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Research Article

Effectiveness of *Parthenium hysterophorus* L. Extracts Against Wheat Aphid, *Sitobion avenae* (Hemiptera: Aphididae) under Field Conditions

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Abstract | The present study regarding the effectiveness of *Parthenium hysterophorus* L. extracts against wheat aphid, *Sitobion avenae* (Hemiptera: Aphididae) and lady bird beetle under field conditions was conducted at Agricultural Research Institute (ARI) Tarnab, Peshawar, Pakistan from December 2019 to June 2020. The experiment was consisted of five aqueous extracts of different parts of *P. hysterophorus* (whole plant, stem, leaves and flower extracts) and control (only water) which were applied randomly within each block. Wheat variety "Faisalabad 2008" was sown in the first week of December and general agronomic practices were applied as per the recommendations for wheat sowing. The pre- and post-spray data were collected after 1, 2, 3, 7, 14 and 21 days. The aphids population was found on the decreasing trend after spray application of each extract of *P. hysterophorus*. Post-spray data revealed that the plot treated with flower extracts had the highest mean number of aphids (32.00 plant^{-1}), whereas the least mean number of *S. avenae* was recorded for stem extracts (25.00 plant^{-1}) after 1 day application. However, after 14 days a significantly lower mean number of aphids was recorded in plot treated with stem extracts (0.001 plant^{-1}) as compared to the others. Data regarding the percent aphids reduction showed that 50% aphids reduction was recorded in plot treated with stem extract and reached to 100% after 21 days. Data regarding ladybird beetle, showed that the highest means number of ladybird beetle was found with whole plant extract (5.00 plant^{-1}) while the least number of ladybird beetle were found with stem, leaves and flower extracts. In post-spray, the highest number of ladybird beetle were found with stem extracts (2.33 plant^{-1}) and the least in other treatments. After 14 days of *P. hysterophorus* spray application, the lady bird beetle population was also found on the decreasing trend in all the treatments. Furthermore, wheat plots treated with *P. hysterophorus* leaves extract resulted in maximum plant height (100.67 cm), spike length (12.33 cm) and total yield (3910.23 kg/ha). Based on the above results, *P. hysterophorus* leaves extract can be recommended in wheat for the management of targeted pest including *S. avenae.*

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Introduction

Wheat (*Triticum aestivum* L.) is an important cereal crop, widely consumed as staple food, particularly in Asian countries. It is one of the main nutritional sources for people with higher value dietary products (Naz and Akmal, 2016). Wheat contributes 9.2 percent to the value added in agriculture and 1.8 percent to the country's GDP. The area under wheat cultivation expanded from 8,805 thousand hectares to 9,178 thousand hectares, reaching a record high production of 27.293 million tons in 2020-21 (GoP, 2021).

Various aphid species, including *Rhopalosiphum maidis*, *Rhopa padi*, *Schizaphis graminum*, *Sitobion avenae*, *Sipha maydis*, *Macrosiphum avenae*, *Aphis nerii*, *Myzus persicae*, *Brevicoryne brassicae*, *Macrosiphum granarium*, and *Rhopalosiphum rufiabdominalis*, are known to infest wheat crops in Pakistan

Wheat crops is prone to several insect pests both in fields and during storages. Various aphid species including *Sitobion avenae, Sipha maydis, Macrosiphum avenae, Rhopalosiphum maidis, R. padi, Myzus persicae* etc. are known to infest wheat crop in Pakistan (Irshad, 2001; Mushtaq *et al*., 2013). Among these, the wheat aphid, *S. avenae* is considered the most damaging insect pest. They have piercing and sucking mouth parts that are used to extract cell sap from different parts of the plant and also cause indirect damage by transmitting the barley yellow dwarf virus. Aphid infestations in wheat significantly impact both productivity and profitability by stunting shoot growth, reducing chlorophyll levels, and ultimately decreasing yield (Czerniewicz *et al*., 2016). A single aphid can cause up to 2.20 % yield loss in wheat crop, whereas 30-40% yield losses have been reported at a population of 15 aphids per plant (Zhou *et al*., 2011).

Farmers mostly depend on systemic insecticides application to control aphid populations in wheat crops. However, frequent applications of synthetic pesticides have different drawbacks, such as increased pest resistance, residues in food, deleterious impact on the environment and negative effects on non-target organisms, including humans. Therefore, in recent years research on alternative methods of aphid control has become more important. One of the alternative strategies to chemical insecticides is the use of plant-derived extracts, which are often more selective, biodegradable, and generally have little or no harmful effects on non-target organisms (Czerniewicz *et al*., 2016). Besides chemicals, some natural enemies of the aphids also attack aphids in wheat crop. Among these, ladybird beetles are generally regarded as beneficial due to their predatory behavior, which helps control populations of soft-bodied insects like aphids and jassids. An adult ladybird beetle can consume a quantity of aphids equal to its body weight each day (Dixon, 2000). Historical usage of nicotine and pyrethrum have encouraged scientists to focus their attention on botanical insecticides. Plant-based extracts with insecticidal properties are widely available and are generally regarded as safer for the environment and public health compared to synthetic chemicals. Research indicates that more than 2,000 plant species from approximately 170 different families possess insecticidal properties (Iqbal *et al*., 2010). In Pakistan, several botanical insecticides derived from plant oils are used to manage aphid populations. Examples of these include neem (*Azadirachta indica* A. Juss.), sweet orange (*Citrus sinensis* L.), balsam pear (*Momordica dioica* R.), wild garlic (*Allium vineale* L.*)*, chili pepper (*Capsicum frutescens* L.) and tobacco (*Nicotiana tabacum* L.) (Shah *et al*., 2017).

Parthenium hysterophorus L. of the family Asteraceae has inhabited many parts of the world and is known as a noxious weed for its harmful effects. It also has other names like carrot weed, congress grass and is one of the ten feared noxious weed species in the world. It is harmful to all the living beings as it causes various serious problems in humans and other mammals. Similarly, its leaves, stem, flowers and roots have strong insecticidal and larvicidal properties (Gupta *et al*., 2020). Chemical analysis of *Parthenium* has revealed that all parts of the plant, including trichomes and pollen, contain toxins known as sesquiterpene lactones, which are used as an active insecticide against various insect species (Tesfu and Emana, 2013). Insect pests caused a great yield loss in wheat production, where cereal aphid only, caused yield reduction estimated by up to 23%. Thus, protection and expansion of the production of wheat is highly desirable for all the plant breeders, plant growers and protection specialists (Awadalla *et al*., 2018). Keeping in view the importance of wheat and efficacy of botanical extracts against insect pests of wheat, this study was carried out to evaluate the toxic effects of different plant parts of *P. hysterophorus* against wheat aphid, (*S. avenae)* under field conditions.

Materials and Methods

The experiment consisted of the following five treatments which were applied randomly within each block. Wheat variety Faisalabad 2008 was sown in lines during the first week of December 2019 adhering to standard agronomic practices and balanced fertilizers as recommended for wheat cultivation.

S. No		Treatments
1	T0	Control
2	T1	Whole plant of *P. hysterophorus* extracts.
3	T2	Stem extracts of *P. hysterophorus*.
4	T3	Leaves extract of *P. hysterophorus*
5	T4	Flower extracts of *P. hysterophorus*

Parthenium plants were collected from local fields and were sun dried. After drying different parts of *Parthenium* plant i.e., whole plant, flowers, leaves, and stem were separated manually and crushed in a mortar. The crushed parts or powders amounting 200gm of each tested part of *Parthenium* plant were weighed and then put in muslin cloth and mixed 5gm of any detergent. The solute was kept in one liter of water boiled up to 80-85°C for 24hrs duration then the extracts will be fully squeezed manually. This gave us a 20% solution and thus was then stored as a stock solution for further experimentation. The prepared Parthenium extracts from different plant parts were then applied at a rate of 1 liter per plot using a knapsack sprayer when the aphid population reached its economic threshold level (ETL) (10-12 aphids/ plant) for wheat (Yahya *et al*., 2017).

Pre-spray data of aphid population along with natural enemies were recorded as a mean number of aphids per plant 1 day before spray application while post-spray data were recorded after 1, 2, 3, 7,14 and 21 days of spray application. Also, ladybird beetle data were recorded before and after spray like aphids data collection. Aphids and ladybird beetle were identified morphologically in Agriculture Research Institute Tarnab.

The effect of plant extracts of *P. hysterophorus* on % reduction of *S. avenae* in the wheat crop was recorded for 1, 2, 7, 14 and 21days using the Henderson-Tilton's formula (Henderson and Tilton, 1955).

$$Aphids\ reduction(\%) = \frac{\text{control} - \text{treatment}}{\text{control}}$$

Data regarding the plant height and spike length (cm) of wheat were measured from 3 replicates plants of each treatment. After harvesting wheat bundles were collected from each plot and weighed through weight balance. After threshing, the weight of grains from each plot was weight through balance which was then converted to total yield (kg/ha). The yield data was recorded as per the following formula (Inamullah *et al*., 2011).

$$\text{Yield (Kg/ ha)} = \frac{\text{weight of grains (Kg)} \times 10000m^2}{\text{Net area harvested}}$$

The data collected for all the parameters were analyzed using ANOVA under a Randomized Complete Block Design (RCBD). Mean differences were estimated using the Least Significant Difference (LSD) test at a 5% significance level, using the statistical software Statistics 8.1 (Steel and Torrie, 1980).

Results and Discussion

The results of the experiment regarding the effectiveness of *P. hysterophorus* against wheat aphid, *Sitobion avenae* and Ladybird beetle in wheat crop (variety Faisalabad 2008) is summarized below.

Aphid population density

The effect of different parts of *P. hysterophorus* extracts against wheat aphid under field conditions is shown in Table 1. Results showed that with every data collection interval, the control treatment, which did not receive any *Parthenium* extract spray application, was found to have the highest average number of aphids. Results showed that after 1 day of flower extract spray (T4), the highest mean number of aphids (32.00 plant^{-1}) was recorded, this was followed by T1 (whole plant extract) (30.67 plant^{-1}) and the least in T2 (stem extract) and T4 (leaves extract) with around (25.00 plant^{-1}) mean number of aphids. After 2 days of spray, the population had drastically decreased, with the resultant highest number of *S. avenae* in T1 (whole plant extract) (18.67 plant^{-1}) and the least number of aphids were recorded in T4 (flower extract) (14.67 plant^{-1}). However, in T2 (stem extract) and T3 (leaves extract), the highest number of aphids per plant was (10.00), after 72hr of spray, whereas the least number of aphids was recorded for T4 (9.00 plant^{-1}). After 7 days, the highest number of aphids ranged from T1 (whole plant extract) (3.33 plant^{-1}) whereas the least number of aphids was recorded in T4 (flower extract)

Table 1: *Effect of different parts of Parthenium hysterophorus extracts on mean number of Sitobion avenae population in wheat crop, during 2019.*

Treatments (Plant extract)	Pre- treatment	Post treatment time interval					
		1 day	2 days	3 days	7 days	14 days	Mean
T0 (control)	53.00a	47.33c	36.33d	25.00f	14.33ghi	5.33jk	25.90
T1 (whole plant)	51.00abc	30.67e	18.67g	9.33ij	3.33kl	0.67kl	16.24
T2 (stem extract)	47.67bc	25.00f	15.00gh	10.00hij	3.00kl	0.001	14.38
T3 (leaves extract)	48.00abc	25.33f	17.00g	10.00hij	2.67kl	0.67kl	14.81
T4 (flower extract)	52.67ab	32.00de	14.67gh	9.00j	2.33kl	0.33kl	15.86
Mean	50.47a	32.07b	20.33c	12.67d	5.13e	1.40e	

Column means sharing different alphabets letter (s) denote significant difference (P < 0.05). LSD value of treatment = NS. LSD value of time period = 2.48. LSD value of treatment x time period = 2.75

(2.33 plant^{-1}). After 14 days of spray, the highest mean number of aphids ware recorded in T1 (whole plant extract), and T3 (leaves extract) (0.67 plant^{-1}) number of aphids as compared to the control (5.33 plant^{-1}) which was the highest among all the treatments. These results are in conformity with the findings of Datta and Saxena (2001) who extracted sesquiterpene lactone from *Parthenium* with various solvents and recorded a high mortality rate of aphids as well as nematodes after application. Areaya *et al.* (2015) also evaluated the flower, leaf and root extracts of *P. hysterophorus* and reported promising results against cockroaches in Ethiopia.

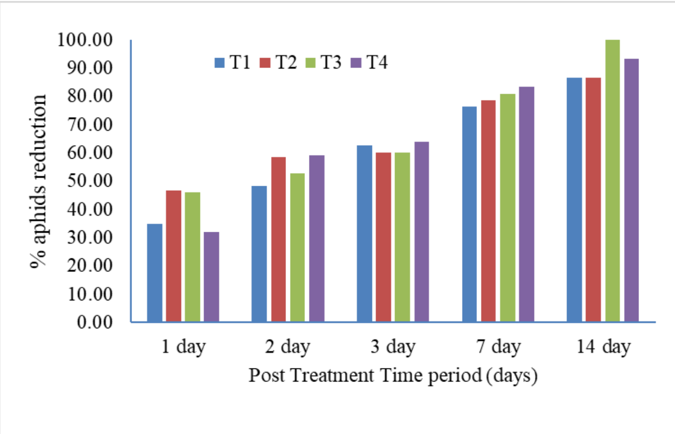

Figure 1: *Effect of plant extracts of different parts of Parthenium hysterophorus on %reduction of Sitobion avenae in wheat crop, during 2019.*

% Aphids reduction

The effect of plant extracts of different parts of *P. hysterophorus* on %reduction of *Sitobion avenae* in wheat crops during 2019 is shown in Figure 1. The results showed that after 1 day of spray application, about 50% aphids reduction was recorded in plot treated with stem extract of *P. hysterophorus*. After 2 days of spray application, nearly 60% aphids reduction was recorded in plots treated with *P. hysterophorus* flower extract. After 7 and 14 days, about 80% and 100% aphids reduction were observed in plots treated with leaves extract of *P. hysterophorus*. Lastly, after 21days, 100% aphids were reduced in all the treatments. Ahsan *et al.* (2021) also reported similar results. They tested different doses of aqueous extract of different parts of *Parthenium* plant against mealybugs on *Dalbergia sissoo* and observed high mortality of 76.67% and 73.33% via the residual method.

Ladybird beetle population density

The ladybird beetle population observed before and after the spray is shown in Table 2. Results showed that with every data collection interval, the control had been found with the highest mean number of ladybird beetles. Results showed that before spray application, the mean number of ladybird beetle was found significantly (*P*-value $\leq$ 0.05) highest with T1 (whole plant extract) with (5.00) ladybird beetle per plant. These results were followed by T2 (stem extract), T3 (leaves extract) and T4 (flower extract) with 4.76 number of ladybird beetle plant^{-1}. The highest numbers of ladybird beetle after one day of spray were recorded for T2 (stem extract) (2.33) followed by T1 (whole plant extract) T3 (leaves extract) and T4 (flower extract) (2.00). Fortunately, after 2 days of spray, the highest number of lady bird beetles (3.33 plant^{-1}) was observed in T4 (flower extract), while the least number of ladybird beetles (2.67 plant^{-1}) was recorded in T1 (whole plant extract). After 3 days of spray the highest number of ladybird beetle were in T1 (whole plant extract), and T2 (stem extract) (2.33 plant^{-1}) whereas the least number of aphids were recorded for T3 (leaves extract) and T4 (flower extract) (2.00 plant^{-1}). After 7 days, the highest number of ladybird beetle ranged from T2 (stem extract) (2.33) whereas the least number of ladybird beetle was recorded in T1 (whole plant extract) T3 (leaves extract) and T4 (flower extract) (1.67). After 14 days of spray the highest number of ladybird beetles was recorded in T1 (whole plant extract) and T3 (leaves extract) (1.00 plant^{-1}) number of ladybird beetle in control was recorded (1.00 plant^{-1}). These results confirm the findings of Nasir and Ahmad (2001) who also found non-significant correlation between lady bird beetle and aphid populations on wheat.

Plant height (cm)

Table 3 shows *P. hysterophorus* different parts and whole plant treatment effect on wheat plant height. Statistically, there was a highly significant difference (P-value ≤ 0.05) between each treatment. Results showed that the plants to which T3 was applied resulted in maximum plant height (100.67 ± 2.08 cm) which was followed by application of T1 (96.33 ± 1.53 cm). The least plant height was observed for T0 (80.00 ± 2.00 cm) which were the control plants, to which no *P. hysterophorus* whole plant or any part was applied. Among the treatments, T4 plants were observed with a mean height of 87.33 ± 2.52 cm, which was followed by T2 treatment with resultant 91.67 ± 2.52 cm plant height. Maximum plant height of 73.72 and 72.47 cm was also recorded in wheat plots sprayed with *Parthenium* by Baloach *et al.* (2014).

Spike length (cm)

Table 3 further shows *P. hysterophorus* different parts and whole plant treatment effect on wheat spikes length. Statistically, there was a highly significant difference (*P*-value ≤ 0.05) between each treatment. Results showed that wheat plants treated with T3 was with the maximum spike length (12.33 ± 1.15 cm) which was followed by the application of T1 (10.00 ± 1.15 cm). The minimum wheat spike length was observed for T0 (5.33 ± 1.00 cm) which were the control plants, to which no *P. hysterophorus* whole plant or any part treatment was applied. Among the treatments, T4 plants were observed with a mean length of 6.33 ± 0.58 cm, which was followed by T2 treatment with resultant 7.33 ± 0.58 cm plant spike length. Baloach *et al.* (2014) also obtained maximum wheat spike length of 11.31 cm in plots treated with aqueous extracts of *Parthenium*. Similar results were also obtained by Majeed *et al.* (2012) who stated that the increase in spike length may be due to the suppression of insect pests and weeds growth in wheat.

Table 2: *Effect of plant extracts parthenium hysterophorus on mean number of Ladybird beetle Population in wheat crop, during 2019.*

Treatments (Plant extracts)	Pre-treatments	Post treatment time interval					
		1 day	2 days	3 days	7 days	14 days	Mean
T0 (control)	4.33a	2.33cde	3.00bc	2.33cde	2.00de	1.00fg	2.14
T1 (whole plant)	5.00a	2.00de	2.67bcd	2.33cde	1.67ef	1.00fg	2.10
T2 (stem extract)	4.67a	2.33cde	3.00bc	2.33cde	2.33cde	0.33g	2.14
T3 (leaves extract)	4.67a	2.00de	2.33cde	2.00de	1.67ef	1.00fg	1.95
T4 (flower extract)	4.67a	2.00de	3.33b	2.00de	1.67ef	0.33g	2.00
Mean	4.67a	2.13c	2.87b	2.20c	1.87c	0.73d	

Column means sharing different alphabets letter (s) denote significant difference (P < 0.05). LSD value of treatment = NS. LSD value of time period = 2.50. LSD value of treatment x time period = 0.53

Table 3: *Effect of different parts of Parthenium hysterophorus extracts on wheat plant heights and spike length.*

S. No.	Treatments (plant extracts)	Plant height (cm)	Spike length
1	T0 (control)	80.00 ± 2.00e	5.33 ± 1.00d
2	T1 (whole plant extract)	96.33 ± 1.53b	10.00 ± 1.15b
3	T2 (stem extract)	91.67 ± 2.52c	7.33 ± 0.58c
4	T3 (leaves extract)	100.67 ± 2.08a	12.33 ± 1.15a
5	T4 (flower extract)	87.33 ± 2.52d	6.33 ± 0.58cd

Column means sharing different alphabets letter (s) denote significant difference (P < 0.05). LSD value of plant height: 6.23. LSD value of spike length: 2.84

Total yield (kg/ha)

Table 4 shows *P. hysterophorus* different parts and whole plant treatment effect on wheat yield (kg/ha). Statistically, there was a highly significant difference (*P*-value ≤ 0.05) between each tested experiment regarding wheat yield. Results showed that the plants to which T3 was applied were recorded with the highest yield (3910.23 ± 112.44 kg/ha) which was followed by the application of T2 (3654.83 ± 17.61 kg/ha), T1 (3623.13 ± 12.70 kg/ha) and T4 (3556.19 ± 11.55 kg/ha). The least wheat yield was observed for T0 (3440.53 ± 79.42 kg/ha) which were the control plants, to which no *P. hysterophorus* plant or any part, was applied. Our results are aligned with the work of Iqbal *et al.* (2010) who obtained maximum grain yield per spike following Parthenium spray application. Cheema *et al.* (2003) and Baloach *et al.* (2014) also used parthenium spray in wheat crop and obtained a higher wheat yield as compared to control plots.

Table 4: *Effect of different plant parts extracts of P. hysterophorus against S. avenae on wheat yield (kg/ha).*

S. No.	Treatments (plant extracts)	Yield (kg/ha)
1	T0 (control)	3440.53 ± 79.42c
2	T1 (whole plant extract)	3623.13 ± 12.70b
3	T2 (stem extract)	3654.83 ± 17.61b
4	T3 (leaves extract)	3910.23 ± 112.44a
5	T4 (flower extract)	3556.19 ± 11.55b

Column means sharing different alphabets letter(s) denote significant difference (P < 0.05). LSD value: 68.03

Conclusions and Recommendations

It was concluded that the leaves extract of *P. hysterophorus* had shown maximum plant height, spike length and total yield (kg/ha). Furthermore, the leaves extract of *P. hysterophorus* had been shown to decrease the population of aphids i.e., *Sitobion avenae* and hence can be recommended for the management of target pests.

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Novelty Statement

This study highlights the efficacy of different parts of *Parthenium hysterophorus* against wheat aphid, *Sitobion avenae*. The study suggested that the leaves extract of *P. hysterophorus* had shown significant effect against aphids i.e., *Sitobion avenae* in wheat crop and hence can be used in the integrated pest management programme of *S. avenae*.

Author's Contribution

Muhammad Salim, Ahamd Ur Rahman Saljoqi: Conceptualization, methodology, formal analysis, investigation, writing.
Muhammad Zakria: Conceptualization, writing, data collection.
Shahid Sattar, Amjad Usman, Hayat Badshah: Formal analysis, methodology, and editing.
Ayhan Gokce: Conceptualization, writing, and editing.

Conflict of interest

The authors have declared no conflict of interest.

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