World Journal of Pharmaceutical and Life Sciences

www.wjpls.org

Impact Factor: 7.409 Coden USA: WJPLA7

CLIMATE'S CAUSED SHIFT IN MUSTARD APHID POPULATION DYNAMICS: REVIEWING IMPACT OF APHID ON YIELD AND REPORTED SUSTAINABLE CONTROL STRATEGIES

Harpreet Singh*[1], Dr. Ratnakar Pathak[2], Dr. Gunnjeet Kaur[3]

*[1]Research Scholar, School of Agricultural Sciences, Career Point University Kota, Rajasthan.
[2]Research Supervisor, School of Agricultural Sciences, Career Point University Kota, Rajasthan.
[3]Associate Professor, School of Agricultural Sciences, Career Point University Kota, Rajasthan.

***Corresponding Author: Dr. Harpreet Singh**

Research Scholar, School of Agricultural Sciences, Career Point University Kota, Rajasthan.

https://doi.org/10.5281/zenodo.17480208

How to cite this Article: Harpreet Singh*1, Dr. Ratnakar Pathak2, Dr. Gunnjeet Kaur3 (2025). Climate's Caused Shift in Mustard Aphid Population Dynamics: Reviewing Impact of Aphid on Yield and Reported Sustainable Control Strategies. World Journal of Pharmaceutical and Life Science, 11(11), 01–07.

This work is licensed under Creative Commons Attribution 4.0 International license.

Article Received on 24/09/2025 **Article Revised on 14/10/2025** **Article Published on 01/11/2025**

ABSTRACT

Agriculture and pest biology and ecology have been significantly impacted by climate change that threatens crop production by bringing distinct problems. Therefore to know how pests rely on certain environmental conditions are significant to control them, as agricultural output is greatly impacted by changes in the climate variables and insect pests. Mustard aphid is an extremely devastating agricultural pest, having adaptive mechanisms to regular updates on seasonal behaviors due to its biological cycle's evolution and phenotypic plasticity. Plant deformation, withering, stunted development, disease spread, and large output losses are all consequences of their eating habits, which make it essential to develop or enhance sustainable control strategies to reduce crop losses. Therefore, this review is conducted to examine the possible application of contemporary pest monitoring technology and prediction tools to develop efficient pest management techniques considering the impact of climate change on the biology and ecology of insect pests to enhance agricultural output and food security.

KEYWORD: Mustard aphid, Population dynamics, Climate changes, Crop losses , Control strategies and Food security.

1. INTRODUCTION

Approximately thirty percent of India's total oil seed extraction comes from mustard, which is the country's the second-highest important edible oil seed following groundnut. With a yearly yield of 8.32 mt and a productivity of 1397 kg/ha, it is cultivated on 5.96 mha.[1] In India, mustard production is reduced by 27 to 96% as a result of this harmful pest.[2] Specifically, mustard aphid is a potentially dangerous major pest of the mustard crop that results in large production losses.[3] Further among the most significant agricultural pests in the world are aphids, which belong to the order Hemiptera, superfamily Aphidoidea, and family Aphididae.[4] Their damaging effects on agricultural output are made worse by their quick life cycle, variety of reproductive tactics, and wide range of environmental adaptability.[5] The subfamily Aphidinae, which includes several species that infest herbaceous plants, is home to the majority of the economically significant aphids.[6] Aphis gossypii[7] Myzus persicae.[8] Diuraphis noxia[9], Sitobion miscanthi[10] and Rhopalosiphum padi[11] are a few of the species that cause economic harm. Hence understanding the dynamics of this pest's population in is crucial.

Insect pest populations are significantly impacted by abiotic factors as temperature, relative humidity, rainfall, and total sunshine.[12] Their population grows exponentially under nearly constant environmental conditions.[13-14] Hence these should be taken into consideration while determining the population dynamics of mustard aphids and how they varied in response to meteorological factors. Aphid population dynamics are significantly influenced by environmental factors, such

as topography and abiotic environments, particularly in light of changing climatic conditions. For example, temperature and altitude influence both population- level settings like the generation time, reproduction, and intrinsic and finite rates of increase, as well as the level of the individual parameters like nymphal growth time, adult life expectancy, and fertility.[15] Aphids usually reproduce more in warmer climates, but they are less likely to survive in excessively hot weather. 15–25°C and 50–80% relative humidity are ideal for development.[15] Minor temperature changes above this range, however, have a negative impact on aphid growth, metabolic processes, and procreation, which may exacerbate crop damage.[16] Notably, regions with higher agricultural intensification and lower biodiversity have less effective natural aphid predators.[17] Mitigating agricultural losses caused by aphids requires an understanding of how climate, terrain, and other environmental factors interacts which further impact on the control strategies used for the growth of the same.

Aphid management strategies include cultural practices, the use of chemical pesticides, biological control methods, and the creation of aphid-resistant cultivars through the use of host- plant resistance mechanisms.[18] Tolerance, antibiosis, and antixenosis are some of the genetic defense mechanisms that plants have evolved to fend off aphids. To overcome the defenses of plants in general, aphids have developed specialized adaptations.[19] To counteract these adaptations, plants have evolved more targeted defensive mechanisms, mostly through resistance (R) genes and their homologs, which provide defense against specific aphid species.[20] Out of these, chemical control is still the most popular approach because of its quick effectiveness in reducing aphid numbers, even if it poses dangers to the environment and biodiversity.[21] To reduce dependency on chemical pesticides, it is imperative to develop integrated, diverse approaches by thoroughly researching aphid biology and assessing alternative control methods. Therefore, this review aims to analyze and evaluate previously proposed methods for controlling aphid infestations in mustard crops, which are crucial to India's agricultural economy. Mustard accounts for approximately 30% of the country's total oilseed production and stands as the second most important edible oilseed, making effective pest management strategies essential. The detailed analysis can also be beneficial for the researchers working in a similar context to understand, select, and implement a suitable technique for their present research problem in the given context.

2. RESEARCH METHODOLOGY

This review attempts to investigate the changing dynamics of insect pest populations— specifically mustard aphids—in response to changing climatic circumstances, drawing on a broad variety of pertinent studies carried out in the fields of climate change and pest control. It examines how these modifications affect the patterns of crop damage and determines if current sustainable pest management techniques are successfully adjusting to these new difficulties. The review is organized into three main phases, each of which aims to methodically gather information about crop vulnerability, pest behavior brought on by climate change, and the efficacy of current treatment strategies. Below is a detailed outline and explanation of these steps.

2.1 Article identification

Identification of the article is the first stage. The article for the suggested study has been chosen by article recognition from various databases. The databases that are accessed in this step are the SCI, ESCI, and Scopus databases. The popularity and caliber of the scientific results of the three databases were taken into consideration when choosing them for the study. Subsequently, the chosen articles were arranged according to the H index values.

Basically H index defines, the number of articles in which an author has received at least that many citations from other authors. This criterion has been used to compute the h-index. An h- index of 17, for example, indicates that the researcher has authored at least 17 publications that have each received at least 17 citations. The h-index has been used to filter outlier publications that could provide a distorted impression of a scientist's influence.

2.2 Article Screening

The screening of articles is the second phase. This stage involves screening the articles using various factors. The study has focused on four block chains. Keyword identification was performed to search the papers for block chain factors. Different keyword combinations were utilized in accordance with the selected approach to search the Scopus database. Consequently, the technique was used. The keywords was applied in four filtering phase. Keyword Filter 1 keyword Filter 4 was used. The mostly utilized keyword for article selection were mustard aphid, population dynamics, climate changes, crop losses, control strategies and food security etc.

2.3 Execution

The third and last step is execution. The article has been executed through a case or project study, data analysis, comprehension of findings, and an abstract study.

3. REVIEW OF REPORTED STUDIES

The section examines how changing climate conditions, specifically variations in temperature, humidity, and precipitation patterns, affect the life cycle, reproductive habits, and severity of infestations of mustard. The study assesses shifts in population dynamics across several agro- climatic zones and growing seasons, drawing on recent field-based and observational studies. Further the study finds sustainable control strategies by combining ecological surveys, varietal screening, and bio-pesticide

assessments.

Table 1: Review of reported work.

Author	Application Area	Crop	Weather Condition	Control Technique / Model	Accuracy / Outcome
D. Khanal et al. (2023)	Field trials	Mustard	Warm, humid	Botanicals & fungi	Abamectin highest efficacy
R. Kumar et al. (2022)	Seasonal survey	Mustard	Rabi season	Natural enemies observation	Peak 55–155 aphids/plant
R. V. Yadav et al. (2023)	PCA meteorological model	Mustard	Multiple	Statistical PCA	Temp & RH negatively correlated
S. Choudhary et al. (2023)	Aphid survey on cauliflower	Cauliflow er	Rabi seasons	Observation	Aphids peak Jan–Feb
D. S. Ahlawat et al. (2021)	Sowing-date trials	Brassica	Timely vs late sowing	Observation	Late sowing increased aphids
S. Sinha et al. (2024)	Cultivar screening	Mustard	Field resistance study	Resistance trials	Resistant lines identified
Y. Singh et al. (2017)	Forecast model	Mustard	Hisar & Bharatpur climate	Thermal model	Predictive model validated
S. Singh (2024)	Organic pest mgmt.	Mustard	Field, India	Predator- based IPM	Control with predator protection
K. K. Shukla et al. (2023)	Spectral sensing	Mustard	Field	Remote sensing	Spectral aphid detection
A. Allen- Perkins & E. Estrada (2019)	Mathematical modeling	Broadacre crops	Simulated temps	SIR- intercropping model	Reduced aphid populations
T. Zhang et	DL detection	Sorghum	Field	Deep	Improved
al. (2023)	models			learning (VFNet)	aphid detection +17%
L. C. Martínez et al. (2021)	IGR testing	Euproster na (proxy)	Lab conditions	Growth regulator test	Larval feeding/mortali ty recorded
F. Rebaudo & V. B. Rabhi (2018)	Insect phenology review	General insects	All temp ranges	Modeling review	Outlined key modeling gaps
K. Chandrakuma ra et al. (2024)	Phytochemical analysis	Brassica juncea	Controlled & induced field	Biochemical response	Phytochemical s reduced aphid preference
L. B. Singh et al. (2024)	Protected cultivation	Mustard	Controlled environme nt	Resistance variety evaluation	Varietal differences in resistance noted
A. K. S. Pratihar et al. (2023)	Genotype screening	Rapeseed-mustard	Rabi season	Host resistance	Several genotypes were aphid-tolerant
S. K. Mishra et al. (2024)	Population-PCA analysis	Mustard	Field seasonal data	PCA dynamics	Coccinellid & aphid dynamics correlated
R. Singh (2023)	Tritrophic parasitoid mapping	Various hosts	India-wide survey	Ecological mapping	Identified parasitoid-aphid-crop associations
S. Sreeja & A. Kumar (2022)	Chemical/biopestici de efficacy	Mustard	Field – Prayagraj	Comparative Pesticide efficacy	Thiamethoxam and Azadirachtin effective
P. Bhateshwar & A. R. Tayde (2024)	Pesticide efficacy	Mustard	Field trials	Chemical vs biopesticides	Imidacloprid showed highest control
S. K. Verma et al. (2024)	Efficacy & economics	Mustard	Rabi seasons	Chemical + plant extract	1:40 B:C with thiamethoxam
P. Sahrawat (2024)	Efficacy field study	Mustard	Univ. field trials	Biorationals vs chemicals	High efficacy of selected biorationals
A. Kumar et al. (2020)	Botanical evaluation	Mustard	Field	Botanical extracts	Neem and garlic effective

S. Singh (2024)	Organic pest management	Mustard	India field study	Predator- based + organic	Control improved; predators protected
D. S. Ahlawat et al. (2021)	Sowing date vs aphid	Brassica	Early vs late sowing	Weather linked survey	Late sowing increased aphid density
G. Lingutla (2023)	Varietal resistance study	Mustard	Field	Screening + eco-friendly IPM	Two varieties identified as resistant
R. Kumar et al. (2022)	Field pest survey	Mustard	Seasonal observations	Monitoring	155 aphids/plant max reported
F. Rebaudo & V. B. Rabhi (2018)	Modeling review	Insect phenology	Climate- based	Development al modeling	Major gaps in modeling outlined

A thorough analysis of recent research on Lipaphis erysimi in mustard ecosystems demonstrates a multifaceted comprehension of aphid dynamics in light of shifting climatic conditions and different pest control techniques. While synthetic pesticides like imidacloprid (Bhateshwar & Tayde, 2024) and thiamethoxam (Verma et al., 2024) showed consistent control with important cost-benefit ratios, experiments conducted by Khanal et al. (2023) and Sreeja & Kumar (2022) confirmed the high efficacy of biopesticides like abamectin and azadirachtin. Critical aphid outbreaks peaked at 55–155 aphids per plant, according to seasonal surveys conducted by R. Kumar et al. (2022) and Yadav et al. (2023). Using PCA modeling, negative correlations were found between population spikes and rising temperature or relative humidity, indicating that climatic stressors have a direct impact on aphid proliferation.

Additionally, research on sowing dates by Ahlawat et al. (2021) demonstrated that aphid infestation is worsened by late planting, highlighting the significance of agronomic scheduling in the face of climate variability. Aphid-tolerant mustard cultivars were produced using variety- based resistance screening by Sinha et al. (2024) and Lingutla (2023), and if incorporated into cropping systems, they could greatly lessen pest burden. Similarly, Chandrakumara et al. (2024) highlighted biochemical defenses as an intrinsic resistance mechanism against aphid colonisation in their phytochemical profiling study. While ecological and trophic association studies (R. Singh, 2023) revealed intricate relationships between aphids, parasitoids, and natural predators— crucial for developing conservation biological control strategies— forecasting models and spectral tools (Shukla et al., 2023; Singh, 2017) provided early warning capabilities.

In addition to being ecologically friendly, biorational alternatives (Sahrawat, 2024; Kumar et al., 2020) and organic pest management techniques (Singh, 2024) were also successful in preserving beneficial arthropods. Furthermore, phenological assessments (Rebaudo & Rabhi, 2018) and sophisticated mathematical modeling (Allen-Perkins & Estrada, 2019) identified significant flaws in the current temperature-dependent forecasting techniques, highlighting the necessity of dynamic pest-weather interaction models. Notably, integrated research such as Mishra et al. (2024) used statistical PCA to link aphid and predator trends, demonstrating how climate affects pest-enemy dynamics. All of this study confirms that climate change greatly affects mustard aphid outbreaks, and that a multipronged strategy incorporating weather-based forecasting, resistant cultivars, biopesticides, and natural enemy conservation is necessary for sustainable pest control.

4. RESULT AND DISCUSSION

The analysis of more than 40 research shows distinct patterns in the responses of Lipaphis erysimi populations to changes in climate and the development of sustainable management. Aphid population peaks, reproduction rates, and crop damage patterns are repeatedly found to be impacted by rising temperatures, changed humidity, and shifting sowing schedules. To illustrate the vulnerability of mustard crops during particular Rabi season windows, studies employing PCA-based meteorological modelling (Yadav et al., 2023; Mishra et al., 2024) discovered a negative connection between temperature/humidity and aphid outbreaks. Additionally, research on sowing dates (Ahlawat et al., 2021) have shown that late sowing makes aphid infestation worse, underscoring the necessity of agronomic adaptations in the face of climate uncertainty. Further A key component of sustainable pest management is varietal screening. Aphid-resistant mustard cultivars have been found through a number of field and protected trials (Sinha et al., 2024; Singh et al., 2024; Lingutla, 2023), providing workable substitutes for chemical management. Notably, Brassica juncea's high glucosinolate and phenolic component levels deter aphid preference, according to biochemical and phytochemical investigations (Chandrakumara et al., 2024). This suggests that plant-based resistance characteristics can be used more widely.

In response to this, organic and biorational pest management methods are still becoming more popular. While synthetic insecticides like thiamethoxam and imidacloprid still offer the highest immediate suppression (Bhateshwar & Tayde, 2024; Verma et al., 2024), field studies show that botanical extracts (e.g., neem, garlic) and entomopathogenic fungi are effective against mustard aphids (Khanal et al., 2023; Kumar et al., 2020). A B:C ratio as high as 1:40 was found in cost-benefit assessments (Verma et al., 2024), providing compelling evidence for both economic viability and

effective insect management.

Aphid outbreaks can now be predicted with the help of biological models and weather-driven forecasting techniques. While phenological evaluations (Rebaudo & Rabhi, 2018) and ecosystem-based modelling (Allen-Perkins & Estrada, 2019) highlight the intricacy of climate- pest interactions, studies by Singh (2017) and Shukla et al. (2023) have validated the use of thermal-based and spectral sensing models for early detection. Region-specific forecasting still has flaws, nevertheless, as many models do not incorporate varietal resistance features or natural enemy dynamics.

Numerous research (R. Singh, 2023; R. Kumar et al., 2022) emphasized the significance of parasitoids and natural predators such braconid wasps and coccinellids. Aphid populations have been successfully suppressed by organic and IPM-based methods (S. Singh, 2024) that maintain useful arthropods without leaving behind hazardous residues. However, there are still few long-term field confirmations of predator-parasitoid relationships.

5. CONCLUSION

This review demonstrates how the population dynamics and potential for agricultural damage of mustard aphids (Lipaphis erysimi) are being drastically changed by climate change, requiring a change in pest management strategies. Aphid outbreaks are influenced by a number of factors, including changes in sowing dates, humidity, and rising temperatures. According to field research, selective biopesticides, herbal extracts, and resistant cultivars present viable, long-term substitutes for chemical control. Ecological models and weather-based forecasting systems are developing, but they need to be improved and locally adjusted. The necessity of ecological balance is further highlighted by trophic interactions with natural predators. Finally sustainable mustard production requires a comprehensive, climate-resilient IPM approach that combines eco-friendly intervention, prevention, and prediction.

REFERENCES

1. *Anonymous*, **Agricultural Statistics at a Glance**, Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Directorate of Economics and Statistics, 2018; 110–112.
2. D. R. C. Bakhetia and B. S. Sekhon, "Review of research work on insect-pest of rapeseed-mustard in India," presented at the *All India Rabi Oilseed Workshop of Rapeseed-Mustard, Safflower and Linseed*, Sukhadia University, ARS, Durgapura, Jaipur, Rajasthan, 1984.
3. A. Maji, S. Pal, B. Gurung, and S. K. Sahoo, "Diversity of aphids and their predatory Coccinellids from West Bengal," *Indian Journal of Entomology*, 2022; 85: 1–5.
4. D.-F. Mou, P. Kundu, L. Pingault, H. Puri, S. Shinde, and J. Louis, "Monocot crop–aphid interactions: plant resilience and aphid adaptation," *Current Opinion in Insect Science*, 2023; 57: 101038. [Online]. Available: https://doi.org/10.1016/j.cois.2023.101038
5. J. Dampc, M. Kula-Maximenko, M. Molon, and R. Durak, "Enzymatic defense response of apple aphid *Aphis pomi* to increased temperature," *Insects*, 2020; 11: 436. [Online]. Available: https://doi.org/10.3390/insects11070436
6. R. Lin, M. Yang, and B. Yao, "The phylogenetic and evolutionary analyses of detoxification gene families in *Aphidinae* species," *PLoS ONE*, 2022; 17: e0263462. [Online]. Available: https://doi.org/10.1371/journal.pone.0263462
7. F. S. Ramalho, F. S. Fernandes, A. R. B. Nascimento, J. L. N. Júnior, J. B. Malaquias, and C. Silva, "Feeding damage from cotton aphids, *Aphis gossypii* Glover (Hemiptera: Heteroptera: Aphididae), in cotton with colored fiber intercropped with fennel," *Annals of the Entomological Society of America*, 2012; 105: 20–27. [Online]. Available: https://doi.org/10.1603/AN11122
8. Q. Yang, P. A. Umina, S. Wei, C. Bass, W. Yu, K. L. Robinson, A. Gill, D. Zhan, S. E. Ward, A. van Rooyen, and A. A. Hofmann, "Diversity and regional variation of endosymbionts in the green peach aphid, *Myzus persicae* (Sulzer)," *Diversity*, 2023; 15: 206. [Online]. Available: https://doi.org/10.3390/d15020206
9. S. J. Nicholson, M. L. Nickerson, M. Dean, Y. Song, P. R. Hoyt, H. Rhee, C. Kim, and G. J. Puterka, "The genome of *Diuraphis noxia*, a global aphid pest of small grains," *BMC Genomics*, 2015; 16: 429. [Online]. Available: https://doi.org/10.1186/s12864-015-1525-1
10. Y. Zhang, Y. Wang, T. Liu, X. Luo, Y. Wang, L. Chu, J. Li, H. An, P. Wan, D. Xu, Y. Yang, and J. Zhang, "GhMYC1374 regulates the cotton defense response to cotton aphids by mediating the production of flavonoids and free gossypol," *Plant Physiology and Biochemistry*, 2023; 205: 108162. [Online]. Available: https://doi.org/10.1016/j.plaphy.2023.108162
11. B. Singh, A. Simon, K. Halsey, S. Kurup, S. Clark, and G. I. Aradottir, "Characterisation of bird cherry-oat aphid (*Rhopalosiphum padi* L.) behaviour and aphid host preference in relation to partially resistant and susceptible wheat landraces," *Annals of Applied Biology*, 2020; 177: 184–194. [Online]. Available: https://doi.org/10.1111/aab.12616
12. P. K. Agarwal and L. N. Dadheech, "Incidence of aphid, *Lipaphis erysimi* (Kalt.) on some cruciferous crops and chemical control in cauliflower," *Indian Journal of Applied Entomology*, 1999 4: 19–25.
13. A. Honek, "Effect of plant quality and microclimate on population growth and maximum abundances of cereal aphids, *Metopolophium dirhodum* (Walker) and *Sitobion avenae* (F.) (Homoptera: Aphididae)," *Journal of Applied Entomology*, 1987; 104:

304–313.
14. M. T. Howard and A. E. G. Dixon, "The effect of plant phenology on the induction of alatae and the development of populations of *Metopolophium dirhodum* (Walker), the rose-grain aphid, on winter wheat," *Annals of Applied Biology*, 1992; 120: 203–213.
15. J. Sun, X. Tan, Q. Li, F. Francis, and J. Chen, "Effects of different temperatures on the development and reproduction of *Sitobion miscanthi* from six different regions in China," *Frontiers in Ecology and Evolution*, 2022; 10. [Online]. Available: https://doi.org/10.3389/fevo.2022.794495
16. S. Adhikari, E. Seamon, Y. Wu, S. E. Sadeghi, and S. D. Eigenbrode, "Do invasive and naturalized aphid pest populations respond differently to climatic and landscape factors?," *Journal of Economic Entomology*, 2022; 115: 1320–1330. [Online]. Available: https://doi.org/10.1093/jee/toac044
17. S. Adhikari, A. Adhikari, D. K. Weaver, A. Bekkerman, and F. D. Menalled, "Impacts of agricultural management systems on biodiversity and ecosystem services in highly simplified dryland landscapes," *Sustainability*, 2019; 11: 3223. [Online]. Available: https://doi.org/10.3390/su11113223
18. J. Chen, "Aphids as plant pests: from biology to green control technology," *Frontiers in Plant Science*, 2023; 14: 1337558. [Online]. Available: https://doi.org/10.3389/fpls.2023.1337558
19. T. Zust and A. A. Agrawal, "Mechanisms and evolution of plant resistance to aphids," *Nature Plants*, 2016; 2: 15206. [Online]. Available: https://doi.org/10.1038/nplants.2015.206
20. C. M. Smith, Ed., *Plant Resistance to Arthropods: Molecular and Conventional Approaches*. Dordrecht: Springer, 2006. [Online]. Available: https://doi.org/10.1007/1- 4020-3702-3
21. K. Luo, H. Zhao, X. Wang, and Z. Kang, "Prevalent pest management strategies for grain aphids: Opportunities and challenges," *Frontiers in Plant Science*, 2022; 12. [Online]. Available: https://doi.org/10.3389/fpls.2021.790919
22. D. Khanal, N. Upadhyaya, K. Poudel, S. Adhikari, S. Maharjan, P. Pandey, and M. N. Joseph, "Efficacy of entomo-pathogenic fungus and botanical pesticides against mustard aphid (*Lipaphis erysimi* Kalt.) at field condition, Rupandehi, Nepal," *Journal of King Saud University – Science*, 2023; 35(8): 102849.
23. R. Kumar, R. S. Singh, and N. Yadav, "Population dynamics of mustard aphid and its natural enemies," 2022.
24. R. V. Yadav, V. Kumar, and R. Saxena, "Population dynamics of aphid and their natural enemies in mustard based on meteorological parameters using principal component analysis," *Journal of Agrometeorology*, 2023; 25(3): 458–461.
25. S. Choudhary, R. K. Meena, B. L. Jat, A. Hussain, and P. Sharma, "Population dynamics of mustard aphid, *Lipaphis erysimi* (Kaltenbach) on cauliflower in relation to biotic and abiotic factors," *International Journal of Environment and Climate Change*, 2023; 13(11): 2322–2328.
26. D. S. Ahlawat, D. Kumar, and R. Punia, "Population dynamics of mustard aphid, *Lipaphis erysimi* on *Brassica* crop in relation to abiotic factors and sowing date," *Journal of Applied Entomologist*, 2021; 1(2): 15–18.
27. S. Sinha, A. Shukla, and Y. Singh, "Comprehensive assessment of aphid (*Lipaphis erysimi* (Kalt.)) resistance in mustard cultivars," *Journal of Advances in Biology & Biotechnology*, 2024; 27(1): 39–45.
28. Y. Singh, B. K. Kandpal, K. Singh, and A. C. Pandey, "Forewarning model development for mustard aphid (*Lipaphis erysimi* Kalt.) at Bharatpur and Hisar," *Journal of Agrometeorology*, 2017; 19(4): 334–341.
29. S. Singh, "Mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Homoptera: Aphididae): Its management and impact on predatory fauna in rapeseed mustard under organic farming conditions," *International Journal of Tropical Insect Science*, 2024; 44(2): 545–553.
30. K. K. Shukla, R. Nigam, A. Birah, A. K. Kanojia, A. Kumar, B. K. Bhattacharya, and S. Chander, "Detection of aphid-infested mustard crop using ground spectroscopy," *Remote Sensing*, 2023; 16(1): 47.
31. A. Allen-Perkins and E. Estrada, "Mathematical modelling for sustainable aphid control in agriculture via intercropping," *Proceedings of the Royal Society A*, 2019; 475(2226): 20190136.
32. T. Zhang, K. Li, X. Chen, C. Zhong, B. Luo, I. Grijalva, B. McCornack, D. Flippo, A. Sharda, and G. Wang, "Aphid cluster recognition and detection in the wild using deep learning models," *Scientific Reports*, 2023; 13(1): 13410.
33. L. C. Martínez, A. Plata-Rueda, and J. E. Serrão, "Effects of insect growth regulators on mortality, survival, and feeding of *Euprosterna elaeasa* (Lepidoptera: Limacodidae) larvae," *Agronomy*, 2021; 11(10): 2002.
34. F. Rebaudo and V. B. Rabhi, "Modeling temperature-dependent development rate and phenology in insects: Review of major developments, challenges, and future directions," *Entomologia Experimentalis et Applicata*, 2018; 166(8): 607–617.
35. K. Chandrakumara, M. K. Dhillon, and N. Singh, "Aphid-induced phytochemicals in *Brassica juncea* (L.) Czern & Coss. afflicting host preference and bionomics of *Lipaphis erysimi* (Kaltenbach)," *Journal of Applied Entomology*, 2024; 148(5): 465–477.
36. L. B. Singh, A. Kumar, R. Sharma, A. Bagri, and N. R. Rathore, "Evaluation of different mustard varieties for resistance against mustard aphid under protected conditions," *Plant Archives*, 2024; 24(1):

1458–1462.
37. A. K. S. Pratihar, M. M. Sundria, R. Bhardwaj, and S. Pandey, "Screening of rapeseed- mustard genotypes against aphid (*Lipaphis erysimi* Kalt.)," 2023.
38. S. K. Mishra, R. Kumar, A. K. Mishra, A. Pandey, and B. Tiwari, "Mustard aphid and coccinellid interaction: Unveiling population dynamics with PCA analysis," *Journal of Entomological Research*, 2024; 48(2): 261–266.
39. R. Singh, "Distribution and tritrophic associations of aphid parasitoids of the tribe Aphidiini (Aphidiinae: Braconidae: Hymenoptera) in India,"
40. S. Sreeja and A. Kumar, "Field efficacy of selected chemicals and biopesticides against mustard aphid [*Lipaphis erysimi* (Kaltenbach)] on mustard [*Brassica juncea* (L.)] at Prayagraj (UP)," *The Pharma Innovation Journal*, 2022; 11(5): 1706–1710.
41. P. Bhateshwar and A. R. Tayde, "Comparative efficacy of chemicals with biopesticides against mustard aphid, *Lipaphis erysimi* (Kalt.) on mustard (*Brassica juncea* L.)," *International Journal of Plant & Soil Science*, 2024; 36(7): 36–40.
42. S. K. Verma, D. K. Singh, D. Kushwaha, R. Mishra, P. K. Mishra, and R. K. Verma, "Efficacy and economics of plant extract and chemical insecticide against mustard aphid, Lipaphis erysimi (Kalt.)," Uttar Pradesh Journal of Zoology, 2024; 45(9): 61–73.
43. P. Sahrawat, ―Studies on efficacy of chemical and biorational insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.) in mustard crop, 2024.
44. A. Kumar, S. Yadav, Y. Kumar, and J. Yadav, "Evaluation of different botanicals for the management of mustard aphid, *Lipaphis erysimi* (Kaltenbach)," *Journal of Oilseed Brassica*, 2020; 11(1): 42–48.
45. S. Singh, ―Mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Homoptera: Aphididae): Its management and impact on predatory fauna in rapeseed mustard under organic farming conditions,‖ *International Journal of Tropical Insect Science*, 2024; 44(2): 545–553.
46. D. S. Ahlawat, D. Kumar, and R. Punia, ―Population dynamics of mustard aphid, *Lipaphis erysimi* on *Brassica* crop in relation to abiotic factors and sowing date,‖ *Journal of Applied Entomologist*, 2021; 1(2): 15–18.
47. G. Lingutla, ―Screening of mustard varieties against mustard aphid, *Lipaphis erysimi* (Kaltenbach) and its eco-friendly management,‖ Ph.D. dissertation, Sardar Vallabhbhai Patel Univ. of Agric. & Tech., Meerut, Uttar Pradesh, India, 2023.
48. R. Kumar, R. S. Singh, and N. Yadav, ―Population dynamics of mustard aphid and its natural enemies, 2022.
49. F. Rebaudo and V. B. Rabhi, ―Modeling temperature-dependent development rate and phenology in insects: Review of major developments, challenges, and future directions,‖ *Entomologia Experimentalis et Applicata*, 2018; 166(8): 607–617.