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Critical Determinants of Rice Tungro Disease Devastation and Its Vector Population Dynamics in Bangladesh

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ABSTRACT

Rice Tungro disease caused by Rice Tungro Viruses (Rice Tungro Bacilliform Virus and Rice Tungro Spherical Virus) transmitted by vector Green Leaf Hopper (GLH), *Nephotettix virescens*. Every year tungro disease infection is devastating in several rice growing areas in Cumilla region as well as country-wide. Rice Tungro disease is a major limiting factor of rice production. In Bangladesh, yield loss due to tungro was reported to be as high as 100% under severe conditions. Three crop rice (Rice-Rice-Rice) areas are most vulnerable to Tungro disease infection. Weather parameters such as temperature, rainfall, relative humidity and light trap data of GLH from BRRI Cumilla and GLH data from rice field of Nangalkot Upazila were investigated. The previous tungro disease data were collected from the survey of different Upazila of Cumilla district during 2017 to 2024. In the farmers field condition, GLH data were collected by hand sweeping and light trap from both seedbed to main fields. From the study, intensive rice cultivation (Rice- Rice- Rice), susceptible rice varieties, presence of abundant GLH in the seedbed (20 GLH/hand sweep) as well as viruses with disease symptom, monthly average maximum (>25°C)) and minimum temperature (<17°C) during July to September, and average % relative humidity (70 %) at evening are found the most critical determinants for tungro disease devastation in Cumilla region. The rainfall during January to March and July to September was found very weak relation with GLH population. It is also confirmed and first report that the severe tungro disease infections in the main field come from the virus-infected seedlings of the seedbed for tungro-prone areas in Bangladesh.

Keywords: Determinants, Tungro, disease, temperature, rainfall, humidity, green leaf hopper.

INTRODUCTION

Rice is the main carbohydrate source and main dish for Bangladeshi people as well as different Asian countries. Food security mainly depends on rice security of 160 million people in Bangladesh (Kabir *et al.*, 2016). Change of macroclimate triggers the change of weather factors, which activate the development of numerous biotic and abiotic pressures, which are the bottle-neck for rice production. Tungro disease of rice mainly caused by concurrent infection of rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV). Along together of RTBV and RTSV are existing in a plant, no distinct symptoms in earlier infection, the later causes minor stunting and slight yellowing of the leaves, and at last it results in mottled leaves, severe growth stunting, and discoloration of the leaves as orange to yellow, which remarkably decreases yield (85% above) (Kumar & Dasgupta, 2020). It is one of the extreme economically vital rice viral diseases in Bangladesh as well as Southeast Asia

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and 38-100% yield loss is carried out due to severe infection of tungro disease of different countries like India, Pakistan, Vietnam, Philippines, Nepal, China, Japan, Srilanka and Indonesia (Gour and Purohit, 2004). Most destructive disease like RTD causes world's annual loss in rice production of about US $1.5 billion and upto 10% rice yield reduction in South and Southeast Asia (Dai and Beachy, 2009).

Tungro disease symptom appears as stunting plant growth, orange yellow color in leaves, tiller number reduction, stunted root growth, hampers of panicle exertion, upper three leaves position in the same node and unfilled black grains. Every year tungro disease infection is devastating in many rice growing areas in Cumilla region specially 3 rice growing areas like Nangalkot, Laksam, Debidwar, Sadar Dakkhin, Lalmai, Burichang, Muradnagar in Bangladesh. Tungro disease is also predominant in different locations of Indian border side areas of Brahmanbaria. Every year hundreds hectare of rice lands infected with tungro disease and huge rice yield loss is occurred. Hundred percent rice yield loss may occur due to tungro disease under severe out-break during early stage of infection (Latif *et al.*, 2013). During T. Aman 2018 season, an eruption of tungro disease caused devastating crop losses in Cumilla region and RTD may cause the 20-100% yield loss of BRRI released high yielding rice varieties. (BRRI, 2018-2019). During T. Aman 2022, 50-100% incidence of RTD and 75-99% yield loss were reported in rice varieties of BRRI dhan71, BRRI dhan75, Binadhan-7, Binadhan-16, Binadhan-17, Binadhan-22. (BRRI, 2022-2023).

In pest management policies, a comprehensive information of the effect of abiotic factors on insect pests is crucial. Different weather parameters and climatic circumstances are recognised to significantly affect the dynamics of insect pests population (Kennedy and Storer, 2000). Information of abiotic factors such as maximum and minimum temperature, day length, daily rainfall and percent relative humidity can be considered as important components in predicting and forecasting the severity of vector population. (Milford and Dugdale, 1990). The dynamics of pest population knowledge is crucial for evolving sustainable crop guard policies and for understanding and forecasting the reply of taxonomic clusters to weather outlines fluctuating on a daily basis, seasonally or as a long-term significance of global climate variation (Denholm *et al.*, 2001). The population dynamics of GLH information in relation to different weather factors under the condition of Cumilla region is not recognised. Very few studies reported the main reasons or factors of tungro disease devastation in Bangladesh condition. Henceforth, considering the importance of tungro vector GLH population dynamics and its correlation with different weather factors, an attempt has been made to study the main critical factors of rice tungro disease prevalence and devastation year after year in Bangladesh.

METHODOLOGY

ODK Digital field survey

Digital field survey was conducted using Open Data Kit (ODK) mobile apps. ODK formerly called "Open Data Kit" was founded by Borriello, 2011. ODK is an open-source mobile data collection platform. It enables users to fill out forms offline and send form data to a server when a connection is found. Once on the server, the data can be viewed, downloaded, and acted upon. It supports a wide range of question and answers types and is designed to work well offline. ODK Collect downloads blank forms and submits filled forms to a server. It displays forms as input prompts that can include logic, constraints, and repeating sub-structures. Users work through the prompts and can save their data at any point (Sergio *et al.*, 2020). Disease incidence and severity data were collected by following the Standard Evaluation System (SES, IRRI, 2013), where the disease scores (Disease Score 1: No symptom observed, Score 3: 1-10% height reduction, no distinct yellow to yellow orange leaf discoloration, Score 5: 11-30% height reduction, no distinct yellow to yellow orange leaf discoloration, Score 7: 31-50% height reduction, with distinct yellow to yellow orange leaf discoloration, Score 9: More than 50% height reduction, with distinct yellow to yellow orange leaf discoloration) are included. The scientists of Plant Pathology division was developed a "Rice disease survey" form, where different data pages like plot ID, record GPS from the centre of the plot, Date of survey, season, year, name of the data collector & designation, site name, district, upazila, village, land unit, variety name (inbred, hybrid, local etc.), date of sowing & transplanting, growth stages, name of the major rice diseases with % disease incidence and disease severity of leaf, neck, node blast, tungro, bacterial leaf blight, sheath blight, kresek, seedling blight, bacterial leaf streak, bakanae, brown spot, false smut, sheath rot, leaf scald, yellow dwarf, grain spot and others, farmers name, mobile number, seed source, fungicides application or not, name of fungicides, major cropping pattern, land type, ecosystem, % yield reduction due to major problem, estimated yield at healthy and disease plot (kg/5m^2), were included.

Tungro disease prevalence

Digital field survey was conducted from T. Aman 2017 to Boro 2024-25; eight years and 16 seasons. Percent disease incidence and disease severity data were recorded from different Upazila, namely Adarsha Sadar, Sadar Dakshin, Chandina, Barura, Burichang, Debidwar, laksam and Nangalkot of Cumilla district.

Data Collection

The dataset used in this study comprises daily weather parameters and the Green Leaf Hopper (GLH) population data. The weather parameters include maximum temperature (Max Temp.), minimum temperature (Min Temp.), rainfall (mm), and % relative humidity (% RH) at 6 am and 12 pm were collected from BRRI regional station, Cumilla. The GLH population was recorded on a daily basis. The data spans a period of time that provides sufficient variability in weather conditions and GLH population fluctuations.

Green Leaf Hopper data collection

Getting tungro-prone areas of Nangalkot, Laksam and other Upazila in Cumilla region, three villages of Nangalkot were selected for vector GLH population conditions during Aus 2019, Aman 2019 and Boro 2019-20 seasons. Number of Green Leaf Hopper were counted from the seedbed and main field of three-cropped areas of Ossodia, Jorpukuria and Mandra villages in Nangalkot. The GLH population data were presented in twenty complete sweeping with a sweep net.

Rice varieties

Disease data of different rice varieties of BR16, BR22, BR23, BRRI dhan32, BRRI dhan29, BRRI dhan46, BRRI dhan48, BRRI dhan49, BRRI dhan52, BRRI dhan71, BRRI dhan74, BRRI dhan75, BRRI dhan87, BRRI dhan94, BRRI dhan95, BRRI dhan103, Binadhan-17, Binadhan-26, BRRI hybrid dhan4, Hybrid 7006, Hybrid Balia2, Hybrid Hera-5, Hybrid Micro1, Hybrid oryzae, Hybrid shakti, Hybrid Sonar Bangla were collected which were cultivated by farmers own choice.

Data Analysis

For showing the spots of tungro disease survey, Google Earth Pro geographic software was used. The mobile apps of ODK survey was installed into a smart phone and downloaded the disease survey form described above. During survey, the ODK apps opening and click "start new form" then click "Rice disease survey" form then give the plot ID then click the "Geo point" and save the data form. After submitting the data from mobile, the data including GPS were colleted from online "KoboToolbox".

Scatter Plot Visualization of Weather Parameters and GLH Population

Data Preprocessing

Before conducting the analysis, the dataset underwent cleaning to address missing values, which were imputed using appropriate methods such as mean imputation or forward-fill where necessary. Outliers were identified and handled using standard techniques, such as the interquartile range (IQR) method. All variables were then standardized to ensure comparability across different scales, as the weather parameters are measured in different units (e.g., temperature in °C, rainfall in mm, humidity in %).

Scatter Plot Visualization

Scatter plots were created to visually explore the relationships between each weather parameter and the GLH population. In this study, scatter plots were generated for the following pairs: Max Temp. vs GLH Population; Min Temp. vs GLH Population; Rainfall (mm) vs GLH Population; RH (%) 6 am vs GLH Population; RH (%) 12 pm vs GLH Population.

Statistical Analysis

Although the scatter plots primarily served as a visual tool, Pearson's correlation coefficients were also calculated to quantify the strength and direction of the linear relationships observed in the scatter plots.

Software and Tools

The scatter plots were generated using Matplotlib and Seaborn, both of which are Python libraries that provide flexible plotting capabilities. The data manipulation and preprocessing were performed using the Pandas library, while the correlation analysis was conducted with the scipy library. The visualization process allowed for an intuitive interpretation of the relationships between weather variables and GLH population dynamics.

Correlation Between Weather Parameters and GLH Population

To explore the relationships between the weather parameters and the GLH population, Pearson's correlation coefficients were computed. Pearson's correlation is a measure of the linear relationship between two continuous variables, with values ranging from -1 to 1. A coefficient of +1 indicates a perfect positive linear relationship, while -1 indicates a perfect negative linear relationship, and 0 signifies no linear relationship.

The correlation coefficients were computed for each pair of variables, including: Temp. Max vs GLH Population; Temp. Min vs GLH Population; Rainfall (mm) vs GLH Population; RH (%) at 6 am vs GLH Population; RH (%) at 12 pm vs GLH Population. A correlogram (heatmap of the correlation matrix) was created using Seaborn and Matplotlib libraries in Python. Values closer to 1 or -1 indicate stronger correlations, while values near 0 suggest weaker relationships. All correlation analyses and visualizations were conducted using the Python programming language. Pandas was used for data manipulation, scipy for statistical tests, and Seaborn and Matplotlib for visualization.

RESULTS

Tungro disease of rice is mainly transmitted by Green Leaf Hopper (GLH), where the vector as well as virus (RTBV & RTSV) was present then tungro disease may occur. If the vector is present but the virus is absent in a localized area, the disease cannot occur. In this study, we explored the factors which are responsible for tungro disease devastation. The critical factors are described below.

Base-line survey of tungro disease

Digital field survey was made from Aman 2017-2024 (8 years), and Boro 2018-2025 (8 years), using OKD mobile apps in eight Upazila of Cumilla and locations were presented in Fig. 1. Disease incidence (DI) and disease severity (DS) data were collected from 290 spots in 8 Upazila shown on google earth using Google Earth Pro software (Fig. 2). Percent disease incidence of rice tungro disease was observed almost all the season ranged from 17-100% with DS 3-9 (Fig. 3). During survey, BR16, BRRI dhan52, BRRI dhan75, BRRI dhan74, BRRI dhan87, Binadhan-17, and hybrid rice were found highly infected by tungro disease (Fig. 3).

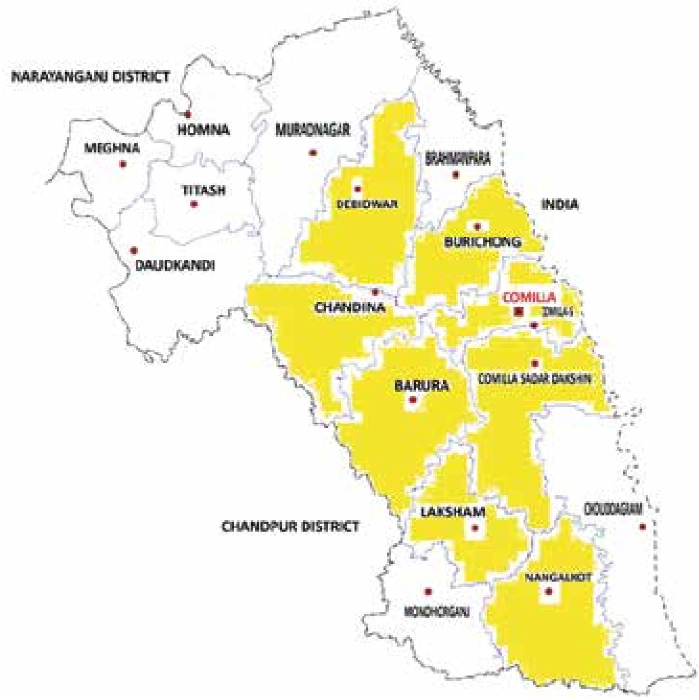


Fig. 1. Yellow color showing the areas of tungro disease prevalence during Aman 2017 to Boro 2024-25 season (8 years 16 seasons survey report).

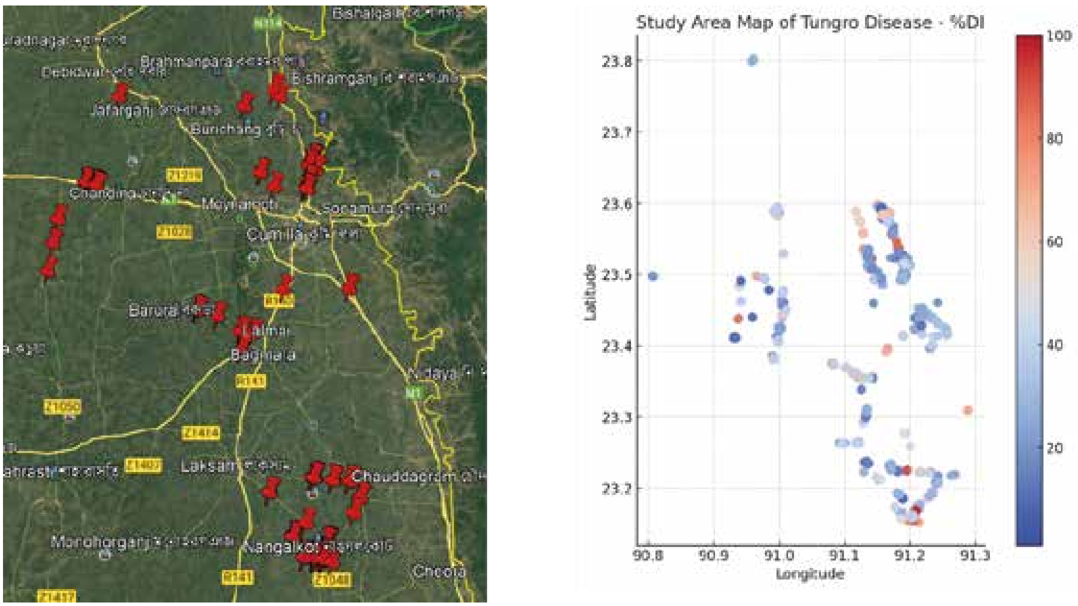


Fig. 2. Google earth pro and Machine Learning Tools showing the tungro disease survey spots (290 field spots) in different Upazila Adarsha Sadar, Sadar Dakshin, Chandina, Barura, Burichang, Debidwar, laksam and Nangalkot of Cumilla district during Aman 2017 to Boro 2024-25 seasons.

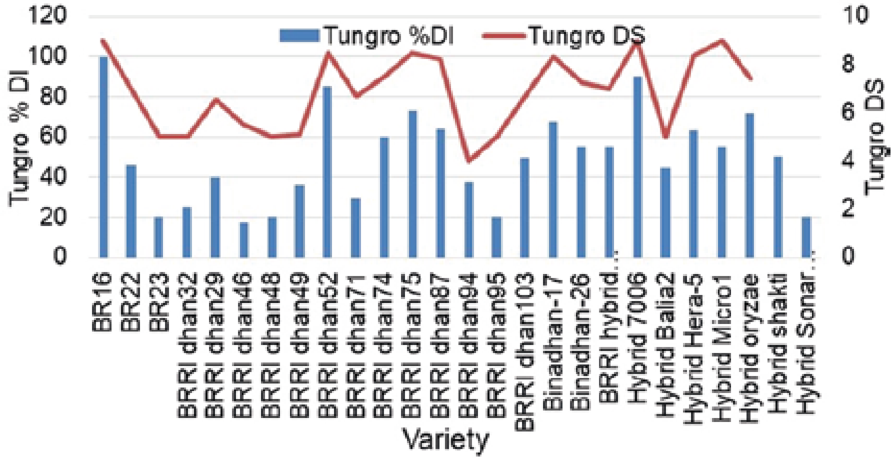


Fig. 3. Tungro disease occurrence during Aman 2017 to Boro 2024-25 season (8 years 16 seasons survey report).

i) **Intensive rice cultivation**

Most of the surveyed and tungro disease infected areas are 3 cropped areas of rice-rice-rice cropping pattern. For this why, tungro disease was observed almost every season in different areas in Cumilla during disease survey, where GLH can get the host year-round (Fig. 3).

ii) Cultivation of susceptible rice cultivar

Different rice varieties of BRRI, BINA and private companies Hybrids like BR16, BR22, BR23, BRRI dhan32, BRRI dhan29, BRRI dhan46, BRRI dhan48, BRRI dhan49, BRRI dhan52, BRRI dhan71, BRRI dhan74, BRRI dhan75, BRRI dhan87, BRRI dhan94, BRRI dhan95, BRRI dhan103, Binadhan-17, Binadhan-26, BRRI hybrid dhan4, Hybrid 7006, Hybrid Balia2, Hybrid Hera-5, Hybrid Micro1, Hybrid oryzae, Hybrid shakti, Hybrid Sonar Bangla were found as susceptible rice cultivar during disease survey from 2017-2024 (Fig. 3). During Aus 2018, Aman 2018 and Boro 2018-19, seasons severe tungro disease was observed in some susceptible rice varieties (Table 1) in many rice growing locations of Nangalkot and Laksam (Table 2 & 3).

Table 1. Tungro disease infection records in different rice varieties in Nangalkot and Laksam, Cumilla during 2018-19 (Rice-Rice-Rice).

Aus 2018	DS	T. Aman 2018	DS	Boro 2018-19	DS
BRRI dhan28	7	BR22	7	BRRI dhan28	5
BRRI dhan43	7	BRRI dhan75	9	BRRI dhan29	3
BRRI dhan48	7	BRRI dhan49	5	BRRI dhan48	7
Hybrid Tia	9	Swarna masuri	9	BRRI dhan58	3
Moyna	7	Swarna	9	Hybrid 1203	3
Chokka	9	Pazam	9	Jonokraj	7

DS indicate disease severity.

Table 2. Block-wise tungro disease infection in Nangalkot, Cumilla during 2018-2019.

Block	Season	Cultivated area (ha)	Tungro infected area (ha) DS
Ossodia, Kadra, Nurpur, Peria, Sreefolia, kakoirtola, Raykot, Mahini, Jhatiapara, Moukora, Bisnapur, Majhipara, Pourasava, Mokrabpur, Bannogor, Bhuluapara, Hesakhal uttar, Hesakhal Dakkhin, Patowar, Rajapara, Dhalua, Sijiara, Monnara, Doulkhar, Kasipur, Boxgonj, Shuvapur, Ostogram	Aus 2018	7550	106 (DS 7-9)
Ossodia, Bangadda, Kadra, Nurpur, Sreefolia, Raykot, Mahini, Jhatiapara, Moukora, Bisnapur, Majhipara, Pourasava, Mokrabpur, Bannogor, Bhuluapara, Hesakhal Uttar, Hesakhal Dakkhin, Patowar, Addra, Shaktoli, Volaine, Jodda, Rajapara, Manikmura, Dhalua, Sijiara, Monnara, Doulkhar, Kasipur, Boxgonj, Shuvapur, Ostogram	T. Aman 2018	12750	529 (DS 7-9)
Ossodia, Shaktoli, Volaine, Jodda, Nurpur, Kadra, Rajapara, Manikmura, Dhalua, Monnara, Doulkhar, Kasipur, Boxgonj	Boro 2018-19	12990	190 (DS 5-9)
Ossodia, Kadra, Shaktoli, Volaine, Jodda, Rajapara, Manikmura, Dhalua, Monnara, Doulkhar, Kasipur	Boro 2017-18	12650	130 (DS 5-9)

Table 3. Block-wise tungro disease infection in Laksam, Cumilla, 2017-2019.

Block	Season	Cultivated area (ha)	Tungro infected area (ha) DS
Pechra, Norpati, Fulgao, Ajgora, Borbam, Charbaria, Pourashova, Bijra, Koitra, Noapara, Chongao	Aus 2018	4800	90 (DS 5-9)
Pechra, Norpati, Fulgao, Ajgora, Borbam, Charbaria, Pourashova, Bijra, Koitra, Noapara, Chongao	T. Aman 2018	5100	280 (DS 7-9)
Pechra, Norpati, Fulgao, Ajgora, Borbam, Charbaria, Pourashova, Bijra, Koitra, Noapara, Chongao	Boro 2018-19	9050	70 (DS 3-9)
Pechra, Norpati, Fulgao, Ajgora, Borbam, Charbaria, Pourashova, Bijra, Koitra, Noapara, Chongao	Boro 2017-18	8700	20 (DS 5-9)

iii) **Status of GLH Population in the seedbed and light trap**

GLH data collection spots of the villages of Nangalkot, Cumilla were shown in GPS map in Fig. 4. Huge GLH were present in the seedbed upto 180 number per 20 sweeping and the tungro virus is present in these areas, which is most critical factor of tungro disease development (Fig. 5). At BRRI farm, Cumilla, GLH population was counted higher in the light trap during seedbed time from 2018 to 2024 (Fig. 6).

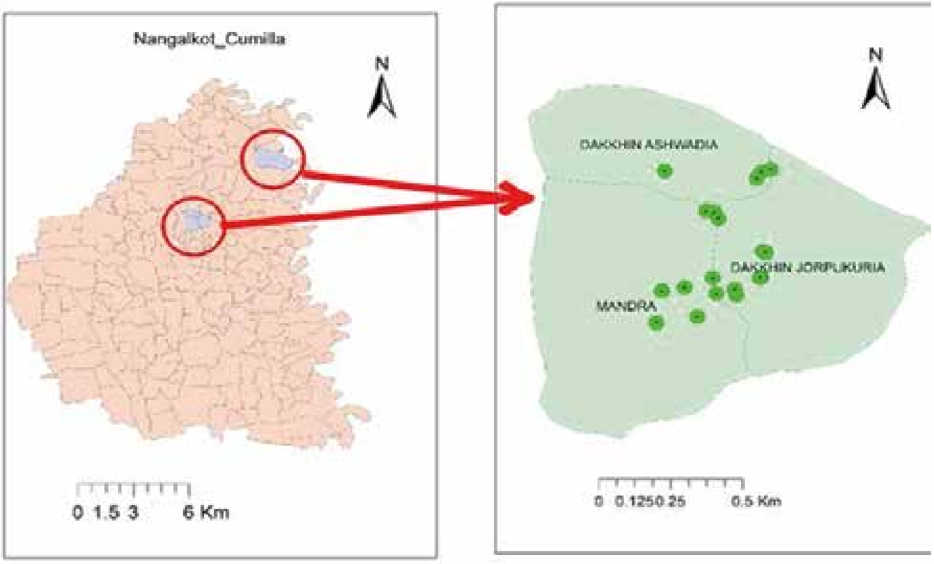


Fig. 4. GPS Location of the seedbed in Nangalkot Upazila in Cumilla during Aus, Aman and Boro season 2019-20.

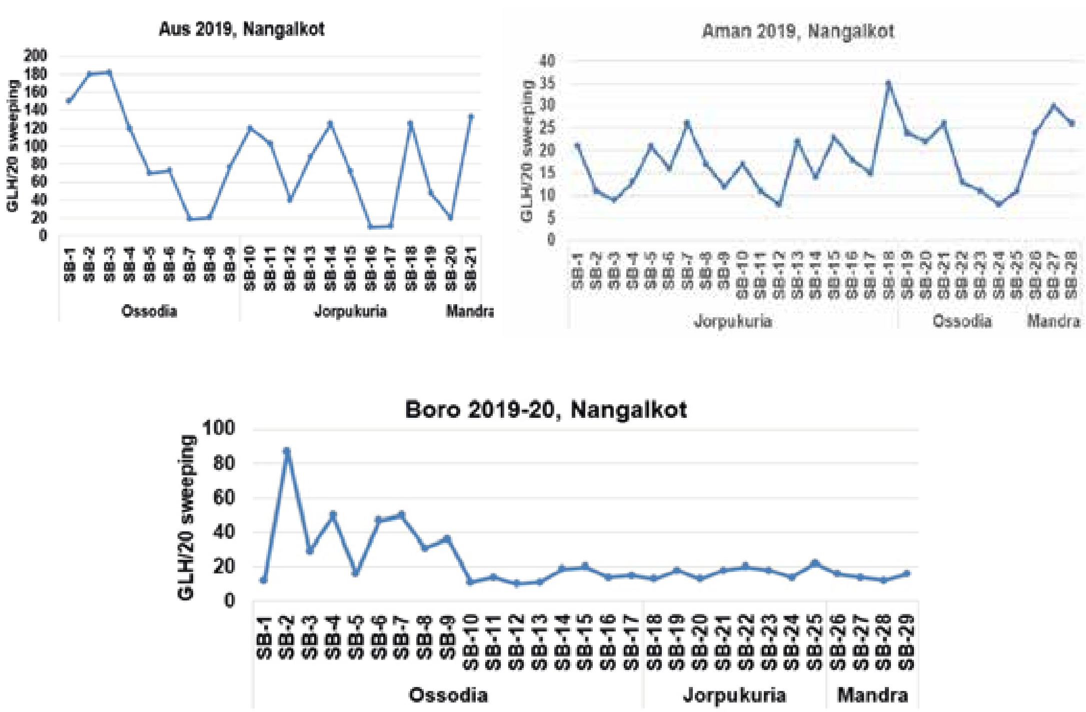


Fig. 5. GLH population collected from the farmers seedbed in Nangalkot Upazila in Cumilla during Aus, Aman, Boro 2019-20. SB= Seedbed.

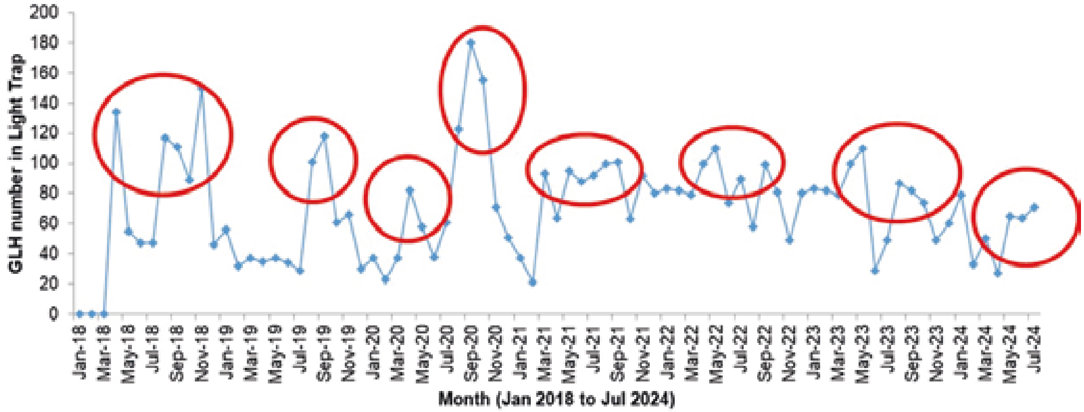
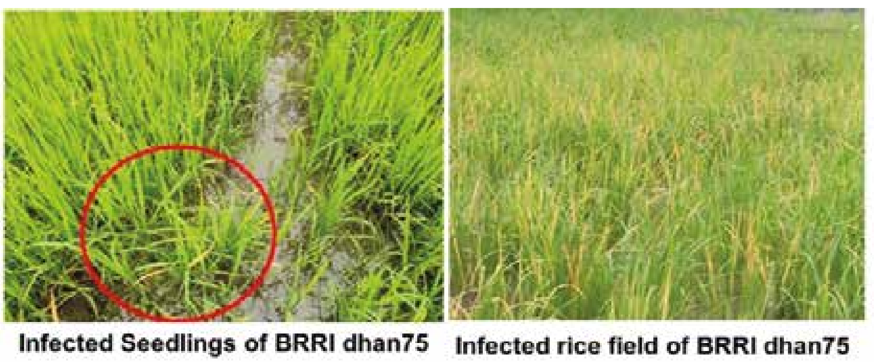


Fig. 6. Month-wise total GLH data collection at BRRI Cumilla during Jan 2018-Jul 2024.

iv) **Seedbed is the main source of tungro devastation**

During Aman 2020 season, we observed that tungro disease symptom was observed even in the seedbed of BRRI dhan75, which is highly susceptible to tungro disease and after transplanting the whole plots were severely infected by tungro disease in at Atakora village, Nangalkot, Cumilla. In the infected plot, 0.56 t/ha yield was obtained and 91% yield was reduced due to tungro devastation (Fig. 7). Another observation that rice seedlings were transplanted in two different places of Kadra village of Nangalkot, Cumilla, during Aman 2020 season by two farmers and tungro disease symptoms were observed same severe as 80-85 % DI with 7-9 DS and the yield was loosed 84-87% (Fig. 8). This is the first report that the tungro disease devastation is depends upon the seedlings infected with viruses in the seedbed by virus infected vector GLH.



Variety	Tungro %DI	Tungro DS	Yield t/ha	Expected Yield t/ha	% Yield loss
BRRI dhan75	95	9	0.56	6.0	91

Fig. 7. Tungro symptom was observed even in the seedbed and yield loosed after transplanting at Atakora in Nangalkot, Cumilla during Aman 2020.

Variety	Tungro %DI	Tungro DS	Yield t/ha	Expected Yield t/ha	% Yield loss
Field-1. BRRI dhan75	85	7-9	0.80	6.0	87
Field-2. BRRI dhan75	80	7-9	0.94	6.0	84

Fig. 8. Tungro symptoms in two different transplanted fields, where the same seedlings are from the same seedbed at Kadra, Nangalkot, Cumilla during Aman 2020 season.

v) **Visualization of Weather Parameters and GLH Population**

The scatter plots presented above illustrate the relationships between various weather parameters and the Green Leaf Hopper (GLH) population (Fig. 9). These visualizations provide a preliminary insight into the potential influence of climatic factors on the abundance of GLH over time.

Temperature (Max and Min): Both maximum and minimum temperatures exhibit weak, non-linear relationships with the daily GLH population. The scatter plot for Max Temp. shows some fluctuation in the population as the temperature varies (Fig. 9). Similarly, Temp. Min shows variations in GLH numbers with changes in minimum temperature.

Rainfall: The scatter plot for Rainfall (mm) does not reveal any strong relationship with the GLH population. The data points are widely dispersed across the plot, suggesting that rainfall, at least in the context of this dataset, does not have a significant impact on the GLH population size (Fig. 9).

Relative Humidity (6 am and 12 pm): The scatter plot for RH (%) at 6 am shows a weak inverse relationship with the GLH population, whereas RH (%) at 12 pm displays a slightly stronger positive relationship (Fig. 9 & Fig. 11).

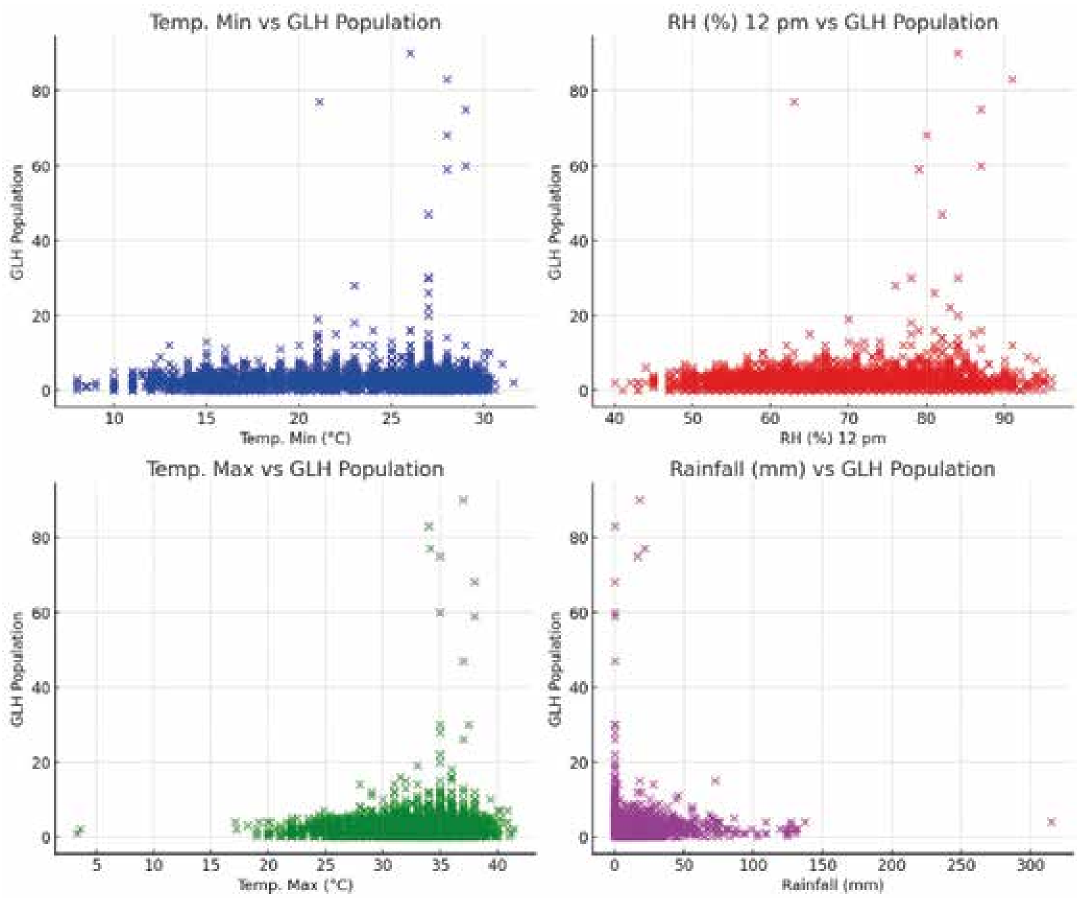


Fig. 9. The scatter plots above visualize the relationships between each weather parameter and the green leaf hopper (GLH) population from Jan 2017 to June 2025.

vi) **Correlation Between Weather Parameters and GLH Population**

The correlogram above illustrates the relationships between the daily and monthly weather parameters and the Green Leaf Hopper (GLH) population from 2017 to 2025, providing insight into how these factors interact (Fig. 10 & Fig. 11). The correlation coefficients, ranging from -1 to 1, indicate the strength and direction of the linear relationships between the variables.

Temperature (Max and Min): Both Temp. Max and Temp. Min show a weak positive correlation with the GLH population (ranging from 0.1 to 0.3) (Fig. 10). Maximum month average temperature (>25°C) and monthly average minimum temperature (<17°C) has slightly stronger relations with GLH population during July to September each year (Fig. 11). These correlations suggest that while temperature may play a role in influencing the GLH population at a certain period of time.

Rainfall: The correlation between daily rainfall (mm) and the daily GLH population is weak and close to zero (Fig. 10), indicating little to no significant relationship. During January to March and July to September month rainfall (<500 mm) have slightly positively correlate with GLH population (Fig. 11).

Relative Humidity (6 am and 12 pm)

The correlation between daily RH (%) at 6 am and the daily GLH population is weakly negative, while RH (%) at 12 pm shows a positive correlation (Fig. 10) and average % RH at 12 pm (70 %) in the month of January to March and October to December have relatively strong correlation with monthly GLH number (Fig. 11). Both values, however, are relatively low, indicating that while relative humidity may have some effect, it is not a strong determinant of GLH population dynamics.

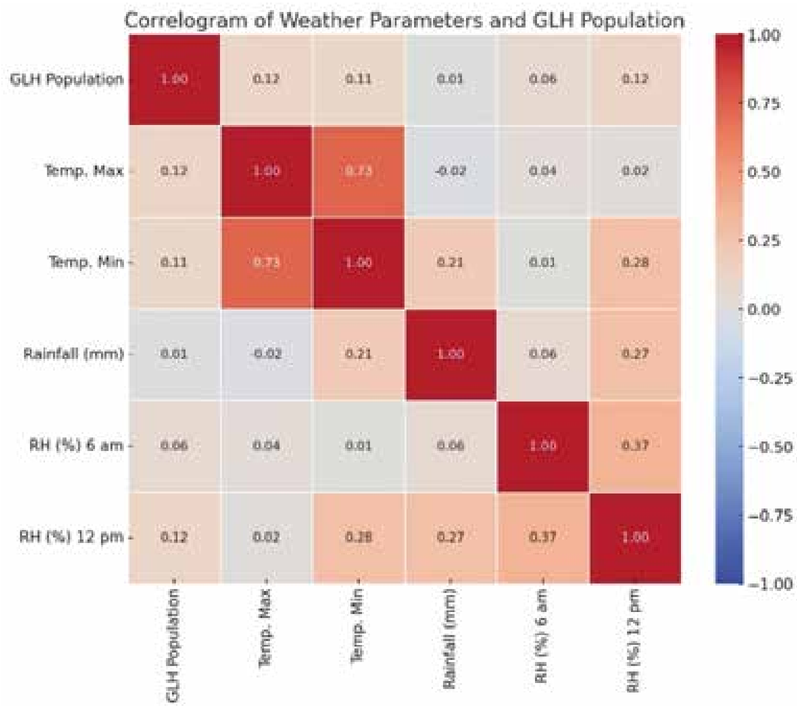


Fig. 10. The correlogram above illustrates the relationships between the weather parameters and the green leaf hopper (GLH) population. The correlation coefficients range from -1 to 1, indicating the strength and direction of the linear relationship between each pair of variables. Positive values indicate a positive correlation, while negative values suggest an inverse relationship. The closer the value is to 1 or -1, the stronger the relationship from Jan 2017 to June 2025.

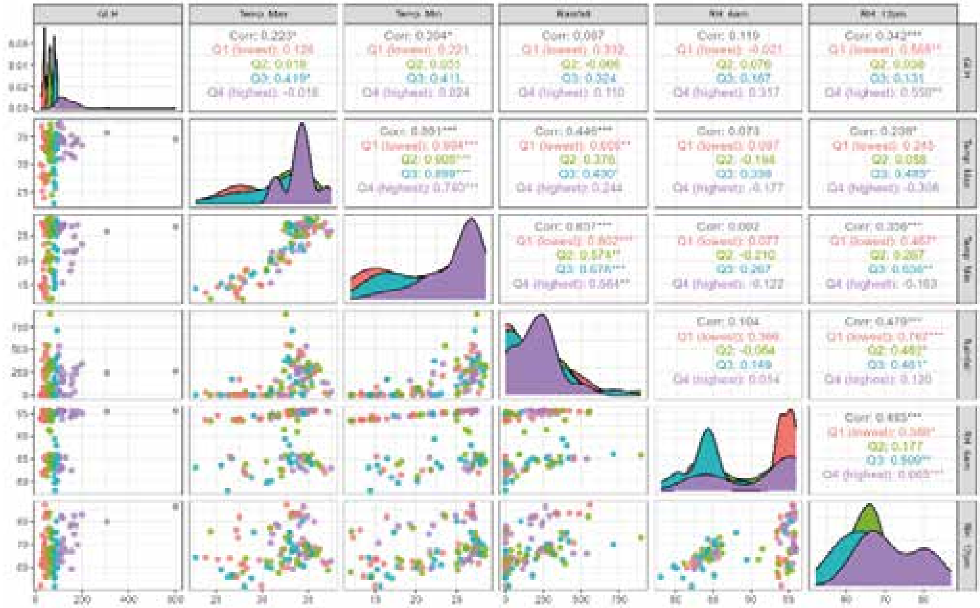


Fig. 11. The correlogram above illustrates the relationships between the monthly weather parameters and the month total green leaf hopper (GLH) population. The correlation coefficients range from -1 to 1, indicating the strength and direction of the linear relationship between each pair of variables. Q1: Jan-Mar, Q2: Apr-Jun, Q3: Jul-Sep and Q4: Oct-Dec each year from 2017 to 2025.

vii) **Feature Importance Analysis of Weather Parameters Influencing GLH Population**

The analysis of feature importance reveals the relative influence of each weather parameter on the Green Leaf Hopper (GLH) population. The results, derived from a Random Forest model, highlight the most influential weather parameters in predicting GLH population dynamics.

Temp. Min emerged as the most important factor, accounting for 34.86% of the model's predictive power. This suggests that the minimum temperature plays a significant role in shaping GLH population abundance, with colder or warmer extremes potentially influencing their survival and reproduction rates.

RH (%) at 12 pm was the second most influential parameter, contributing 30.32% to the prediction of GLH population (Fig. 10). Monthly average % RH at evening influence the GLH population increase and slightly stronger correlations was found during first and third quarter of every year.

Temp. Max contributed 16.75% to the model's performance. While it is less influential than Temp. Min, it still plays a role in influencing the daily fluctuations of the GLH population (Fig. 10).

Rainfall (mm) and RH (%) at 6 am were the least influential, contributing 11.91% and 6.16%, respectively. These results suggest that while rainfall and morning humidity levels may have some effect, their role in determining GLH population size is relatively minor compared to temperature and midday humidity.

DISCUSSION

Out of reported 80 rice diseases, 22 are caused by viruses (Ou, 1985). Rice tungro disease is a widespread in tropical Asia and Asian sub-continent. Some major rice disease distribution mainly depends on location specific climatic condition and other factors. Differences of disease dispersal, environment factors, both microclimate and macroclimate information and the vectors influence on disease progress during the rice crop season.

Yield loss was determined 75-99% of different T. Aman rice varieties due to tungro devastation during T. Aman 2022 season in Debidwar, Cumilla (Nahar *et al.*, 1985; BRRI, 2022-2023). For this why, it is urgent to know the critical factors for tungro disease development.

Different time of planting influences and one of the main causal variables of the appearance of tungro disease. In an asynchronous rice area, there will always be hosts-rice plants, the vector of tungro disease will continue to feed, disperse the virus easily. Both rainfed and irrigated wetland habitats are susceptible to the tungro disease (Sharma *et al.*, 2017). The planting date needs to align with that of other neighbouring farms. Later transplanted rice plants will be more susceptible to tungro disease. The authors suggested that the transplanting period for rice should be varied to reduce the amount of vector populations (Nas & Cortez, 2011). The relationship between the planting of susceptible varieties and asynchronous planting at a given site is critical to expecting tungro incidence (Cabunagan *et al.*, 2001, Holt *et al.*, 1996). They also exhibited the importance of susceptible rice varieties and asynchronism of planting as a vital factor preferring rice tungro devastation. Our study also supports this report that intensive rice cultivation is most vulnerable of tungro disease devastation.

In Bangladesh, the viral disease tungro occur on rice and this disease is a complex disease caused by two virus particles RTSV & RTBV and become severe on rice field during Aus and Aman season (BRRI, 2022-23). The tungro vector, GLH population starts to increase in March, then abruptly decrease in April due to the beginning of monsoon rainfall and wind. Nevertheless, the population rapidly rebuilds to a peak in July. Incidence of tungro disease tracks the GLH population and predominant only during the summer, not during the cool dry winter from October to February when low temperatures suppress the GLH population (BRRI, 1980-81). After 40 years, due to climate change, their findings seem to differ in some cases from our own. We found that tungro disease appears not only in Aus and Aman seasons but also in Boro season. As a result, disease incidence was also appeared in all the seasons and year-round. It is due to increased rice cultivation in Cumilla region. Similar result was obtained from our study that the GLH vector population was obtained year-round and top in July.

Santi *et al.*, (2024) reported that a single vector insect can infect up to 40 seedlings every day in the seedbed. We observed that tungro disease devastation in the main field was due to earlier infection in the seedbed by tungro-infected vectors, resulting in nearly 100% yield loss

Temperature data analysis showed that a weak positive relationship was found between temperature and GLH number and ultimate disease development. These findings are in line with studies indicating that the impact of ambient minimum/maximum temperature can have a mild impact on insect populations, though its effect may be influenced by other environmental and biological factors (Santi *et al.*, 2024). This finding is consistent with previous studies which indicate that temperature can influence insect population dynamics, but the effect may be relatively minor compared to other environmental factors (Madhuri *et al.*, 2017). They reported that during Kharif season, the GLH number was positively correlated with maximum and minimum temperature and negatively correlated with morning and evening relative humidity and rainfall. From our study, it is suggested that both maximum and minimum temperature are necessary for the increasing of GLH population during July to September in every year climatic situation, which is eventually accountable for the spread of tungro disease of rice.

In 1987, the authors reported that the relationship among disease incidence and such climatic factors like minimum temperature, relative humidity, daily rainfall and dew period (Shahjahan *et al.*, 1987). Severe tungro occurrence has been connected with high temperature (25-30 °C) (Kiritani, 1981 and Ou, 1985). The incidence of tungro and other viral diseases like ragged stunt, grassy stunt and transitory orange yellowing in hot and humid regions depends on the temperature requirements of different insect vectors. This result corroborates our present study, where GLH vector population increases due to increase of temperature during July to September, and other months have found a weak relationship.

The scatter plot and correlation for Rainfall have a weak relationship with the GLH population. But our findings suggest that first and third quarter of the year have slightly positive correlations with the number of GLH population. This suggests that rainfall does not substantially influence GLH abundance, aligning with research that suggests other ecological or biological factors may be more influential in shaping GLH populations, rather than rainfall alone (Adiroubane *et al.*, 2007; Kalita *et al.*, 2015; Madhuri *et al.*, 2017).

Our study highlighted the role of midday humidity levels in affecting GLH behavior and distribution. High humidity can create favorable conditions for the survival of GLH population. This finding aligns with literature indicating that GLH number negatively correlated with relative humidity at morning and at evening (Adiroubane *et al.*, 2007; Kalita *et al.*, 2015; Madhuri *et al.*, 2017).

These scatter plots highlighted that while there are some weak correlations between weather parameters and the GLH population, they are not strong enough to conclude that these factors are the primary drivers of GLH dynamics.

CONCLUSION

In summary, the feature importance analysis indicates that GLH population dynamics is influenced by intensive rice cultivation, susceptible rice cultivar, abundance GLH in the seedbed with presence of virus, monthly average maximum (>25°C)) and minimum (<17°C) temperature during July to September, and average mid-day relative humidity (70 %) are the most influential factors for GLH population advancement. The role of rainfall has very weak relations with GLH population dynamics. These findings align with ecological studies that emphasize the role of different parameters in regulating insect populations, while also suggesting that other environmental factors not captured in this analysis may also be significant contributors to GLH abundance.

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