Turkish Journal of Zoology

Volume 47 | Number 1 Article 2

1-1-2023

The impact of wheat resistance and bio-rational insecticides toxicity against cherry-oat aphid, Rhopalosiphum padi L. (Hemiptera: Aphididae)

ANISA HAQ

WAHEED MURAD

SARIR AHMAD

Turkish Journal of Zoology
http://journals.tubitak.gov.tr/zoology/
Research Article
Turk J Zool
(2023) 47: 10-19
© TÜBİTAK
doi:10.55730/1300-0179.3108

The impact of wheat resistance and bio-rational insecticides toxicity against cherry-oat aphid, *Rhopalosiphum padi* L. (Hemiptera: Aphididae)

Anisa HAQ[1], **Waheed MURAD**[1], **Sarir AHMAD**[1,2,*]
[1]Department of Botany, Faculty of Chemical and Lifesciences, Abdul Wali Khan University, Mardan, Pakistan
[2]Department of Plant Protection, Faculty of Crop Protection Sciences, The University of Agriculture Peshawar, Pakistan

Received: 24.06.2022 • **Accepted/Published Online:** 26.12.2022 • **Final Version:** 11.01.2023

Abstract: Aphids cause substantial damage to the wheat crop. In order to determine how host plant resistance and insecticides manage the *Rhopalosiphum padi* L. Current experiments were carried out to find the influence of host plant resistance and bio-rational insecticides against aphids in wheat (*Triticum aestivum* L.) crop. Field experiments were carried out for two growing years (2017/18 and 2018/19) to access the resistance of wheat against the aphids. The field resistance of wheat is highly expressed in Pirsabak-08 variety (infestation range = 1–2.5) while the most susceptible variety is Faisalabad-08 (infestation range > 10). The varietal preference experiment results revealed that 5.33 aphids were attracted towards Pirsabak-08 while Faisalabad-08 stood as the most susceptible variety as 25.0 aphids were found after 72 h. The linear correlation analysis revealed that the aphid attractiveness is negatively correlated to the trichome density. A stage-specific insect growth regulator (IGR) and natural insecticides were applied to a comparatively more resistant variety. The best results were achieved with pyriproxyfen and neem, as the population rapidly declined to 2.66 and 2.60 aphids/plant, respectively. Current findings lead to the conclusion that utilizing resistant hosts against aphids along with the use of safer insecticides can significantly reduce wheat damage.

Key words: Cereal aphids, insect growth regulator's (IGRs), neem oil, *Rhopalosiphum padi* L

1. Introduction

Wheat (*Triticum aestivum* L.), being a cereal crop, belongs to the family Poaceae. It is a staple food that constitutes an integral part of the diet of about 40% of the world's population (Giraldo et al., 2019). Its productivity aids 10% to Pakistan's agriculture sector and 2% to the Gross Domestic Product (GDP) (Faheem et al., 2019). The world food requirements are increasing annually at a tremendous rate due to the increased population. Economists estimated that the world population would surpass 9 billion (Zheng 2021). The agriculture sector needs to incline the production rate to feed such an over-crowded mass.

The basic features that constrain wheat's higher production are both biotic and abiotic. Among the biotic factors include insect pests, diseases, and weeds (Mesterházy et al., 2020). The insect pests account for over 20%–37% of crop losses. The estimated annual losses due to insect pests exceed 70$ annually (Qayyum et al., 2021). Among these insects include small sap-sucking insects, commonly known as wheat aphids (Hemiptera: Aphididae) (WA) (Faheem et al., 2019). WA causes significant losses to the wheat crop directly by sap-sucking and thus lowering the yield. While indirectly, it secretes honeydew which inhibits the normal photosynthesis process. It also harbors growth sites for various fungal and viral pathogens (Khan and Hassan, 2018).

Shahzad et al. (2013) reported 29 species of aphids infesting wheat and causing huge losses. Among these cherry oat aphids, *Rhopalosiphum padi* L. 1758 and grain-aphid, *Sitobion avenae* F. 1794, and the green-bug, *Schizaphis graminum* Rondani. 1852 are three prime aphid species in Pakistan (Abbas and Niaz, 2019; Zeb et al., 2020). Almost 40%–50% yield losses are evident from the aphid infestation in wheat (Kauppi et al., 2021). The aphids most prevalent species in Khyber Pakhtunkhwa are *Rhopalosiphum padi* L. 1758. (Junaid et al., 2016; Ullah et al., 2020).

Integrated Pest Management (IPM) is launched a few decades to tackle insect pests with minimal hazardous effects on the environment. The IPM enables us to utilize two or more management strategies simultaneously to overcome the excess infestation of the insect pest (Hoidal and Koch, 2021). Among these strategies include 1) the use of resistant varieties (Smith, 2021), 2) proper monitoring

* Correspondence: sarirplants@gmail.com

of the insect pest (Preti et al., 2020) and, 3) insect stage and action site-specific insecticides commonly known as insect growth regulators (IGR) (Abbas and Hafez, 2021).

Host plant resistance (HPR) is a practical approach where a host plant is equipped naturally/induced to reduce the infestation and attack of the insect pest. The resistance in host plants might have physical barriers (antixenosis) and biochemical (antibiosis) against the insect pests (Painter, 1951). Till now, the resistance against aphids has come from the wheat wild and breed varieties (Aradottir and Crespo-Herrera, 2021).

The excess use of broad-spectrum pesticides for pest management has brought misery to nontarget organisms and environmental pollution. Researchers desperately look for an alternative to these broad-spectrum pesticides. Insect growth regulators (IGR) provide an economical and eco-friendly solution by acting upon a specific life stage of the insect pest. IGRs play a crucial role in inhibiting growth enzymes that stops a target insect from achieving adulthood (Abbas and Hafez, 2021). Another source of chemical pest management is plant-based insecticides. Plants possess toxic compounds that directly kill the insect pest or affect its biology (Tavares et al., 2021). Shah et al. (2017) reported the potential of plant products against aphids, and its application also increased wheat yield. Likewise, Chakraborty et al. (2019) evaluated different IGR against aphids in laboratory conditions. Their results indicated a positive potential for IGR, but dose and exposure time is essential for effective management.

Previously, HPR in wheat has been solely studied based on field screening of different varieties; from the same region. However, controlled conditions evaluation of host preference/attractiveness have not been explored much. We theorized that *R. padi* seasonal population incidence depends on host susceptibility/resistance, and we also assume that resistant variety, if combined with best IGR/plant extract, would give the best results in the management of *R. padi*. Furthermore, a combination of HPR and IGR would be an adequate package for managing wheat aphids. Therefore, the present studies were carried out to understand the type of resistance in wheat and field management of aphids.

2. Materials and methods

2.1. Experiment 1: Population dynamics of *Rhopalosiphum padi* on three different wheat varieties for two growing seasons under field conditions

This study was conducted at the research farm, Abdul Wali Khan University Mardan. Wheat three varieties, i.e. Faisalabad 2008, Aas 2011 and, Pirsabak 2008 (table 1) were tested against the infestation of aphids for 2 growing seasons, i.e. 2017/18 (annual mean temperature 22.2 °C, while the mean precipitation 559 mm) and 2018/19 (annual mean temperature 23.7 °C, while the mean precipitation 522 mm), respectively.

Population dynamics of *R. padi* were assessed on three different wheat varieties mentioned above. We sowed wheat varieties on 19 November 2017–18 and 15 November 2018–19. Each variety was replicated five times in Randomized Complete Block Design (RCBD). Each plot size was 28.98 m^2 and a 60 cm buffer area was maintained among the plots and the blocks. Varieties were sown in rows keeping a distance of 30 cm among these rows. Usual agronomic practices were applied to all plots equally. *R. padi* population was recorded from randomly selected five wheat plants per plot (Ullah et al., 2020). The mean number of *R. padi*/plant for each variety was calculated.

2.2. Aphid resistance index

The field population infestation (for both the growing seasons i.e. 2017/18 and 2018/19) was scored based on the "aphid resistance index" (ARI) with slight modification from the index of Li et al. (2019), as mentioned in Table 2.

2.3. Experiment 2: Determining host attractiveness in *Rhopalosiphum padi* towards wheat varieties

A pregerminated seedling of each variety was planted in a pot (40 cm diameter × 7 cm height), having an equal distance from the center of the pot. Ten replicates were arranged in a Completely Randomized (CR) Design, each pot containing seedlings of each variety. At a two-leaf stage, fifty *R. padi* adults were released in the center of each pot (Junaid et al., 2016). Plants were covered with anti-aphid nylon cages. The adult attractiveness was observed after 06, 12, and 24 h of infestation, the total number of adults/plant was recorded, and the degree of antixenosis among each tested plant was determined (Flinn et al., 2001).

2.4. Trichome density

Three leaves (upper, middle and lower) were collected and were placed under the microscope for counting the trichome density per mm^2 area. A total of 5 replicates (5 plants and 15 leaves of each variety) were taken from all the tested varieties.

2.5. Experiment 3: Field evaluation of resistant variety and application of different insect growth regulators/plants extracts for an effective IPM package

A variety that is comparatively more resistant was sown in 2019; following the same process as mentioned in Experiment 1. The resistance was determined based on our two years of field evaluation. The treatment details are given in Table 3.

2.6. Preparation of plant extract

The plant leaf extracts were prepared as per suggestions of Abubakar and Haque (2020). The leaves of *Eucalyptus camaldulemsis* and *Azadirachta indica* were collected from the field. They were dried in the laboratory under a shaded area. Then, to make the fine powder of them, the dried

Table 1. Seed morphological characteristics of the different wheat varieties.

Varieties	Seed color	Seed shape	Seed size	Seed hardness
Faisalabad-08	Amber	Oblong	42.4	Hard
Aas-11	Amber	Oblong	45.1	Very hard
Pirsabak-08	Amber	Round	47.3	Very hard

Table 2. Wheat aphid resistance index based on aphid population infestation.

Infestation range	Aphid resistance index (ARI)
0	Highly resistant
1–2.5	Resistant
2.6–5	Moderately resistant
5.1–7.5	Moderately susceptible
7.6–10	Susceptible
10>	Highly susceptible

Table 3. List of treatments and their doses

Treatments	Active ingredients	Manufacturer	Recommended dose
Lefenuron	Benzoylurea	Jaffer group	200 mL/Acre
Pyriproxyfen	4-phenoxyphenyl(RS)-2-(2-pyridyloxy)propyl ether	Jaffer group	500 mL/Acre
Turmeric	Curcumin	Saremco International	2%
Neem	Azadirachtin	-	2%
Eucalyptus	Eucalyptol	-	2%
Imidacloprid	Chloronicotinyl	Syngenta	250 mL/Acre
Simple Distelled Water	-	-	-

leaves were crushed with the help of a mortar and pestle and a mixer grinder. A stock solution was prepared, and further, a standard of 2.0% was evaluated for field efficacy.

2.7. Field application IGRs/plant extracts for efficacy against *Rhopalosiphum padi*

After wheat emergence, five plants in each plot were selected randomly and observed weekly for aphid data. The spray was done when aphid density reached to economic threshold level (10 or more aphids per tiller^{-1}) (Aziz et al., 2013). A mixture of the prepared extracts and IGR solutions was applied at a given dose, while the control plot received simple distilled water. A second spray was applied at the buffer time interval of fifteen days. A knapsack sprayer was used to apply all the solutions. After applying an insecticide in the designated plots, the spray machine was washed and rinsed with water before other insecticide applications. After spraying, the % mortality of aphids was calculated (Gogi et al., 2021).

2.8. Statistical analysis

The analysis was done with the statistical analysis package STATISTIX 8.1 (Tallahassee, FL, United States of America). Data on the field infestation of aphids of different wheat varieties were subjected to ANOVA. A factorial design (aphid population, varieties, and weeks) evaluated wheat varieties against *R. padi*. For the aphid attractiveness, a Randomized Complete Design (CR) was used, while for field evaluation of IGR's/plant based field efficacy, a Randomized Complete Block (RCB) design was used. The means were separated via Tukey's test while the significance was measured at p = 0.05%.

3. Results

3.1. Population dynamics of *Rhopalosiphum padi* on three different wheat varieties under field conditions for the growing season of 2017/18

Comparing means for varieties suggest that the comparatively more resistant variety was Pirsabak-08

(1.34 aphids) followed by Aas-11 (8.91 aphids). The most infested variety was Faisalabad-2008 (11.96 aphids), as shown in Table 4.

Comparing means of different time intervals revealed that the infestation of *R. padi* was initially mild until December. The *R. padi* infestation started to build up from January until the 2nd week of March. Onwards, a peak of *R. padi* (23.03 aphids/plant) was recorded on March 1 week. The population *R. padi* vanished towards the end of the growing season in April, as shown in Table 4.

The interaction among all the varieties and different time intervals varied significantly at p = 0.05%, as shown in Table 4. Initially, the time intervals in January were low on all three tested varieties. The means of interaction for weeks and varieties started to increase in February and spiked in March. A highly significant interaction was observed in Faisalabad-2008 on March 1st, February 4th, and March 2nd week (27.4 aphids/plant), respectively. A peak *R. padi* population on Aas-11 was recorded on March 1st and the second week (28.0 and 27.0 aphids/plant), respectively. A peak of *R. padi* population (3.60 aphids/plant) on Pirsabak-08 was recorded on March 1st week, as shown in Table 4.

3.2. Population dynamics of *Rhopalosiphum padi* on three different wheat varieties under field conditions for the growing season of 2018/19

Comparing means for varieties suggest that the comparatively more resistant variety was Pirsabak-08 (1.41 aphids/plant) followed by Aas-11 (8.73 aphids/plant). The most infested variety was Faisalabad-2008 (11.37 aphids/plant), as shown in Table 5.

Comparing means of different time intervals revealed that the same pattern was witnessed in the previous year (2017/18). Initially, the infestation of *R. padi* was mild until December. The *R. Padi* infestation started to build up from January until the 2nd week of March. Onwards, a peak of *R. padi* (25.32 aphids/plant) was recorded on March 1st week. The population *R. padi* vanished towards the end of the growing season in April, as shown in Table 5. The interaction among all the varieties and different time intervals varied significantly at p = 0.05%, as shown in Table 4. Initially, the time intervals in December

Table 4. Natural infestation of *Rhopalosiphum padi* on wheat varieties for the growing season of 2017/18.

Time Intervals		Varieties			Mean
		Faisalabad-08	Aas-11	Pirsabak-08	
1 (18/12/2017)	December	0.03 ^{v*}	0.26 $^{t-v}$	0.00 ^{v}	0.10 ± 0.04 ^{k}
2 (25/12/2017		0.43 $^{s-v}$	0.03 ^{v}	0.03 ^{v}	0.16 ± 0.07 ^{k}
3 (31/12/2017)		1.20 $^{q-v}$	0.86 $^{q-v}$	0.63 $^{r-v}$	0.90 ± 0.08 ^{jk}
4 (07/01/2018)	January	1.63 $^{p-v}$	1.23 $^{q-v}$	0.83 $^{q-v}$	1.23 ± 0.12 ^{j}
5 (14/01/2018)		1.93 $^{o-t}$	1.80 $^{p-u}$	0.83 $^{q-v}$	1.52 ± 0.17 ^{ij}
6 (21/01//2018)		2.96 $^{l-p}$	2.43 $^{l-q}$	1.23 $^{q-v}$	2.21 ± 0.26 ^{hi}
7 (28/01/2018)		3.83 $^{k-m}$	3.66 $^{k-n}$	1.43 $^{p-v}$	2.97 ± 0.38 ^{gh}
8 (07/02/2018)	February	11.5 ^{h}	6.16 ^{j}	1.60 $^{p-v}$	6.42 ± 1.53 ^{f}
9 (14/02/2018)		19.3 ^{f}	14.0 ^{g}	2.0 $^{n-s}$	11.8 ± 2.56 ^{d}
10(21/02/2018)		22.6 ^{e}	18.1 ^{f}	2.36 $^{l-q}$	14.36 ± 3.06^{c}
11(28/02/2018)		35.3 ^{b}	24.0 ^{e}	3.56 $^{k-0}$	20.96 ± 4.64^{b}
12(07/03/2018)	March	37.4 ^{a}	28.0 ^{d}	3.60 $^{k-0}$	23.03 ± 5.04^{a}
13(14/03/2018)		33.2 ^{c}	27.0 ^{d}	2.23 $^{m-r}$	20.8 ± 4.73 ^{b}
14(21/03/2018)		12.0 ^{h}	8.96 ^{i}	1.0 $^{q-v}$	7.34 ± 1.64 ^{e}
15(28/03/2018)		5.03 ^{jk}	3.96 ^{kl}	0.20 ^{uv}	3.06 ± 0.73 ^{g}
16(05/04/2018)	April	3.00 $^{l-p}$	1.93 $^{o-t}$	0.00 ^{v}	1.64 ± 0.43 ^{ij}
Mean		11.96 ± 1.8 ^{a}	8.91 ± 1.1^{b}	1.34 ± 0.06 ^{c}	

Each value is the mean of five replications
*Mean followed by the same letter do not differ significantly at p = 0.05
LSD for weeks = 0.84
LSD for the interaction of varieties × weeks = 1.70
LSD for varieties = 0.24

Table 5. Natural infestation of *Rhopalosiphum padi* on wheat varieties for the growing season of 2018/19.

Time Interval		Varieties			Mean
		Faisalabad-08	Aas-11	Pirsabak-08	
1 (18/12/2018)	December	0.0 z*	0.03 z	0.0 z	0.01 ± 0.01 n
2 (25/12/2018)		0.10 z	0.13 z	0.0 z	0.07 ± 0.02 n
3 (31/12/2018)		0.50 yz	0.33 yz	0.26 yz	0.3 ± 0.05 m
4 (07/01/2019)	January	1.23 v-x	1.10 wx	0.40 yz	0.9 ± 0.13 l
5 (14/01/2019)		2.06 s-u	1.76 t-v	0.70 xy	1.5 ± 0.21 k
6 (21/01//2019)		3.26 op	3.10 pq	0.80 xy	2.3 ± 0.40 i
7 (28/01/2019)		5.60 m	3.30 op	1.63 u-w	3.5 ± 0.57 h
8 (07/02/2019)	February	9.1 k	6.7 l	1.73 t-v	5.8 ± 1.08 f
9 (14/02/2019)		13.1 i	11 j	2.46 rs	8.8 ± 1.62 d
10(21/02/2019)		21.7 f	15.8 g	2.7 qr	13.4 ± 2.81c
11(28/02/2019)		30.1 d	23.4 e	3.73 no	19.1 ± 3.96b
12(07/03/2019)	March	38.2 a	33.7 b	4.0 n	25.3 ± 5.37a
13(14/03/2019)		32.3 c	21.9 f	2.26 r-t	18.8 ± 4.40b
14(21/03/2019)		14.6 h	9.3 k	1.6 u-w	8.5 ± 1.89 e
15(28/03/2019)		6.60 l	5.50 m	0.30 yz	4.1 ± 0.97 g
16(05/04/2019)	April	3.30 op	2.50 rs	0.00 z	1.9 ± 0.50 j
Mean		11.37± 1.78 a	8.73±1.41b	1.41 ±0.18 c	

Each value is the mean of five replications
*Mean followed by the same letter do not differ significantly at p = 0.05
LSD for weeks = 0.27
LSD for the interaction of varieties × weeks = 0.56
LSD for varieties = 0.08

till January 3rd week were below one aphid/plant on Pirsabak-08. The mean interaction of weeks and varieties was below one aphid/plant for Faisalabad = 08 and Aas-11 in December. However, the mean for both the varieties spiked from January and reached to peak (38.2 aphids/plant on Faisalabad-08 and 33.7 aphids/pant on Aas-11, respectively). A peak of *R. padi* population (4.0 aphids/plant) on Pirsabak-08 was recorded on March 1st week, as shown in Table 5.

3.3. Wheat resistance based on aphid resistance index

The results analysis for field population infestation for two growing seasons (2017/18 and 2018/19) revealed that Pirsabak-08 was found resistant with an infestation score of 1–2.5. Aas-11 variety has an infestation score of 7.6–10 and is susceptible while Faisalabad-08 was found highly susceptible with an infestation score of over 10.

3.4. *Rhopalosiphum padi* varietal preference at various time intervals

The interaction among all the varieties and different time intervals varied significantly at p = 0.05%, as shown in Table 4. Most aphids were attracted towards Faisalabad-08 (25.0 aphids) at 24 h, while a peak attractiveness (21.33 aphids) on Aas-11 was recorded at 24 h. Comparatively more resistant variety was Pirsabak-08 having peak aphid attraction of 5.33 at 6 h, and that vanished to 0.0 attractiveness at 24 h as shown in Figure 1.

3.5. Trichome density (cm^2 leaf area) on wheat varieties

The trichome density analysis revealed a significant difference among varieties at p = 0.00, as shown in Figure 2. The highest trichomes of 24 were present on Pirsabak-08, followed by Aas-11 (10.3). The least trichomes were present on Faisalabad-08 (06).

3.6. Correlation analysis of the aphid variety preference and trichome density

Significant correlation was noted between the aphid attractiveness and trichome density ($p < 0.05$). Faisalabad-08 and Pirsabak-08 varieties had negative correlation (r = –086 and –0.50, respectively) however no correlation was found on Aas-11 (r = 0.0) as shown in Table 6.

3.7. Field evaluation of resistant variety assisted with the application of variius insect growth regulators/plants extracts for an effective IPM package

Data in Figure 3A shows the aphid pre and postpopulation

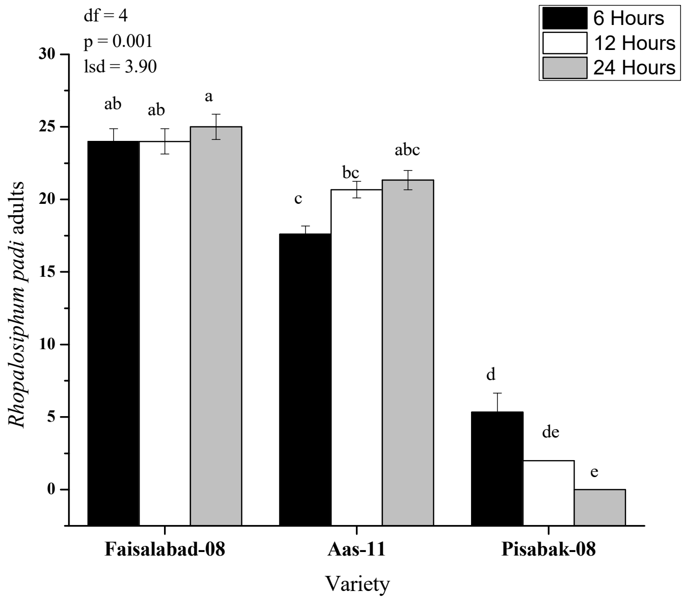

Figure 1: *Rhopalosiphum padi* preference at various time intervals and varieties. Each value is the mean of five replications. *Mean followed by the same letter do not differ significantly at p = 0.05

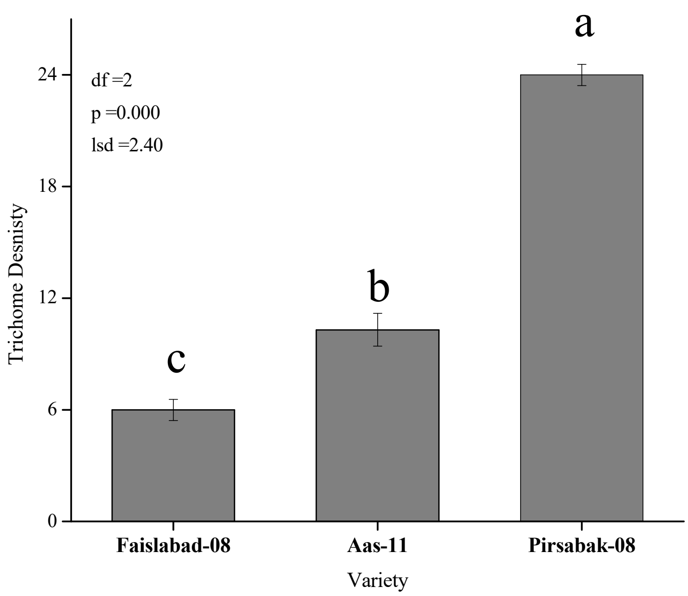

Figure 2: Trichomes density on mm^2 leaf area of various wheat varieties. Each value is the mean of five replications. *Mean followed by the same letter do not differ significantly at p = 0.05

after the 1st spray. All the treatments varied significantly at different time intervals at p = 0.05%. Comparing means of treatments revealed that the most effective treatments were neem and pyriproxyfen (2.60 and 2.66 aphids/plant), respectively. Comparing various time intervals for the first spray suggests that the minuscule population of 1.75 aphids/plant was recorded after 24 h, while the highest population was recorded 24 h before spray (7.40 aphids/plant). The interaction of treatments and time interval reveals that the most effective treatments after 24 h were pyriproxyfen and imidacloprid, having 0.06 aphids/plant, respectively. All the tested varieties significantly reduced the aphid population over the control negative at p = 0.05% significance. However, all treatment effects drastically

Table 6. Correlation (r) of aphid preference and trichome density on wheat varieties in a free-choice test.

Wheat varieties	Trichome density/mm^2 leaf	P-value
Faislabad-08	–0.86	0.000
Aas-11	0.00	0.001
Pirsabak-08	–0.50	0.000

declined after the 14th day of the spray, as shown in Figure 3A.

A second spray result revealed that efficacy increased with the increasing time interval for IGRs but declined effectiveness was witnessed in plant extracts. Comparing means for treatments revealed that highly effective treatments were pyriproxyfen (2.56 aphids/plant) followed by neem and imidacloprid (2.87 and 2.89 aphids/plant). Comparing various time intervals for the second spray suggests that the least 2.41 aphids/plant population was recorded at 24 h while the highest population was recorded 24 h before spray (13.87 aphids/plant). The interaction of treatments and time interval reveals that the most effective interaction was observed in pyriproxyfen and imidacloprid after 24 h having 0.0 aphids/plant, respectively. Neem was effective in keeping the aphid population ≤ one at various time intervals. All the tested varieties significantly reduced the aphid population over the control negative at p = 0.05% significance, as shown in Figure 3B.

4. Discussion

Wheat is an important cereal crop. It has grown in a large area in Pakistan and is considered a primary food source for country needs and export. Despite the high demand, the per hectare yield of wheat is meager in Pakistan compared to advanced countries (Muhsin et al., 2021). It is due to biotic and abiotic factors, which aid in the lower production of wheat. The aphid is considered the most important pest of wheat (Xu et al., 2021). *Rhopalosiphum padi* L. 1758 (Aphididae Hemiptera) drastically decline the wheat yield and cause significant losses. Host plant resistance, insect-stage specific growth regulators (IGR), and plant extracts are effective management strategies for keeping the *R. padi* infestation below the injury level.

Field trials for the varietal resistance against *R. padi* revealed that Pirsabak-08 remained the most resistant variety for both the growing seasons. The field resistance in Pirsabak-08 could be due to physical (antixenosis) resistance or biochemical (antibiosis) resistance. The minor *R. padi* infestation could be because the resistant variety has 1) trichomes and 2) no cue response for the *R. padi* in Pirsabak-08 variety. The current results are confirmed by the previous findings of Zeb et al. (2011).

Population dynamics greatly depend on host availability and abiotic features like temperature, rainfall, and humidity (Wallner, 1987; Faheem et al., 2021). The *R. padi* population initially was low in December and started to build up in January until February. The population reached to peak in March and finally decreased in April towards the seasonal end of the crop. The spike in March could be due to the ambient temperature (28 °C) and less rainfall. A low humidity below 35 RH is suitable for the aphids to carry out reproduction and other life activities. Leather (1985) explained that aphids produced significantly more progeny at a lower humidity range than at higher humidity. In addition, minimal rainfall could be the reason for aphids' severe population in the spring.

Varietal preference revealed that Pirsabak-08 exhibited maximum resistance than the other two varieties. The reason for resistance could be directly linked with the presence of maximum trichomes (24 cm^2 leaf area) present on Pirsabak-08. The trichomes play a crucial role in host selection by aphids. It negatively affects the landing of aphids on the leaf surface; the nymphs cannot freely move/feed on the dense trichome leaf surface (Khan et al., 2000). The current results are in line with the previous findings of Khan and Hassan (2018). However, this disagrees with the findings of Junaid et al. (2016), who reported that none of the tested wheat varieties had antixenosis resistances. The life tables or *R. padi* analysis suggest that progeny production and adult survival were highest on Faisalab-08 and least on Pirsabak-08. The reasons could be due to the availability of a sufficient amount of nutrients in Faisalabad-08. The resistance in Pisrsabak-08 could also be due to the trichomes density and allelochemicals that negatively influence progeny production and adult survival (Pourya et al., 2020).

A resistant field variety harms the biology of insect pests. We sowed the Pirsabak-08 resistant variety, and *R. padi* infestation was tried to manage with IGRs and plant extracts. A combined effect of the resistant type (Pirsabak-08) and pyriproxyfen significantly reduced the *R. padi* population, followed by Lufenuron and neem. The lower population of pyriproxyfen could be due to its effect on the nymphs that disables the enzyme essential for nymphs to reach adulthood. Iftikhar et al.

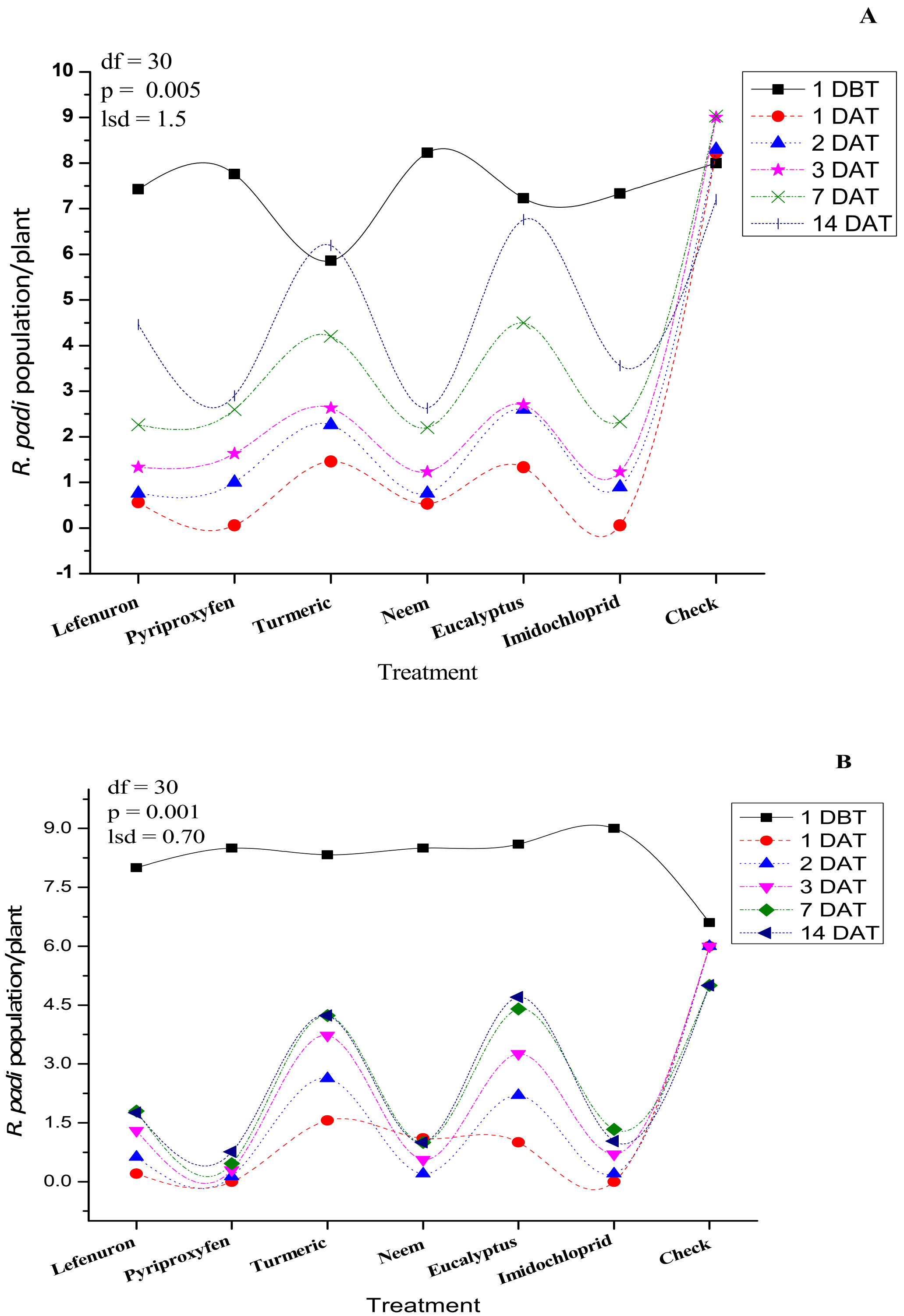

Figure 3. Effect of IGR's and plant extracts application on the population of *Rhopalosiphum padi.* **A**. After the first spray, **B**. After the second spray DBT (day before treatment), DAT (day after treatment).

(2020) reported that pyriproxyfen is a juvenile hormone analog that mimics the enzyme required by nymphs to reach maturity. Richardson et al. (2007) confirmed the current performance of pyriproxyfen, and reported that pyriproxyfen caused a significant reduction in the aphid population.

Chitin is the outer protective layer of insects. A lufenuron is a chitin synthesis inhibitor that does not allow chitin synthesis in exposed insects. The performance of lufenuron could be due to the lack of chitin synthesis development and thus leaving the internal organs exposed aerial that leads to *R. padi* mortality (Refaat et al., 2021). Neem extract was much more effective than the other extracts. Its effect could be due to compounds like *Azadirachtin* A and B, *Salannin*, and *Meliantriol*. Neem has been used against various insects. Neem can act as repellent and larvicidal and affects egg hatching and reduce fertility in insect pests, resulting in their progeny inhibition. It can also disturb the chemoreceptors of insects and impair their feeding (Li et al., 2019). The current performance of neem is in line with the previous findings of Pathania et al. (2022).

5. Conclusion and recommendations

The field population reaches to peak in March. The trichome density present on the Pirsabak-08 had a negative impact on the *R. padi.* IGRs like pyriproxyfen and lufenuron significantly reduced the aphid population below a threshold level. We recommend that the resistant variety, i.e. Pirsabak-08, be cultivated and proper monitoring of the *R. padi* population is advised. A quick spray of IGRs and plant extract like pyriproxyfen, lufenuron, and neem should be applied to push the aphid population before causing any damage.

Statements and declarations

This article is original research work that is not in consideration for publications elsewhere. All the authors have read the manuscript. The authors declare no conflict of interest.

References

Abbas N, Hafez AM (2021). Resistance to insect growth regulators and age-stage, two-sex life table in *Musca domestica* from different dairy facilities. PLoS One 16, e0248693. https://doi.org/10.1371/journal.pone.0248693

Abbas S, Niaz U (2019). Effect of aphid species infestation on wheat crop, *Triticum aestivum* L. and its yield. Journal of Agricultural Science and Botany 3 (2): 17-20.

Abubakar AR, Haque M (2020). Preparation of medicinal plants: basic extraction and fractionation procedures for experimental purposes. Journal of Pharmacy and Bioallied Sciences 12 (1): 1-14. https://doi:10.4103/jpbs.JPBS_175_19

Aradottir GI, Crespo-Herrera L (2021). Host plant resistance in wheat to barley yellow dwarf viruses and their aphid vectors: a review. Current Opinion in Insect Science 45:59-68. https://doi:10.1016/j.cois.2021.01.002

Aziz M, Ahmad M, Nasir M, Naeem M (2013). Efficacy of different neem (*Azadirachta indica*) products in comparison with imidacloprid against english Grain aphids (*Sitobion avenae*) on Wheat. International Journal of Agricultural Biology 15 (2): 279-284.

Chakraborty T, Nahar N, Khatun MR, Das G (2019). Potentiality of some insect growth regulators on the mortality of bean aphid, *Aphis craccivora* (Koch.). Journal of Entomology and Zoology Studies 7 (5): 199-203.

Faheem M, Saeed S, Sajjad A, Wang S, Ali A (2019). Spatio-temporal variations in wheat aphid populations and their natural enemies in four agro-ecological zones of Pakistan. PLoS One, 14, e0222635. https://doi.org/10.1371/journal.pone.0222635

Faheem U, Abbas Q, Ahmad S, Ahmad G, Karim A et al. (2021). Linking Meteorological Parameters and Population Dynamics of Jassid (*Amrasca biguttula biguttula)* in Cotton. Sarhad Journal of Agriculture 37 (1): 302-306. http://dx.doi.org/10.17582/journal.sja/2021/37.1.302.306

Flinn M, Smith CM, Reese JC, Gill B (2001). Categories of resistance to greenbug (Homoptera: Aphididae) biotype I in *Aegilops tauschii* germplasm. Journal of Economical Entomology 94 (2): 558-563. https://doi.org/10.1603/0022-0493-94.2.558

Giraldo P, Benavente E, Manzano-Agugliaro F, Gimenez E (2019). Worldwide research trends on wheat and barley: A bibliometric comparative analysis. Agronomy 9 (7): 352. https://doi.org/10.3390/agronomy9070352

Gogi MD, Syed AH, Atta B, Sufyan M, Arif MJ et al. (2021). Efficacy of biorational insecticides against *Bemisia tabaci* (Genn.) and their selectivity for its parasitoid *Encarsia formosa* Gahan on Bt cotton. Scientific Reports 11: 1-12. https://doi.org/10.1038/s41598-021-81585-x

Hoidal N, Koch RL (2021). Perception and Use of Economic Thresholds Among Farmers and Agricultural Professionals: A Case Study on Soybean Aphid in Minnesota. Journal of Integrated Pest Management 12 (1): 156-163. https://doi.org/10.1093/jipm/pmab003

Iftikhar A, Hafeez F, Hafeez M, Farooq M, Aziz MA et al. (2020). Sublethal effects of a juvenile hormone analog, Pyriproxyfen on demographic parameters of non-target predator, *Hippodamia convergens Guerin-Meneville* (Coleoptera: Coccinellidae). Ecotoxicology 29: 1017-1028. https://doi.org/10.1007/s10646-020-02159-7

Junaid K, Khan SA, Khan I, Ali S, Khan Z (2016). Study on Different Components of Resistance in Wheat Genotypes to Green Bug (*Schizaphis graminum*)(Rondani). Pakistan Journal of Zoology 48 (4): 981-987.

Kauppi K, Rajala A, Huusela E, Kaseva J, Ruuttunen P et al. (2021). Impact of Pests on Cereal Grain and Nutrient Yield in Boreal Growing Conditions. Agronomy 11 (3): 592. https://doi.org/10.3390/agronomy11030592

Khan M, Kundu R, Alam M (2000). Impact of trichome density on the infestation of Aphis gossypii Glover and incidence of virus disease in ashgourd [*Benincasa hispida* (Thunb.) Cogn.]. International Journal of Pest Management 46 (3): 201-204. https://doi.org/10.1080/096708700415535

Khan SN, Hassn G (2018). Response of different wheat genotypes to aphids infestation under irrigated and rainfed conditions. Sarhad Journal of Agriculture 34 (2): 443-449.

Leather SR (1985) Atmospheric humidity and aphid reproduction. Journal of Applied Entomology 100 (1): 510-513. https://doi.org/10.1111/j.1439-0418.1985.tb02813.x

Li L, Song X, Yin Z, Jia R, Zou Y (2019). Insecticidal activities and mechanism of extracts from neem leaves against *Oxya chinensis*. Brazilian Journal of Veterinary and Animal Science 71 (1): 1-10. https://doi.org/10.1590/1678-4162-8958

Mesterházy Á, Oláh J, Popp J (2020). Losses in the grain supply chain: Causes and solutions. Sustainability 12 (6): 2342. https://doi.org/10.3390/su12062342

Muhsin M, Nawaz M, Khan I, Chattha MB, Khan S et al. (2021). Efficacy of seed size to improve field performance of wheat under late sowing conditions. Pakistan Journal of Agriculture Research 34 (1): 247-253. http://dx.doi.org/10.17582/journal.pjar/2021/34.1.247.253

Painter RH (1951). Insect resistance in crop plants. LWW; Vol. 72. http://dx.doi.org/10.1097/00010694-195112000-00015

Pathania M, Kaur J, Singh B (2022). Efficacy of Neem Based Formulations Against Wheat Aphids Under Semi-Arid Irrigated Conditions in South-West Punjab. Indian Journal of Entomology 1-4. https://doi.org/10.55446/IJE.2021.134

Pourya M, Shakarami J, Mardani-Talaee M, Sadeghi A, Serrão JE (2020). Induced resistance in wheat *Triticum aestivum* L. by chemical-and bio-fertilizers against English aphid *Sitobion avenae* (Fabricius)(*Hemiptera: Aphididae*) in greenhouse. International Journal of Tropical Insect Science 40: 1043-1052. https://doi.org/10.1007/s42690-020-00164-1

Preti M, Verheggen F, Angeli S (2020). Insect pest monitoring with camera-equipped traps: strengths and limitations. Journal of Pest Science 94: 203-217. https://doi.org/10.1007/s10340-020-01309-4

Qayyum MA, Saeed S, Riaz H, Ahmed N, Wakil W et al. (2021). Diversity and Correlation of Entomopathogenic and Associated Fungi with Soil Factors. Journal of King Saud University- Science 22 (6): 101520. https://doi.org/10.1016/j.jksus.2021.101520

Refaat AM, El-Sheikh EA, Ragheb DA, Shalaby AA (2021). The comparative efficacy of spinosad, lufenuron and hexythiazox on some strawberry pests under laboratory and field conditions. Zagazig Journal of Agricultural Research 48 (3): 679-688. https://doi.org/10.21608/ZJAR.2021.191288

Richardson M, Lagos D (2007). Effects of a juvenile hormone analogue, pyriproxyfen, on the apterous form of soybean aphid (*Aphis glycines*). Journal of Applied Entomology 131 (5): 297-302. https://doi.org/10.1111/j.1439-0418.2007.01163.x

Shah FM, Razaq M, Ali A, Han P, Chen J (2017). Comparative role of neem seed extract, *moringa* leaf extract and imidacloprid in the management of wheat aphids in relation to yield losses in Pakistan. PLoS One 12: e0184639. https://doi:10.1371/journal.pone.0184639

Shahzad MW, Razaq M, Hussain A, Yaseen M, Afzal M et al. (2013). Yield and yield components of wheat (*Triticum aestivum* L.) affected by aphid feeding and sowing time at Multan, Pakistan. Pakistan Journal of Botany 45 (6): 2005-2011.

Smith CM (2021). Conventional breeding of insect-resistant crop plants: still the best way to feed the world population. Current Opinion in Insect Science 45: 7-13. https://doi.org/10.1016/j.cois.2020.11.008

Tavares CS, Santos-Amaya OF, Oliveira EE, Paula-Moraes SV, Pereira EJG (2021). Facing Bt toxins growing up: Developmental changes of susceptibility to Bt corn hybrids in fall armyworm populations and the implications for resistance management. Journal of Crop Protection 146: 105664. https://doi.org/10.1016/j.cropro.2021.105664

Ullah F, Gul H, Said F, Ali A, Tariq K et al. (2020). Population dynamics of wheat aphids *Rhopalosiphum padi* (Linnaeus) and *Sitobion avenae* (Fabricius) at District Mardan, Khyber Pakhtunkhwa Pakistan. Pure and Applied Biology (PAB) 9: 27-35. http://dx.doi.org/10.19045/bspab.2020.90004

Wallner W (1987). Factors affecting insect population dynamics: differences between outbreak and non-outbreak species. Annual Review in Entomology 32: 317-340. https://doi.org/10.1146/annurev.en.32.010187.001533

Xu Y, La G, Fatima N, Liu Z, Zhang L et al. (2021). Precise mapping of QTL for Hessian fly resistance in the hard winter wheat cultivar 'Overland'. Theoretical and Applied Genetics 134 (12): 3951-3962. https://doi:10.1007/s00122-021-03940-w

Zeb Q, Badshah H, Ali H, Shah RA, Rehman M (2011). Population of aphids on different varieties/lines of wheat and their effect on yield and thousands grain weight. Sarhad Journal of Agriculture 27 (3): 443-450.

Zeb Q, Rondon SI, Badshah H, Khan A (2020). Influence of Cultivar on Aphids (*Hemiptera*: Aphididae) and Associated Natural Enemies in Pakistani Wheat Ecosystems. Pakistan Journal of Zoology 52 (2): 503-512. https://dx.doi.org/10.17582/journal.pjz/20181009151041

Zheng X (2021). The Uncertainties of Population Research: Challenges and Opportunities. China CDC Weekly, 3: 591. https://dx.doi:10.46234/ccdcw2021.156