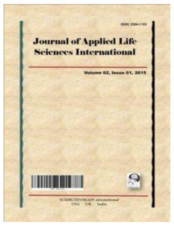

Journal of Applied Life Sciences International
8(4): 1-8, 2016; Article no.JALSI.28620
ISSN: 2394-1103

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Insecticide Application Schedule to Control Sesame Webworm *Antigastra catalaunalis* (Duponchel) Humera, North Ethiopia

Zenawi Gebregergis[1*], Dereje Assefa[2] and Ibrahim Fitwy[2]

[1]Department of Crop, Humera Agricultural Research Center (HuARC) P.O.Box 62, Ethiopia.
[2]Department of Crop and Horticultural Science, Mekelle University, Ethiopia.

Authors' contributions

This work was carried out in collaboration between all authors. Author ZG designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author DA managed the literature searches, analyses of the study performed the spectroscopy analysis and author IF managed the experimental process. Author ZG identified the species of plant. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JALSI/2016/28620
Editor(s):
(1) Martin Koller, University of Graz, Research Management and Service, c/o Institute of Chemistry, Austria.
Reviewers:
(1) Hermione Elly Melara de Campos Bicudo, University of the State of São Paulo, Brazil.
(2) Sanjay Mishra, IFTM University, India.
Complete Peer Review History: http://www.sciencedomain.org/review-history/16599

Original Research Article

Received 28th July 2016
Accepted 6th September 2016
Published 18th October 2016

ABSTRACT

Sesame webworm (*Antigastra catalaunalis*) is the major pest, which is causing heavy losses in Humera areas, northern Ethiopia. The present study aims to determine schedule of insecticide application for control of the pest. An experiment with a randomized complete block design (RCBD) was conducted at Humera Agricultural Research Center to evaluate nine insecticide application schedules. Result of the experiment indicated that weekly spray (S9) resulted in lower webworm incidence (19.5%) and better grain yield (536.6 kg/ha); and highest incidence (99.27%) and lowest grain yield (154.9 kg/ha) was recorded from control. Maximum level of leaf and flower was scored on control and once sprayed plots, while the lowest was on the frequently sprayed. In conclusion, twice application of insecticide at 2 and 4 weeks after emergence was found better for controlling *A. catalaunalis*.

Keywords: A. catalaunalis; Sesamum indicum; insecticide schedule; incidence; capsule damage.

**Corresponding author: E-mail: zenawigg@gmail.com;*

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is an annual plant that belongs to the *Pedaliaceae* family. It is one of the world's oldest oil seed crop grown mainly for its high oil content of the seeds that contain approximately 52 to 57% oil and 25% protein content [1,2].

Despite its ideal adaptation to dry sites, sesame can also be cultivated in humid, tropical and sub-tropical regions. It is an erect herbaceous annual plant with either single stemmed or branched growth habits and two growth characteristics of indeterminate and determinate, reaching up to 2 m height and with a large tap root of up to 90 cm [3,4].

More than 9.42 million hectares of the total world crop area is under sesame cultivation with about 4 million metric tons of total production [5].

The Ethiopian whitish Humera-type variety is known for its taste (sweet) in the world market, hence it is exported to the confectionary market where white seeded types are demanded by the consumers [6,7]. In 2014/15 cropping season sesame coverage of the country was estimated 3.35% (about 420,490.98 ha) and 1.07% (about 288,770.08 tons) of the total grain crop area and grain production respectively [8]. The four major sesame growing regions in the country are mainly Tigray (36%), Oromia (17%) Benishangul Gumuz (15%) and Amara (31%) [9]. Within Tigray, western zone is the main sesame production area with large commercial farms and many small-scale farmers and sesame is a good source of income in these areas. Sesame in Ethiopia is a very crucial crop in many aspects, but there are many hurdles for its production and productivity such as limited research endeavor, lack of economically feasible and technically appropriate production technologies.

Production and productivity of sesame is seriously affected by biotic and abiotic factors, pest infestations, delay in sowing, poor distribution of rainfall and high evapotranspiration affects the yield of sesame in *Humera* (0.35-0.4 t/ha) [10,11]. Insect pests are the most important factor affecting production of sesame both in quality and quantity. Sesame webworm (leaf roller) is the most serious pest of sesame accounting for approximately 90% of yield losses [12]. Despite the increasing demand and price of sesame in the world market, productivity of sesame is declining from 0.8 to 0.3 t/ha [13] because of inappropriate agronomic practice and pest out breaks in most parts of Ethiopia.

In the study area sesame webworm is becoming the most severe that attacks sesame starting from 2 weeks after emergence up to threshing. And therefore producers are spraying chemicals repeatedly (up to 5-times) on their infested field to control sesame webworm. Repeated insecticide spray increased cost of production through frequent sprays, because one spray costs about USD 31. Studies on schedule of chemical application (time and frequency of application) to control sesame webworm have not been conducted yet. Although farmers/producers are spraying insecticide many times they did not control sesame webworm effectively. This is attributed to knowledge gap on the time and frequency of application of the chemical. Objective of this study was

- To determine optimum insecticide application schedule (time and frequency) for managing sesame webworm infestation and enhancing sesame grain yield

2. MATERIALS AND METHODS

2.1 Experimental Location

A field experiment to investigate nine insecticide application schedule (time and frequency) was conducted in western Tigray at Humera Agricultural Research Center (HuARC), which is located at latitudes of 14°15' N, longitude 36°37' and elevation of 608m. The experimental site, *Humera* is under the administration of *Kafta Humera* district.

2.2 Experimental Design

The field experiment was conducted in 2015 cropping season laid out in randomized Complete Block Design (RCBD) with three replications. In order to minimize drift-effect during chemical spray the path between blocks and plots were wide enough (2 m and 2.5 m, correspondingly). net plot area was 9.6m^2. Total area of the experiment was 2288 m^2. Sesame seeds were planted in 40 cm inter and 10cm intra row spacing.

2.3 Insecticide Application Schedule

Dimethoate 40% a broad spectrum Pesticide was applied at a rate of 2 l/ha (factory recommendation rate) according to the treatments under natural environment. Larva detection has started two weeks after crop emergence (WAE).

Therefore, application of the insecticide was started 2WAE except for the weekly spray (check) which has started spraying before start of *A. catalaunalis* infestation (one week after emergence) up to maturity. The insecticide was applied at a rate of 800 g of active ingredient per hectare. Hand operated knapsack sprayer was used for chemical application. The treatments for the insecticide application schedule (*S*) is displayed bellow:

1. No spray(Control) (S1)
2. Once @ 2- weeks after emergence (WAE) (S2)
3. Once @ 4-WAE(S3)
4. Once @ 6-WAE (S4)
5. Once @8-WAE (S5)
6. Twice @2- and 4-WAE (S6)
7. Thrice @ 2,4- and 6-WAE (S7)
8. Four times @ 2,4,6- and 8-WAE (S8)
9. Weekly spray (check) (S9)

2.4 Data Collection

From the net plot area (8 central rows) five plants were selected randomly and tagged to collect the phenological, growth and yield component traits. Furthermore, the eight experimental rows excluding both margins (1 row each) to reduce boarder effect were harvested, tied in sheaves and were made to stand separately until the capsules opened. After the sheaves have dried out fully and all of the capsules opened, they were tipped out onto sturdy cloths and threshing was accomplished by knocking the sheaves. The seeds from each plot were weighed for yield determination. The detail description of the infestation is described below.

- **Incidence (INC %):** incidence of *A. catalaunalis* was recorded through total count of infected plants at any of plant part (leaf, flower and/or capsule) in the plot for six times in a fortnightly basis. It was calculated using the following equation:

$$\text{Incidence} = \frac{no.of\ infested\ plant}{\text{total plant in the plot}} * 100 \quad (1)$$

- **No. of larva (NLP):** larvae were counted from five randomly selected plants per plot. It was counted for six times in a fortnightly basis from plant part (leaf, flower, capsules and/or stem).

- **Leaf damage (LD%):** leaves that have some symptoms of *A. catalaunalis* attack like eaten internal part of the leaf (mesophyll tissue) and webbed leaves were taken as damaged leaves.

$$\text{Leaf Damage} = \frac{no.of\ infested\ leaf}{\text{total inspected leaves}} * 100 (2)$$

- **Flower damage (FD %):** webbed and tunneled flowers were considered as damaged flowers. Damaged flower per plant were recorded from flowers of the five randomly selected plants.

$$\text{Flower damage} = \frac{no.of\ infested\ flower}{\text{total inspected flowers}} * 100 \quad (3)$$

- **Capsule damage (CD%):** All burrowed capsules were taken as damaged capsules. Damaged capsules per plant were recorded from the five randomly selected plants and it was counted for three times in a fortnightly basis from capsules of the five plants.

$$\text{Capsule Damage} = \frac{no.of\ infested\ capsule}{\text{total inspected capsule}} * 100 \quad (4)$$

- **Seed loss of damaged capsule (SL%):** difference in number of seeds of the healthy and damaged capsules was considered as a seed loss. A single damaged and healthy capsules was taken from the same plant of five randomly selected plants for each plot during harvesting and number of seeds per each damaged and healthy capsules were counted, then the average of the counted seeds was taken. Seed loss was calculated as the following equation.

$$SL\,\% = \frac{NSPHC - NSPDC}{NSPHC} * 100 \quad (5)$$

Where, SL= % of seed loss of the damaged capsule, NSPHC= number of seeds per healthy capsule, NSPDC= number of seeds per damaged capsule

2.5 Data Analysis

A computer statistical software, Genstat-14 edition was used for data analysis. Means were compared using Duncan's Multiple Range Test

(DMRT), at P value of 0.01 probability level. Graphs were made using micro soft excel.

2.6 Economic Analysis

Price of grain per kg and total sale from one hectare, price of insecticides, cost of labor for spray and spray equipment rented was considered. Price of grain (Birr/kg) was obtained from local market and total sale from one hectare was computed. To measure the increase in net return associated with each additional unit of cost (marginal cost) [14], the marginal rate of return (MRR) was calculated as:

$$MRR\ (\%) = \frac{\Delta NI}{\Delta IC} \tag{8}$$

Where, MRR is marginal rate of returns, ∆NI – change in net income compared with control, ∆IC – change in input cost compared with control.

3. RESULTS AND DISCUSSION

3.1 *A. catalaunalis* Incidence

Time insecticide application schedule has a significant difference (p<0.01) on *A. catalaunalis* incidence. The maximum level of incidence (99.27%) was observed on the control plot which statically in par with all the one time sprayed plots, while lower incidence was observed on the frequently sprayed plots (Table 1). Comparing incidence of *A. catalaunalis* among sesame growth stages, capsule developmental stage of the crop has found to be the most infected (62.3%), while seedling growth stage was less infested (3.7%) (Fig. 2A).The reaction of leaf roller/capsule borer (*A. catalaunalis*) and gall fly to two sprayings of Endosulfan 0.07% at 30 and 45 days after planting proved to be the most effective [15].

The larval population has not statically differed among the insecticide application schedules except for the weekly sprayed one, which population buildup was lowered to about 3.5 larva per plant (Table 1). Number of larva per plant has significantly increased from 2.6 at seedling stage to 7.3 at capsule development (Fig. 2A). This could be due to the favorable environmental condition during the later growth stages of the crop (higher temperature and lower rainfall). Kumar et al. [16] reported that a strong negative correlation between larval population, maximum temperature, maximum relative humidity and limited rainfall. Similarly incidence of *A. catalaunalis* was higher in dry sunny weather than in wet weather condition, and out-break occurred, when a long dry spell had been preceded by heavy rains [17]. Same author added that there was a positive correlation between the abundance of the moth and the number of hours of sunshine and damage was found high, when the temperatures was high and the rainfall was low.

Generally the population beauildup is very high among all treatments, since 1-3 larva can distroy a fully grown sesame plant [18] and the economic injury level of the pest is 0.25 larva per meter square [19].

3.2 Sesame Damage by *A. catalaunalis*

With regard to the effect of insecticide application schedule, there was a minimum leaf and flower damage on the weekly sprayed plots and statically similar with all frequently sprayed plots (S6-S8). The highest damage of leaf (78-99%) and flower (36-38%) was recorded on the control and once sprayed plots (S1-S5). Minimum percent of seed loss per damaged capsule (32.01%) was calculated on the weekly sprayed plot (S9), while the maximum percent of seed loss per damaged capsule (91.46%) was recorded at the control (Table 1). From the results it could be noted that frequent insecticide spray had less leaf, flower and capsule damage and reduced seed loss. Four foliar applications of lambda cyhalothrin 5 EC, gave low % leaf damage (4.0%) followed by spinosad (4.8%) and the untreated check recorded highest % leaf damage (11%) in a field trial [20]. Related study had revealed that leaf and capsule damage were significantly lower (2 % each) on lambda-cyhalothrin sprayed plot, whereas there were higher in the unsprayed plots [21]. Considering the cost of applying pesticides, twice insecticide application at 2 and 4 weeks after sesame emergence gave good control for the pest Karuppaiah [22]. Similarly flower and capsule damage caused by *A. catalaunalis* was significantly controlled in three times Endosulfan sprayed plots, whereas maximum damage were in the unprotected plots [23]. Moreover, application of Spinosad 0.001% two times has significantly reduced larval population, flower and capsule damage over the control [24].

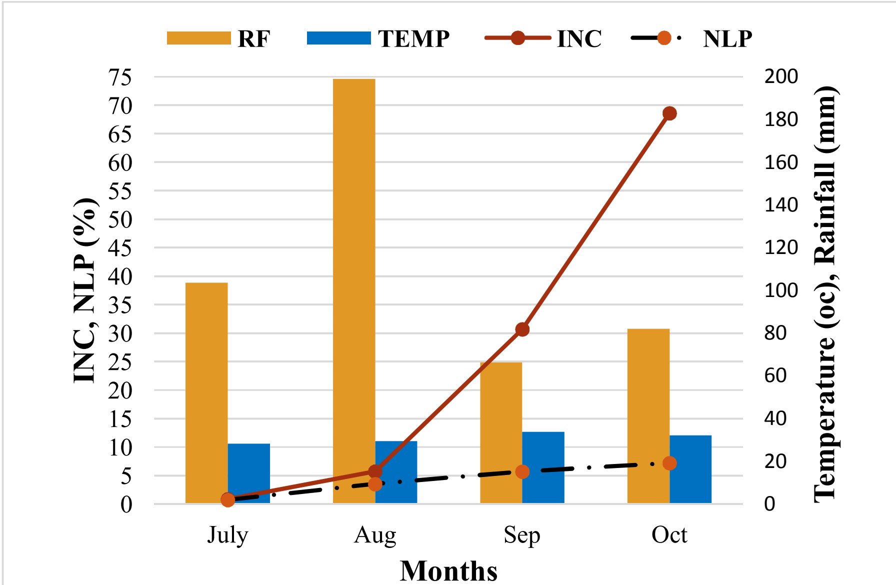

Fig. 1. ***Antigastira catalaunalis*** **infestation across months in the growing season**

INC= incidence (%), NLP=number of larva per plant, RF=rainfall (mm), TEMP= average temperature (°c)

Table 1. Main effect of time of Dimethoate application on A. catalaunalis incidence, yield and yield component of sesame

Treatments	INC (%)	LD (%)	FD (%)	CD (%)	SL (%)	NLP	NBP	NCP	NSC	GY (kg/ha)
S1	99.27^{b}	7.89^{c}	36.59^{b}	38.12^{a}	91.46^{d}	6.4^{ab}	2^{b}	35.13^{b}	38.87^{abc}	154.9^{a}
S2	78.67^{b}	4.25^{ab}	33.29^{ab}	38.99^{a}	33.86^{ab}	9^{b}	2.33^{c}	40.8^{c}	37.47^{ab}	260^{bc}
S3	81.46^{b}	6.77^{bc}	38.28^{b}	41.62^{a}	49.96^{abc}	10.4^{b}	2.53^{d}	42.93^{d}	27.8^{a}	287.2^{c}
S4	97.83^{b}	4.38^{ab}	37.54^{b}	31.65^{a}	77.83^{cd}	9.07^{b}	2.2^{c}	39.33^{c}	48.33^{bcd}	210.9^{b}
S5	89.05^{b}	6.04^{abc}	36.85^{b}	29.53^{a}	66.54^{bcd}	10.33^{b}	1.47^{a}	30.33^{a}	$48.4b^{cd}$	158.9^{a}
S6	36.31^{a}	4.08^{ab}	25.97^{ab}	29.58^{a}	58.93^{a-d}	6.87^{ab}	2.8^{e}	48.67^{f}	53.6^{cd}	391.1^{de}
S7	27.49^{a}	3.92^{ab}	25.43^{ab}	27.16^{a}	41.48^{ab}	7.47^{ab}	2.73^{e}	45.27^{e}	$47b^{cd}$	368.6^{d}
S8	30.99^{a}	3.78^{ab}	20.38^{a}	32.01^{a}	41.81^{ab}	6.53^{ab}	2.87^{e}	54.13^{g}	$51.6b^{cd}$	422.9^{e}
S9	19.5^{a}	3.20^{a}	19.61^{a}	31.74^{a}	32.01^{a}	3.47^{a}	3.27^{f}	58.67^{h}	55.8^{d}	536.6^{f}
SD(±)	10.95	1.79	8.38	7.85	17.65	2.43	0.09	1.01	8.23	28.574
CV (%)	17.6	36.4	27.5	23.5	32.2	31.4	3.6	2.3	18.1	9.2

Means followed by the same letter are not statistically different from each other (DMRT, at 1%), INC= percent of A. catalaunalis incidence per plant, LD=leaf damage, FD= percent of flower damage per plant, CD=percent of capsule damage per plant, SL=% of seed loss per damaged capsule, NLP= number of larva per plant, NBP=number of branch per plant, NCP= number of capsules per plant, NSC=number of seeds per capsule, BY= biomass yield, GY= grain yield, S=schedule, SD=standard deviation

As illustrated in (Fig. 2.B), the severity of damage of sesame plant parts varied from 4.9% on leaf up to 33.4% on capsule and (30.4%) on flower. Therefore, flower and capsule were the most exposed sesame parts to *A. catalaunalis* damage. This is in line with Karuppaiah and Nadarajan [25] who reported that 32.67% flower damage and 24.69% capsule damage. In the seedling stage leaf damage was as high as 47.7% but lower (4.9%) in the capsule developmental stage. This is exactly because of the radical increment of total leaves per plant from seedling to capsule developmental stage.

3.3 Yield and Yield Components of Sesame as Affected by Insecticide Application Schedules

When the insecticide application schedule was examined, the highest branch per plant (3.27) was recorded on the weekly sprayed plot and fewer branches per plant (1.47) from the 8WAE sprayed plot (S5). From this result, it can be concluded that early infestation of *A. catalaunalis* (seedling and vegetative stages) has a remarkable effect on number of branches, because infestation at seedling stage and during branch formation prohibit and kill growth of branches through direct feeding and webbing of young growing points.

In the comparison of means of insecticide application schedule, the highest number of capsule per plant and number of seed per capsule (58.67 and 55.8, correspondingly) was recorded on the weekly sprayed (S9), while the lowest (30.33) on 8WAE (S5) and number of seed per capsule (27.8) from 4 WAE but similar with the control statically (Table 1). The fact behind the higher capsule per plant and number of seed per capsule could be that the lower damage of leaf, flower and capsule in the weekly sprayed plot. In a sense it has high number of healthy leaf and flower, which allow to bear more fertile capsules. On the other way in the control there was high damage of leaf and flower that possibly reduced the number of healthy capsule as well as seeds.

In the inspection of insecticide application schedule, better grain yield (536.6 kg/ha) was harvested from the weekly sprayed, while the lowest (154.9 kg/ha) was from the control (Table 1). The weekly sprayed (S9) and all the more than one sprayed plots (S6-S9) have showed less incidence and severity but the control and all the one time sprayed plots were higher in incidence and severity. Muez [26] reported that highest yield (714kg/ha) of sesame was recorded from the plot treated with Dimethoate 40%EC applied at 2 l/ha for *A. catalaunalis*. Nayak, Gupta [23] reported that three spray of 0.07% endosulfan significantly reduced the capsule damage caused by *A. catalaunalis* and also increased the grain yield in all varieties of sesame.

3.4 Correlation of Sesame Grain Yield with *A. catalaunalis* Infestations

Yield of sesame was significantly related to all *A. catalaunalis* infestation parameters (Table 2). Grain yield per hectare was negatively and strongly correlated with *A. catalaunalis* incidence (r=-0.883) number of larva per plant (r=-0.745), leaf damage (r=-0.659), flower damage (r=-0.720), capsule damage (r=-0.693) and seed loss per damaged capsule (r=-0.626).

3.5 Economic Analysis

Results of the partial budget analysis indicated that insecticide application at 2 and 4 WAE had the higher net profit and a corresponding marginal rate of return. The most frequently sprayed (S9) plot has less net profit due to the cost of the sprayed chemicals (Table 3). Therefore, application of Dimethoate two times at 2 and 4 WAE (S6) had the higher net profit (USD **254.31)** which clearly confirmed that the additional capital invested in 2 and 4WAE insecticide application schedule has produced USD **2.06.**

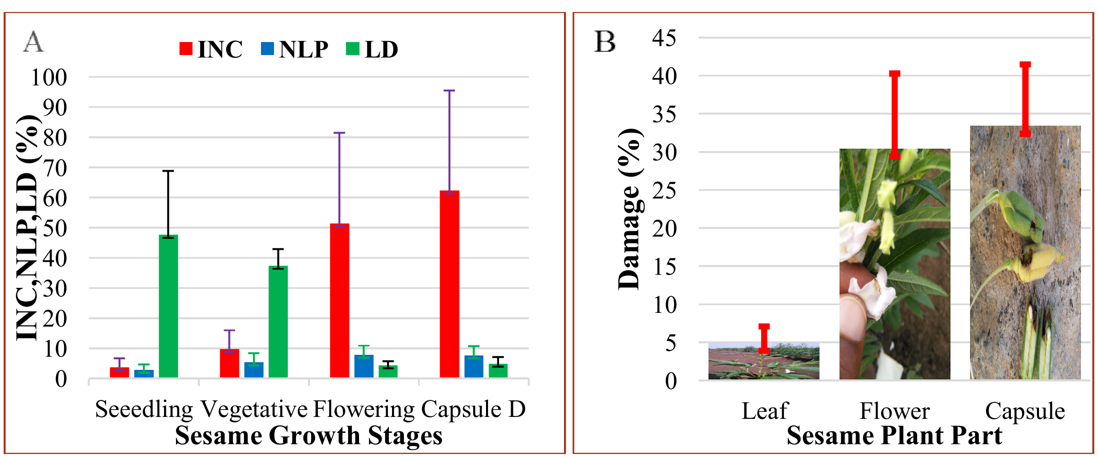

Fig. 2. *A. catalaunalis* incidence across sesame growth stages (A) and severity of damage across sesame plant parts (B)

INC=incidence, NLP=number of larva per plant LD=leaf damage,capsule D=capsule development

Table 2. Correlation of incidence severity and yield

	INC (%)	NLP	LD (%)	FD (%)	CD (%)	SL (%)
GY (kg/ha)	-0.883**	-0.745**	-0.659**	-0.720**	-0.693**	-0.626**

*** Highly significant at 0.0001% probability level NLP=number of larva per plant, LD=leaf damage, FD= flower damage, CD= capsule damage, SL = % of seed loss per damaged capsule, GY= grain yield*

Table 3. Partial budget analysis for schedule of insecticide application on *A. catalaunalis* at western zone of Tigray, Humera 2015

S/no	Cost benefit data	Insecticide application schedules (S)								
		S1	S2	S3	S4	S5	S6	S7	S8	S9
1	Yield kg/ha	139.41	234	258.48	189.9	143.01	351.9	331.74	380.7	482.94
2	Price USD/kg	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
3	Total revenue USD/ha (1*2)	125.47	210.60	232.63	170.91	128.71	316.71	298.57	342.63	434.65
4	Total input cost USD/ha	0.0	31.2	31.2	31.2	31.2	62.4	93.7	124.9	312.2
5	Net profit USD/ha (3-4)	125.47	179.40	201.43	139.71	97.51	**254.31**	204.87	217.73	122.45
6	Dominance (D)				D	D		D	D	D
					MRR					
7	Marginal cost USD/ha	0.0	31.2	31.2			62.4			
8	Marginal benefit USD/ha	0.0	53.93	75.96			128.84			
9	MRR (8/7) %	-	170.0	243.46			**206.47**			

MRR=marginal rate of return, WAE=weeks after emergence, S=Insecticide application schedules

4. CONCLUSIONS AND RECOMMONDATIONS

These insect is a major pest of sesame which can cause substantial yield loss. It is very difficult to eradicate the pest and its influence even through frequent insecticide application but up to 71% of yield could be saved if scheduled spray has been applied. The economic analysis revealed that, application schedule at 2 and 4 WAE is better for controlling *A. catalaunalis*. Further studies should be conduct on its integrated management basically for two reasons, I) to control the pest efficiently and II) to produce an organic sesame, since sesame buyers are demanding an organic grain due to consumer's safety aspects.

ACKNOWLEDGEMENTS

The authors are grateful for Tigray Agricultural Research Institute and sesame business network [27] for the financial support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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