EFFICACY OF VARIOUS PLANT EXTRACTS AND SYNTHETIC INSECTICIDE AGAINST WHITEFLY AND *EPILACHNA* BEETLE IN BRINJAL CROP

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ABSTRACT

The Brinjal production is seriously hampered by the severe attack of whitefly (*Bemisia tabaci)* and *Epilachna* beetle. In order to control pest issue in brinjal crop botanical and conventional insecticides were used against whitefly (*Bemisia tabaci)* and *Epilachna* beetle. In present study, three natural plant extracts (@ 5% *Solanum nigrum*, *Ricinus communis* and Neem oil) and one synthetic insecticide (Imidacloprid 20 Sc) were used to evaluate the efficacy of natural plants extracts against these two insect pests of brinjal. The results indicated that all the botanical extracts and Imidacloprid significantly reduced the population of whitefly and Epilachna beetle. The mean minimum population of whitefly leaf^{-1} (0.94) was observed from Imidacloprid followed by Neem oil (4.03) The lowest mean infestation (0.77) of *Epilachna* beetle was recorded on Imidacloprid followed by Neem oil (2.12). However, maximum percent biological efficacy against whitefly (90.21) was observed on Imidacloprid followed by Neem oil (58.19). The highest percent biological efficacy against *Epilachna* beetle (83.74) was observed in Imidacloprid followed by Neem oil (55.36). Furthmore, the highest yield (5308.6 kg ha^{-1}) was obtained from Imidacloprid treated plots followed by Neem oil (4748.2 kg ha^{-1}). Our results indicates that, Imidacloprid significantly showed better efficacy against whitefly and *Epilachna* beetle among the tested treatments, while in botanicals, Neem oil gives best result for the control of whitefly and *Epilachna* beetle.

Key words: Whitefly, *Epilachna* beetle, Botanical leaf extract, Imidacloprid, brinjal

INTRODUCTION

Brinjal is one of the most important nutritional crops in vegetables (Murugesan and Murugesh, 2009). The overall production of brinjal crop is 55.19million tons per annum which is cultivated on 1,847,787 ha throughout the world. The total production of this crop in Asia is 52 million tons per year which is cultivated on 1691755 ha. Ninety four percent of the contribution in the production of brinjal comes from Asian sub-continents. The brinjal crop production in Pakistan is 89724 tons per year which is cultivated on an area of 8566 ha (FAOSTAT, 2019). In Khyber Pakhtunkhwa total production of brinjal crop 9319 tons which is cultivated on an area of 975 ha (Agri. Stat. Pak., 2018-19).

Brinjal production is reduced day by day. There are several reasons of low production; however, insect pests play an important role in low production of brinjal crop. It is attacked by brinjal borers, aphids, white fly, Jassids, thrips and mites. These sucking pests play a major part in decreasing the production of brinjal crop (Purohit and Khatri, 1973; Allam *et al.,* 1982). The significant losses are caused by brinjal fruit and shoot borer (70%), which becomes unfit for human consumption (Duara *et al.,* 2003). It has been stated that in the South East Asia the sucking pest caused 67% production losses. Yield injuries due to insect pests are very high in South Asia (Thapa, 2010).

The whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) is the most destructive pest of brinjal crop. It affects the crop directly by its feeding and also acting as a vector of pathogens such as viruses etc. The reduction percentages of white fly on different growth parameters of brinjal crop, leaf fresh weight, leaf area, leaf dry weight, rate of photosynthesis and chlorophyll content were 26.6, 21.8, 19.3, 9.7, and 65.9%, respectively (Islam *et al.,* 2010 and Abrahamian and Abou-Jawdah, 2014). However, the Epilachna beetle or Hadda beetle (*Henosepilachna vigintioctopunctata*) is a serious and most destructive pest of brinjal crop which is found in Asian sub-continent (Anam *et al.,* 2006: Rahman *et al.,* 2008). It causes heavy damages to crop at both, larval and adult stages which destruct the epidermal tissues of plant leaves, flower as well as fruits by scraping the chlorophyll content which cause high losses in yield (Ghosh and Senapati, 2001).

The farmers used hazard and conventional chemicals for the management of these insect pest in brinjal crop (Talekar, 2002). The indiscriminate use of these pesticides results in the pollution of environment, bio-accumulation and bio-magnification (Dadmal *et al.*, 2004). It was reported that Maximum Residue Limit (MRL) was exceeds in the residue of brinjal fruits in India as several occasions (Chandrase, 2005). The safety and quality of the agricultural and food products is considered to be the most important purpose for the producer and consumers, which can be achieved through organic farming and pesticide free products (Ikeura, 2012). Botanical extracts are environment friendly and should be included in the Integrated Crop Management (ICM) and Integrated Pest Management (IPM) programs (Koul and Walia, 2009).

Various wild plants contain different alkaloids and other useful substances that have insecticidal properties. Scientific reports proved that plants extracts are more effective against various insect pest of different important crop which is used in integrated pest management program (Kinae *et al*., 2000; Tedeschi *et al*., 2011). For example; Neem tree (*Azadirachta indica*), *Madhuca latifolia* and *Pachira glabra* have lethal and anti-feeding effect on most destructive pest *Epilachna* beetle (Swaminathan *et al.,* 2010), Castor oil (*Ricinus communis*), Indian Thornapple (*Datura metel*) and Calotropis (*C. Procera*) are also showed high toxicity effects against this beetle which shows adverse effect on its oviposition and eggs hatching, it also prolonged larval duration, pupae duration and adult emergence (Islam *et al.*,2011).

It has been stated that brinjal crop was infested by different insect pest at fruiting stage. But sucking insect pest caused 67% losses. Due to the aforementioned problems of insect pest and use of harmful chemicals against them, the current study was conducted to evaluate the best botanical extracts and synthetic insecticide against whitefly and *Epilachna* beetle in brinjal crop and to investigate the effect of various natural plant extracts and synthetic insecticide on yield of brinjal crop.

MATERIALS AND METHODS

Experimental design

The research trial was carried out at Agricultural Research Station Swabi, Khyber Pakhtunkhwa, Pakistan during the year 2019. Seedlings of brinjal variety

Shamli were purchased from local market and were transplanted in the first week of April, 2019. There were five treatments and each treatment was replicated three (3) times in Randomized Complete Block Design (RCBD). The distance between row to row was kept at 0.6 m, while the distance between plant to plant was kept at 0.45m. There were two rows consisting of 16 plants per treatment. The total size of subplot was 4.32m^2. The treatments and replications were separated from one another by a non–cropped area of 0.8m and 1.0m, respectively. The agronomic practices were carried out uniformly containing hoeing, irrigation, weeding and ploughing etc throughout the cropping season.

Field layout

Replication 1	Replication 2	Replication 3
T_5	T_2	T_1
T_2	T_1	T_3
T_1	T_3	T_2
T_3	T_4	T_5
T_4	T_5	T_4

Treatments

1. *Solanum nigrum* leaf extracts @ 5%
2. *Ricinus communis* leaf extracts @ 5%
3. Neem oil @ 5%
4. Imidacloprid 20 SC
5. Control

Preparation of Plant Extracts

***Solanum nigrum* leaf extracts**

Fresh and young leaves were picked from *Solanum nigrum*p lants and these leaves were cleaned with water. These clean *Solanum nigrum* leaves were dried for 14 days in a shady area. These dried leaves were ground through the electrical grinder. The ungrounded parts of leaves were removed and then fine powder form was collected and sieved. 0.5 kilogram of grinded leaf extracts were taken in muslin cloth and then soaked

for 24 hours in pure boiled water of one liter. After 24 hours filtered solution of 50 percent concentration was prepared. Five percent concentration solution of *Solanum nigrum* extract was obtained. The desired concentration was calculated by the given formula.

$C_1V_1 = C_2V_2$

C_1 = Concentration of the stock solution

C_2 = Required concentration

V_1=Volume required from the stock solution for making the desired concentration

V_2 = Required volume

***Ricinus communis* leaf extracts**

Fresh and young leaves were picked from *R. communis* plants and were cleaned through water. These clean *R. communis* leaves were dried for 14 days in a shady area. These dried leaves were ground through electrical grinder, after that ungrounded parts of leaves were removed and fine powder form was collected and sieved. 0.5 kilogram of grinded leaf extracts were taken in muslin cloth and then soaked for 24 hours in pure boiled water of one liter. After 24 hours filtered solution of 50 percent concentration prepared. Five percent concentration solutions of *R. communis* extract were obtained.

Neem oil

Neem oil extracts were purchased from the local market Khyber Pakhtunkhwa, Pakistan. Neem oil was applied at 5 percent concentration.

Treatment Application

Crops were monitor closely; botanical extracts and synthetic insecticide were applied when number of whitefly or *Epilachna* beetle reached to its Economic threshold Level (ETL). Whitefly (ETL) 8-10 leaf^{-1} and *Epilachna* beetle (ETL) 2-3 beetle leaf^{-1}. Spray application was repeated in the rest of the crop season when whitefly or *Epilachna* beetle reached to (ETL). The data on the relevant parameters were noted at 3, 7 and 10 days after the botanical extracts and synthetic insecticide application till termination of the experiment.

Data collection

The data was recorded at 3, 7 and 10 days interval after each application on the following parameters.

Whitefly population

Population density of whitefly per leaf was recorded at 3, 7 and 10 days intervals during experimental period after application. Five plants per treatment were randomly selected and population of whitefly were noted down on three leaves i.e., one each from top, middle and bottom of canopy of the brinjal crop in the field.

***Epilachna* beetle population**

Epilachna beetle population trend per leaf was recorded at 3, 7 and 10 days intervals during experimental period after application. Five plants per treatment were randomly selected and population of *Epilachna* beetle were noted down on three leaves i.e., one each from top, middle and bottom of canopy of the brinjal crop in the field.

Biological efficacy

Biological efficacy (B.E) of natural plant extracts and synthetic insecticide was calculated in term of % mortality of pest by using Abbott's formula.

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

Yield per treatment

The brinjal fruits are prepared for the harvest when the fruit length reached 5-10 cm and the width reached 1-2 cm and the color of the fruits become deep purple. Fruits from each treatment of the experiment were counted after each picking and were weighed by an electronic balance.

Statistical Analysis

The collected data were subjected to statistical analysis through Statistical software of Statistix 8.1 and for Least Significant Difference (LSD) test at 5% level of significance was used to separate the means that were significantly different (Steel and Torrie., 1980).

RESULTS

Table 1. Effect of various plant extracts and Imidacloprid on the population density of whitefly leaf^{-1} after 1st application in brinjal crop

Treatments	3 Days	7 Days	10 Days	Mean
Solanum nigrum leaf extract @ 5%	7.55gh	8.51f	10.00d	8.69c
Ricinus communis leaf extract @ 5%	7.98fg	9.15e	10.68c	9.27b
Neem oil @ 5%	3.24j	4.49i	7.08h	4.94d
Imidacloprid 20 SC	0.80k	0.84k	0.89k	0.84e
Control	11.47b	11.51b	12.21a	11.73a
Mean	6.21c	6.90b	8.17a	

The means which have different alphabets in the table are statistically different from each other at 5% level of significance using LSD test.

LSD value for time interval (T.I) = 0.2470

LSD value for treatments (T) = 0.3189

LSD value for (T. I) * (T) = 0.5523

Population density of whitefly after 1st spray

The results regarding the effect of various plant extracts and Imidacloprid on the mean population density of whitefly after its application in brinjal crop showed highly significant difference. Mean maximum whitefly per leaf (11.73) was recorded from the control, followed by *Ricinus communis* (9.27) and *Solanum nigrum* (8.69) respectively. Mean minimum (0.84) whitefly leaf^{-1} was noted in synthetic insecticide Imidacloprid which was statistically lower than Neem oil (4.94) (Table 1).

The data presented in table 1 showed significant variation for the time interval. Mean maximum population density of whitefly leaf^{-1} (8.17) was examined during 10 days of the post treatment followed by day 7 (6.90) while lowest mean population of whitefly per leaf (6.21) was noted on day 3.

The interaction between treatments effects and time interval was statistically found significant (Table 1). Statistically high infestation of whitefly leaf^{-1} (12.21) was recorded in control plot on day 10 whereas the lower infestation (0.80) was observed in Imidacloprid on day 3. In botanicals, the minimum population of whitefly per leaf (3.24) was noted in Neem oil on day 3 while maximum population (10.68) was recorded in *Ricinus communis* on day 10.

Table 2. Effect of various plant extracts and Imidacloprid on the population density of whitefly leaf^{-1} after 2nd application in brinjal crop

Treatments	3 Days	7 Days	10 Days	Mean
Solanum nigrum leaf extract @ 5%	6.86e	7.91d	9.09bc	7.95b
Ricinus communis leaf extract @ 5%	7.06e	8.48cd	9.31b	8.28b
Neem oil @ 5%	3.38h	4.25g	5.72f	4.45c
Imidacloprid 20 SC	0.80i	0.84i	0.88i	0.84d
Control	11.84a	12.06a	12.47a	12.12a
Mean	5.99c	6.71b	7.49a	

The means which have different alphabets in the table are statistically different from each other at 5% level of significance using LSD test.

LSD value for time interval (T.I) = 0.2870

LSD value for treatments (T) = 0.3706

LSD value for (T. I)* (T) = 0.6418

Population density of whitefly after 2nd spray

Mean population density of whitefly leaf^{-1} differs significantly among the treatments applied. Significantly lower population of whitefly leaf^{-1} (0.84) was recorded in the plot treated with Imidacloprid followed by Neem oil (4.45). Highest population of whitefly per leaf (12.12) was observed in control plot followed by *Ricinus communis* (8.28) and *Solanum nigrum* (7.95) respectively. These two treatments were statistically at par each other (Table 2).

The results regarding effect of time interval on the effectively of treatments on the population of whitefly has been shown in table 2. Mean values for different time intervals showed high significant variation. Mean maximum population of whitefly

leaf^{-1} (7.49) was observed on day 10. Mean minimum whitefly population per leaf (5.99) was calculated on days 3 followed by day 7 (6.71).

The interaction effect between treatments and time interval showed that highest population of whitefly per leaf (12.47) was examined in control plot on day 10 whereas the minimum population of whitefly (0.80) was calculated in Imidacloprid on day 3. Among the botanicals, minimum population of whitefly per leaf (3.38) was noted on day 3 in Neem oil. The maximum population (9.31) was recorded in *Ricinus communis* on day 10.

Table 3. Effect of various plant extracts and Imidacloprid on the population density of whitefly leaf^{-1} after 3rd application in brinjal crop

Treatments	3 Days	7 Days	10 Days	Mean
Solanum nigrum leaf extracts @ 5%	2.97fg	3.66e	3.75de	3.46c
Ricinus communis leaf extracts @ 5%	3.20f	3.93cd	4.19c	3.77b
Neem oil @ 5%	2.15h	2.76g	3.18f	2.70d
Imidacloprid20 SC	0.81j	1.24i	1.39i	1.15e
Control	5.11ab	5.19a	4.90b	5.07a
Mean	2.85c	3.36b	3.48a	

The means which have different alphabets in the table are statistically different from each other at 5% level of significance using LSD test.

LSD value for time interval (T.I) = 0.1187

LSD value for treatments (T) = 0.1533

LSD value for (T. I)* (T) = 0.2655

Population density of whitefly after 3rd spray

The results regarding the effect of various plant extracts and synthetic insecticide on the population density of whitefly after its application on brinjal crop showed significant difference. The mean maximum population density (5.07) leaf^{-1} of whitefly was recorded in control, followed by *Ricinus communis* (3.77) and *Solanum nigrum* (3.46) per leaf respectively. The lowest population density leaf^{-1} of whitefly was recorded in Imidacloprid (1.15) followed by Neem oil (2.70 leaf^{-1}) (Table 3).

The effect of time interval on the affectivity of the treatments has been shown in table 3. There was statistically highly significant difference recorded in treatments effect with the passage of time after its application. The highest mean population (3.48) leaf^{-1}of whitefly was observed on 10 days' time interval after treatments application, followed by day 7 (3.36). Similarly, the mean minimum population per leaf was examined on 3rd day (2.85).

The interaction between treatments effects and time interval on the mean population density (leaf^{-1}) of whitefly is presented in table-3. The minimum mean population density (0.81) was recorded in Imidacloprid on day 3 after its application whereas the maximum mean population (5.19) was recorded in control on day 7. In botanicals, the lowest mean population (2.15) was observed in Neem oil on day 3 while the highest mean population (4.19) was recorded in *Ricinus communis* on day 10.

Table 4. Biological efficacy of various plant extracts and Imidacloprid on population density of whitefly leaf^{-1} in brinjal crop

Treatments	Mean Infestation 1st, 2nd& 3rd Spray	Biological efficacy (%)
Solanum nigrum	6.70	30.49%
Ricinus communis	7.10	26.27%
Neem oil	4.03	58.19%
Imidacloprid	0.94	90.21%
Control	9.64	

The data presented in table 4 showed the percent biological efficacy of various treatments included *Solanum nigrum*, *Ricinus communis*, Neem oil and Imidacloprid were used against whitefly percent mortality. Maximum Biological efficacy against whitefly was observed from the plots treated with Imidacloprid (90.21%) followed by Neem oil (58.19%) while the minimum biological efficacy (26.27%) was recorded in *Ricinus communis* followed by *Solanum nigrum* (30.49%).

Table 5. Effect of various plant extracts and Imidacloprid on the population density of *Epilachna* beetleleaf^{-1} after 1st application in brinjal crop

Treatments	3 Days	7 Days	10 Days	Mean
Solanum nigrum leaf extract @ 5%	2.69	3.19	3.88	3.25b
*Ricinus communis*leaf extract @ 5%	2.97	3.37	4.28	3.54b
Neem oil @ 5%	1.59	2.17	2.82	2.19c
Imidacloprid 20 SC	0.64	0.72	0.88	0.75d
Control	5.64	5.66	6.33	5.87a
Mean	2.70c	3.02b	3.64a	

The means which have different alphabets in the table are statistically different from each other at 5% level of significance using LSD test.

LSD value for time interval (T.I) = 0.2699

LSD value for treatments (T) = 0.3485

LSD value for (T. I)* (T) = N.S

Population density of *Epilachna* beetle after 1st spray

The results showed that significant variation among the applied treatments against *Epilachna* beetle after 1st application in brinjal crop. The interaction of treatments and time interval was showed non-significant effect as given in table 5. The mean maximum population density of *Epilachna* beetle leaf^{-1} (5.87) was recorded on control plot followed by *Ricinus communis* (3.54) and *Solanum nigrum* (3.25) whereas the mean minimum population of *Epilachna* beetle per leaf (0.75) was observed from the plot treated with Imidacloprid followed by Neem oil (2.19).

The statistical analysis showed effect of time interval on the effectively of treatments on the population of *Epilachna* beetle has been shown in table 4. The highest mean of *Epilachna* beetle per leaf (3.64) was noted on day 10 followed by day 7 (3.02) while the mean minimum population (2.70) was recorded on day 3.

Table 6. Effect of various plant extracts and Imidacloprid on the population density of *Epilachna* beetleleaf^{-1} after 2nd application in brinjal crop

Treatments	3 Days	7 Days	10 Days	Mean
Solanum nigrum leaf extract @ 5%	2.89e	3.23cd	3.66b	3.26b

*Ricinus communis*leaf extract @ 5%	3.03de	3.32c	3.75b	3.37b
Neem oil @ 5%	1.83g	2.30f	3.13cd	2.42c
Imidacloprid20 SC	0.63i	0.72i	1.29h	0.88d
Control	5.46a	5.60a	5.60a	5.55a
Mean	2.77c	3.03b	3.48a	

The means which have different alphabets in the table are statistically different from each other at 5% level of significance using LSD test.

LSD value for time interval (T.I) = 0.0970

LSD value for treatments (T) = 0.1252

LSD value for (T. I)* (T) = 0.2169

Population density of *Epilachna* beetle after 2nd spray

Mean population density of *Epilachna* beetle leaf^{-1} differs highly significant effect among the treatments applied (Appendix-5). Mean presented significantly minimum population of *Epilachna* beetle per leaf (0.88) was recorded from the plot treated with Imidacloprid. Among the botanicals extract Neem oil gives significantly better efficacy against *Epilachna* beetle per leaf with (2.42) than *Ricinus communis* leaf extracts (3.37) and *Solanum nigrum* leaf extracts (3.26), these two treatments were statistically at par each other. Significantly high population of *Epilachna* beetle per leaf (5.55) was examined in the control plot as shown in table 6.

Mean data regarding time interval efficacy of applied treatments showed highly significant difference as given in table-6. Mean maximum population of *Epilachna* beetle per leaf (3.48) was calculated on day 10. The Mean minimum population of *Epilachna* beetle per leaf (2.77) was observed on days 3 followed by day 7 (3.03).

The interaction between times interval vs. treatments were showed statistically high significant influence effect on each other. The highest number of *Epilachna* beetle per leaf (5.60) same values were recorded in control plot on various time interval day 7 and day 10 while lowest number (0.63) was noted in Imidacloprid on day 3. In botanicals, the maximum population *Epilachna* beetleleaf^{-1} (3.75) was examined in *Ricinus communis* on day 10 whereas the minimum population (1.83) was observed in Neem oil on day 3 as shown in table 6.

Table 7. Effect of various plant extracts and Imidacloprid on the population density of *Epilachna* beetleleaf^{-1}after 3rd application in brinjal crop

Treatments	3 Days	7 Days	10 Days	Mean
Solanum nigrum leaf extract @ 5%	2.23	2.32	2.42	2.32b
*Ricinus communis*leaf extract @ 5%	2.29	2.38	2.47	2.38b
Neem oil @ 5%	1.67	1.76	1.85	1.76c
Imidacloprid 20SC	0.63	0.68	0.76	0.69d
Control	2.82	2.82	2.92	2.85a
Mean	1.93c	1.99b	2.08a	

The means which have different alphabets in the table are statistically different from each other at 5% level of significance using LSD test.

LSD value for time interval (T.I) = 0.0527

LSD value for treatments (T) = 0.0680

LSD value for (T. I)* (T) = N.S

Population density of *Epilachna* beetle after 3rd spray

The analysis of variance for infestation of *Epilachna* beetle per leaf showed highly significant effect was recorded in treatments with the passage of time after its application. Significantly highest mean population of *Epilachna* beetle per leaf (2.85) was observed from control plot followed by *Ricinus communis* (2.38) and *Solanum nigrum* (2.32) whereas the lowest mean population (0.69) was recorded on Imidacloprid followed by Neem oil (1.76) the data presented in table 7.

The time interval data revealed that days showed highly significant variation among the treatments after its application. Mean maximum efficacy of treatments against population of *Epilachna* beetle per leaf (1.93) was observed on day 3 while mean minimum population (2.08) was calculated on day 10 followed by (1.99) on day 7 as shown in table 7.

Table 8. Biological efficacy of various plant extracts and Imidacloprid on population density of *Epilachna* beetle in brinjal crop

Treatments	Mean Infestation	Biological efficacy (%)

	1st, 2nd& 3rd Spray	
Solanum nigrum	2.94	38.12%
Ricinus communis	3.09	34.89%
Neem oil	2.12	55.36%
Imidacloprid	0.77	83.74%
Control	4.75	

The data presented in table 8 showed that the percent biological efficacy of various treatments included *Solanum nigrum*, *Ricinus communis*, Neem oil and Imidacloprid against *Epilachna* beetle in brinjal during 2019. Maximum Biological efficacy (83.74%) was observed from the plots treated with Imidacloprid followed by Neem oil (55.36%) while the minimum biological efficacy against *Epilachna* beetle (34.89%) was recorded in *Ricinus communis* followed by *Solanum nigrum* (38.12%).

Table 9. Effect of various plant extracts and Imidacloprid on yield per treatment in brinjal crop

Treatments	Mean yield kgplot^{-1}	Kg ha^{-1}
Solanum nigrum leaf extract @ 5%	1.44c	3331.5c
*Ricinus communis*leaf extract@ 5%	1.24d	2879.6d
Neem oil @ 5%	2.05b	4748.2b
Imidacloprid 20SC	2.29a	5308.6a
Control	0.41e	941.5e
LSD (0.05)	0.117	271.85

The means which have different alphabets in the table are statistically different from each other at 5% level of significance using LSD test.

Yield of Brinjal crop

Data regarding yield of brinjal after application of various treatments against whitefly and *Epilachna* beetle as given in table 9. Significantly different yield recorded in the field treated with different treatments. Results revealed that maximum yield kg ha^{-1} (5308.6) was recorded from the plots treated with Imidacloprid followed by Neem oil (4748.2). Minimum yield kg ha^{-1} (941.5) was observed from the control plot followed by treatment *Ricinus communis* (2879.6) and *Solanum nigrum* (3331.5) respectively.

DISCUSSION

The experiment was carried out to evaluate the effectiveness of various botanicals extracts and Imidacloprid against whitefly and *Epilachna* beetle in brinjal crop under field condition at Agricultural Research Station Swabi during 2019. Various treatments were applied in this experiment *Solanum nigrum* @ 5%, *Ricinus communis*@ 5%, Neem oil @5%, Imidaclopridand untreated control. The treatments showed significant efficacy against whitefly and *Epilachna* beetle. The plots treated with Imidacloprid showed better effect on whitefly and *Epilachna* beetle and significantly higher yield followed by Neem oil @ 5%. Minimum yield and highest population of whitefly and *Epilachna* beetle was recorded on control plots followed by *Ricinus communis* @ 5%.

Population density of whitefly differs significantly among the treatments applied and various time intervals. Results reported that plots treated with synthetic insecticide i.e., Imidacloprid significantly reduced the population of whitefly followed by Neem oil while highest population was attained by control. These results revealed that Imidacloprid is significantly better than natural plants extract. Similar results were obtained by Das and Tarikul (2014) who concluded that Imidacloprid proved to be superior against whitefly mortality. Imidacloprid action was to be much faster and effect on the reduction of whitefly population density as compared to untreated control. Whitefly population was reduced at one day interval after spray and the effect of chemical was determined up to seven days. The results about the synthetic insecticide (Imidacloprid) are also in conformity with Ursani *et al.* (2014) who reported that chemical control (Imidacloprid) proved more effective against whitefly in brinjal crop which is followed by Neem extracts. These findings are also in lined with Ali*et al*. (2004) who concluded that persistency of insecticide was affected up to 15 days after application. Imidacloprid 20 SL showed better efficacy than other insecticide on *B. tabaci* population where the minimum population was recorded 1.18-3.03 leaf^{-1}.

Imidacloprid was followed by Neem oil 5@ % treatment. Among the botanicals extracts Neem oil showed the lowest whitefly infestation as compared to other plants extracts and control plot. Better efficacy of Neem oil botanical insecticides including Azadirachtin. Azadirachtin have diverse mode of action (deter insect from plants) properties Halder *et al.* (2013). Similar results were recorded by Tangtrakulwanich and Reddy (2014) and Mpumi *et al.* (2016) who reported that Neem oil is effective against sucking pests are those with feeding deterrent action, so their indiscriminate use could

result in the development of resistance. Other similar results are also confirmed by Haq (2006) who investigated that efficacy of bio-pesticides such as Neem leaf extracts was highly effective sucking insect pests like whitefly etc. According to Kunbhar *et al.* (2018) who documented that maximum percent reduction of whitefly in Neem extracts with (61.90) was examined after application.

The application of *Solanum nigrum @ 5%* against whitefly showed better results as compared to *Ricinus communis @ 5%*and control plot. Our results are in lined with Omar *et al.* (2012) who concluded that *S. nigrum* had causes 36% mortality against sucking insect pests. These findings were also confirmed by Spochacz, *et al.* (2018) who revealed that *S. nigrum* include GAs that effect different stages of life cycle of various insects. *S. nigrum* fruit and leaf extracts are used as alternatives of synthetic insecticides. Similar results were also obtained by Weissenberg *et al.* (1998) who concluded that GAs have been examined on *Tribolium castaneum* belong to same family of *tenebrio molitor* and resulted that GAs acted as growth inhibitor in insect larval stage. Same findings were also mentioned by Aydin *et al.* (2017) who documented that application of *S. nigrum* extract changes in decreasing the oviduct activity of insect. Similar recorded data were also calculated by Ventrella *et al*. (2015) that black nightshade (*S. nigrum*) leaf extracts was applied against the *Zophobas atratus* (Tenebrionidae), heart and at a concentration of 0.5 mm, it caused a reversible negative chronotropic effect.

The study investigated that *Ricinus communis* leaf extracts showed lower efficacy against whitefly in applied botanicals and showed better results as compared to control plot. Similar findings were demonstrated by Rodriguez-Hernandez (2005) who reported that the ricinine and castor oil are active ingredients of *R. communis* leaf and seed extracts that act against sucking insects. Hexane extract of leaves shows insecticidal activity against *S. frugiperda.* Same findings are also in line with Kang *et al.* (1985) and Upanasi *et al.* (2003) who documented that ricinine compound which is responsible for the activity of extracts. Ricinine is found in leaf and seed as well. Insecticidal activity of these ricinine due to this alkaloid is not soluble in hexane.

The mean values of Imidacloprid showed significantly difference among the treatments applied. Our results revealed that lowest population of *Epilachna* beetle was recorded in plot treated with Imidacloprid. The findings are in line with Yadav and Raghuraman

(2014); Das and Islam (2014) who concluded that synthetic insecticide (Imidacloprid) is significantly better than botanicals extract. The efficacy of Imidacloprid (confidor) showed best result against major insects of brinjal crop.

Imidacloprid treatment was followed by plot treated with Neem oil @ 5% against *Epilachna* beetle in brinjal crop during 2019. Neem oil showed better efficacy among the botanical extracts. These findings were confirmed by Swaminathan *et al*. (2010) who investigated that Neem oil @ 5% caused (60%) against *Henosepilachna vigintioctopunctata.* The leaf extracts had also antifeedant activity. Similar findings were also recorded by Vishwakarma *et al*. (2011) who indicated that *M. anisopliae* @ 3 g per liter significantly highest control population density of *Epilachna* beetle up to 75 % in bottle gourd crop.

The findings regarding better efficacy of *Solanum nigrum* treatment as compared to plot treated with *Ricinus communis* against *Epilachna* beetle. Same results were obtained by Verma and Yadava (2003) who stated that *E. globulus* in the form of leaf extract inhibited the growth and development of *Epilachna* beetle. The leaf and fruit extracts were prepared from *A. Arabica* plant. These findings are also in line with Raiand Carpinella (2006) who documented the repellent activity of various natural botanicals extracts from the genus *S. nigrum*. The same findings were also obtained by Hamouda *et al.* (2015); Obeng-Ofori and freeman (2001) who concluded that efficacy of *S. nigrum* was observed against *Tribolium castaneum*.

The experiment showed lowest efficacy of *Ricinus communis* against *Epilachna* beetle in all botanical extracts. The findings are in agreement with Rao *et al.* (1990) who revealed that leaf extracts of *R. communis* (0.5%) showed better efficacy against 2nd instar larvae of *H. vigintioctopunctata* indicating high antifeedant effect. These findings are also in line with Ahmed *et al.* (2010) who documented that efficacy of bio pesticide castor (*R. communis*), sesame oil, Neem seed oil and custard apple (*Annona saquamosa*) were applied against *Epilachna* beetle. The custard apple showed better efficacy while *R. communis* and other treatments also exhibited better results as compared to control. Same results are also in agreements with Islam *et al*. (2011) who studied that *R. communis*, *Calotropis procera* and *Datura metel* were used against *Epilachna* beetle aiming at its control under laboratory conditions and reported that Larvicidal bioassays of the extracts showed the following order of toxicity *R. communis*

(LC50=18.40%) > *C. Procera* (LC50=23.70%) > *D. metel* lethal concentration (LC50=29.61%).

Mean values regarding the yield, applied treatments showed a highly significant variation. Plot treated with Imidacloprid gave highest yield followed by Neem oil 5%. Control treatment was recorded the lowest yield in brinjal crop followed by a plot treated with *Ricinus communis* leaf extracts. Our results about the yield are in conformity with Prodhan *et al.* (2018) who documented that Imidaclopridis useful insecticide on improvement of quality brinjal production. The maximum brinjal yield was obtained from a plot treated with confidor (Imidacloprid) as compared with untreated plot. Same results were also observed by Rakibuzzaman *et al.* (2019) who stated that highest weight of total fruit per plant was recorded on plot treated with Neem oil this is due to low infestation and more healthy branches of plant while the lowest fruit weight was recorded in untreated plot due high infestation of pest.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The following conclusions were made from the current experiment:

Synthetic insecticide (Imidacloprid) significantly showed better efficacy among the treatments against whitefly and *Epilachna* beetle by reducing the population density in brinjal crop. Furthermore, this chemical significantly resulted in high brinjal yield.

Neem oil 5% gave significantly best result among the natural botanical extracts used in present experiment and reduced the brinjal crop pest population.

From the current experiment it is revealed that all the botanical extracts used in present trial decrease the brinjal pest population as compared to untreated plot.

Recommendation

On the basis of the above conclusions the following recommendations are made:

Neem oil@ 5% spray is most effective against whitefly and *Epilachna* beetle in brinjal crop as compared to other botanical extracts such as *Ricinus communis*leaf

extracts @ 5% and *Solanum nigrum* leaf extracts @ 5%. It may be used in IPM for the control of whitefly and *Epilachna* beetle in brinjal crop.

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