data are presented in Table 7. The data recorded after 24 h showed that all insecticides gave significant control of larvae of safflower fly better than check. However, Endosulfan ranked first by reducing pest population to zero followed by Chlorpyriphos (0.93 larvae of safflower fly inside ten flower heads). Results of Monochrotophos (2.53), Deltamethrin (2.66), Malathion (2.93) and Supracide (3.80) were not significantly different from each other. Whereas in check the population was maximum (14.20 larvae of safflower fly inside ten flower heads).

The data recorded after one week of the second spray revealed that all insecticides gave significant control of larvae safflower fly. Endosulfan proved to be the best of all insecticides reducing the population to 1.13 larvae of safflower fly inside ten flower heads. Chlorpyriphos was 2nd by reducing the population to 2.66 larvae of safflower fly inside ten flower heads followed by Monochrotophos,

Deltamethrin, Malathion and Supracide with a population of 4.20, 4.26, 5.73, and 6.73 larvae of safflower fly inside ten flower heads. The maximum numbers recorded from check (14.26 larvae of safflower fly inside ten flower heads).

Results obtained after 2nd week of spray showed that all insecticides proved better than check. Endosulfan proved to be the best of all insecticides in reducing larvae of safflower fly population to 2.33 larvae of safflower fly inside ten flower heads. Chlorpyriphos ranked 2nd followed by Monochrotophos, Deltamethrin, Malathion and Supracide with a population of 4.53, 5.66, 6.60, 8.56 and 9.66 larvae of safflower fly inside ten flower heads, respectively. The population density recorded in check was 14.28 larvae of safflower fly inside ten flower heads.

Results obtained after 3rd week of spray revealed that all the insecticides provided good control of the pest as compared to check. Endosulfan ranked first by reducing the larvae of safflower fly population to 4.46 larvae of safflower fly inside ten flower heads followed by Chlorpyriphos (6.20), Monochrotophos (7.86), Deltamethrin (9.20), Malathion (9.80) and Supracide (11.40) larvae of safflower fly inside ten flower heads, respectively. The highest population of the larvae of safflower fly was recorded in check plots where it was 17.47 larvae of safflower fly inside ten flower heads.

Post spray data recorded on 4th week indicated that all insecticides were effective to suppress the pest population as compared to check. Minimum pest population was recorded in Endosulfan (6.13) treated plots followed by Chlorpyriphos (7.86), Monochrotophos (8.80), Deltamethrin (9.80), Malathion (10.73) and Supracide (13.13) larvae of safflower fly inside ten flower heads, respectively. The maximum pest population was recorded in check plots where it was 16.87 larvae of safflower fly inside ten flower heads.

For the residual effect post spray, data were also recorded after 5 and 6th weeks. Results obtained after 5th week indicated that all the insecticides were effective to suppress pest population. Results of the Endosulfan and Chlorpyriphos were non-significant, however, Endosulfan, was still ranked 1st having minimum pest population (7.40 larvae of safflower fly inside ten flower heads) followed by Chlorpyriphos (8.46 larvae of safflower fly inside ten flower heads). Similarly Monochrotophos, Deltamethrin and Malathion were statistically the same 10.33, 11.13 and 11.33 larvae of safflower fly inside ten flower heads, respectively. The results of Supracide (13.47 larvae of safflower fly inside ten flower heads) were significantly greater from the above 5 insecticides but significantly lower than from the check plots where it was 16.60 larvae of safflower fly inside ten flower heads.

Data collected after 6th week showed that all the insecticides were effective in comparison to control. Endosulfan (9.13 larvae of safflower fly inside ten flower heads) was ranked first followed by Chlorpyriphos (10.27 larvae of safflower fly inside ten flower heads). The remaining four insecticides, Monochrotophos, Deltamethrin, Malathion and Supracide were in the 3 rd category and statistically similar to each other 13.53, 13.67, 13.80 and 14.20 larvae of safflower fly inside ten flower heads respectively. The highest population of larvae safflower fly was recorded in the check plot where it was 15.80 larvae of safflower fly inside ten flower heads.

Overall 2nd spray results revealed that all insecticides were effective as compared to control. Means indicated that Endosulfan ranked first throughout the spray followed by Chlorpyriphos. Both were persistent for six weeks. The remaining four insecticides; Monochrotophos, Deltamethrin, Malathion and Supracide were found superior is control and less persistent than Endosulfan and Chlorpyriphos.

Percent decrease of larvae safflower fly population over time in comparison to control

The result of the first spray (overall means) Table 8, revealed that Endosulfan (74.22) showed best performance followed by Chlorpyriphos (64.93), Monochrotophos (56.09), Deltamethrin (49.63), Malathion (37.76), and Supracide (40.96). After first spray, the maximum percent decrease of larvae safflower fly population over time in comparison to control was recorded in Endosulfan 35 EC and the minimum in Supracide 40 EC .

The result of the 2nd spray (overall means) Table 8 indicated that Endosulfan (85.56) showed best performance followed by Chlorpyriphos (73.10), Monochrotophos (65.96), Deltamethrin (62.81), Malathion (47.64), and Supracide (54.54). After 2 nd spray, the maximum percent decrease of larvae safflower fly population over time in comparison to control was recorded in Endosulfan and minimum in Supracide. Overall, a greater percent decrease was observed in the 2nd spray as compared to the 1st spray.

As evident from the results, all insecticides significantly controlled the *Acanthiophilus helianthi* up to four weeks after first spray application. Endosulfan 35 EC remained highly effective against *A. helianthi* during two sprays, followed by Chlorpyriphos 20 EC, Monochrotophos 28 EC, Deltamethrin 2.8 EC, Malathion 56 EC and Supracide 40 EC.

Similarly, percent decrease of larvae safflower fly over time in comparison to control was high in Endosulfan 35 EC followed by Chlorpyriphos 30 EC, Monochrotophos 28 EC, Deltamethrin 2.8 EC, Malathion 56 EC and Supracide 40 EC both in the first and second spray. Overall, the performance of Endosulfan 35 EC with its Knockdown effect proved best of all treatments where minimum of larvae safflower fly population and maximum percent decrease over control was recorded.

The present study confirmed the efficacy of these insecticides against safflower fly *Acanthiophilus helianthi* of safflower in Iraq. As the time passes more and more new products are being introduced to the market which

Table 8. Percent decrease of larvae safflower fly population over time in comparison to control after both sprays.

S/N	Insecticides		1st spray	2nd spray
	Common name	Trade name		
1	Endosulfan 35% EC	Kohiban	74.22 A	85.56 A
2	Chlorpyriphos 20% EC	Decis	64.93 B	73.10 B
3	Monochrotophos 28% EC	Sholay	56.09 C	65.96 C
4	Deltamethrin 2.8% EC	Kohiban	49.63 D	62.81 C
5	Malathion 56% EC	Kohiban	37.76 E	47.64 D
6	Supracide 40% EC	Courage	40.96 E	54.54 D

Means followed by the same letters in a column are not significantly different from each other (*P>0.05*), using DMR test.

need close monitoring and evaluation. The present study was such an effort in which various insecticides were tested for their efficacy. The present studies also revealed that all the insecticides were effective in controlling the pest. Based on the present finding it could be suggested that Endosulfan 35 EC should be listed in the spray schedule for the control of safflower fly.

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