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THE EFFECT OF DIFFERENT PLANT EXTRACTS AND AN INSECTICIDE AGAINST SUCKING INSECT PESTS AND THEIR ASSOCIATED PREDATORS IN TOMATO (LYCOPERSICON ESCULENTUM Mill) CROP

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Abstract

Background: *Sucking insects (Sulzer, Lindeman, Ishida) haram several vegetables including tomato across the world tomato crops and reduce yield. Farmers often use insecticides, which may also harm useful insects. This study looks at plant extracts as safer pest control methods.*

Objective: *To investigate the effect of different plant extracts and an insecticide against sucking insect pests and their associated predators in tomato (Lycopersicum esculentum Mill) crop.*

Methodology: *The experiment conducted was laid out in RCB Design with five treatments including insecticide Confidor20%SL and different plant extracts i.e. Azadirachta indica 3 %, Parthenium hysterophorus 5%, Datura alba 5% and control. Each treatment was replicated thrice to find the most effective treatment for controlling the sucking insect pests.*

Results: *The findings showed that, as compared to the control, all plant extracts and confidor considerably reduced the number of sucking insect pests in tomato crops. Plots treated with Confidor had the lowest infestation of tomato sucking insect pests, followed by A. indica seed extract. The control plots had the highest infestation of tomato sucking insect pests, followed by D. alba and P. hysterophorus. Like this, the control plots had the largest populations of predators, such as ladybird beetles, green lacewings, and syrphid flies, followed by D. alba and P. hysterophorus. Conversely, confidor and A. indica had the lowest populations compared to other plant extracts. Yield results showed that highest*

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tomato yield (8090.8kg ha^{-1}) was obtained from confidor treated plots followed by seed extract of A. indicia (7285.8 kg ha^{-1}) meanwhile, lowest tomato yield (4230kg ha^{-1}) was obtained from control plots followed by D. alba (5208.3 kg ha^{-1}) and P. hysterophorous (5382.5 kg ha^{-1}) respectively.

Conclusion: *Overall, A. indica seed extract proved to be an effective and comparatively safer alternative to chemical insecticides for managing sucking insect pests in tomato.*

INTRODUCTION

The tomato, or Lycopersicon esculentum Mill., is one of the most important and nutrient-dense vegetable crops in the world. It belongs to the Solanaceae (night shade) family and is positioned next to potatoes because of its greater versatility, large production, and many applications. Tomato cultivation and consumption are widespread worldwide (Vijayakumar et al., 2016). It has been introduced to Peru from tropical area, Mexico (Maerere et al., 2006).

Tomato crop has been cultivated as a productive cash and industrial vegetable crop throughout the world (Babalola et al., 2010). Worldwide Production of tomato from 4.8-million-hectare area is 161.96 million tons that is 33.6 tons average yield per hectare. Tomato leading countries are China followed by India, U.S.A, Turkey, Iran, Italy, Spain, Brazil and Mexico respectively. According to Food and Agriculture Organization ranking Pakistan reserves 34th position (FAO, 2015).

Area under cultivation of tomato during 2015-16 in Pakistan was 62.2 thousand hectares with total 587.1 thousand tons production. Tomato cultivation in Sind province estimated is 27.9 thousand hectares following by 13.6 thousand hectares in Khyber Pakhtunkhwa, 12.9 thousand hectares in Balochistan and 8.2 thousand hectares in Punjab respectively with 206.5 thousand tons, 130.0 thousand tons, 144.4 thousand tons and 106.2 thousand tons production (Pakistan Bureau of Statistics, 2016).

Insect pests and diseases are among several factors that cause yield reduction and have been reported the most serious factors (Kagezi et al., 2000). Certain types of insect pests infest tomato crops since they serve as food, shelter and reproduction sites to many insect pests. From tissue destruction, scaring and abreaction of shape or color of fruit to growth disturbance and plant death are relating issues to insect pests (Lange and Bronson 1981). Low tomato production is due to damage causing nature of insect pests (Praveen and Dhandapani, 2001). Sucking insect pests have been detected as key pests found in open fields and high tunnels. Key or major pests refer to the insect pests causing more than 10% damage (Butani and Jotwani, 1984). Pests' resurgence, their resistance to insecticides and elimination of natural enemies along with outbreak of secondary pests have encouraged the present condition. Disastrous tomato aphids are found around certain Punjab districts located near the province of Sindh (Aslam and Razaq, 2007).

Myzus persicae (Sulzer) also called peach aphid is listed among the most destructive tomato crop pests. Myzus persicae is a pest from the family aphididae (Homoptera). Aphids Puncture Plants for sucking cell sap via their stylet. Watery and gelling saliva are two sorts of saliva injected at the time of penetration. The mentioned two kinds of saliva are of great importance in case of plant tissues removal (depositions) and recently investigation made on aphid's saliva constituent indicated important role on impact of defense responses of host plant. (Will et al., 2007).

Peach Aphid is among the most recognized pests worldwide. This pest normally starts feeding at the tips of young growing tissues and then spread to the whole plant as its population enhances in size which then results in curling down of the effected leaves. Severe aphid infestation leads to stunted plant growth. Blossom drop and fruit deformities are caused by Myzus persicae due to its preferences, specifically to blossoms. However,

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studies indicated that above 50% of infestation (plant leaves) is required before observing reduction in yield (Kuhar et al., 2009). Besides the losses caused directly by Myzus persicae capability of more than 150 viral diseases in variant plant hosts, more especially in vegetable from solanaceae family have been reported. Pepper, potato and tomato have been found infested with Potato Virus Y, Potato Leaf roll Virus, similarly watermelon Mosaic Virus and Cucumber Mosaic Virus have been detected in cucurbits and finally Cauliflower and Cucurbit Mosaic Viruses and Turnip Mosaic Virus have infested crucifers (Cloyd and Sadof, 1998).

Climatic conditions on Myzus persicae (Sulzer) are of vital role and hence it is suggested to be implanted as convenient and successful modern crop protection package in modern Integrated Pest Management Programs. Influence of this pest on above ground surface is found on whole plants round the vegetative stage till maturity. Consecutive feeding of this species of aphid causes stunting, twisting or yellowing of green foliage of tomato crop (Berlendier and Sweetingham, 2003).

Thrips, Thrips tabaci (Lindeman) are tiny cosmopolitan long slender light white to dark brown colored bodied insects. They are 0.1 to 15 mm in length with two pairs of thin cilia-fringed wings possessing bristles on the veins. Buccal apparatus is found single where only right mandible is fully developed (Mound et al., 1993; Johansen and Mojica, 1997). There are about 6,000 species of thrips throughout the world where only 1% are recognized economically convenient agricultural pests and most of them are placed in Thripidae family (Ananthakrishnan, 1979). Feeding associated problems of both immature nymphs and adults at the time of feeding on fresh juicy tissues of leaves are epidermal cells destruction (Koschier et al., 2002) and result in transferring spotted wilt virus disease of tomato to many crops (Nagaraja et al., 2005). Yield loss to tomato caused by thrips is 23.7% (Kagezi et al., 2000). Many crops such as potato, onion and tomato have been reported to have thrips (Thysanoptera: Thripidae) infestation, besides this they are also a serious threat to cell sap and virus transmission in tomato, onion and potato crops (Birithia et al., 2014).

Amrasca biguttula biguttula (Ishida) commonly known cotton leafhopper belongs to Cicadellidae family of Homoptera order. It is economically important insect pest of numerous field crops such as cotton, okra, potato, tomato, eggplant, sunflower, cluster bean, cowpea, castor and some wild plants for instance, country mallow and so on. Hopperburn or phytotoxemia is associated with nymphal and adult sapping of the leaves and is the symptom helping in the identification of leafhopper attack (Hooda et al., 1997). Cell sap sucking from plants is an associated problem trace back to jassid which causes stunted plant growth (Asi et al., 2008). Its nature of injecting toxic substance through feeding process interrupts photosynthetic process (Bhatangar and Sharma, 1991). Stunted growth of plants results in inability to flower and fruit (Hokkanen, 1991). Both nymphs and adult jassids are found feeding and sucking the plant sap on leaves underside which causes yellowing and curling of leaves. Toxic material is injected while sucking the plant sap resulting in burn symptoms and leaves drop off in severe infestation (Rahman et al., 2009). 50% loss in yield resulted and damage starts right from seedling to fruit setting stage (Bindra and Mahal, 1981).

Basic and fundamental way of the infestation management is the dependence on chemicals, but it is less productive because of insects' resistance toward pesticides (Siebert et al., 2012). Phytophagous insect pests are controlled through synthetic insecticides. One of their drawbacks is detected in the form of residues in food and air and creating environmental pollution. To keep insect pests away from plants chemical is designed. Due to overuse application of synthetic pesticides environmental hazards and impact on non-target organisms have been noted (Savary et al., 2006). In many developing countries synthetic insecticides are widely used for controlling insect pests of food crops. Since the near past environmentally friendly bio pesticides such as plant extracts have been used widely. Several trees and plants have been found effective against many insect pests, hence raise in utilizing

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bio pesticides has been reported in recent years due to their efficacy against more than 200 different species of insects from several orders (Osman and Port, 1990). Reduction in fitness and sterility, growth along with oviposition and feeding repellency and deterrence are some of the biological activities of plant extracts. Products derived from neem are host specific (selective in nature) don't have negative effect on natural enemies of pests and were also found having least to no poisonous effect on warm blooded animals (Schmutterer, 1990).

Biological Control refers to environmentally sound and effective means used for suppressing pests and their effects, utilizing natural enemies. It comprises parasitism, predation, herbivory or any other natural mechanisms, typically involves the active role of human management. Modern investigations and experiments enhancing the importance of predators in pest controlling. The positive influence of predacious arthropods in natural communities and agricultural crops have got special attention in near past. One of the important predators Chrysoperla carnea (Stephens) commonly known as green lacewing representing Neuroptera order. Due to its carnivorous habits it's agriculturally important their larvae are commonly called aphid lions and are all good predators (Canard et al., 1984). Green lacewing is generally considered an important generalist predator (Sarwar, 2014). Their larvae prefer feeding soft bodied insects including thrips, aphids, whitefly, mealy bugs, mites, leaf hoppers, jassids, caterpillars and eggs of several insects (Ulhaq et al., 2006) however, prefer aphids the most (Solangi et al., 2014). Adults of Crysoperla carnea (Stephens) are not predators by themselves feed on pollen and honey, but their nonstop supply of predatory larvae in the ecosystem is guaranteed and can be utilized in IPM programs (Memon et al., 2015).

Many species of Coccinellids comprise predatory insects. These predaceous insect beetles are useful for controlling many soft bodied insect pests for example, aphids (Aphididae: Homoptera), whiteflies (Alerodidae: Homoptera), mealybugs (Pseudococcidae: Homoptera), Thrips (Thripidae: Thysanoptera), jassids (Cicadellidae: Homoptera) and psyllids (Psyllidae: Homoptera) (Ullah et al., 2012). They are also reported to consume tiny larvae, eggs of insects and phytophagous mites harmful to agricultural and forest plantations (Gordon, 1985).

Syrphid flies are also called hover flies or flower flies. Adults were reported feeding on pollen and nectar, but the maggots are aphidophago. Adults of different species of syrphid flies are variant in size, color along with flying pattern (Delfinado and Hardy, 1973). They were reported to occur in most of the biomes rather than deserts and tundra at extremely high altitudes as well as in Antarctica (Ghorpade, 1981). Reports from several laboratory studies showed that larvae of Syrphid fly can suppress aphid populations (Van Rijn et al., 2006). These larvae are aphidophagous thus active predators of aphids and explaining the reason that why females oviposit near aphid colonies. When they hatch eggs crawl and start nourishing themselves through aphid species. Different species have different feeding habits some are specialist target only one specific aphid species, while the generalist feeds over four to five aphid species. It is also reported that some of their species' feed over other pests along with aphids (Sadeghi and Gilbert, 2000).

MATERIALS AND METHODS

In 2018–19, ARI, Agricultural Research Institute Tarnab Peshawar, Khyber Pakhtunkhwa, Pakistan conducted an experiment titled "The effect of different plant extracts and an insecticide against sucking insect pests and their associated predators in tomato (Lycopersicon esculentum Mill) crop." A total of five treatments were reproduced three times in this RCB (Randomized Complete Block) design experiment.

The following listed treatments were utilized:

- Confidor20% SL @ 250ml /acre
- Seed extract of Azadirachta indica @ 3%
- Leaves extract of Parthenium hysterophorus L. @ 5%
- Leaves extract of Datura alba @ 5%
- Control

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Preparation procedure of Parthenium hysterophorus and Datura alba extracts

To extract Parthenium hysterophorus and Datura alba, tiny, chopped leaves from each plant were first dried in a scientific oven for 72 hours at 650 degrees Celsius. After that, they were pulverized using a grinder to produce tiny particles that were around 2 mm in size. To create a 10% stock solution, half a kilogram of the ground sample from each plant was wrapped in a larger piece of muslin cloth along with ten grams of detergent as an adjuvant. The mixture was then combined with five liters of boiling water for twenty-four hours to create a five percent concentration (Hazara et al., 1999).

Preparation of neem seed (Azadirachta indica) extract

We purchased 500 kilos of Azadirachta indica neem seed from the local market in Peshawar, Khyber Pakhtunkhwa, Pakistan. A grinder was used to crush the specified quantity of neem seeds, which were then combined with one liter of water and filtered through a bigger piece of muslin fabric. The concentration of the extract was administered at a rate of 3%. (Shah et al., 2015)

. The following formula was utilized:

C1V1= C2V2

Here C1, V1, C2, V2 respectively stand for the following:

- C1: Represents total stock concentration of the solution
- V1: Is the volume to be taken from the stock solution to get the preferred concentration
- C2: Required concentration
- V2: Required volume

Preparation of field

The hybrid F1/2565 tomato seedlings were moved to prepared fields on ridges. 30 × 20 m = 600 m^2, or 0.06 hectares, was the experimental area. It was then divided into three blocks, each of which has five subplots. The subplots were each 8×5 m^2. The buffer zone was left at one meter, while the plant-to-plant and row distances were maintained at 75 cm and 1 m, respectively. All the agronomic techniques were followed during the season.

Application of treatments

Plant extracts and insecticides were applied using a backpack sprayer. First, a blank spray was sprayed in order to assess the real spray solution quantity. After computation, the recommended pesticide dosage was sprayed. In a similar vein, the amount of time needed to apply treatments was determined by the bug population.

Parameters

The following parameters were studied:

- Number of aphids leaf $^{-1}$
- Number of jassids leaf $^{-1}$
- Number of thrips leaf $^{-1}$
- Number of predators plant^{-1}
- Yield kg ha^{-1}

Data collection

Data on tomato sucking insect pests and their associated predators was recorded from their occurrence till termination of the experiment on five randomly selected tomato plants per sub plot and per replication. Visual inspection was made for Aphids, Jassids, thrips and predators (Shukla et al., 2005).

Data of Yield

Tomato yield was recorded after each picking and then converted to kg per hectare.

Statistical Analysis of data

Statistix 8.1 program was used for data analysis. Construction of Analysis of variance and Least Significant Difference for the differentiation of mean was performed.

RESULTS

The effect of different treatments, time interval (days) and its interaction on mean number of aphids per leaf in tomato crop during 2018-19

Table 1 showed that all treatments reduced aphids compared to the control. Confidor gave the lowest aphid count (0.65 aphids/leaf), followed by neem seed extract (1.55

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aphids/leaf), while the control had the highest count (3.82 aphids/leaf). The highest aphid population was observed on the first day after treatment (2.70 aphids/leaf). A gradual decrease in aphid numbers was recorded on the 3rd, 5th, 7th, and 14th days. The lowest aphid population (0.26 aphids/leaf) was observed in the Confidor treatment on the 14th day.

Table 1: The effect of different treatments, time interval (days) and its interaction on mean number of aphids per leaf in tomato crop during 2018-19

Treatments	Post-Treatments Time Interval (Days)					
	1st	3rd	5th	7th	14th	Mean
Confidor20%SL	1.12i	0.86j	0.61k	0.41l	0.26m	**0.65e**
Neem seed extract 3%	2.40e	1.98g	1.58h	1.06i	0.76j	**1.55d**
Parthenium hysterophorus leaf extract 5%	3.09c	2.60d	2.11g	1.49h	1.09i	**2.08c**
Datura alba leaf extract 5%	3.15c	2.71d	2.25f	1.51h	1.18i	**2.16b**
Control	3.74c	3.81b	3.84ab	3.84ab	3.89a	**3.82a**
Mean	**2.70a**	**2.39b**	**2.08c**	**1.66d**	**1.43e**	

The means in the table which have different alphabets are statistically different from one another at 5% level of significance using LSD test ($P < 0.05$)
LSD value for treatments= 0.0602
LSD value for Time Interval= 0.0602
LSD value for Time Interval*treatments= 0.0670

The effect of different treatments, time interval (days) and its interaction on the mean number of jassids per leaf in tomato crop during 2018-19

Table 2 showed that all treatments significantly reduced jassid infestation compared to the control. The lowest mean jassid population (0.93 jassids/leaf) was recorded in Confidor-treated plots, followed by neem seed extract (1.26 jassids/leaf), while the control had the highest population (3.11 jassids/leaf). The highest jassid density was observed on the first day after treatment (2.15 jassids/leaf). A gradual reduction in jassid numbers was observed on the 3rd, 5th, 7th, and 14th day after treatment. The minimum jassid population (0.51 jassids/leaf) was recorded in the Confidor × 14th day interaction.

Table 2: The effect of different treatments, time interval (days) and its interaction on mean number of jassids per leaf in tomato crop during 2018-19

Treatments	Post-treatments Time Interval (Days)					
	1st	3rd	5th	7th	14th	Mean
Confidor20%SL	1.45h	1.18i	0.90k	0.63l	0.51m	**0.93e**
Neem seed extract 3%	1.78f	1.45h	1.22i	1.01j	0.86k	**1.26d**
Parthenium hysterophorus leaf extract 5%	2.15d	1.81fef	1.62g	1.38h	1.18i	**1.63c**

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Datura alba leaf extract 5%	2.32c	1.88e	1.62g	1.38h	1.21i	**1.68b**
Control	3.06b	3.08b	3.08b	3.14ab	3.20a	**3.11a**
Mean	**2.15a**	**1.88b**	**1.69c**	**1.51d**	**1.39e**	

The means in the table which have different alphabets are statistically different from one another at 5% level of significance using LSD test ($P < 0.05$)
LSD value for treatments= 0.0431
LSD value for Time Interval= 0.0431
LSD value for Time Interval*treatments= 0.0964

The effect of different treatments, time interval (days) and its interaction on mean number of thrips per leaf in tomato crop during 2018-19

Table 3 showed that all treatments significantly reduced thrips infestation compared to the control. The lowest mean thrips population (0.59 thrips/leaf) was recorded in Confidor-treated plots, followed by neem seed extract (0.79 thrips/leaf), while the control showed the highest population (2.55 thrips/leaf). The highest thrips density was observed on the first day after treatment (1.48 thrips/leaf). A gradual decrease in thrips numbers was recorded on the 3rd, 5th, 7th, and 14th days after treatment. The minimum thrips population (0.31 thrips/leaf) occurred in the Confidor × 14th day interaction.

Table 3: The effect of different treatments, time interval (days) and its interaction on mean number of thips per leaf in tomato crop during 2018-19

Treatments	**Post-treatments Time Interval (Days)**					
	1st	**3rd**	**5th**	**7th**	**14th**	**Mean**
Confidor20%SL	0.93g	0.76h	0.56j	0.42l	0.31m	**0.59d**
Neem seed extract 3%	1.14e	0.94fg	0.80h	0.61ij	0.48k	**0.79c**
Parthenium hysterophorus leaf extract 5%	1.41d	1.17e	0.99f	0.78h	1.62ij	**0.99b**
Datura alba leaf extract 5%	1.42d	1.18e	1.00f	0.80h	0.63i	**1.01b**
Control	2.50c	2.52bc	2.55bc	2.57ab	2.61a	**2.55a**
Mean	**1.48a**	**1.31b**	**1.18c**	**1.03d**	**0.93e**	

The means in the table which have different alphabets are statistically different from one another at 5% level of significance using LSD test ($P < 0.05$)
LSD value for treatments= 0.0259
LSD value for Time Interval= 0.0259
LSD value for Time Interval*treatments= 0.0578

The effect of different treatments, time interval (days) and its interaction on mean number of green lacewing per plant in tomato crop during 2018-19

Table 4 showed that all treatments effectively controlled sucking insect pests but also reduced green lacewing populations compared to the control. The lowest mean number of green lacewings (0.44 per plant) was recorded in Confidor-treated plots, followed by neem seed extract (0.53 per plant), while the control had the highest number (1.34 per plant). The highest green lacewing population was observed on the

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first day after treatment (1.09 per plant). A gradual decline in green lacewing numbers was recorded on the 3rd, 5th, 7th, and 14th days after treatment. The minimum green lacewing population (0.10 per plant) occurred in the Confidor × 14th day interaction.

Table 4: The effect of different treatments, time interval (days) and its interaction on mean number of green lacewing per plant in tomato crop during 2018-19

Treatments	Post-treatments Time Interval (Days)					
	1st	3rd	5th	7th	14th	Mean
Confidor20%SL	0.83f	0.59i	0.41m	0.26o	0.10r	**0.44e**
Neem seed extract 3%	1.02e	0.67h	0.48k	0.34n	0.16q	**0.53d**
Parthenium hysterophorus leaf extract 5%	1.14d	0.71g	0.56j	0.43lm	0.21p	**0.61c**
Datura alba leaf extract 5%	1.15d	0.73g	0.57ij	0.44l	0.24op	**0.62b**
Control	1.30c	1.30c	1.34b	1.35b	1.40a	**1.34a**
Mean	**1.09a**	**0.80b**	**0.67c**	**0.56d**	**0.42e**	

The means in the table which have different alphabets are statistically different from one another at 5% level of significance using LSD test ($P < 0.05$)
LSD value for treatments= 0.0123
LSD value for Time Interval= 0.0123
LSD value for Time Interval*treatments= 0.0275

The effect of different treatments, time interval (Days) and its interaction on mean number of ladybird beetle per plant in tomato crop during 2018-19

Table 5 showed that all treatments effectively controlled sucking insect pests but also reduced ladybird beetle populations compared to the control. The lowest mean number of ladybird beetles (0.46 per plant) was recorded in Confidor-treated plots, followed by neem seed extract (0.59 per plant), while the control showed the highest population (1.38 per plant). The highest ladybird beetle count was observed on the first day after treatment (1.06 per plant). A gradual decrease in ladybird beetle numbers was recorded on the 3rd, 5th, 7th, and 14th days after treatment. The minimum population (0.10 per plant) occurred in the Confidor × 14th day interaction.

Table 5: The effect of different treatments, time interval (days) and its interaction on mean number of Ladybird beetle per plant in tomato crop during 2018-19

Treatments	Post-treatments Time Interval (Days)					
	1st	3rd	5th	7th	14th	Mean
Confidor20%SL	0.81f	0.57j	0.49k	0.32n	0.10p	**0.46e**
Neem seed extract 3%	0.93e	0.71h	0.64i	0.44l	0.23o	**0.59d**
Parthenium hysterophorus leaf extract 5%	1.11d	0.90e	0.76g	0.54j	0.33mn	**0.73c**

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Datura alba leaf extract 5%	1.14d	0.94e	0.80fg	0.56j	0.37m	**0.76b**
Control	1.34c	1.35c	1.38bc	1.40b	1.45a	**1.38a**
Mean	**1.06a**	**0.89b**	**0.81c**	**0.65d**	**0.50e**	

The means in the table which have different alphabets are statistically different from one another at 5% level of significance using LSD test ($P < 0.05$)
LSD value for treatments= 0.0191
LSD value for Time Interval= 0.0191
LSD value for Time Interval*treatments= 0.0427

The effect of different treatments, time interval (days) and its interaction on the mean number of Syrphid fly per plant in tomato crop during 2018-19.

Table 6 showed that all treatments were effective against pests but also reduced syrphid fly populations compared to the control. The lowest mean number of syrphid flies (0.55 per plant) was recorded in Confidor-treated plots, followed by neem seed extract (0.63 per plant), while the control had the highest population (1.52 per plant). The highest syrphid fly count was observed on the first day after treatment (1.16 per plant).
A gradual decrease in syrphid fly numbers was noted on the 3rd, 5th, 7th, and 14th days after treatment. The minimum syrphid fly population (0.02 per plant) occurred in the Confidor × 14th day interaction.

Table 6: The effect of different treatments, time interval (days) and its interaction on mean number of Syrphid fly per plant in tomato crop during 2018-19

Treatments	**Post-treatments Time Interval (Days)**					
	1st	**3rd**	**5th**	**7th**	**14th**	**Mean**
Confidor20%SL	1.06bc	0.82def	0.63gh	0.21ij	0.02j	**0.55c**
Neem seed extract 3%	1.13bc	0.90de	0.70ef	0.32hi	0.11ij	**0.63b**
Parthenium hysterophorus leaf extract 5%	1.19b	0.96cd	0.77def	0.45gh	0.21ij	**0.72b**
Datura alba leaf extract 5%	1.21b	0.94cd	0.78def	0.44gh	0.17ij	**0.71b**
Control	1.46a	1.48a	1.51a	1.55a	1.58a	**1.52a**
Mean	**1.16a**	**1.02b**	**0.88c**	**0.59d**	**0.42e**	

The means in the table which have different alphabets are statistically different from one another at 5% level of significance using LSD test ($P < 0.05$)
LSD value for treatments= 0.0383
LSD value for Time Interval= 0.0383
LSD value for Time Interval*treatments= 0.0857

The effect of different treatments on mean yield (kg) in tomato crop during 2018-19.

Table 7 showed that all treatments significantly improved yield compared to the control. The highest yield (32.48 kg per treatment) was recorded in Confidor-treated plots, followed by neem seed extract (29.17 kg). The lowest yield (16.92 kg) was observed in the control plots. Datura alba and Parthenium hysterophorus produced intermediate yields of 20.83 kg and 21.53 kg, respectively. Overall, significant

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differences in yield were observed among all treatments.

Table 7: The effect of different treatments on mean yield (kg) in tomato crop during 2018-19

Treatments	Mean yield / treatment	Yield (kg ha^{-1})
Confidor20%SL	32.48a	8090.8a
Neem seed extract 3%	29.17b	7285.8b
Parthenium hysterophorus leaf extract 5%	21.53c	5382.5c
Datura alba leaf extract 5%	20.83c	5208.3c
Control	16.92d	4230d
LSD	**2.3963**	**609.13**

The means in the table which have different alphabets are statistically different from one another at 5% level of significance using LSD test ($P < 0.05$)

DISCUSSION

The experiment titled "The effect of different plant extracts and an insecticide against sucking insect pests and their associated predators in tomato (Lycopersicon esculentum Mill) crop" was conducted at the Agricultural Research Institute (ARI), Tarnab, Peshawar, Pakistan. Three plant extracts Azadirachta indica, Parthenium hysterophorus, and Datura alba were tested along with the insecticide Confidor 20% SL.

Overall, almost all treatments were found highly effective in comparison to control plots, but Confidor gave best result followed by neem seed extract over other treatments. The results on infestation of sucking insect pests i.e. aphids, jassids, thrips and population of predators, green lacewing, ladybird beetle and syrpid fly as well as tomato yield showed significant differences for all treatments. Lowest infestation of sucking insect pests and highest tomato yield was recorded in confidor treated plots followed by neem seed extract. The results revealed that confidor is significantly more effective than plant extracts followed by neem seed extract. Our findings on the efficacy of confidor against sucking insect pests is well matched with (Solangi et al., 2014) who reported that among the biopesticides chemical insecticide confidor was the most effective after first and second spray against whitefly, thrips and aphids with (85.95%, 96.29%), (99.56%, 98.94%) and (96.27, 89.73%) efficacy respectively followed by neem based biopesticides after first and second spray where the efficacy against whitefly, thrips and aphid was (75.35%, 82.56%), (81.00%, 78.72%) and (79.71% , 76.43%) respectively. Results on neem seed extract are supported by (Lowry and Isman,1994) who sprayed neem based biopesticide and reported 50 % mortality of aphids. The effectiveness of neem seed kernel in controlling insect pests with highest cost benefit ratio was stated by Kumar and Singh (2001). We are also in line with Singh and Kumar (2003) who reported extract of neem kernel most effective for the control of aphids and jassids among Azadirachta indica based biopesticides against sucking complex. We have also similar findings with Baidoo et al. (2012) who reported minimum population of aphids in Azadirachta indica seed extract plots followed by Parthenium hysterophorus. The effectiveness of seed extract of Datura alba was also reported by Khaliq et al. (2014). Broad spectrum property of allelochemicals with their no adverse effects on environment and human health against vegetable insect pests was also reported by Koul and Walia (2009). The seed of Azadirachta indica and Parthenium hysterophorus has shown inhibitory effects on the development of wooly aphid (Wabale and Kharde, 2010). They act as repellent, growth regulator, antifeedants and easily degradable in sunlight (Sarwar, 2015).

Differences on population of predators, ladybird beetle, green lacewing and syrphid fly per plant was observed in plots treated with confidor, neem

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seed extract, Parthenium hysterophorus, Datura alba and control plots. Due to the sufficient prey and no treatments application highest population of predators per plant was recorded in control plots followed by Datura alba and Parthenium hysterophorus. Furthermore, lowest population of predators per plant was recorded in plots treated with confidor. Similar finding on toxicity of confidor to biological agents as compared with plant extracts was reported by Smith and Krischik (1999). Investigations reported from the laboratory studies indicated that synthetic insecticide adversely affected natural enemies such as coccinellids, Hymenoptera and Apidae (Schmuck et al., 2001). The adverse effect on biological agents of synthetic chemicals was also reported by Kourdoumbalos et al. (2006). Effect on predatory beetles in okra crop was reported by Mommaerts et al. (2010). Natural enemies are sensitive to chemical residues available in habitats after their application for controlling pests (Charlet, 1995). Arif et al. (2012) stated that insecticides adversely influenced Chrysoperla carnea, spider and coccinellids, whilst Sohail et al. (2011) investigated the effect of insecticides on aphid and its predatory ladybird beetle on mustard. Plots treated with neem oil have a smaller number of predators in comparison to other plant extracts, due to the inhibition property of azadirachtin in neem oil on oviposition effecting the fertility and fecundity of Chrysoperla carnea. In addition, predation rate of natural enemies is decreased when exposed to the compound Azadirachtin, inhibiting them finding their prey (Cloyd, 2012).

Results showed significant differences regarding tomato yield among all the treatments. Almost all treatments significantly gave more yield in comparison to control plots. Highest tomato yield was obtained from confidor plots followed by neem seed extract in comparison to other plant extracts and control. Lowest tomato yield was recorded in control plots followed by Datura alba and Parthenium hysterophorus. Our results regarding confidor treated plots are compatible with Ella (2016) who stated that better wheat yield was obtained from plots treated with confidor (Imidacloprid). Our findings on yield are also well-matched with Wargantiwar et al. (2010) who stated that chemical treated plots contributed significantly higher yield as compared with botanicals. Highest (222.0 t/ha) marketable yield was obtained from chemicals treated plots followed by botanicals Sahana and Tayde (2017). Imidacloprid 17.8 SL @ 0.008% gave highest yield followed by Thiamethoxam 25WG @ 0.175% reported by Bharpoda et al. (2014). Hossain et al. (2013) also reported significantly higher yield (1.73 t/ha) from Imidacloprid plots as well as Rashid et al. (2012). Ma et al. (2000) investigated positive effects of chemical pesticides followed by botanical extracts on cotton seed yield. Our results are also well matched with Asif et al. (2018) who reported that seed water extract (3%) and neem oil (5%) resulted in significantly more yield than control plots after chemical insecticide. Our results are consistent with Rashid et al. (2012), who reported higher cotton seed yield from 1.5% and 2% neem oil and 3% neem seed water extract. Similarly, Khattack et al. (2001) found that combinations of insecticides and neem extracts significantly increased yield compared to the control. Ma et al. (2000) also observed that azadirachtin-treated cotton plots produced higher yields due to its effect on reducing bollworm infestation.

CONCLUSION

Confidor was the most effective treatment in reducing sucking insect pest infestation compared to the plant extracts (Azadirachta indica, Parthenium hysterophorus, and Datura alba). However, it also had a greater adverse effect on natural predators such as ladybird beetles, green lacewings, and syrphid flies. Among the plant extracts, neem seed extract (Azadirachta indica) was the most effective in controlling sucking pests. Azadirachta indica showed the highest toxicity to predators compared to the other plant extracts.

Author's contribution

Conceptualization: DM, AURS
Methodology: RAS, SU.
Formal analysis: AN. SS
Writing review and editing: TVF, AMK, SA

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