# Quantitative Analysis of Environmental Influences on Mustard Aphid Population Dynamics Using Statistical Modelling

**Anu[1], O. P. Sheoran[2], Manju Singh Tonk[3], Kiran Devi[4]**

*[1,2,3,4] Department of Mathematics & Statistics, COBS&H, CCS HAU, Hisar*

---

**Abstract:-** *This study investigates the complex relationship between mustard aphids (Lipaphis-erysimi* kalt.*) and various weather factors. Through advanced statistical methods and visualizations, the investigation dissects how temperature, humidity, sunshine hours and rainfall influence aphid behaviours and populations. The findings, backed by robust techniques like multiple linear regression and correlation analysis, highlight the substantial impact of these weather parameters on aphid dynamics. The consistency of patterns across different years further strengthens these conclusions. In essence, this research uncovers the connection between meteorological conditions and mustard aphid behaviours, equipping agricultural stakeholders with insights to design effective pest management strategies. This knowledge fosters resilient farming practices and reduces the potential harm caused by aphid-related crop damage.*

***Key Words*: Mustard aphid, Weather factors, MLR, Population dynamics, Statistical methods etc.**

## 1. Introduction:

The exploration of aphid population dynamics assumes a pivotal role in ecological and agricultural research, beckoning the scientific community to unravel the intricate tapestry of interactions that define these enigmatic organisms. At the epicentre of this investigation lies the Alate Mustard Aphid (*Lipaphis erysimi* Kalt.), a species whose population fluctuations reverberate across diverse ecosystems. The significance of probing these dynamics transcends academic curiosity, for it resides at the crossroads of ecological stability and agricultural productivity. [1]

The scientific realm witnesses an interesting convergence of artistry and empirical precision when it comes to constructing mathematical relationships between variables, a phenomenon elegantly exemplified by the prowess of regression analysis. [2] This sophisticated analytical tool is not merely an exercise in numerical manipulation; it stands as a robust mechanism for unravelling the complicated patterns woven between dependent and independent variables. Through a meticulous process of unravelling the fluctuations embedded within independent factors and discerning their influence on a dependent variable, regression analysis aspires to forge an equation that encapsulates their intimate association. [20] The term 'dependent variable,' signifying the outcome to be predicted, finds its symbolic representation in the notation $'Y,'$ while the 'independent variables,' often heralded as predictors or influences, are denoted as $'X_1, X_2, X_3, \dots X_n.'$ Through the fusion of these variables, the equation $Y = f(X_1, X_2, X_3, \dots X_n)$ emerges as a conduit of approximation, facilitating estimations, inferences, and predictions with remarkable precision. [3]

Within the pantheon of regression methodologies, the spotlight casts a brilliant glow on Multiple Linear Regression (MLR), an analytical titan proficient in handling the complexity inherent to multiple predictors. [4] As the confluence of multiple independent variables coalesces within MLR, it delves beyond the confines of conventional linear regression, elucidating both the collective and singular influences these predictors exert upon the dependent variable. [5] Across diverse sectors spanning agriculture, economics, and finance, the utility of MLR emerges as a beacon, guiding the comprehension of intricate interactions and unveiling predictive insights from data's silent narratives.

In the agricultural sphere, the prowess of MLR finds resonance in the dynamic tapestry of India's mustard cultivation, a vital domain due to its prominence as an oilseed crop. [6] Yet, this coveted crop is beset by a formidable adversary – the *Lipaphis erysimi* Kalt., commonly known as the mustard aphid. These minuscule assailants inflict substantial harm upon the plant, wreaking havoc upon its shoots and leaves, and subsequently compromising yield and overall health. [7] The gravity of the situation elevates the quest for effective aphid control into a paramount priority for mustard cultivation. Intriguingly, the population dynamics of these mustard aphids are inextricably linked to the vagaries of the environment. Temperature, a essential meteorological parameter, emerges as a formidable influencer on aphid development and reproductive patterns. Elevated temperatures propel accelerated breeding, fostering heightened population densities, while a downturn in temperature corresponds to a retreat in aphid numbers. Likewise, humidity, a pivotal player in the environmental theatre, casts its influence upon aphid survival and reproductive prowess. [8] In a country like India, where agriculture constitutes a bedrock of sustenance, deciphering the interplay between aphid population dynamics and meteorological conditions takes on transcendent significance. This inquiry assumes an innovative dimension with the proposition of constructing an insect-weather model, an analytical construct that melds pest population and climatic data collected across temporal and spatial axes. This model, a tour de force in scientific ingenuity, serves as a vehicle for prognosticating potential pest outbreaks, thus fostering an enhanced capacity for pre-emptive pest management strategies. [9]

Against this backdrop, this research endeavour unfurls its wings with a mission to delve into the intricate symphony of meteorological influences on mustard aphid population dynamics. [10] Through a rigorous quantitative approach entailing robust statistical modelling, this study aspires to not only dissect the nuances of these influences but also to craft an apt model that mirrors these dynamics. [11] This scholarly endeavour, akin to a delicate brushstroke upon the canvas of science, holds the promise of unveiling insights that could revolutionize pest management practices and safeguard vital crops such as mustard from the clutches of pest-induced detriment.

## 2. Methods and Materials:

This investigation took place during the Rabi Season, spanning from November to March in India and neighbouring countries. This period is significant as it marks the time for winter crops such as mustard to be cultivated.

The focus of this study was to gain insights into the mustard aphid population dynamics. The observation span covered two consecutive years, namely 2019-2020 and 2020-2021, both falling within the Rabi season. For data collection, collaboration was established with the Oilseeds Section of the Department of Genetics and Plant Breeding at CCS HAU, Hisar. This partnership facilitated the collection of data pertaining to the count of mustard aphids captured in traps on a weekly basis. These traps were positioned in fields and monitored from the aphids' initial emergence until the end of March. Meteorological data were also accumulated for analysis. Variables such as Maximum Temperature, Minimum Temperature, Morning Relative Humidity, Evening Relative Humidity, Sunshine Hours, Rainfall, and the Mean number of aphid (Alate) population per trap were meticulously recorded daily for both crop seasons. This comprehensive dataset for two consecutive years is succinctly presented in Tables 1 and Table 2. The core objective was to ascertain the relationship between weather conditions and insect infestation levels. The exploration involved the application of the multiple linear regression model and the correlation coefficient value. By employing these methodologies, the study aimed to unveil the interconnections between weather parameters and insect infestation. This investigation allowed us to assess the strength and direction of this association, particularly in deciphering whether specific weather conditions influenced the level of insect infestation.

**Table 1: Monitoring of Alate mustard aphid on sticky traps at Hisar during 2019-20**

| Standard Week | Temperature (°C) | | Relative Humidity (%) | | Sunshine Hours ($X_5$) | Rainfall (mm) ($X_6$) | Mean aphid (Alate) population per trap ($Y$) |
|---|---|---|---|---|---|---|---|
| | Max. ($X_1$) | Min. ($X_2$) | Morning ($X_3$) | Evening ($X_4$) | | | |
| 49 | 23.1 | 6 | 88 | 47 | 6.2 | 0 | 0 |
| 50 | 19.2 | 8.3 | 95 | 73 | 2.2 | 4.5 | 0 |
| 51 | 13.7 | 6.1 | 99 | 81 | 1.1 | 0 | 0.4 |
| 52 | 11.9 | 2.6 | 97 | 76 | 1.7 | 0 | 2.4 |
| 1 | 17.3 | 5.7 | 96 | 60 | 3.5 | 0 | 5.8 |
| 2 | 17.7 | 5.7 | 96 | 64 | 3.3 | 3.2 | 8.7 |
| 3 | 13.4 | 4.7 | 100 | 82 | 2.1 | 0 | 4.5 |
| 4 | 19.2 | 5 | 97 | 56 | 5.9 | 7.2 | 10.2 |
| 5 | 18.8 | 3.9 | 98 | 61 | 6.3 | 0 | 4.1 |
| 6 | 20.1 | 2.8 | 92 | 46 | 7.2 | 0 | 11.4 |
| 7 | 24.7 | 4.8 | 93 | 36 | 8.7 | 0 | 13.3 |
| 8 | 23.8 | 10.5 | 89 | 61 | 6.4 | 10.9 | 31.8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | 26 | 12.1 | 95 | 55 | 6.7 | 0.2 | 25.7 |
| 10 | 23.1 | 11.7 | 90 | 66 | 5.7 | 61.8 | 96.5 |
| 11 | 23.8 | 9.8 | 94 | 53 | 6.5 | 11.6 | 59.3 |
| 12 | 29.2 | 14.4 | 91 | 52 | 6.3 | 1.5 | 64 |
| 13 | 27.6 | 15 | 92 | 55 | 5.2 | 20.6 | 28.8 |

The computational analysis was facilitated through the utilization of MATLAB software. Renowned for its statistical and mathematical capabilities, MATLAB was instrumental in determining the correlation coefficient and executing the multiple linear regression analysis, thereby providing the analytical underpinning for this study.

**Table 2: Monitoring of Alate mustard aphid on sticky traps at Hisar during 2020-21**

| Standard Week | Temperature (°C) | | Relative Humidity (%) | | Sunshine Hours ($X_5$) | Rainfall (mm) ($X_6$) | Mean aphid (Alate) population per trap ($Y$) |
|---|---|---|---|---|---|---|---|
| | Max. ($X_1$) | Min. ($X_2$) | Morning ($X_3$) | Evening ($X_4$) | | | |
| 47 | 23.1 | 7.7 | 88 | 43 | 6.5 | 0 | 0.0 |
| 48 | 23.3 | 8.4 | 92 | 42 | 6.6 | 1.7 | 0.0 |
| 49 | 25.5 | 9.1 | 90 | 53 | 5.9 | 0 | 0.0 |
| 50 | 20.8 | 5 | 96 | 63 | 5.3 | 0 | 0.0 |
| 51 | 19.7 | 3 | 92 | 42 | 6.2 | 0 | 0.0 |
| 52 | 19.5 | 2.6 | 96 | 51 | 5.8 | 0 | 0.0 |
| 1 | 17.5 | 9.6 | 96 | 82 | 1.8 | 8.9 | 0.4 |
| 2 | 15.8 | 4.6 | 98 | 72 | 2.7 | 0.0 | 0.6 |
| 3 | 16.4 | 6.7 | 99 | 74 | 2.7 | 0.0 | 1.4 |
| 4 | 18.8 | 4.9 | 96 | 59 | 5.2 | 0.0 | 2.2 |
| 5 | 22.6 | 5.2 | 94 | 46 | 7.5 | 8.7 | 14.1 |
| 6 | 22.6 | 5.5 | 98 | 53 | 6.7 | 0.0 | 27.2 |
| 7 | 25.2 | 8.4 | 100 | 51 | 5.6 | 0.0 | 42.1 |
| 8 | 27.6 | 9.1 | 97 | 43 | 7.1 | 0.0 | 34.3 |
| 9 | 29.3 | 9.7 | 93 | 34 | 8.4 | 0.0 | 59.4 |
| 10 | 30.7 | 14.1 | 91 | 43 | 6.8 | 0.0 | 84.7 |
| 11 | 30.7 | 13.9 | 89 | 40 | 6.0 | 1.2 | 120.2 |
| 12 | 31.4 | 14.5 | 88 | 37 | 5.9 | 4.4 | 65.7 |
| 13 | 33.5 | 14.3 | 75 | 26 | 7.7 | 0.0 | 46.4 |
| 14 | 35.0 | 13.3 | 69 | 18 | 8.2 | 0.0 | 9.2 |

## 3. Results and Discussion:

Graphical representations (Fig. 1 and Fig. 2) were employed to present the mean number of mustard aphids per trap alongside weather parameters for the year 2019-20 and 2020-21. These visualizations offer insights into how different weather conditions might impact aphid populations and can aid in understanding the complex interplay between environmental factors and insect dynamics. [10]

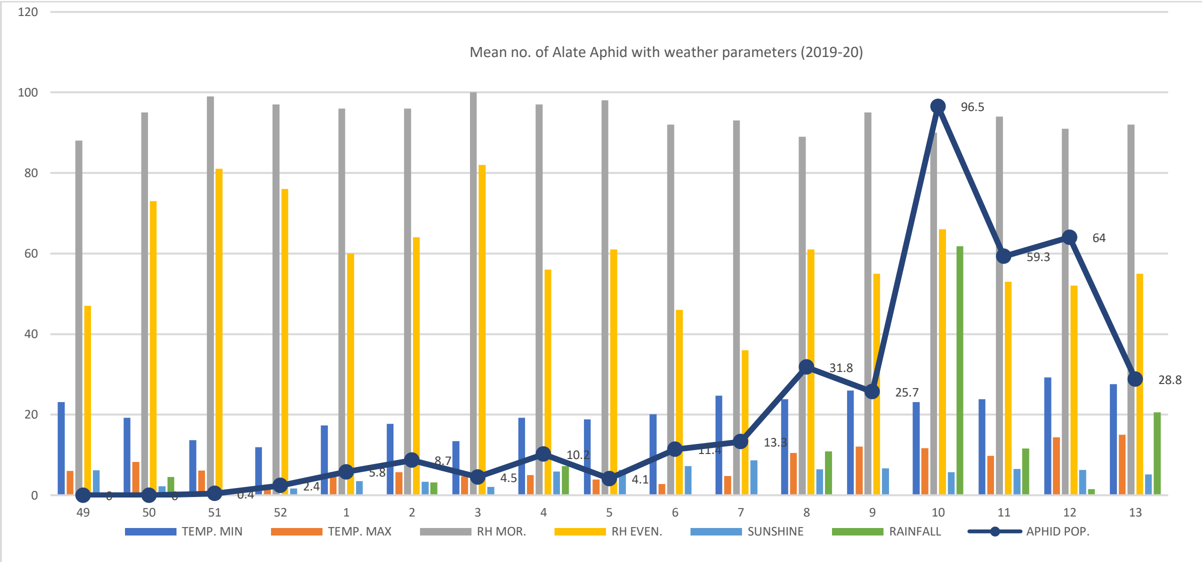


**Fig 1: Mean number of Mustard aphids/trap with weather parameter during 2019-20**

The average number of aphids captured in individual traps over the 2019-2020 crop season have been depicted in Fig 1. The presence of aphids became apparent from December 17, 2019, marking the onset of the 51$^{th}$ standard week. Initially, a modest count of 0.4 aphids per trap was observed. This is often due to factors such as the availability of suitable host plants and favourable weather conditions. As time progressed, this count gradually rose, beginning with the 2$^{nd}$ standard week at 8.7 aphids per trap is likely influenced by environmental conditions becoming more conducive for their reproduction and growth. Subsequently, during the following weeks, the aphid population reduced by approximately half compared to the previous week, reaching 4.5 aphids per trap could be attributed to various factors, such as natural predators, diseases, or changes in the availability of host plants. [7]

However, an intriguing surge occurred, with the aphid population growing nearly 2.5 times from the prior week to the next standard week, measuring 10.2 aphids per trap could be due to various factors coming together. These might include optimal weather conditions, reduced predation pressure, and sufficient resources for reproduction. This growth was followed by a swift decline to 4.1 aphids per trap suggests that some factor, perhaps unfavourable weather or increased predation, could have curbed their population growth. Notably, this pattern of aphid population ratios shifting and fluctuating was evident from the 51$^{th}$ to the 5$^{th}$ standard week indicates fluctuations in environmental conditions, natural cycles, or interactions with other organisms. These changes might have impacted the aphid population dynamics during this period.

From the 6$^{th}$ to the 8$^{th}$ standard week, aphid populations exhibited proportional growth could be due to a combination of favourable factors, including suitable temperatures, host plant availability, and limited predation. The peak in aphid population at 25.7 per trap during the 9$^{th}$ standard week suggests a period of optimal conditions for aphid reproduction and population expansion. Subsequently, during the 10$^{th}$ standard week, there was a notable spike in insect population, recording 96.5 aphids per trap might be attributed to specific environmental conditions or factors that promoted rapid aphid reproduction and population growth.However, a significant decline in the mustard aphid population followed, and by the 13$^{th}$ standard week, the crop was entirely free of this pest. The sharp decline in aphid populations after the 13$^{th}$ standard week could be due to factors like changing weather conditions or the buildup of natural predators and parasites that targeted the aphids. The complete elimination of aphids by the end of March might indicate that these natural control mechanisms became highly effective, leading to the elimination of the pest population. [10]

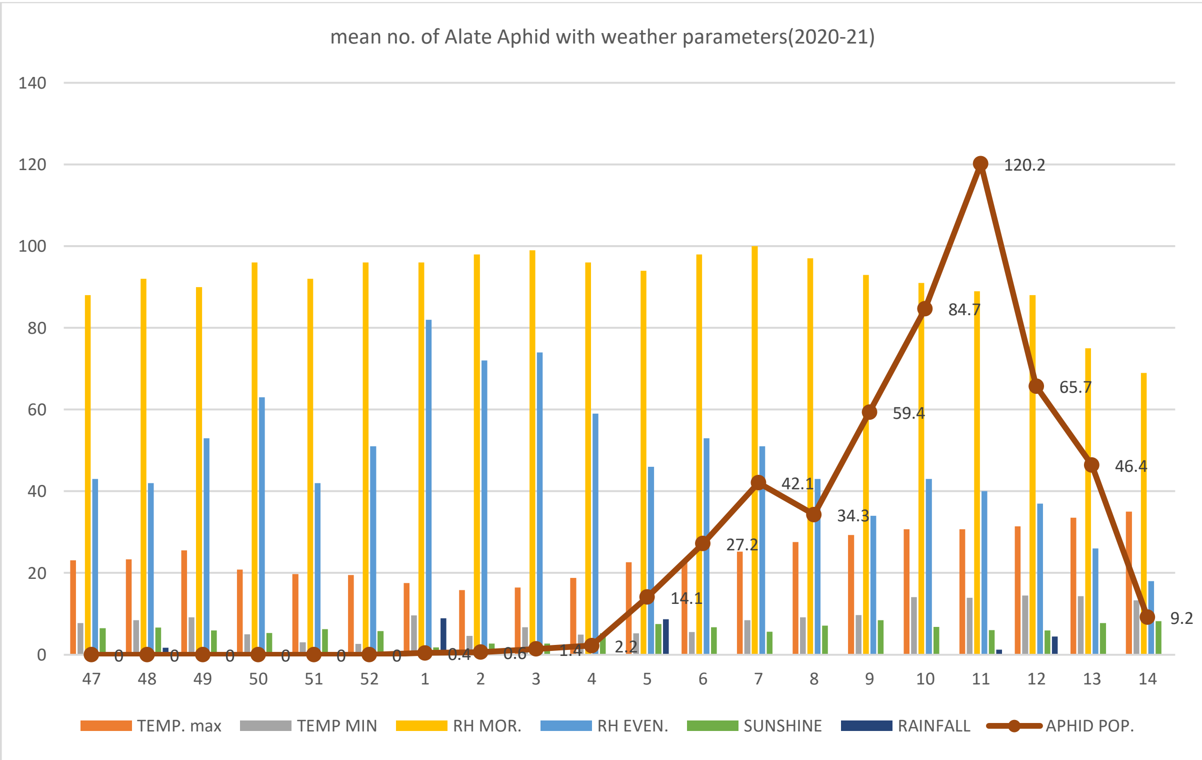


**Fig 2: Mean number of Mustard aphids/trap with weather parameter during 2020-21**

For the year 2020-21, Fig. 2 depicts the population dynamics of mustard aphids. The emergence of mustard aphids commenced on January 1st, coinciding with the first standard week of the year. This period might have offered suitable conditions for aphid reproduction and colonization. The initial low incidence of 0.8 aphids per trap could be attributed to a slow initial buildup due to various factors, including the availability of host plants and favourable environmental conditions. The subsequent week witnessed a slight increase to 0.6 aphids per trap. This modest rise could be influenced by a combination of factors such as favourable temperatures, humidity levels, and the presence of host plants that promoted the growth and reproduction of aphids. [16]

A noteworthy surge in the aphid population was recorded during the seventh standard week, with numbers reaching 42.1 aphids per trap. This substantial increase might be attributed to optimal conditions for aphid reproduction, such as a combination of suitable temperatures, abundance of host plants, and potential reductions in natural enemies or predators during that period. As the year progressed, the incidence of mustard aphids decreased. This decline could be related to various ecological factors coming into play, including the presence of natural predators, parasitoids, and diseases that limit aphid populations. [17] Additionally, changes in weather conditions and the availability of host plants could contribute to these fluctuations.

Despite the overall decline, the aphid population continued to grow, reaching 84.7 aphids per trap in the 10th standard week. This resurgence could be driven by intermittent periods of favourable conditions that support aphid growth and reproduction, along with factors that temporarily suppress natural control agents. The 11th standard week stood out as a period of peak insect population, recording 120.2 mustard aphids per trap. This significant spike could be linked to a convergence of ecological factors that favour aphid reproduction, such as optimal weather conditions, an abundance of host plants, and a temporary reduction in the activity of aphid predators and parasites. [19]

Following the peak, the aphid population gradually declined in the subsequent weeks. This decline might be associated with seasonal changes, shifts in weather patterns, and the restoration of natural balance as predators and parasitoids regain control over aphid populations. It is noteworthy that a similar pattern of insect incidence was observed by Mishra. This consistency suggests the existence of recurring factors or seasonal cycles that influence aphid dynamics in this region.

The population dynamics of mustard aphids were observed over two agricultural years, 2019-2020 and 2020-2021. In the former year, aphids emerged in mid-December, gradually increased to a peak of 23.8 aphids per trap, and declined thereafter. Conversely, in the latter year, aphids appeared in early January, experienced a rapid surge to 42.1 aphids per trap, peaked at a higher count of 120.2 aphids per trap, and then declined. The consistent recurrence of patterns in both years implies the influence of recurring environmental and ecological factors. This phenomenon was visually linked with weather parameters.

**Associations Between Mustard Aphid and Meteorological Factors**

The data from Table 3 uncovers the relationship between meteorological variables and mean aphid populations during the distinct periods of 2019-20 and 2020-21. The findings highlight a significant positive correlation between aphid numbers and both maximum temperature ($T_{max}$) and minimum temperature ($T_{min}$), with correlation coefficients of 0.633 and 0.703, respectively observed in 2020-21. Conversely, there's an insignificant negative relationship between aphid populations and morning relative humidity ($RH_1$), indicated by a correlation coefficient of -0.167. Further analyses reveal a negative correlation with afternoon relative humidity ($RH_2$) (-0.335), alongside positive associations with sunshine hours (0.040) and rainfall (0.424). In the preceding year (2019-2020), the Table 3 showcases the positive correlation of mustard aphid occurrence with the highest temperature (0.588) and lowest temperature (0.691). Morning relative humidity negatively correlates (-0.503), while showing a positive alignment with rainfall (0.7772) [9]. These associations illuminate the intricate dependencies between mustard aphid behaviour and climatic variables. [12 ]

**Table 3: Correlation of weather parameters with mean aphid population**

| Weather variables | Correlation Coefficient (Mean aphid Populations) | |
|---|---|---|
| | 2019-20 | 2020-21 |
| Maximum Temp | .588* | 0.633** |
| Minimum Temp | .691** | 0.702** |
| RH Morning | -0.503* | -0.167 NS |
| RH Evening | -0.183NS | -0.424* |
| Sunshine Hours | 0.385NS | -0.335 NS |
| Rainfall | 0.772** | -0.040 NS |

* Significant at 5 % level, ** Significant at 1 % level and NS Non Significant

Notably, strong positive correlations with maximum and minimum temperatures emphasize the pivotal role of temperature in shaping aphid dynamics. Morning relative humidity demonstrates a negative correlation in 2019-20, suggesting potential hindrance to aphid proliferation. However, this pattern lacks statistical significance in 2020-21. [18] Correlations with evening relative humidity remain marginal across both periods. Sunshine hours exhibit insignificant correlations, implying limited direct sunlight influence. Notably, divergent rainfall correlations are observed between the two years, with 2019-20 showing a positive correlation suggesting enhanced growth with increased rain, while this dynamic differs in 2020-21, hinting at varying ecological influences. These correlation insights underscore the complex interactions between weather parameters and aphid populations within the context of the studied agricultural landscape.

**Statistical Modelling of Mean aphid population with weather parameters**

The aim was to understand how weather impacts the population of mustard aphids (*Lipaphis erysimi* Kalt.). To do this, the data spanning two years (2019–2021) on both weather conditions and the count of these aphids were collected. The count of aphids was considered as the main factor of interest (dependent variable "Y"), while factors like maximum temperature ($T_{max}$), minimum temperature ($T_{min}$), morning relative humidity ($RH_1$), evening relative humidity ($RH_2$), sunshine hours (SSH), and rainfall (RF) were studied as independent variables. In order to uncover how different environmental conditions affect the aphid population, we employed multiple linear regression with high precision and low errors, along with tests to ensure statistical significance. Parameters like $R^2$ (which gauges the accuracy of the equations) and standard error were used to assess the equations' importance. [13] The goal of regression analysis was to find the most accurate model that explains the relationship between these factors. This model can then be used to predict or estimate aphid numbers based on weather patterns. Our analysis found that weather conditions from a year earlier (with an $R^2$ value of 0.80) had a substantial impact on aphid behaviour, highlighting that meteorological factors influence aphid populations significantly. The developed models for years are given below

**Year 2019-20**

$$Y = -354.985 + 4.138T_{MAX} + 4.144T_{MIN} + 3.888RH_1 - 1.335RH_2 - 8.113SSH - .040RF \quad (R^2 = 0.76)$$

**Year 2020-21**

$$Y = 77.309 + 5.407T_{MAX} + 7.183T_{MIN} - 0.365RH_1 - .228RH_2 + 8.818SSH + .824RF \qquad (R^2 = .80)$$

In the case of *Lipaphis erysimi* kalt., a notable linkage emerged between weather variables and the observed variability, accounting for 77% to 80% (with p-values of 0.00148 and 0.00448, respectively). [14] The investigation aimed to discern how meteorological conditions influence aphid populations on mustard plants. Employing stepwise regression analysis, a statistical methodology, the examination revealed a strong association between weather patterns and aphid numbers. Results underscored the considerable influence of factors like relative humidity, temperature, and rainfall on aphid population dynamics. Understanding the intricate interplay of environmental elements, particularly temperature, relative humidity, and rainfall, in relation to aphid infestations in mustard crops, holds critical importance for accurate prediction and effective management. [21] This insight empowers farmers and agricultural experts to implement targeted pest management strategies, mitigating the risk of aphid-induced crop damage [15].

## 4. Conclusions:

In conclusion, this comprehensive study delved into the intricate dynamics between mustard aphids (*Lipaphis-erysimi* kalt.) and a spectrum of meteorological variables. The investigation employed rigorous statistical analyses, including multiple linear regression, to elucidate the associations between independent atmospheric factors and aphid populations. The findings underscore the pivotal role played by temperature, humidity, and rainfall in influencing the behaviour and population trends of mustard aphids. These weather variables emerged as significant drivers of aphid dynamics, as evidenced by their substantial impact on aphid numbers and behaviours. The correlation coefficients, $R^2$ values, and other statistical indicators collectively affirm the strength and validity of these associations.

## 5. References

[1] Achintya,P.& Debjani D.(2012). Influence of weather parameters on population dynamics of *Lipaphis erysimi* (Kaltenbach) and its parasitoid *Diaeretiella rapae* (Mclntosh) in mustard. Journal of Entomological Research,36:305-08.

[2] Kanyongo, G. Y., Certo, J., & Launcelot, B. I. (2006). Using Regression Analysis to Establish the Relationship between Home Environment and Reading Achievement: A Case of Zimbabwe. International Education Journal, 7(4), 632-641.

[3] Kutner, Michael H., et al. (2005). Applied linear statistical models (Vol. 5). Boston: McGraw-Hill.

[4] Zwicker, J. G., & Montgomery, I. (2012). Application of motor learning principles to handwriting instruction and intervention. Handwriting Today, 11, 9-19.

[5] Sapra, N., & Pandya, H. (2022). AN IN VITRO ANALYSIS AND ETHNOBOTANICAL PROFILE OF JASMINUM SAMBAC L. International Association of Biologicals and Computational Digest, 1(1), 76-82.

[6] Verma, U., Piepho, H. P., Goyal, A., Ogutu, J. O., & Kalubarme, M. H. (2016). Role of climatic variables and crop condition term for mustard yield prediction in Haryana. Int. J. Agric. Stat. Sci, 12, 45-51.

[7] Mishra, M. & Mukherjee, U. (2020). Effect of various environmental parameters on population of mustard aphid (*Lipaphis erysimi Kalt.*). Journal of Entomology and Zoology Studies, 8(5): 291-295.

[8] Patel, S., & Singh, C. P. (2017). Development of weather based forewarning model for mustard aphid, *Lipaphis erysimi* (Kalt.) in Tarai region of Uttarakhand. Journal of Agrometeorology, 19(4), 382-382.

[9] Jahnavi, A. P., Megeri, S. N., Reddy, K. S., & Patil, S. S. (2022). Study on influence of weather parameters on growth and development of insect population sunflower (Helianthus annus). significance, 1, 2.

[10] Ahuja, D.B. (1990). Population dynamics of mustard Lipaphis erysimi (Kalt.) on Indian mustard, *Brassica juncea* (subsp*. juncea).* Indian J Plant Prot, 18:233-35.

[11] Ansari, Z.A. & Lal, M.N. (2008). Reaction of Brassica genotypes to mustard aphid, *Lipaphis erysimi* (Kalt.) infestation. J. Prog. Agric., 8 (1):17-18.

[12] Abbas, J., Muzaffar, A., Mahmood, H. K., Ramzan, M. A., & Rizvi, S. S. U. H. (2014). Impact of technology on performance of employees (a case study on Allied Bank Ltd, Pakistan). World Applied Sciences Journal, 29(2), 271-276.

[13] Debnath, P., & Pal, S. (2021). Population dynamics of mustard aphid (*Lipaphis erysimi*) with relation to some micro-meteorological parameters. Journal of Pharmacognosy and Phytochemistry, 10(1), 879-884.

[14] Dhaliwal, L.K., Hundal, S.S., Kular, J.S., Sarabjot, Chahal. & Aneja, A.K.(2007) Effect of meteorological parameters on aphid, Lipaphis erysimi (Kalt.) population Indian mustard, *Brassica juncea* (L.) Czern & Coss. Journal of Oilseeds Research, 24(1):151-154.

[15] Malik, R.& Sachan, S.K. (2013). Population build-up of mustard, *Lipaphis erysimi* (Kalt.) on Indian mustard in relation in relation to some abiotic factors. Progressive Agriculture,13(1):153-157.

[16] Singh, S.S.& Lal, M.N.(1999). Seasonal incidence of mustard aphid *Lipaphis erysimi* (Kalt.) on mustard crop. Journal of Entomological Research, 23:165-167.

[17] Singh, S.V. & Malik, Y.P(1998). Population dynamics and economic threshold of *Lipaphis erysimi* (Kaltenbach) on mustard. Ind. J Ent., 60:43-49.

[18] Singh, A.K., & LAL,M.N.(2012). Population dynamics of mustard aphid, *Lipaphis erysimi* (kalt.) on mustard in relation to weather parameters. Asian Journal of Bio Science, Volume 7, October, 216-218.

[19] Sinha, R.P., Yazdani, S.S. & Verma, G.D. (1989). Population dynamics of mustard aphid (*Lipaphis erysimi* Kalt.) in relation to ecological parameters. Indian J. Entomology., 51(3): 334-339.

[20] Uttam, S. K., Mohan, K., & Tripathi, R. A. (1993). Studies on population dynamics of mustard aphid, *Lipaphis erysimi* Kalt. Annals of Plant Protection Sciences, 1(1), 34-37.

[21] Saxena, S., Murty, N. S., & Singh, C. P. (2012). Effect of weather parameters on population dynamics of mustard aphid (*Lipaphis erysimi Kalt)* in Tarai region of Uttarakhand. Journal of Agrometeorology, 14(2), 176-177.