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# Weather patterns and their impact on Fruit Borer Population in Tomato Crops

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**Abstract**
The fruit borer population in tomato crops initially started at 0.00 individuals per plant and reached 3.10 individuals per plant by week 4 (January 22-28). This population surge was associated with moderate maximum temperatures averaging 32.29°C, which created favorable conditions for the pests. The absence of rainfall during this period reduced resource competition, further promoting the pest's growth. Stable minimum temperatures of 25.86°C also provided an optimal environment for their activity. Correlation and regression analyses highlighted the relationship between weather parameters and fruit borer populations. Maximum humidity showed a moderate positive correlation ($\rho = 0.447$), suggesting that higher humidity enhances pest survival and activity. In contrast, maximum temperature exhibited a weak negative correlation ($\rho = -0.251$), while rainfall and minimum temperature had negligible impacts. Linear regression analysis revealed that maximum relative humidity (R2=0.199) was the most significant predictor of pest populations, although none of the variables showed statistically significant relationships, indicating other influencing factors. Multiple linear regression analysis further emphasized the role of maximum relative humidity in fruit borer populations, but the relationship was not statistically significant. Other weather factors, such as temperature and rainfall, had weak or negligible effects, suggesting the involvement of additional, unexamined environmental variables in pest dynamics.

**Keywords:** Correlation, fruit borer, regression, tomato, weather

## Introduction
Tomatoes rank second among the most important vegetables grown worldwide, valued for their high nutritional content and widespread consumption. The commercially cultivated tomato, scientifically known as *Solanum lycopersicum L.*, is a genetically enhanced species belonging to the genus *Solanum* and the nightshade family (*Solanaceae*). They can be cultivated outdoors, in greenhouses, or in net houses across the globe. Tomatoes are rich in various vitamins, minerals, and secondary metabolites (Luthria *et al.*, 2006) [1]. A 100-gram serving of fresh tomatoes can fulfill over 46% of the daily potassium requirement, along with 8% of vitamin C and 3.4% of both vitamin A and C (Gebhardt and Thomas, 2002; Canene Adams *et al.*, 2005) [2,3]. Additionally, tomatoes are excellent sources of antioxidants and minerals such as iron (Fe), phosphorus (P), manganese (Mn), and potassium (K). Lycopene, the primary antioxidant that gives tomatoes their red color, has been associated with a reduced risk of several cancers, including those of the stomach, lungs, and prostate. Due to their unique nutritional profile, tomatoes are considered a healthful food. In terms of global production, India ranks second to China in both area and output, contributing 11% of the world's tomato production (Anonymous, 2021) [4]. India produces approximately 20.3 million metric tons (MT) of tomatoes annually from an area of 778 thousand acres. Andhra Pradesh is the leading tomato-producing state, followed by Madhya Pradesh and Karnataka. Assam cultivates tomatoes on 18.79 thousand hectares, yielding 430.83 thousand tonnes (Anonymous, 2022) [5]. Despite being relatively easy to cultivate, several challenges significantly reduce tomato yield. Among these, insect pests are a major concern as they adversely affect both crop quality and overall productivity. Common pests include jassids, aphids, tobacco caterpillars, leaf miners, flea beetles, and fruit borers (Sajjad *et al.*, 2011) [6].

Key insect pests of tomatoes include whiteflies (*Bemisia tabaci*), thrips (*Thrips tabaci*, *Frankliniella* sp.), aphids (*Myzus persicae* and *Aphis gossypii*), mealybugs (*Maconellicoccus* sp., *Phenacoccus solenopsis*), mites (*Tetranychus* spp.), tobacco caterpillars (*Spodoptera litura*), leaf miners (*Liriomyza trifolii*), and fruit borers (*H. armigera*), with the latter being particularly significant, causing 22-38% of crop losses (Dhandapani *et al*., 2003; Kuldeep, 2013) [7,8]. Under extreme conditions, yield losses can range from 72.19% to 77.79% (Aheer *et al*., 1998) [9]. The dynamics of insect pest populations are frequently altered by changing climatic conditions and environmental insecticide restrictions. The interaction between pest activity and abiotic factors aids in the creation of predictive models for forecasting pest incidence. This research aims to investigate the seasonal occurrence of fruit borer population and the impact of abiotic factors on their populations in the Yercaud region of Salem, Tamil Nadu.

## Materials and methods

An investigation was conducted at the Horticultural Research Station in Yercaud, Salem, Tamil Nadu, using the popular tomato hybrid Shivam during the Kharif season of 2021-2022. In the unprotected plots, observations of the pest population began seven days after transplanting (DAT) and continued every seven days (standard weeks) until harvest. At 16 and 18 WAT, *H. armigera* larval population, the chilli fruit borer, had been determined on 5 randomly selected plants in each treatments. There had been three distinct treatments were performed.

### Correlation coefficient

Correlation coefficient measures the strength of the linear relationship between two variables X and Y.
It is calculated by using following formula,

$$r = \frac{n\,\Sigma XiYi - \Sigma XiYi}{\sqrt{n\Sigma Xi\,2 - (\Sigma Xi)\,2\,(n\Sigma Yi\,2 - (\Sigma Yi)\,2}}$$

Testing correlation coefficient: The significance of Correlation coefficient (r) is tested using t test. Hypothesis is set as
H0: ρ= 0
H1: ρ ≠ 0

Test statistic is as follows

$$t = \frac{|\,r - 0\,|}{\sqrt{\frac{1-r2}{n-2}}}$$

Where, r – Sample correlation coefficient
n- Sample size"
The "calculated t-value must be contrasted with the critical t-value to obtain (n-2) degrees of freedom in order to generate significant conclusions.

### Simple regression analysis

Data on insect pests examined with fundamental linear regression, with insect" pest eggs & dead heart as dependent factors, including weather conditions & sowing date as independent variables.

A "simple linear regression model is,

$$Y = \alpha + ß\,X + \varepsilon$$

Where, Y- Dependent Variable. X- Independent variable.
Where, α - is the intercept, β -is the slope of the regression line, and ε -is the random error". $\hat{a}$ and $\hat{b}$ are the estimates of α and β.

Where, $\hat{b} = \frac{n\Sigma XiYi - \Sigma Xi\Sigma Yi}{n\Sigma Xi2 - (\Sigma Xi)2}$
Where, $\hat{a} = Y - bX$

### Significance of the regression coefficient.

Regression coefficient relevance is verified employing the F statistic.

$$\text{"F} = \frac{\text{Regression mean sum of squares (n}-2)}{\text{Error mean sum of squares}}$$

$$\text{Where, Regression" SS} = b\left(\Sigma XiYi - \frac{\Sigma Xi\Sigma Yi}{n}\right)$$

$$\text{Error sum of squares} = \left[\Sigma\,(Yi - Y)2 - b\left[\Sigma XiYi - \frac{\Sigma XiYi}{n}\right]\right.$$

### Coefficient of determination (R2)

The coefficient of determination ($R^2$) value served as metric for variation of the fitted model.

$$R^2\,(\%) = \frac{\text{Sum of square due to regression}}{\text{Total sum of squares}} = \frac{b\,\Sigma\,(Xi - \bar{X})\,(Yi - \bar{Y})}{\Sigma\,(Yi - Y)2}$$

### Multiple regression model

When numerous independent factors elucidate the dependent variable, a multiple linear regression model is applicable. Here, the model is,

$$Y = \alpha + ß\,1X1 + ß\,2X2 + \text{-----} + ß\,\rho\,X\,\rho + \varepsilon$$

Where, Y is the dependent variable and Xi are independent variables with ßi as the partial regression coefficients of Y on *X*i where I =1, 2…P.
Current" investigation, Y considered as incidence of pests & *Xi* "weather parameters *viz.*, temperature, rainfall, & relative humidity.
In this mode, the estimates of coefficients (βi's and α) are to be computed using the method of least" squares.

## Results and discussion

### Fruit Borer Population

The fruit borer populations commenced at 0.00 individuals per plant and peaked at 3.10 individuals per plant in week 4 (January 22-28). This increase occurred during a period of moderate maximum temperatures, averaging approximately 32.29°C, likely creating favorable conditions for their development. The absence of rainfall during these weeks may have minimized competition for resources, thus enhancing conditions for the fruit borers to thrive. Moreover, minimum temperatures stabilized around 25.86°C, creating an optimal environment for their activity. These findings are consistent with the earlier work of Wakil *et al.* (2010) [10], which demonstrated a positive relationship between higher temperatures and fruit borer populations. The current results suggest that both temperature and stable environmental conditions are critical factors that contribute to the proliferation of fruit borers. The relationship established here indicates a potential need for integrated pest management approaches that consider these climatic influences to mitigate pest impacts on tomato crops.

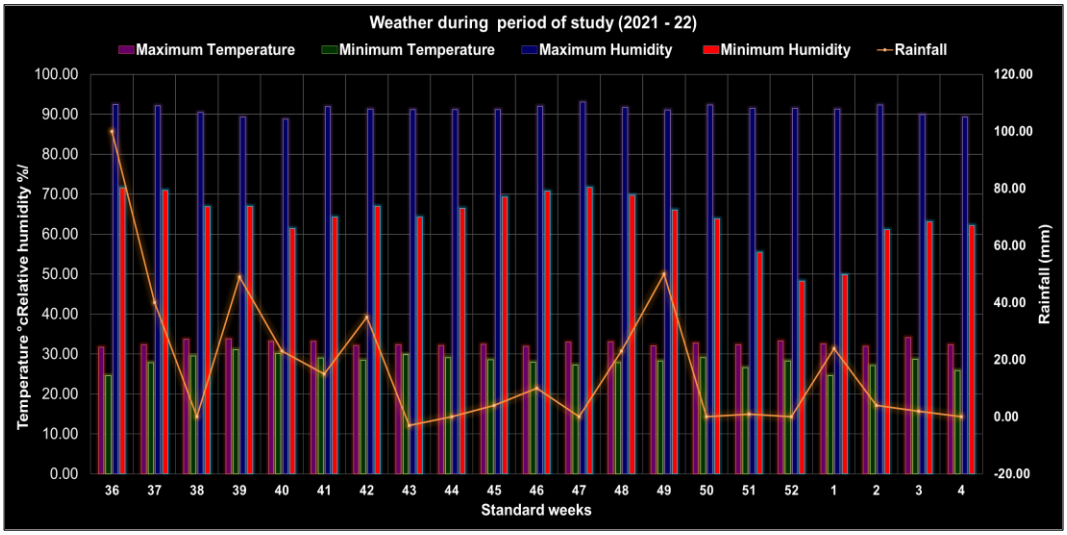


**Fig 1:** Patterns in the weather variables during 2021 – 22

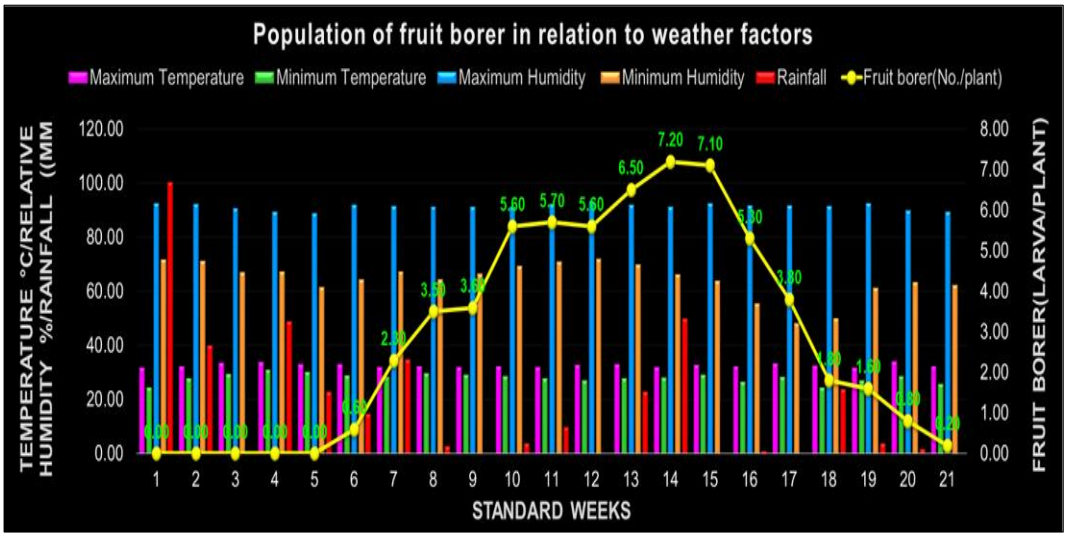


**Fig 2:** Population dynamics fruit borer in relation to weather factors

**Table 1:** Correlation coefficient between population dynamics of major pests and their damage on tomato and weather parameters

| Weather parameters/ Insect Population 2021 - 22 | | Temperature °C | | Relative humidity % | | Total Rainfall (mm) | $R^2$ | Regression Equation |
|---|---|---|---|---|---|---|---|---|
| | | Max. Temp | Min. Temp | Max. Hum | Min. Hum | | | |
| Fruit borer | $R^2$ | 0.063 | 0.004 | 0.199 | 0.003 | 0.076 | 0.348 | Fruit borer = - 73.092 - (0.962 x Max. Temp) + (0.384 x Min. Temp) + (1.073 x Max. Hum) – (0.010 x Min. Hum) – (0.031 x Rainfall) |
| | r | -0.251 | 0.005 | 0.447* | 0.062 | -0.277 | | |

**Table 2:** Regression model developed for population dynamics of major pests in tomato

| Insect pest infestation | Max. Temp (°c) (X1) | Min. Temp (°c) (X2) | Max. RH (%) (X3) | Min. RH (%) (X4) | Rainfall (mm) (X5) |
|---|---|---|---|---|---|
| Fruit borer | y = -0.9671x + 34.501 | y = 0.0074x + 2.7056 | y = 1.0532x - 93.132 | y = 0.0253x + 1.2866 | y = -0.0291x + 3.4448 |

**Table 3:** Correlation and linear regression coefficients between major pests of tomato in relation to weather factors

| Weather parameters | Fruit borer | | |
|---|---|---|---|
| | r | b | a |
| Max. Temp (°c) | -0.251 | -0.967 | 34.501 |
| Min. Temp (°c) | 0.005 | 0.007 | 2.705 |
| Max. RH (%) | 0.447* | 1.053 | -93.132 |
| Min. RH (%) | 0.062 | 0.025 | 1.286 |
| Rainfall (mm) | -0.277 | -0.029 | 3.444 |

* And ** indicate significance of values at P=0.05 and 0.01, respectively

Correlation and regression among weather parameters against fruit borer population in tomato

**Simple Correlation Studies**

The Pearson correlation coefficient (ρ) was used to examine the relationships between weather variables and pest populations in tomatoes. Figure 3 displays heat maps illustrating the ρ-values for five selected meteorological variables: minimum temperature (°C), maximum temperature (°C), minimum humidity (%), maximum humidity (%), and rainfall (mm), in relation to the population of fruit borers in tomatoes. In the heat map, a strong positive correlation is represented by red (ρ = 1), while a strong negative correlation is indicated by violet (ρ = -1). For fruit borers, maximum temperature showed a weak negative correlation (ρ = -0.251), indicating a slight reduction in activity at higher temperatures, while minimum temperature exhibited an almost negligible correlation (ρ = 0.005), suggesting no significant impact. Maximum humidity emerged as the most significant factor, with a moderate positive correlation (ρ = 0.447), implying that higher humidity levels favor fruit borer survival and activity. Minimum humidity displayed a very weak positive correlation (ρ = 0.062), indicating minimal influence, whereas rainfall showed a weak negative correlation (ρ = -0.277), suggesting that increased rainfall slightly disrupts fruit borer populations. Overall, maximum humidity was identified as the most critical environmental parameter influencing fruit borers, while rainfall and maximum temperature had weaker, primarily negative effects.

**Linear Regression Studies:** The regression analysis highlights the impact of environmental factors on fruit borer populations. Maximum relative humidity emerged as the most significant predictor (R2=0.199), showing a moderate positive correlation (y=1.0532x−93.132), indicating that higher humidity levels foster favorable conditions for pest proliferation. Maximum temperature displayed a weak negative correlation (y=−0.9671x+34.501, R2=0.063), while rainfall showed a minor negative impact (y=−0.0291x+3.4448, R2=0.076). Minimum temperature (R2=0.004) and minimum humidity (R2=0.003) exhibited negligible effects. However, none of these variables demonstrated statistically significant relationships with fruit borer populations, suggesting that other factors may also play a crucial role in influencing pest dynamics.

**Multiple linear regression studies**

A multiple linear regression analysis was conducted to assess the influence of weather parameters—maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, and rainfall—on fruit borer populations. The results showed that maximum relative humidity had the most notable positive impact, with a regression coefficient of 1.073, suggesting a potential increase in fruit borer populations under higher humidity conditions. However, this relationship approached but did not achieve statistical significance (p = 0.093). Maximum temperature (b=−0.962) and rainfall (b=−0.031) showed weak negative correlations, while minimum temperature (b=0.384b = 0.384b=0.384) and minimum relative humidity (b=−0.010) exhibited minimal or negligible effects. None of the variables demonstrated statistically significant relationships with fruit borer populations, indicating that other unexamined factors may play a more critical role in influencing pest dynamics.

**Table 4:** Multiple regression with fruit borer population and weather parameters

| Weather parameters | Partial regression coefficients | Standard error | 't' Value | $R^2$ |
|---|---|---|---|---|
| Intercept | -73.092 | 71.317 | -1.025 | 0.348 |
| X1 - Max. Temp (°c) | -0.962 | 1.010 | -0.952 | |
| X2 - Min. Temp (°c) | 0.384 | 0.457 | 0.840 | |
| X3 - Max. RH (%) | 1.073 | 0.597 | 1.797 | |
| X4 - Min. RH (%) | -0.010 | 0.104 | -0.099 | |
| X5 - Rainfall (mm) | -0.031 | 0.025 | -1.237 | |

N= 54, *Significant at p=0.05 **Significant at p=0.01, NS- Non Significant
Multiple R- Squared = 0.348, Adjusted R-Square = 0.131,
F Statistic = 1.604, on 5, p-value = 0.000, Significant codes = *

**Table 5:** Final run of linear regression model with the one most significant independent variables

| Variables | Coefficient | Standard Error | t-value | p-value | Rank of t-value |
|---|---|---|---|---|---|
| Min Humi | 1.053 | 0.484 | 2.176 | 0.040 | 1 |

The regression equation that characterizes the relationship between fruit borer populations and various weather parameters is articulated as follows:

Fruit Borer Population=−73.092−(0.962×Max. Temp)+(0.384×Min. Temp)+(1.073×Max. Humidity)−(0.010×Min. Humidity)−(0.031×Rainfall)

The regression equation indicates that the baseline fruit borer population is -73.092 when all variables are constant. Maximum temperature (−0.962) and rainfall (−0.031) show weak negative impacts on fruit borer populations, while minimum temperature (0.384) and maximum relative humidity (1.073) exhibit positive associations, with maximum humidity having the strongest effect. Minimum relative humidity (−0.010) has a negligible negative influence. This analysis highlights the distinct positive and negative effects of weather parameters on fruit borer populations.

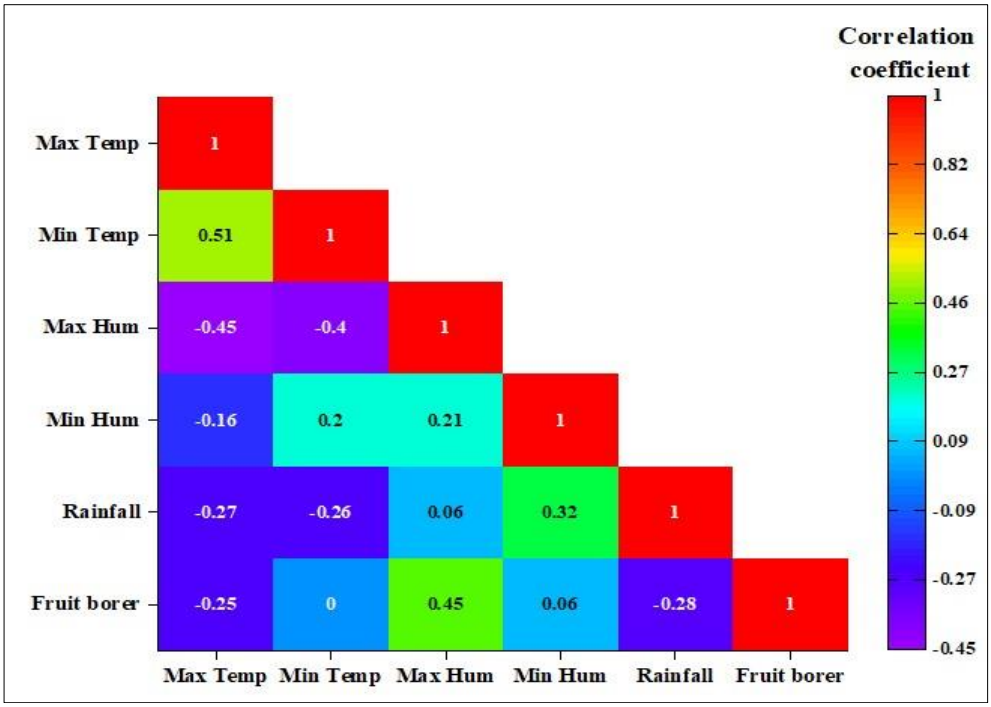


**Fig 3:** Heat map correlation (Pearson correlation) on influence of weather factors on population of fruit borer and the results of the correlation analysis have been scaled by a color gradient that goes from red (positive correlation) to violet (negative correlation) by increasing color density, significant correlation coefficients at $p \leq 0.05$, ** $p \leq 0.01$, and *** $p \leq 0.001$

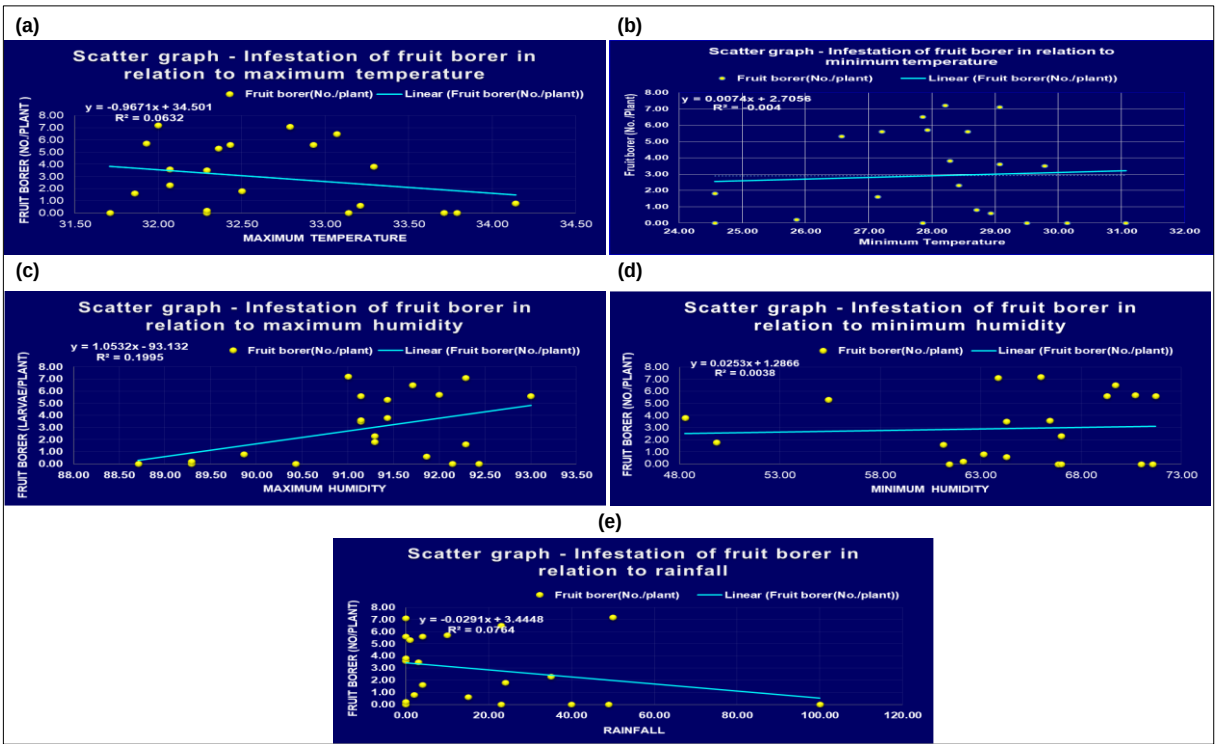


**Fig 4:** Scatter graph of population of fruit borer in relation to weather factors (a) Minimum temperature (b) Maximum temperature (c) Minimum humidity (d) Maximum humidity (e) Rainfall

The correlation and regression analyses reveal that weather parameters significantly influence fruit borer populations in tomatoes, aligning with previous studies on pest dynamics. The finding that maximum humidity positively correlates with fruit borer activity (r = 0.447) supports earlier research suggesting that increased humidity enhances pest survival and reproduction (Gafni *et al.*, 2022) [11].

This indicates that moisture levels are critical for pest management strategies. Conversely, the weak negative correlation with maximum temperature (r = -0.251) reflects findings by Khaliq & Shankar (2020) [12], who noted that extreme heat could deter pest activity. The negligible correlation with minimum temperature (r = 0.005) and minimum humidity (r = 0.062) is consistent with previous research indicating that these parameters have limited impacts on pest dynamics. Rainfall's weak negative correlation (r = -0.277) suggests a possible disruption of pest habitats management frameworks that enhance the sustainability and productivity of tomato cropping systems in the face of climate variability.

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