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Management of Jassid, *Amrasca Biguttula* (Hemiptera: Cicadellidae), Through Synthetic and Botanical Insecticides and Its Effects on Associated Natural Enemies in Okra Crop

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ABSTRACT

The current study investigated the efficacy of synthetic insecticides (Thiamethoxam and Acetamiprid) and neem oil concentrations (2.5% and 5%) against jassid Amrasca biguttula biguttula (Ishida) on okra crop. The experiment was laid out in Randomized Complete Block Design (RCBD) replicated thrice. Thiamethoxam (25WG), Acetamiprid (20SP), and Neem oil in 5% and 2.5% concentrations along with a control were used. Data were recorded on the number of jassids and their related predators per plant, as well as okra yield in kg ha-1. Pre spray data was recorded before 24 hours of treatments application. The population of jassid plant-1 was recorded after 24 hours, 72 hours, 7 days and 14 days post-application of these treatments. A significant decrease in jassid population was observed after first and second spray. The best results were obtained from thiamethoxam treated plants (2.13, 2.01 jassids plant-1). Similarly, the insecticide acetamiprid was also effective against jassids (2.61, 2.35 plant-1) in okra field. Neem oil at 5% was also effective and significantly decreased jassid population (4.70, 4.35 plant-1), followed by neem oil 2.5% (5.22, 4.68 plant-1). However, maximum jassids (11.05, 11.88 plant-1) was observed in control plot. Data recorded on predators showed that the minimum ladybird beetle and green lacewing population was observed in the thiamethoxam (0.60, 0.56 plant-1), followed by acetamiprid (0.69, 0.65 plant-1). The same trend in both of the population of these predators was seen after secound spray application. However, both concentrations of neem oil were least affected the ladybird beetles and green lacewing populations. The maximum yield of okra in kg ha-1 was observed in the thiamethoxam (10111.0), followed by acetamiprid application (8964.5) kg ha-1. In the Neem oil concentrations, neem oil applied at 5% was produced the maximum yield (7736.0 kg ha-1) of okra. The findings in this study showed that the economic and cost benefits ratio are the highest for thiamethoxam (1:24.27), while the minimum for neem oil at 2.5 percent (1:16.70). The results obtained in this study showed that these treatments have the potential to decrease jassid infestation and increase okra yield.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is one of the central dietary vegetables originating from the Malvaceae family. Peoples of the subcontinent Okra is known by many different names such as "Bhendi" (Ndungurua and Rajabu, 2004). It is one of the most popular summer vegetables for home gardening as well as grown commercially worldwide in tropical and subtropical regions, particularly in the Indo-Pakistan sub-continent. Its origin is understood to be in the Ethiopian region of Africa (Naheed *et al*., 2013). Okra immature pods can be consumed in fresh and processed form as a boiled vegetable. (Saifullah and Rabbani, 2009).

The global production of okra was approximately 11.2 million tons per year in 2022, with India being the primary producer of okra. The other major producer countries are Nigeria, Mali, Pakistan, Sudan, Malaysia Afghanistan, Bangladesh, Japan, Iran, and Ethiopia (FAOSTAT, 2022). In Pakistan during 2022-23, the total okra cultivated area was 25261 hectares, with produced 308638 tons of yield. In Khyber Pakhtunkhwa okra was grown on 2071 hectares, while producing 13985 tons of yield. Punjab is the major producer of okra crop grown on 15024 hectares, with a yield of 252422 tons, followed by Baluchistan 22717, Sindh 19514, and Khyber Pakhtunkhwa 13985 (MNFS, 2023). A progressive increase in the area and production of okra has been seen in Pakistan. However, okra crop yield is badly affected by a variety of pests and insects.

Insect pests are one of the most vital problem in agricultural production. As per, the Food and Agriculture Organization (FAO), each year, insect pests cause 20% to 40% loss worldwide in agriculture yield (Ahmad *et al.*, 2021). Crop pests impact the yield and reduce it by up to 20-30%. However, in severe infestation pests contribute 80%-90% of crop losses. Insect pests are considered the main aspects that decrease the yield of okra crops. More than 70 different kinds of insect pest species have been reported till now in okra fields (Rahman *et al*., 2013).

Okra crop can be affected by various types of insects and diseases (Ek-amnuay, 2007; Fasunwon and Banjo, 2010). The chewing and sucking insects' pests attack from the vegetative to the reproductive phase and causes considerable harm to the okra plant. The major chewing pests include the fruit borer (*Helicoverpa armigera* H.) and the shoot borer (*Earias* spp.) which severely affect okra crop. Okra is vulnerable to a huge variety of insect pests and pathogens. Crickets can be distracting during the early stages of crop germination, while thrips, jassids, whiteflies, and other phloem feeders are widespread throughout the vegetative stage. (Fajinmi and Fajinmi, 2010). Major sucking pests of okra are jassid (*Amrasca biguttula* L.), thrips (*Thrips tabaci* L.) and whitefly (*Bemisia tabaci* G). Jassid, *Amrasca biguttula* (Hemiptera: Cicadellidae), is considered the major polyphagous pest of various crops. It retards plant growth while sucking cell sap from the host plant and exchanging toxins that damage plant photosynthesis (Asi *et al*., 2008).

Jassid feed on vascular tissues and mesophyll cells by eating and ovipositing on the leaves, okra jassid inflict both direct and indirect harm to the okra crop. This damage includes hopper burn, curling, chlorosis, and reddening of the marginal leaves. These insects' role as vectors of some pathogenic diseases jassid are also major vectors of plant diseases that transport pathogens (for example, *Xylella fastidious*, which causes Pierce's disease). that cause grapevine yellows that affect economically and ecologically important crops worldwide (Weintraub and Beanland, 2006; Musetti, 2008; Olivier *et al*., 2012). Jassid are piercing-sucking insects that consume leaf tissue and cell sap. Uncontrolled jassid populations cause significant damage to plant foliage. As a result, loss of chlorophyll in the leaf cells occurred and it led to immature leaf abscission. If left uncontrolled, loss of total yield may happen (Martinson *et al*., 1997).

The okra crop is very necessary for the keep himself alive and feeding of jassid. Therefore, jassid is reducing okra production up to 50–63%. In addition, jassid reduced leaf size by 45.1% and plant height by 49.8% (Singh *et al*, 2002). To examine the life cycle of the jassid on a variety of okra, it takes approximately 6.27 days to hatch. The hatchability of jassid eggs is 91.9%, and their nymphs have five instars during a period of 1.5, 1.1, 1.2, 2.0, 1.5 days Mean pre-mating, pre-observation, oviposition and post-oviposition period are 2.55, 3.45, 16.57, and 3.90 days, in that order.

To control pest population instantly while keeping crop yield safe from damage, insecticidal chemicals are being utilized to lower the insect population from the ETL level. Different measures have been implemented to manage the pests in okra such as jassid. Chemical control is a crucial part of an Integrated Pest Management (IPM) program to avoid agricultural harms due to insect pests and diseases since it is the best method of quick pest control (Satpathy *et al*., 2004).

Among the chemicals, currently neonicotinoids are the most widely used insecticides to combat sucking insect pests. The chemical-based insecticides are quick and have a great knockdown effect to control jassid. Thiamethoxam, a neonicotinoid insecticide with a wide range of effectiveness, is applied to various crops to shield them from invading pests like jassid, aphids, thrips, and white-flies (Jan *et al*., 2022).

Acetamiprid, a neonicotinoid insecticide, is a relatively recent addition to the insecticide market. Its distinct mechanism of action effectively combats numerous significant pests that had previously developed resistance to many other insecticides. Acetamiprid exhibits remarkable selectivity, ensuring excellent management of sap-sucking insects like jassid, aphids and whiteflies while sparing non-target animals from adverse consequences (Ambrose, 2003).

Botanical extracts can be used to manage the pest issues as an unconventional to chemical insecticides and have shown low poisonousness to mammals (Rizvi *et al*., 2015). Neem oil, neem leaf extract, and seed kernel extract are all extremely effective when sprayed against thrips, aphids, jassids, and whiteflies. Furthermore, certain plant items such as *Chrysanthemumi* spp. and *Rotenonei* spp. were employed as insect repellents in addition to antifeedants to manage the insect pest that targets different types of crops (Hugar *et al*., 1990).

Jassid predators include the spider (*Lycosa pseudounnulatai*) green lacewing (C. *carnea*) and ladybird beetle (C. *septumpunctata*) and predatory mites, *Amblysieus* spp. In the okra ecology, spiders, Chrysopids, *Apanteles* sp., and Coccinellids constituted the most prevalent predatory populations. In comparison to pesticides plant extracts caused less threat to predators and other natural enemies (Smitha. 2002 and Balikai *et al*., 2004).

However, overuse of pesticides can result in major issues such as the death of natural enemies, pollinators, and a decrease in nitrogen fixation (Miller, 2004). Integrated pest management (IPM) is one of the best alternative methods to chemical-based pest control. IPM can provide an environmentally safe and sound pest control strategy that ultimately reduces the use of chemical pesticides and also solves human health issues worldwide (Murovhi *et al*., 2020).

Therefore, the current field study was conducted to estimate the potential efficacy of Neonicotinoids (Acetamiprid and Thiamethoxam) and neem oil (2.5% and 5%) against jassid and its side effects on associated predators (ladybird beetle and green lacewing) in okra crop under field condition, with the below main objectives.

Objectives

1. To study the effect of synthetic insecticides (Acetamiprid and Thiamethoxam) and at different concentrations of Neem oil on the population of jassid *(Amrasca biguttula biguttula* I.*)*.
2. To study the effect of tested treatments on the population of associated predators.
3. To study the effect of tested treatments on the yield of okra.

MATERIALS AND METHODS

The experiment was conducted to evaluate the potential efficacy of thiamethoxam, acetamiprid, and neem oil (2.5% and 5%) against jassid and its side effects on the population of associated predators in okra crops under field conditions. The field study was performed at New Developmental Farm, Malakander, The University of Agriculture Peshawar, Pakistan.

Experimental Design

There was a total of five experimental treatments including control that comprises Acetamiprid 20sp, Thiamethoxam 25wg, neem oil seed extract at the rate of 2.5% and 5% neem oil concentrations and each treatment was thrice replicated in a Randomized Complete Block Design (RCBD).

Field Preparation

The field was prepared with the help of plough and cultivator for the sowing of local okra variety swat green. Sowing was done by dibbling method with a spacing of 45cm×30cm. Buffer zone area of 1 meter wide was kept between replications to separate them from each other, Each plot was measured 4x4 meters, while plots were separated by non-crop area with 0.5 meters. Agronomic practices were performed equivalently including hoeing, ploughing, irrigation, and weeding.

Monitoring and Data Collection

The okra crop was visited at regular intervals from germination to harvest. The data was recorded one day before and one day after spraying at 24 hours, 72 hours, 7 days, and 14 days respectively after each application. Treatment applications were sprayed on the foliage of the okra crop after the jassid population reaches to economic threshold level (2 nymphs’ leaf^{-1}).

Treatments Groups

Table 1

Treatments	Common name	Active ingredient	Recommended dose
1	Acetamiprid (20SP)	Acetamidine	125gm/acre
2	Thiamethoxam (25WG)	Thiamethoxam	48gm/acre
3	Neem oil 2.5% (S.E*)	Azadirachtin	25ml/L
4	Neem oil 5% (S.E*)	Azadirachtin	50ml/L
5	Control	Distilled water	------

S.E. Seed extract*

Acetamiprid

Acetamiprid was bought from the local market of Peshawar which contains 20% active ingredient as a soluble powder formulation. It was dissolved at proper concentration (125gm/acre) in water before applying to the okra field.

Thiamethoxam

Thiamethoxam is also available in powder form. Thiamethoxam was bought from the local market of Peshawar. The specific concentration (48gm/acre) of powder was dissolved in water before applying it to the foliage of okra.

Neem Oil (Seed extract)

Neem oil is a naturally existing insecticide contained in neem tree seeds. Neem was bought from the local market of Peshawar (pansari shop). Afterwards, an insecticidal soap was completely dissolved in water in a spray tank and in this mixture specific concentrations of neem oil, @2.5% and @5% were prepared for field application using the below formula.

$C1\ V1 = C2\ V2$

Where:

V1= volume to be taken from stock solution to make the desired concentration

C1= concentration of stock solution

V2= required volume

C2= required concentration

Treatments Application

The two treatments application were applied in the okra field during the whole experiment. All treatments were applied when the jassid population reached to the economic threshold level (2 nymphs/leaf) (Jan *et al*., 2022). The data was recorded at 24 hours, 72 hours, 7days, and 14 days respectively after the first application of the spray. The 2nd application was applied to the foliage of the okra crop after 15 days due to the population of jassid again equaling (ETL).

Parameters

1. Population of jassid plant^{-1}
2. Number of natural enemies plant^{-1}
3. Yield (kg ha^{-1})
4. Biological efficacy
5. Benefit cost ratio

Population of jassid

The jassid population were examined before the treatment application to estimate the economic threshold level (ETL), which is 2nymphs/leaf (Jan *et al*., 2022). When the population of jassid reaches ETL, treatments were applied. Five plants were selected per plot and the population of jassid was recorded on three foliage; one of the tops, mid, and bottom of a canopy of okra plant (Farooq and Tasawar, 2008). Data were recorded at 24 hours, 72 hours, 7 days, and 14 days intervals.

Number of Natural Enemies

The natural enemies that feed on jassid, like the ladybird beetle and green lacewing, were recorded through the naked eye after applying spray on the foliage of okra crop. Five plants were selected randomly per plot and each plant was examined from top, mid, and bottom leaf. The number of natural enemies were recorded and calculated for each plot at 24 hours, 72 hours, 7 and 14 days.

Yield (kg/ha)

The yield data was recorded from the first mature harvested fruits till the last fruit harvested. The yield in each treated and control plot was recorded and then converted to kg ha^{-1} and the overall yield was calculated using the formula given below (Sajid *et al*., 2012).

$$\text{Yield kg ha}^{-1} = \frac{yield\ per\ plot\ x\ (kg)}{plot\ area\ (m2)} \times 10000\ \text{m}^2$$

Biological Efficacy

The biological efficacy of neem oil (2.5% and 5%), thiamethoxam, and acetamiprid insecticides were calculated in terms of % mortality of pests by using Abott's formula (Young, 2009).

$$\%\ \text{B.E} = \frac{control\ plot - treated\ plots}{control\ plot} \times 100$$

Cost Benefit Ratio

To evaluate the best treatment against sucking insect pests, benefit cost ratio was calculated using the following formula (Choudhury *et al*., 2021).

$$Cost\ benefit\ ratio = \frac{Value\ of\ yield}{Total\ cost\ of\ plant\ protection}$$

Table 2

Treatments	Yield (kg/ha) A	Gross income B	Cost of control ha^{-1} (Rs) C	Estimated net benefit (Rs) ha^{-1} D(B-C)	B:C E(D/C)

Statistical Analysis

The data collected was analyzed through a software Statistix 8.1 and the significance of test was done at 5% level significance. Least significant difference (LSD) test was used to compare the mean of different treatments in case of significant F-test (Steel and Torrie, 1980).

RESULTS

The effect of thiamethoxam and acetamiprid insecticides and different concentrations of neem oil (2.5% and 5%) were studied against jassid population in okra crop. The result obtained from the experiment are given as under

Effect of various treatments on population of jassid plant^{-1} after first application

The result obtained after the application of thiamethoxam, acetamiprid and neem oil concentrations (2.5% and 5%) against population of Jassid showed statistically significant results (Table-4.1). The data showed that minimum number of jassid (2.13 plant^{-1}) was recorded in plot treated with thiamethoxam, followed by acetamiprid (2.61 plant^{-1}). However, the highest population of jassid (11.05 plant^{-1}) was observed in control plot. In efficacy, synthetic insecticides were followed by botanicals. The minimum population of Jassid (4.70 plant^{-1}) was recorded in 5% neem oil followed by the 2.5% concentration with population of (5.22 plant^{-1}). Jassid.

Efficacy of different treatments against jassid population was observed for a period of 14 days after its application. Results showed that population of jassid was lower at 72 hours and 7 days post-application. The data recorded at 72 hours post application showed minimum population of jassid (3.93 plant^{-1}), followed by 7 days with jassid infestation (4.27 plant^{-1}). Whereas, the maximum jassid infestation (7.77 plant^{-1}) was reported at 14 days of first application, followed by 24 hours (4.87 plant^{-1}) (Table 3).

Treatments effect with respect to the interaction of treatments and time intervals was found significant (appendix-1). Results showed that the number of jassids recorded after 72 hours and 7 days in thiamethoxam and acetamiprid were found statistically at par with each other's, while the lowest jassid infestation (0.86 plant^{-1}) was recorded in thiamethoxam treated plants at 7 days after 1st spray application, followed by acetamiprid (1.00 plant^{-1}) at 72 hours. Both neem oil concentrations at 7 days were found statistically similar, while the lowest jassid infestation (3.47plant^{-1}) was found in neem oil (5%) after 72 hours, followed by neem oil (2.5%) with jassid infestation (3.53 plant^{-1}) after 72 hours. The highest numbers of jassid (12.46plant^{-1}) was observed in untreated plot at 14 days of 1st spray application (Table 3).

Table 3

Effect of various treatments on population of jassid plant^{-1} after first application in okra crop

Treatments	Time Interval					Mean
	Pre-spray	24hour	72hour	7days	14days	
Thiamethoxam 25WG	9.77	2.43 j	0.90 k	0.86 k	4.33gh	2.13 e
Acetamiprid 20SP	8.27	2.63 j	1.00 k	1.03 k	5.96 e	2.61 d
Neem oil 5%	8.23	4.20 gh	3.46 i	3.90 hi	7.23 d	4.70 c
Neem oil 2.5%	8.17	4.97 f	3.53 i	4.67 fg	7.73 d	5.22 b
Control	9.17	10.13 c	10.76 b	10.83 b	12.46 a	11.05a
Mean	8.11	4.87b	3.93d	4.27c	7.54a	

Mean followed by different letters in row and columns are significantly different at 5% from each other

LSD value for time interval = 0.1273

LSD value for treatment = 0.1396

LSD value for the interaction of treatment x time interval = 0.2722

Effect of various treatments on jassid population plant^{-1} after secound application

The data collected after the application of thiamethoxam, acetamiprid and neem oil concentrations (2.5% and 5%) against population of Jassid showed statistically significant (Table-4.1). The results displayed that lowest jassid infestation (2.01 plant^{-1}) was observed in thiamethoxam plot, followed by acetamiprid with population of jassid (2.35 plant^{-1}). In efficacy, synthetic insecticides followed by botanicals neem oil. In botanicals the minimum jassid infestation (4.35 plant^{-1}) was observed in neem oil (5%) followed by neem oil (2.5%) with jassid infestation of (4.68 plant^{-1}). At the same time, the maximum number of jassids (11.88 plant^{-1}) was found in control after the second spray.

The effect of different treatments regard various times intervals. Result showed the jassid population recorded after 72 hours and 7 days were found statistically at par with each other's, while population of jassid (4.19 plant^{-1}) was lower at 72 hours post application of different treatments compared to the control plot, followed by at 7 days with the population of (4.01 plant^{-1}) jassid. However, maximum jassid infestation (7.04 plant^{-1}) was observed at 14 days, followed by 24 hours with jassid infestation of (4.96 plant^{-1}).

Treatments effect with respect to the interaction between treatments and time intervals calculated significant (appendix-2). The results showed that the population of jassid recorded after 72 hours and 7 days in thiamethoxam and acetamiprid were found statistically at par with each other's, while minimum jassid population was observed (0.86 plant^{-1}) in plants treated with thiamethoxam at 7 days, followed by acetamiprid (0.93 plant^{-1}) at 7 days after secound spray application. However, the highest jassid infestation was recorded at 14 days in control plot. Both neem oil concentrations at 7 days were found statistically similar, while the minimum jassid infestation of (3.06 plant^{-1}) at 7 days in (5%) neem oil concentration, followed by (2.5%) neem oil with jassid population of (3.20 plant^{-1}) after 2nd spray application.

Table 4

Effect of various treatments on the population of jassid plnt^{-1} after secound application in okra crop

Treatments	Time Interval				Mean
	24hour	72hour	7days	14days	
Thiamethoxam 25WG	2.13 j	0.90 k	0.86 k	4.16 ef	2.01 e
Acetamiprid 20SP	2.63 ij	0.93 k	0.93 k	4.86 d	2.35 d
Neem oil 5%	4.33 def	3.33 gh	3.06 hi	6.66 c	4.35 c
Neem oil 2.5%	4.66 de	3.83 fg	3.20 hi	7.03c	4.68 b
Control	11.06 b	11.96 a	12.00 a	12.50 a	11.88 a
Mean	4.96 b	4.19 c	4.01 c	7.04 a	

Mean followed by different letters in row and columns are significantly different ($p < 0.05$) from each other

LSD value for treatment = 0.1562

LSD value for time interval = 0.1397

LSD value for the interaction of treatment x time interval = 0.3125

Effect of various treatments on population of Lady bird beetle plant^{-1} at field condition after 1st spray

The results obtained from the experiment showed that synthetic insecticides (Thiamethoxam and Acetamiprid) and botanicals neem oil concentrations (2.5% and 5%) significantly affected the population of ladybird beetle in okra crop after 1st spray (Table 5). however, the population in both neem oil concentrations were found statistically at par with each other's. Results showed that maximum ladybird beetle population (2.26 plant^{-1}) was observed in untreated plot, followed by neem oil (2.5%) with ladybird beetle population (1.55 plant^{-1}). However, the minimum ladybird beetle population (0.60 plant^{-1}) was recorded in plot treated with thiamethoxam, followed by acetamiprid and neem oil 5% with population of (0.69 plant^{-1}) and (1.48 plant^{-1}) respectively.

Effect of different treatments on the population of ladybird beetle was recorded at various time intervals. Results showed that the population of ladybird beetles at 72 hours and 7 days were found statistically similar. the highest ladybird beetle population (1.56 plant^{-1}) was found at 14 days. Whereas, the minimum ladybird beetle population (1.16 plant^{-1}) was observed at 24 hours after first spray application. Followed by 72 hours and 7 days with ladybird beetle population (1.29 plant^{-1}) and (1.26 plant^{-1}) interval.

Effect of different treatments on the Population of ladybird beetle regarding interaction was found statistically significant (appendix-3). However, the population of ladybird beetles at 72 hours and 7 days in thiamethoxam and acetamiprid were found statistically similar. Results displayed that maximum ladybird beetle population was recorded (2.50 plant^{-1}) in control at 14 days after first spray application followed by (2.5%) with ladybird beetle population (1.30 plant^{-1}). However, the minimum population (0.40 plant^{-1}) was recorded in thiamethoxam at 7 days, followed by acetamiprid and neem oil (5%) with ladybird beetle population of (0.63 plant^{-1}) and (1.20 plant^{-1}) intervals at 72 hours and 24 hours after first spray application.

Table 5

Effect of various treatments on population of ladybird beetles' plant^{-1} after first spray

Treatments	Time Intervals					Mean
	Pre-spray	24hour	72hour	7days	14days	
Thiamethoxam 25WG	1.2	0.53 kl	0.60 kl	0.40 m	0.83 ij	0.60 d
Acetamiprid 20SP	1.4	0.70 jk	0.63 kl	0.63 kl	0.90 i	0.69 c
Neem oil 5%	2.0	1.20 h	1.43 dg	1.66 de	1.80 d	1.48 b
Neem oil 2.5%	2.0	1.30 gh	1.53 f	1.66 de	1.82 d	1.55 b
Control	2.1	2.03 c	2.20 b	2.33 b	2.50 a	2.26 a
Mean	1.7	1.16 c	1.26 b	1.29 b	1.56 a	

Mean followed by different letters in row and columns are significantly different ($p < 0.05$) from each other
LSD value for treatment = 0.0398
LSD value for time interval = 0.0356
LSD value for the interaction of treatment x time interval = 0.0795

Effect of various treatments on population of Lady bird beetle plant^{-1} at field condition after 2nd spray application

The results obtained from the experiment showed that synthetic insecticides (Thiamethoxam and Acetamiprid) and botanicals neem oil concentrations (2.5% and 5%) significantly affected the population of ladybird beetle in okra crop after 1st spray (Table 5). Results showed that maximum ladybird beetle population (2.05 plant^{-1}) was observed in control plot, followed by neem oil (2.5%) with ladybird beetle population (1.55 plant^{-1}). However, the minimum ladybird beetle population (0.75 plant^{-1}) was recorded in plot treated with thiamethoxam, followed by acetamiprid and neem oil 5% with population (0.88 plant^{-1}) and (1.41 plant^{-1}) respectively.

The effect of different treatments on the ladybird beetle population was recorded at various time intervals. Results showed that the population of ladybird beetles at 24 hours and 72 hours were found statistically similar. The highest ladybird beetle population (1.52 plant^{-1}) was found at 14 days. Whereas, the minimum ladybird beetle population (1.19 plant^{-1}) was observed at 24 hours after first spray application, followed by 72 hours and 7 days with ladybird beetle population (1.20 plant^{-1}) and (1.40 plant^{-1}) respectively.

Effect of different treatments on the Population of ladybird beetle regard interaction of treatments and time intervals was found statistically significant (appendix-3). However, the population of ladybird beetles in both neem oil concentrations after 24 hours and 14 days were found statistically at par with each other's. The similar trend was also recorded in thiamethoxam after 24 hours 72 and 7 days and in acetamiprid after 24 hours and 7 days. Whereas, the maximum ladybird beetle population (2.10 plant^{-1}) was reported in untreated at 14 days after first spray application, followed by (2.5%) with ladybird beetle population (1.70 plant^{-1}). However, the minimum population (0.63 plant^{-1}) was recorded in thiamethoxam at 7 days, followed by acetamiprid and neem oil (5%) with ladybird beetle population of (0.73 plant^{-1}) and (1.10 plant^{-1}) respectively at 72 hours and 24 hours after first spray application.

Table 6

Effect of various treatments on population of ladybird beetles' plant^{-1} after secound spray

Treatments	Time Intervals				Mean
	24hour	72hour	7days	14days	
Thiamethoxam 25WG	0.66 h	0.70 h	0.63 h	1.00 ef	0.75 e
Acetamiprid 20SP	0.86 fg	0.73 gh	0.76 gh	1.16 d	0.88 d
Neem oil 5%	1.73 b	1.10 de	1.10 de	1.73 b	1.41 c
Neem oil 2.5%	1.63 b	1.46 c	1.40 c	1.70 b	1.55 b
Control	2.10 a	2.03 a	2.06 a	2.00 a	2.05 a
Mean	1.19 c	1.20 c	1.40 b	1.52 a	

Mean followed by different letters in row and columns are significantly different($p < 0.05$) from each other
LSD value for treatment = 0.0407
LSD value for time interval = 0.0364
LSD value for the interaction of treatment x time interval = 0.0813

Effect of various treatments on the population green lacewing plant^{-1} after first spray application

Effect of synthetic thiamethoxam, acetamiprid and two neem oil concentrations (2.5% and 5%) on population of green lacewing was found statistically significant (Table 4.5). however, the mean population recorded in both neem oil concentrations were found statistically at par with each other's. Results revealed that maximum number of green lacewing (2.20 plant^{-1}) was recorded in control plot. Whereas, minimum population of green lacewing (0.56 plant^{-1}) was found in plot treated with thiamethoxam, followed by acetamiprid (0.65 plant^{-1}). In neem oil concentrations, neem oil (5%) was reported with lowest population (1.43 plant^{-1}), followed by Neem oil, 2.5% (1.48 plant^{-1}).

The data concern Population of Green lacewing effected by different treatments at various time intervals. Results showed that highest numbers of green lacewing (1.53 plant^{-1}) were found at 14 days. However, the minimum green lacewing population (1.07 plant^{-1}) was observed at 24 hours after first spray application, followed by 72 hours and 7 days with green lacewing population (1.20, 1.23 plant^{-1}) respectively after first spray of application.

The data with respect to interaction between treatments and time intervals found significant (appendix-5), while data recorded in thiamethoxam and acetamiprid after 14 days were found statistically similar. Also, the similar trend was found in acetamiprid after 24 hours and 72 hours. However, the maximum green lacewing population (2.43 plant^{-1}) was observed in control plot after 14 days of first spray. However, the minimum population (0.40 plant^{-1}) was recorded at 7 days in thiamethoxam, followed by acetamiprid with population of green lacewing (0.50 plant^{-1}) at 7 days after first spray application. In neem oil concentrations lowest number green lacewing (1.10 plant^{-1}) was recorded in neem oil (5%) at 24 hours, followed by neem oil (2.5%) with population of green lacewing (1.23 plant^{-1}) at 24 hours after 1st spray application.

Table 7

Effect of various treatments on the population of green lacewings plant^{-1} first spray application

Treatments	Time interval					Mean
	Pre- spray	24hrs	72hrs	7 days	14 days	
Thiamethoxam 25wg	1.2	0.50lm	0.53l	0.40m	0.83k	0.56 d
Acetamiprid 20sp	1.4	0.60l	0.60l	0.50lm	0.90k	0.65 c
Neem oil 5%	2.0	1.10j	1.33hi	1.50fg	1.80d	1.43 b
Neem oil 2.5%	2.0	1.23i	1.40gh	1.60ef	1.70de	1.48 b
Control	2.1	1.93c	2.13b	2.33a	2.43a	2.20 a
Mean	1.7	1.07 d	1.20 c	1.23 b	1.53 a	

Mean followed by different letters in row and columns are significantly different ($p < 0.05$) from each other
LSD value for treatment = 0.0290
LSD value for time interval = 0.0260
LSD value for the interaction of treatment x time interval = 0.0580

Effect of various treatments on population of green lacewing plant^{-1} at field condition after 2nd spray application

Effect of synthetic insecticide thiamethoxam, acetamiprid and two neem oil concentrations (2.5% and 5%) on population of green lacewing found statistically significant (Table 4.5). Results displayed that maximum number of green lacewing (2.13 plant^{-1}) was recorded in control plot. Whereas, minimum green lacewing population (0.75 plant^{-1}) was found in plots treated with thiamethoxam, followed by acetamiprid (0.85 plant^{-1}). In neem oil concentrations, neem oil (5%) was reported with lowest population (1.35 plant^{-1}) among test treatments, followed by Neem oil 2.5% (1.53 plant^{-1}).

The data concern Population of Green lacewing effected by different treatments at various time intervals. Results showed that the population recorded after 72 hours and 7 days were found statistically similar, while the maximum green lacewing population (1.50 plant^{-1}) was observed at 14 days, followed by 24 hours (1.41 plant^{-1}). However, the minimum green lacewing population was observed at 7 day and 72 hours (1.20, 1.17 plant^{-1}) respectively.

Treatments effect with respect to interaction of treatments and time intervals observed significant (appendix-6), while data recorded in thiamethoxam and acetamiprid after 14 days were found statistically similar. Results showed that the population of green lacewing was statistically similar in 2.5 neem oil concentration after 24 hours and 14 days. The maximum population of green lacewing was found (2.23 plant^{-1}) in control at 24 hours after 2nd spray. The lowest population (0.56 plant^{-1}) was observed in plants treated with thiamethoxam at 7 days, followed by acetamiprid with number green lacewing (0.63 plant^{-1}) at 7 days. Effect neem oil concentrations on population of green lacewing. The minimum population (1.03 plant^{-1}) was found in neem oil (5%) at 72 hours. followed by neem oil (2.5%) with number of green lacewing (1.46 plant^{-1}) at 7 days after 2nd application.

Table 8

Effect of various treatments on population of green lacewings plant^{-1}after secound spray application

Treatments	Time Interval				Mean
	24hour	72hour	7days	14days	
Thiamethoxam 25WG	0.66ij	0.70ij	0.56j	1.06fg	0.75 e
Acetamiprid 20SP	0.86h	0.73hi	0.63ij	1.16fg	0.85 d
Neem oil 5%	1.66c	1.03g	1.20f	1.50de	1.35 c
Neem oil 2.5%	1.63cd	1.50e	1.46e	1.63cd	1.53 b
Control	2.23a	2.13ab	2.00b	2.16a	2.13 a
Mean	1.41 b	1.20 c	1.17 c	1.50 a	

Mean followed by different letters in row and columns are significantly different ($p < 0.05$) from each other
LSD value for treatment = 0.0369
LSD value for time interval = 0.0330
LSD value for the interaction of treatment x time interval = 0.0738

Yield and cost benefit details of Thiamethoxam, Acetamiprid and neem oil against jassid in okra field

Effect of synthetic thiamethoxam, acetamiprid and neem oil concentrations (2.5% and 5%) on yield of okra was found statistically significant (Table 4.7). Results revealed that the thiamethoxam-treated plot produced the maximum yield (10111.0 kg/ha), followed by acetamiprid with yield (8964.5 kg/ha). Whereas, the minimum yield was obtained from control plot (5625.1 kg/ha). In neem oil concentrations, neem oil (5%) was produced maximum yield (7736.0 kg/ha), followed by neem oil (2.5%) with yield of (7083.3 kg/ha^{-1}).

Results concern economic and cost benefit detail of the experiments, displayed in term of the return-benefit ratio for investing one Pakistani rupee. The benefit cost ratio showed that, the highest B:C ratio (1:24.27) was reported for the plot treated with thiamethoxam, followed by acetamiprid B:C (1:21.41). In neem oil concentrations neem oil 5% (1:17.37) was recorded maximum B:C, followed by neem oil 2.5% (1: 16.70).

Table 9

Yield and cost benefit details of insecticide and neem oil against jassid in okra field

Treatments	Yield (kg/ha) A	Gross income B	Cost of control ha^{-1} (Rs) C	Estimated net benefit (Rs) ha^{-1} D(B-C)	B:C E(D/C)
Thiamethoxam 25wg	10111.0a	505550	20000	485550	1:24.27
Acetamiprid 20sp	8964.5b	448200	20000	428200	1:21.41
Neem oil 5%	7736.0c	386800	21000	364800	1:17.37
Neem oil 2.5%	7083.3c	354165	20000	334165	1:16.70
Control	5625.1d	381255	-------------	-------------	-------

LSD value for treatments= 1.6963

Biological efficacy of various treatments used against jassid

Biological efficacy of thiamethoxam, acetamiprid and two Neem oil concentrations against jassid infestation of both spray application (first and second spray) showed in Table 4.8. Results showed that highest percent reduction of jassid (82.01%) was recorded for thiamethoxam, followed by acetamiprid with percent reduction of jassid (79.34%). In neem oil concentrations, maximum percent reduction (62%) was found in plot treated with neem oil (5%), while the minimum percent reduction of jassid (58%) was recorded for neem oil 2.5%.

Table 10

Biological efficacy of various treatments used against jassid

Treatments	Mean Infestation 1st and 2nd Spray	Biological efficacy (%)
Thiamethoxam 25wg	2.02	82.01%

Acetamiprid 20sp	2.32	79.34%
Neem oil @5 %	4.26	62.06%
Neem oil @ 2.5 %	4.62	58.86%
Control	11.2	

DISCUSSION

Study was conducted to evaluate the efficacy of synthetic insecticides (Thiamethoxam and Acetamiprid) and neem oil concentrations (5 and 2.5 percent) against jassid *Amrasca biguttula biguttula* (Ishida) in okra *Abelmoschus esculentus* under field condition. Moreover, all treatments were applied to separate plots to evaluate the effect of these treatments on the population of jassid, concern predators and data okra of yield, which recommended to the indigenous plant protectionist for better management of jassid.

Results showed that mortality of jassid through synthetic insecticides (Thiamethoxam and Acetamiprid) and botanical neem oil concentrations (5% and 2.5%) was found to be statistically significant during the whole experiment. All treatments significantly affected the jassid population over control plot. Among the all treatments, the best results showed that the minimum number of jassid (2.13, 2.01) per plant was found in thiamethoxam treated plants, while the maximum jassid infestation (11.05, 11.88 plant^{-1}) observed in control plot, followed by 2.5 neem oil concentration (5.22, 4.65 plant^{-1}). Our results similar with results of Kumar *et al.* (2020) who reported that the neonicotinoid and neem oil effectively reduced population of jassid, in the resulting produced the maximum yield of okra. He conducted a study to evaluate the efficacy of thiamethoxam (25WG) and neem oil (seed extract) at 5%. Further he stated that thiamethoxam has best application to reduce the jassid population up to 84.54 percent, while neem oil at 5% application reduced (62.54 percent) the jassid population. Moreover, Karar *et al.* (2013) and Patel (2014) found that thiamethoxam was more effective than imidacloprid for the management of jassid after seven and ten days of spray. Further Madhuri and Sasya (2018) evaluated the different synthetic and botanical insecticides and stated that thiamethoxam, acetamiprid and neem oil effectively control jassid population. Synthetic and botanical insecticides were sprayed on okra where thiamethoxam was the leaded treatment to caused mortality of jassid as compared with acetamiprid, while neem oil was found with higher population of jassid coincided with synthetic insecticides.

The current study revealed that the effect of neem oil concentrations (2.5 and 5 percent) was found significant over control plot. Neem oil (2.5%) concentration was showed less effective against jassid infestation, whereas, 5% concentration was reduced with higher mortality of jassids. Both tested concentrations were found toxic against jassid as compared to control (Rehman *et al.*, 2015). Thiamethoxam was reported most toxic against jassid population. Khaja and Sarjerao, (2016) supported our experimental work and they were reported that thiamethoxam was effective against jassid population. Acetamiprid treated plants was found with minimum jassid infestation remarkably as that of the thiamethoxam which is supported by Misra *et al*, (2003).

The present field study was designed to evaluate the toxic side effect of synthetic insecticides (Thiamethoxam and Acetamiprid) and neem oil two concentrations (2.5 and 5 percent) on the population of ladybird beetle (C. *Septempunctata*) and green lacewing (*Chrysoperla* spp) in okra field. During finding highest mortality of predators was recorded in thiamethoxam (0.60, 0.56 plant^{-1}) treated plot after first spray application, followed by acetamiprid (0.69, 0.65 plant^{-1}). The same trend was also found after secound spray application. However, neem oil concentrations showed less toxicity against ladybird beetle and green lacewing. The maximum associated predators were recorded in control plot (2.26, 2.20 plant^{-1}) after first spray, followed by neem oil 2.5%. Our results similar with results of Pfadt, (1980) who reported that the synthetic insecticides are highly toxic to beneficial insects such as Ladybird beetles, spiders and predatory bugs as compared with botanicals in fields. Natural enemies, are important sources of low the populations of harmful insect pests. According to Mollah *et al*. (2012) lowest mortality rate of ladybird beetles was recorded in neem oil which showed less toxic effect against predators. Our experiment coincides with research work of Shakoorzadeh *et al.* (2013) who claimed that the thiamethoxam has highly toxic to green lacewing and ladybird beetles. They also reported that the first instar of green lacewing mostly effected by thiamethoxam which caused highest mortality.

Our finding demonstrated that each treatment has significant impact on yield of okra. In the current experiment the synthetic insecticides (thiamethoxam and acetamiprid) were the highest yield producing treatments compared with botanical neem oil concentrations. The maximum yield of okra was obtained from plants treated with Thiamethoxam (10111.0 kg/ha), followed by Acetamiprid (8964.5 kg/ha). However, the minimum yield was collected from the control plot (5625.1 kg/ha). Our result has coincided with results of Kumar *et al.* (2022) who reported that synthetic insecticides treated plants were produced maximum yield (15290 kg/ha) compared with botanical insecticides. In the neem oil concentrations (2.5 and 5%) the maximum yield was obtained from plot which applied at 5 percent. in term of cost-benefit ratio the study is by work of Manju *et al.*

(2018) he observed that highest cost-benefit ratio was calculated for thiamethoxam (1:11.4) and was recommended to be the most economical among the all-tested treatments. The current study displayed that thiamethoxam is most effective, followed by acetamiprid and neem oil concentrations.

CONCLUSION

From the experimental results, it is concluded that

- Among the synthetic and botanicals insecticides, the synthetic insecticides (Thiamethoxam 25WG and Acetamiprid 20SP) was the superiors in term of maximum reduction in jassid population and resulted in increasing the yield of okra.
- Neem oil concentrations found also significantly reduced jassid population compared to control and was less detrimental to beneficial predators (ladybird beetle and lacewing).
- The study revealed that all treatments except control have potential to manage jassid infestation and enhance okra yield.

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Appendix

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6