

The relationship between ecological factors and the population dynamics of aphid occurrence in potato (*Solanum tuberosum* L.) cultivars

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Abstract

In a field trial conducted at the District Seed Farm, Department of Agriculture, Government of West Bengal, Burdwan, West Bengal, thirteen potato cultivars were assessed for aphid incidence, specifically *Myzus persicae* (Sulzer) and *Aphis gossypii* Glover (Aphididae: Hemiptera), during the *Rabi* seasons from 2020-2021 to 2022-2023. The combined data indicated that aphid activity began in the third week of December, with a peak observed in the third week of February. The aphid population demonstrated a significant positive correlation with maximum and minimum temperatures, temperature gradient, and bright sunshine hours, while showing a negative correlation with maximum and minimum humidity across all potato cultivars. Multiple regression analysis indicated that, collectively, these weather parameters significantly explained the variability in aphid population for the Kufri Pukhraj and Kufri Jyoti cultivars, as reflected by the adjusted R² values.

Keywords: Potato cultivars, aphid occurrence, population dynamics, weather factors, and correlation analysis

Introduction

Potato (*Solanum tuberosum* L.) is a key component of our daily diet, alongside other essential vegetables. It is cultivated across the country in a variety of agro-climatic conditions and holds the fourth position in terms of cultivation area and third in global potato production (Pandey *et al.* 2007) [26]. India produced 53.04 million tonnes of potatoes from 2.16 million hectares of land, with an average yield of 24.56 tonnes per hectare (Indian Horticulture Database, 2019) [15]. Potatoes are grown in nearly all states across a wide range of conditions. However, pest infestations are a significant challenge in achieving higher crop production. Herbivorous insects are estimated to consume 26% of potential food production, with India losing approximately 30% of its crops annually due to pests and various viral diseases (Pawar and Bharpoda, 2014; Sharma and Rao, 2012) [27, 29]. Insect pests alone cause around 40% of crop losses in vegetable production (Gaurav, 2011) [12]. Approximately 100 insect and non-insect pests infest potato crops worldwide. Among these, the aphids *Myzus persicae* (Sulzer) and *Aphis gossypii* Glover (Hemiptera: Aphididae) are significant sucking pests that not only damage plants by extracting sap but also transmit various potato viruses (Bhatnagar, 2007; Dharpure, 2002; Konar *et al.* 2003; Konar and Paul, 2005) [7, 9, 20, 21]. A comprehensive study on the incidence patterns of this insect pest in various resistant or tolerant potato cultivars, along with the correlation between ecological factors and pest population fluctuations, is crucial for effectively managing harmful potato pests (Ananda *et al.* 2010; Hossain *et al.* 2013) [4, 14]. The occurrence and growth of these insect pests are highly influenced by prevailing environmental factors (Aheer *et al.* 1994; Akashe *et al.* 2009) [1, 2]. Therefore, understanding the role of various abiotic factors is crucial, as they significantly affect the survival, development, and population dynamics of pests. It is important to note that developing weather-based forecasting systems requires a thorough understanding of population dynamics in relation to weather conditions (Lanunocheta and Pankaj, 2012; Shera *et al.* 2013) [24, 30]. Additionally, research on seasonal

abundance and population fluctuations will aid in developing effective management strategies for these sucking pests within the potato agro-ecosystem (Furiatti *et al.* 2008; Khan *et al.* 2012) [11, 18]. Therefore, this study focused on the seasonal abundance of aphids across different potato cultivars and the influence of various abiotic factors on the population fluctuations of *Myzus persicae* (Sulzer) and *Aphis gossypii* Glover in the plains of West Bengal (Gavkare *et al.* 2013; Kachot *et al.* 2018) [13, 16].

Materials and methods

The current investigation was carried out over three consecutive years during the *Rabi* seasons of 2020-21, 2021-22, and 2022-23 at the District Seed Farm, located at 23.2324° N latitude, 87.8615° E longitude, and 30 meters above sea level. This study was conducted under the Department of Agriculture, Government of West Bengal, in Burdwan District, West Bengal. The experiment was designed using a randomized block design (RBD) with three replications. Thirteen potato cultivars were randomly assigned, including T₁ = Kufri Shailaja, T₂ = Kufri Khyati, T₃ = Kufri Sadabahar, T₄ = Kufri Chandramukhi, T₅ = Kufri Himalini, T₆ = Kufri Pukhraj, T₇ = Kufri Chipsona-2, T₈ = Kufri Surya, T₉ = Kufri Ashoka, T₁₀ = Kufri Lalima, T₁₁ = Kufri Chipsona-3, T₁₂ = Kufri Jyoti, and T₁₃ = Kufri Atlantic. Each plot measured 3×4 square meters, with a spacing of 60 cm between rows and 20 cm between plants. The crop was planted at the end of November each year, and standard agronomic practices were adhered to, excluding pesticide application. In all plots, the crop was dehaulmed 90 days after sowing (during the first week of March) and harvested 100 days after sowing (during the second week of March). Observations on the incidence of various insect pests in different potato cultivars were taken weekly. For assessing the aphid population, the 100-leaf index method (Simpson, 1940) [31] was utilized. Data on aphid populations were collected from 30 compound leaves per plot, selecting one upper, one middle, and one lower compound leaf from 10 randomly chosen plants in each plot. Consequently, the population dynamics of various insect pests were analyzed

using standard statistical methods. Data on different meteorological parameters were sourced from the Department of Agrometeorology in Burdwan. The mean population data collected from the various potato cultivars during weekly observations were subjected to simple correlation analysis with meteorological parameters, including maximum and minimum temperatures (°C), maximum and minimum humidity (%), rainfall (mm), and bright sunshine (hours). Additionally, the cumulative effects of these parameters were assessed through multiple regression analysis using the Ordinary Least Squares (OLS) technique (Draper and Smith, 1981) [10]. The abiotic factors included in the regression model provided a comprehensive view of the relationship between pest populations and these factors. However, it is not necessarily the case that all abiotic factors significantly affect pest populations. To eliminate the least significant factors progressively, step-down regression analysis was performed. In the first step, the least significant factor was removed, and multiple regression models were adjusted accordingly. This process

continued in subsequent steps, removing non-significant variables until only those that significantly contributed to pest populations remained in the regression model. The findings derived from the regression equations were evaluated using significance tests for the coefficient of determination (R²). Regression models were constructed to estimate pest populations by employing multiple regression equations, utilizing SPSS software (version 16.0) for analysis. This approach enabled the identification of significant relationships between the independent variables and pest populations, thereby facilitating a more nuanced understanding of the contributing factors.

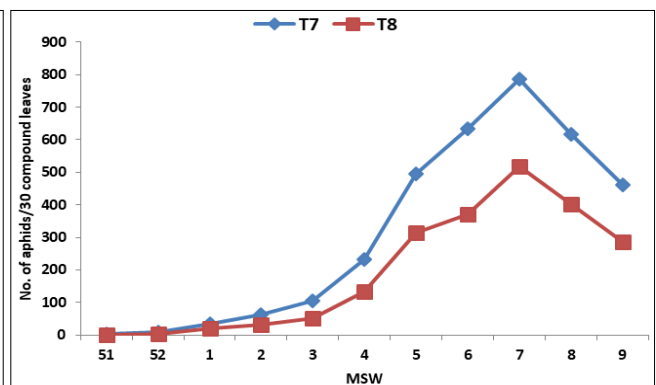
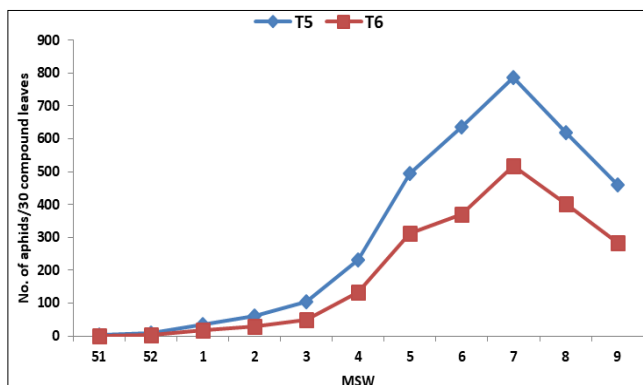
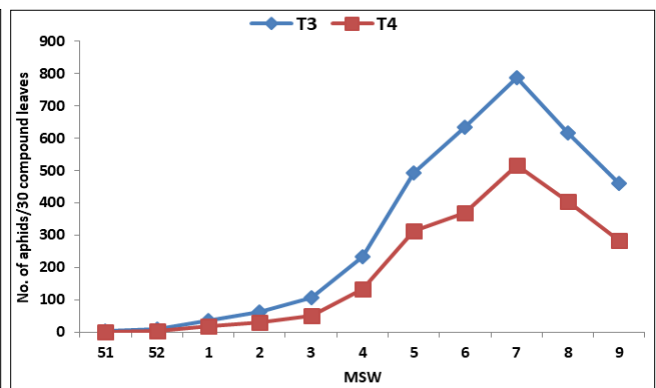
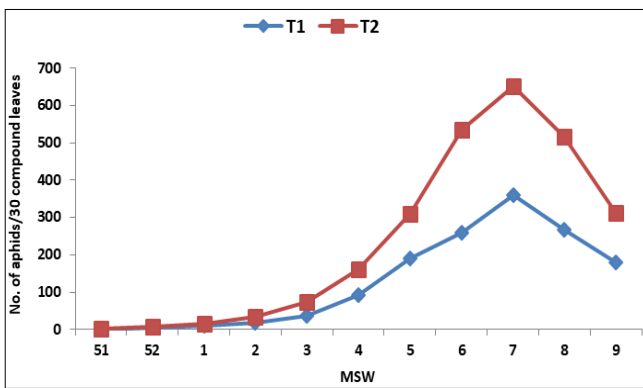
Result and Discussion

From the pooled data over three years, aphids were first detected in the third week of December and remained active throughout the growing season, with varying population densities across different potato cultivars (Fig. 1). The population peaked during the crop’s vegetative stage in the third week of February (Table 1).

Table 1: Aphid Population Dynamics throughout Potato Growing Seasons (Three-Year Pooled Data)

Parameters	No. of aphids/30 compound leaves												
	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	T ₁₁	T ₁₂	T ₁₃
Initial population	0.3 (51)	1.5 (51)	3.1 (52)	6.3 (51)	2.5 (51)	0.3 (51)	0.3 (51)	0.6 (51)	10.6 (51)	7.2 (51)	3.5 (51)	0.3 (51)	10.2 (51)
Peak Population	360.0 (7)	650.6 (7)	296.7 (7)	801.6 (7)	738.0 (7)	113.6 (7)	146.2 (7)	556.7 (7)	1070.6 (7)	820.0 (7)	787.4 (7)	517.4 (7)	1127.5 (7)
Terminal population	179.8 (9)	311.5 (9)	140.3 (9)	510.2 (9)	404.0 (9)	66.2 (9)	68.8 (9)	296.0 (9)	566.6 (9)	503.0 (9)	460.8 (9)	284.8 (9)	603.0 (9)
Population Range	0.3-360.0	1.5-650.6	3.1-296.7	6.3-801.6	2.5-738.0	0.3-113.6	0.3-146.2	0.6-556.7	10.6-1070.6	7.2-820.0	3.5-787.4	0.3-517.4	10.2-1127.5
Attainment of max. population	259.6-266.1 (6-8)	533.9-516.9 (6-8)	212.5-256.5 (6-8)	656.8-600.4 (6-8)	586.3-577.7 (6-8)	77.3-101.3 (6-8)	107.5-118.1 (6-8)	417.9-422.7 (6-8)	747.2-736.9 (6-8)	690.5-624.1 (6-8)	635.1-617.7 (6-8)	370.0-403.2 (6-8)	796.8-817.7 (6-8)

*T₁: K. Shailaja; T₂: K. Khyati; T₃: K. Sadabahar; T₄: K. Chandramukhi; T₅: K. Himalini; T₆: K. Pukhraj; T₇: K. Chipsona-2; T₈: K. Surya; T₉: K. Ashoka; T₁₀: K. Lalima; T₁₁: K. Chipsona-3; T₁₂: K. Jyoti; T₁₃: K. Atlantic
 **Data in parentheses indicate meteorological standard week



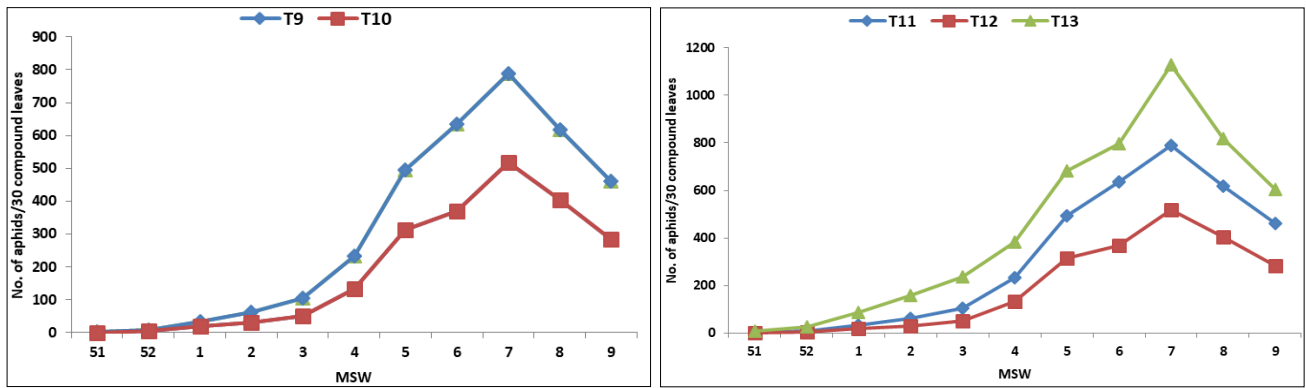


Fig 1: Population fluctuation of aphid population in different cultivars of potato during the different meteorological standard weeks (MSW) of crop growing seasons

Kufri Atlantic, Kufri Ashoka, Kufri Lalima, Kufri Chandramukhi, Kufri Chipsona-3 and Kufri Himalini supported higher pest populations, while Kufri Sadabahar, Kufri Shailaja, Kufri Jyoti, Kufri Surya and Kufri Khyati maintained moderate pest levels. The low aphid incidence in Kufri Pukhraj and Kufri Chipsona-2 may be attributed to their morphological traits, as these cultivars have rough, coarse, narrower, and smaller leaves compared to others (Konar and Paul, 2006) [22]. Additionally, the taller height of these cultivars may create an unfavorable microclimate within the crop canopy, as aphid populations showed a positive correlation with temperature and a negative correlation with relative humidity during the *Rabi* season (Bhatnagar *et al.* 2012; Khalequzzaman and Nahar, 2008) [6, 17]. Observations also indicated that aphid populations were highest on the lower leaves, while upper leaves had the lowest populations, suggesting aphids prefer senescing leaves in shaded conditions. Konar and Singh (2009) [23] also found Kufri Ashoka and Kufri Chandramukhi

susceptible to aphids, with Kufri Jyoti and Kufri Jawhar showing tolerance, while Kufri Chipsona-1 and Kufri Chipsona-2 exhibited resistance to the pest. The correlation analysis results indicated that aphid populations were influenced by multiple abiotic factors rather than a single one, with these factors affecting population buildup differently across seasons. As shown in Table 2 (three-year pooled data), aphid populations had a positive correlation with maximum and minimum temperatures (T_{max} and T_{min}), temperature gradient, and bright sunshine hours (BSS). In contrast, both maximum and minimum humidity percentages showed a negative correlation with all cultivars. Significant correlations were observed between aphid populations, T_{max} , and BSS. These findings align with those of Konar and Paul (2006) [22], who reported that aphid populations on potato crops were positively correlated with temperature, rainfall, and sunshine hours but negatively correlated with relative humidity.

Table 2: Correlation coefficients between abiotic factors and Aphid populations across various potato cultivars (three-year pooled data)

Weather parameters	Potato cultivar												
	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	T ₁₁	T ₁₂	T ₁₃
Maximum Temperature (°C)	0.847**	0.833**	0.850**	0.848**	0.857**	0.887**	0.873**	0.863**	0.811**	0.828**	0.863**	0.862**	0.824**
Minimum Temperature (°C)	0.793**	0.788**	0.816**	0.757**	0.800**	0.832**	0.832**	0.810**	0.733*	0.732*	0.785**	0.820**	0.744**
Temperature Gradient (°C)	0.660*	0.637*	0.625*	0.737**	0.676*	0.690*	0.653*	0.672*	0.680*	0.730*	0.715*	0.644*	0.697*
Maximum Humidity (%)	-0.444	-0.452	-0.495	-0.461	-0.456	-0.473	-0.440	-0.446	-0.427	-0.461	-0.468	-0.446	-0.440
Minimum Humidity (%)	-0.058	-0.053	-0.081	-0.124	-0.066	-0.076	-0.031	-0.054	-0.110	-0.144	-0.102	-0.053	-0.120
Sunshine (h)	0.752**	0.741**	0.744**	0.790**	0.765**	0.757**	0.737**	0.748**	0.758**	0.786**	0.782**	0.741**	0.757**
Rainfall (mm)	0.210	0.190	0.192	0.154	0.183	0.185	0.220	0.200	0.232	0.160	0.157	0.242	0.222

*T₁: K. Shailaja; T₂: K. Khyati; T₃: K. Sadabahar; T₄: K. Chandramukhi; T₅: K. Himalini; T₆: K. Pukhraj; T₇: K. Chipsona-2; T₈: K. Surya; T₉: K. Ashoka; T₁₀: K. Lalima; T₁₁: K. Chipsona-3; T₁₂: K. Jyoti; T₁₃: K. Atlantic
 **Significant at 5% * **Significant at 1%

Multiple regression analyses were conducted over three consecutive years (2020-21, 2021-22, and 2022-23) during the potato growing seasons to assess the combined effects of

all abiotic factors on aphid population abundance in the crop field. The coefficient of determination (adjusted R²) was calculated for this purpose.

Table 3: Multiple regression analysis of abiotic factors and aphid populations across potato cultivars during growing seasons (three-year pooled data)

Potato cultivar	Prediction equation (stepwise regression)	Adjusted R ²	Significant (p=0.05)
T ₁	Y= 182.30 +2.46X ₁ + 16.04X ₂ - 8.80X ₄ + 4.50X ₅ + 35.01X ₆ + 80.91X ₇	0.713	Non-significant
T ₂	Y= 424.62 +5.23X ₁ + 28.57 X ₂ - 17.21X ₄ + 8.60X ₅ + 62.33X ₆ + 147.14X ₇	0.636	Non-significant
T ₃	Y= 361.54+ 3.95X ₁ +11.88 X ₂ - 9.40X ₄ + 3.40X ₅ + 22.98X ₆ + 73.14X ₇	0.728	Non-significant

T ₄	$Y=382.34 - 2.82X_1 + 60.12 X_2 - 20.75X_4 + 10.91X_5 + 74.06X_6 + 161.78X_7$	0.719	Non-significant
T ₅	$Y=315.72 + 5.80X_1 + 37.90 X_2 - 18.11X_4 + 9.58X_5 + 71.95X_6 + 158.11X_7$	0.721	Non-significant
T ₆	$Y=151.04 + 3.60X_1 + 13.77 X_2 - 6.18X_4 + 2.63X_5 + 15.00X_6 + 47.20X_7$	0.776	Significant
T ₇	$Y= 56.29 + 2.33X_1 + 5.75 X_2 - 3.12X_4 + 1.53X_5 + 10.93X_6 + 28.68X_7$	0.754	Non-significant
T ₈	$Y= 280.09 + 6.06X_1 + 29.50 X_2 - 14.02X_4 + 7.03X_5 + 47.02X_6 + 119.74X_7$	0.717	Non-significant
T ₉	$Y= 715.76 - 7.15X_1 + 49.18 X_2 - 25.90X_4 + 12.38X_5 + 112.45X_6 + 255.85X_7$	0.706	Non-significant
T ₁₀	$Y= 544.36 - 6.91X_1 + 59.65 X_2 - 22.27X_4 + 10.92X_5 + 78.93X_6 + 176.80X_7$	0.689	Non-significant
T ₁₁	$Y= 367.53 + 2.74X_1 + 53.80 X_2 - 20.60X_4 + 10.60X_5 + 72.00X_6 + 161.73X_7$	0.727	Non-significant
T ₁₂	$Y= 142.73 + 2.93X_1 + 7.61 X_2 - 5.38X_4 + 2.30X_5 + 19.51X_6 + 52.25X_7$	0.789	Significant
T ₁₃	$Y= 1003.38 - 6.58X_1 + 66.09 X_2 - 31.20X_4 + 13.66X_5 + 99.46X_6 + 269.54X_7$	0.715	Non-significant

*T₁: K. Shailaja; T₂: K. Khyati; T₃: K. Sadabahar; T₄: K. Chandramukhi; T₅: K. Himalini; T₆: K. Pukhraj; T₇: K. Chipsona-2; T₈: K. Surya; T₉: K. Ashoka; T₁₀: K. Lalima; T₁₁: K. Chipsona-3; T₁₂: K. Jyoti; T₁₃: K. Atlantic

**Y: Aphid population (Dependent variable); X: Weather parameters (Independent variables)

***X₁=Max. Temp. (°C), X₂=Min. Temp. (°C), X₄= Max. Humidity (%), X₅= Min. Humidity (%), X₆= Sunshine (h), X₇= Rainfall (mm)

X₂ (Temp. Gradient) excluded ** Significant at 5%; ** ***** Significant at 1%

Based on the pooled data (Table 3) over three years, the coefficient of determination (adjusted R²) between aphid population and independent variables was as follows for each cultivar during the potato growing season: 0.713 (Kufri Shailaja), 0.636 (Kufri Khyati), 0.728 (Kufri Sadabahar), 0.719 (Kufri Chandramukhi), 0.721 (Kufri Himalini), 0.776 (Kufri Pukhraj), 0.754 (Kufri Chipsona-2), 0.717 (Kufri Surya), 0.706 (Kufri Ashoka), 0.689 (Kufri Lalima), 0.727 (Kufri Chipsona-3), 0.789 (Kufri Jyoti), and 0.715 (Kufri Atlantic). The combined influence of all weather parameters on aphid population fluctuation was significant for Kufri Pukhraj and Kufri Jyoti.

Understanding the abiotic factors influencing pest populations is essential for designing effective and precise management strategies for specific pests. Currently, significant attention is given to this area to develop detailed procedures and models for identifying key factors that affect insect pest abundance and distribution. Weather-based models of population phenology can improve decision-making for pest control, offering better opportunities for pest management within integrated pest control programs (Akbari *et al.* 2012; Damos and Soultani, 2010) [3, 8]. Aphid infestation displayed a strong sensitivity to weather changes over the study period. Analysis showed a significant positive correlation between aphid infestation rates and both maximum and minimum temperatures, as well as bright sunshine hours. Correlation coefficient data indicated that as temperatures rose in February, infestation levels gradually increased (Table 1). The significant correlations identified between aphid infestation and abiotic factors could be instrumental in developing a predictive model to forecast pest outbreaks, allowing for timely implementation of control measures. Although predicting the impact of climate change on various insect pests remains challenging, it can influence pest responses to host plants. Overall, the impact depends on how climate changes affect the relationships among insects, host plants, and natural enemies. Linear regression analysis showed that environmental variables significantly influenced aphid densities ($P < 0.05$), supporting the correlation analysis results. Relative humidity and pest incidence were important in explaining significant portions of the variance in aphid densities across different potato cultivars. Stepwise regression analysis further identified which abiotic factors most contributed to the variance in aphid populations (Table 3). Regression analysis indicated that maximum and minimum temperatures at the study site significantly and positively influenced pest population variation, while maximum and minimum humidity had a negative effect on population

build-up (Banerjee *et al.* 2014; Khan *et al.* 2011) [5,19]. The study demonstrated that various abiotic factors interact with existing weather conditions, impacting aphid populations. Both aphid species, *Myzus persicae* and *Aphis gossypii*, maintained varying population densities throughout the crop season, with infestations beginning in the third week of December across different potato cultivars. The pest population steadily increased, reaching its peak in the 3rd and 4th weeks of February across various potato cultivars. Correlation and regression analyses examined the influence of weather parameters on aphid population development, both individually and collectively. Results indicated that the same abiotic factors did not consistently impact pest population development across different potato cultivars; instead, their influence varied from one cultivar and crop season to another. Among the various weather factors, maximum and minimum temperatures (°C) and bright sunshine hours (BSS) showed a significant positive correlation with aphid populations in nearly all cultivars, while maximum and minimum humidity percentages displayed a negative correlation with aphid species populations. This study highlighted the seasonal abundance of aphids and the critical influence of different weather parameters on their population fluctuations within the potato agroecosystem, providing valuable insights for forecasting and developing effective management strategies for this insect pest (Nag *et al.* 2018; Sarwar *et al.* 2011) [25, 28]. Anticipating the peak abundance of pests and diseases in advance facilitates timely crop pest management. The correlation and multiple regression analyses clearly demonstrated the significance of weather factors in pest incidence. Among the various models, regression can be employed for pest forecasting and can also be used in agro-advisories once validated with specific seasonal data.

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