SPATIAL DISTRIBUTION ANALYSIS OF LEAFMINER (*Lyriomyzae trifolii* Burgess) IN ONION GROWING AREAS OF NUEVA ECIJA USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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ABSTRACT: Analyzing the spatial distribution of a particular pest using various parameters can give an overall view and easy understanding of the condition and continuity of its life cycle. Leafminers (*Lyriomyza* sp.*)* are important agricultural pests producing larval mines in leaves affecting many high value crops. In Nueva Ecija, leafminer is one of the destructive onion pests, however most local farmers ignore its infestation because of the presence of other insect pest called armyworm, well in fact it can also cause a lot of damage to onion like armyworm do. Since most of the attention is focused in armyworm, leafminer infestation and extent of damage to onion areas were often overlooked or neglected by the authorities and local farmers. Geographic Information System offers an advanced technique in creating informative maps which can give further visualization on the present condition of any pest outbreak. To further understand the spatial distribution of leafminer in the onion fields of Nueva Ecija, GIS was utilized of which Getis-Ord Statistics or Hot Spot Analysis were used to map the distribution of leafminer using the data gathered from field assessment during onion season. Buffer analysis were also used to determine the spatial relationship between alternate hosts and onion, while, regression analysis was used for temperature-leafminer relationship. The hot spot areas of leafminer during the month of January are the same areas where infested alternate hosts were also located. On the month of March when temperature is higher, an outbreak of leafminer occurred in almost all of the onion areas in Nueva Ecija most especially in onion areas of San Jose City and Rizal. Thus, the results shows that there is a strong possibilities of recurrence of the leafminer infestation in areas with elevated temperature and the presence of alternate hosts which coincides during bulb formation stage. The study was able to determine the spatial relationship and distribution pattern of leafminer with the infested onion areas, as well as the influence of temperature on leafminer outbreak.

1. INTRODUCTION

Leafminer (*Liriomyza* sp.) are important agricultural pests in many high value crops (Li et al. 2012). The larvae produced larval mines that forms in narrow, linear, spiral or blotch type which are always visible from the outside of the leaves (Ismaeel et al. 2016). Leafminers can cause both direct and indirect damage in plants. The larval mining of this pest in palisade parynchema tissue can reduce photosynthetic capacity of plants up to 60% and can cause leaves to fall from heavy infestations (Johnson et al. 1983) (EPPO , 2009). These important pests attack a very wide host range of terrestrial plants, including cultivated plants (Derocles et al. 2015). These pests are polyphagus or commonly observed in various host plants under families of; Solanaceae, Asteraceae, Cucurbitaceae, Brassicaceae, Fabaceae, and even with some ornamental plants (Ismaeel et al. 2016). Despite the potential impact on important crops, these pests were poorly investigated and neglected by local farmers. Thus, crop rotation within favorable host plants in any farming areas can give continuous support for the life cycle of leafminers, resulting to damages.

In the Philippines, leafminer (*Liriomyza* sp.*)* is one of the common agricultural pests affecting high value crops. In the province of Nueva Ecija, onion production is very challenging since it is very susceptible in various diseases and pests, which includes the leafminer (*Lyriomyza* sp.). Heavy infestation of *Lyriomyza* sp can create significant impact on the growth and development of onions. It can cause underdevelopment of bulbs and weight loss, thus, affecting the income of the farmers. Though leafminer infestation is being set aside by the farmers at the moment, it should be taken into account that it is still considered as one of the most destructive insect pests in onion production areas, and the possibility of this pest to increase its population into an unmanageable level should be anticipated.

Geographic Information System (GIS) is one of the most reliable technology in understanding the spatial distribution of any objects within any regions. With the availability of product of new technologies such as personal computers, GPS, remote sensing, and GIS and statistical approaches have found new applications (Trematerra and Sciarretta, 2014). GIS also provides collection of tools for the conceptualization and management of spatial data and analysis (Krivoruchko and Gotay, 2003). The technology can offer effective methods in detecting and monitoring insect pests in the field, as well as understanding their spatial dynamics thru creation of high resolution maps (Dminić et. al, 2010) (Roberts et al. 1993). Thus, GIS can be used in analysis in detection of pests outbreaks, based on the spatial data that it provides. GIS also covers spatial statistics that is based on the non-independence of observations and interpolation of the data (Krivoruchko and Gotay, 2003),which can be used in analyzing patterns within specific locations.

The use of GIS in relating insect\pest distributions in physiographic regions is important in pest management and predict future pest's metapopulation dynamics. The prediction which can be generated is based from the patterns which analyzed from the map layers and field data, showing spatial relationships over time (Beckler et al. 2005). Weather data is an example of datasets that can be integrated in analyzing the distribution patterns of pests, since in most cases, favorable temperature is critical for pest development, population growth, and pest epidemics (Olatinwo and Hoogenboom, 2013). Thus, determination of spatial distribution analyzing its patterns can be achieved with the availability of datasets which can be integrated and interpolated using GIS.

2. MATERIALS AND METHODS

2.1 Location of the study and datasets used

Nueva Ecija as the leading onion producer in Central Luzon was surveyed and chosen where the study will be conducted. It has a total onion growing areas of 10,743.70 has (Figure 1). An available thematic layers of onion fields which were surveyed from January – March, 2019 was used as primary layer and where the data were integrated.

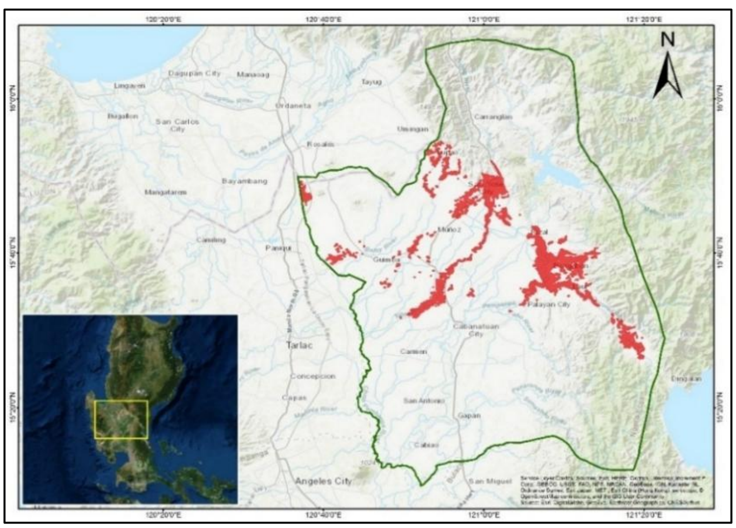


Figure 1. Location of onion growing areas in Nueva Ecija

2.2 Location of alternate hosts and field assessment

Identified alternate host plants of Leafminers belonging to family Cucurbitaceae, Leguminosae and Solanaceae were recorded before and during land preparation of onion fields. The GPS locations of leafminer infested and unaffected high value crops were also recorded. The data collected were used as reference or subjects as possible sources of infestation of leafminer during the onion season.

Start of the field survey was conducted at the start of onion season up until the harvest season to assess the status of onion fields against leafminer incidence. The level of incidence and severity of damaged in onion by leafminer were recorded and evaluated using the methods of (Alberto et al. 2019) that were used in assessing the condition of armyworm infestation in onions. The incidence level was determined using 1m x 1m quadrat with 10 samples/ha and computed using the formula (Eq. 1). On the other hand, the level of damage cause by leafminer infestation was categorized based on the percentage larval mined on the leaves. The scale for the assessment of incidence and damage of the infestation generalize the damage into four (4) categories; low, moderate, high and very high.

$$\text{(Eq. 1) Leafminer Incidence (\%)} = \frac{\text{Number of onion plants infested}}{\text{Total number of onion plants}} \times 100$$

2.3 Data Integration, Analysis, and Interpolation

The collected data of incidence and damage level of leafminer infestation during field assessment were integrated as attributes in the available thematic layer of onion fields. The data from field assessment during the months of January, February and March, 2019 were integrated into the thematic layer to create hot spot analysis per month. These data were further generalized to generate intensity level ranging from "1" (Very Low) to "5" (Very High) using a matrix (Alberto et al. 2019). The value of intensity level were used to generate hot spot analysis using ArcGIS.

2.3.1 Hot Spot Analysis – The thematic layer of onion fields with intensity level were run using Optimized Hot Spot Analysis tool of ArcMap 10.2.2. Hot Spot Analysis is also known as Getis-Ord (Gi*) statistical analysis, a method used for analyzing related location tendency or clustering using spatial point data (Ding et al.). The Gi* determines the heterogeneity of levels based on the intensity or weighed values in a point data or objects (2015Songchitruska and Zeng, 2010).

The "hot" and "cold" spot is determined by Gi* statistics returned for each feature or the z-score. For statistically significant positive z-scores, the larger the z-score, the more intense the clustering of high values (hot spot), while the smaller the z-score, the more intense the clustering of low values (cold spot) (Jana and Sar, 2016). Using the generalize intensity value from the datasets, the hot spot analysis tool was used to generate hot and cold spot areas using the Getis-Ord Gi* statistic (Eq. 2)

$$\text{(Eq. 2)} \qquad G_i^* = \frac{\sum_{j=1}^{n} W_{i,j}X_j - \bar{X}\sum_{j=1}^{n} W_{i,j}}{s\sqrt{\frac{\left[n\sum_{j=1}^{n} W_{i,j}^2 - \left(\sum_{j=1}^{n} W_{i,j}\right)^2\right]}{n-1}}} \quad (1)$$

Where: x_j is the attribute value for feature ***j***,
w_{ij} is the spatial weight between feature ***i*** and
j, ***n*** is equal to the number of features and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2}$$

If the G_i^* statistic is a z-score, no further calculations are necessary.

2.3.2 Ordinary Kriging (OK) – To generate a general spatial pattern of the distribution of leafminer from the result of the hot spot analysis, ordinary kriging was used to interpolate the data. Ordinary kriging is one of the most commonly used as kriging techniques or tool for interpolation. It is considered as the best linear unbiased predictor and most utilized technique (Sciarretta and Trematerra, 2014).

The estimated Z at non-sampled location x_0 is:

$$Z(x_0) = \sum_{i=1}^{n} w_i(x_0)Z(x_1)$$

Where: w_i – weight calculated for the sampled location x_i
$Z(x_i)$ – observed value of x_i
n – number of locations

In addition, Ordinary Kriging was also used to generate raster data of temperature. From the study of Bakis et al. 2017, Ordinary Kriging method has been determined to have an accurate estimation. The data for daily temperature that were used were obtained from free source website of (https://darksky.net), backed by a wide range of weather data sources, which were aggregated to provide the most accurate forecast possible for a given location. The weekly data of temperature were averaged into monthly format before processing using the Kriging tool.

2.4 Spatial Analysis for Alternate Host, Temperature in Leafminer Incidence

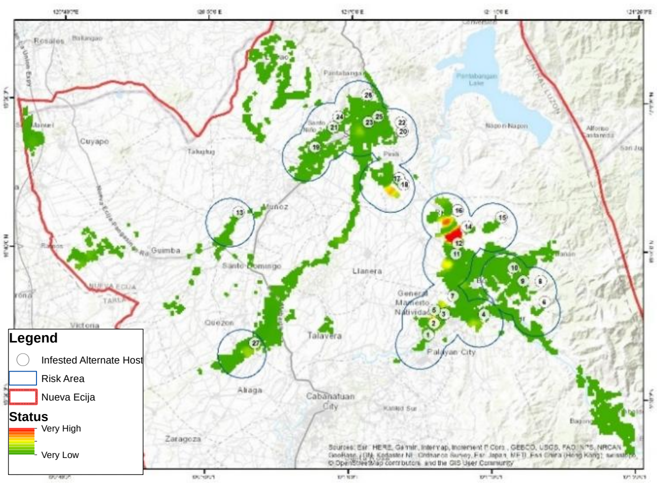
The **GPS** locations of alternate host crops of leafminer recorded from field assessment were used as datasets to determine the possible source for leafminer incidence during the onion season. The raster value from the hotspot analysis were extracted using the GPS points of infected alternate hosts by utilizing the "extract values tool" of spatial analysis. The extracted values were used to validate and analyzed the relationship of the incidence of leafminer during the first month of onion season and the presence of infested alternate hosts. Buffer tool was used to create a predicted risk area of the leafminer throughout the onion season. Although circular buffer zones are normally used in environmental assessment, the results obtained may not be entirely accurate due to certain factors (Jayajit et al. 1997). To evaluate the output of buffer zone, regression analysis using temperature raster data and spread of leafminer were used to determine the spatial relationship between the two variables.

3. RESULTS AND DISCUSSION

3.1 Spatial Distribution of Alternate Hosts of Leafminer in Nueva Ecija

Determination of primary source or nesting ground of pest is valuable in decision making for pest and crop management. Alternate hosts are very essential for leafminers to continue their life cycle by just moving from their original host. During field surveys, *Lyriomyzae trifolii* species was identified as the dominant leafminer species infesting the onion areas in Nueva Ecija.

The generated map shows the distribution of infested alternate host and hot spot status of leafminer infestation in the onion areas during the month of January 2019 [Figure 2]. The data shows that the hot spot areas of leafminer in the onion areas were exactly found out where infested alternate hosts (i.e. String beans) were also located. The data also shows that 74% or 20 out of the total 27 locations of infested alternate hosts, confirmed the occurrence or attacked from Leafminers, which indicates a strong possibility of migration of the leafminer from alternate host to the onion areas. From the study of Arida et al. 2013, *L. trifolii* is the leafminer species recorded to affect the onion growing areas in Nueva Ecija, which is also the species known to infest yard-long or string beans (Schreiner 1993).



Infested Alternate Host

PT_ID	ALT_HOST	RASTERVALU	JAN_ONION
2	String Beans, Eggplant, Bitter Gourd, Pepper	3	INFESTED
3	String Beans, Pepper, Eggplant	3	INFESTED
5	Eggplant	3	INFESTED
6	String Beans, Tomato	3	INFESTED
7	String Beans, Squash	3	INFESTED
11	String Beans, Eggplant, Tomato	3	INFESTED
12	String Beans, Eggplant	3	INFESTED
19	Pepper, Tomato, Squash	3	INFESTED
21	Tomato, Pepper	3	INFESTED
24	Tomato	3	INFESTED
25	String Beans, Squash, Tomato	3	INFESTED
27	String Beans, Squash	2.934094	INFESTED
26	Squash Tomato	2.825719	INFESTED
23	String Beans, Tomato, Mung Beans,	2.748861	INFESTED
16	String Beans, Tomato	2.558365	INFESTED
14	String Beans, Eggplant	1.997715	INFESTED
15	String Beans, Eggplant	1.812599	INFESTED
4	String Beans, Pepper	1.012397	INFESTED
18	Pepper	0.265543	INFESTED
22	String Beans, Tomato	0.248577	INFESTED
17	String Beans, Tomato	0	INFESTED
20	String Beans	-0.314422	NOT INFESTED
13	Sponge Gourd, Melon, Watermelon	-1.035661	NOT INFESTED
1	Bottle Gourd, Bitter Gourd, Eggplant	-1.615051	NOT INFESTED
8	String Beans, Tomato, Bitter Gourd, Eggplant	-1.66699	NOT INFESTED
9	String Beans	-2.228441	NOT INFESTED
10	Tomato, Bitter Gourd	-2.919466	NOT INFESTED

Figure 2. Distribution of infested alternate hosts in onion growing areas in Nueva Ecija

3.2 Effect of Temperature in Leafminer Distribution

Like in most insects, temperature has a strong relationship for growth, development and fecundity of Leafminers. To analyze the survivorship of *L. trifolii* during the onion season, temperature data converted into raster image was used to assess the possibilities of the continuity of life cycle of *L. trifolii*. Figure 3 shows the map of high hot spot areas which were located in Municipality of Rizal, with temperature ranging at 24°C-26°C. On the other hand, mild hot spot areas were also located in the municipality of General Natividad, and the City of San Jose which is also to have the same average temperature with Rizal. From the study of Owino (2014), the optimum temperature for the fecundity of *L. trifolii* is 27°C, thus, the location of infested alternate hosts has temperature suited for infestation, and this leafminer species can proceed to the onion areas and may able to multiply and spread in the areas with same temperature.

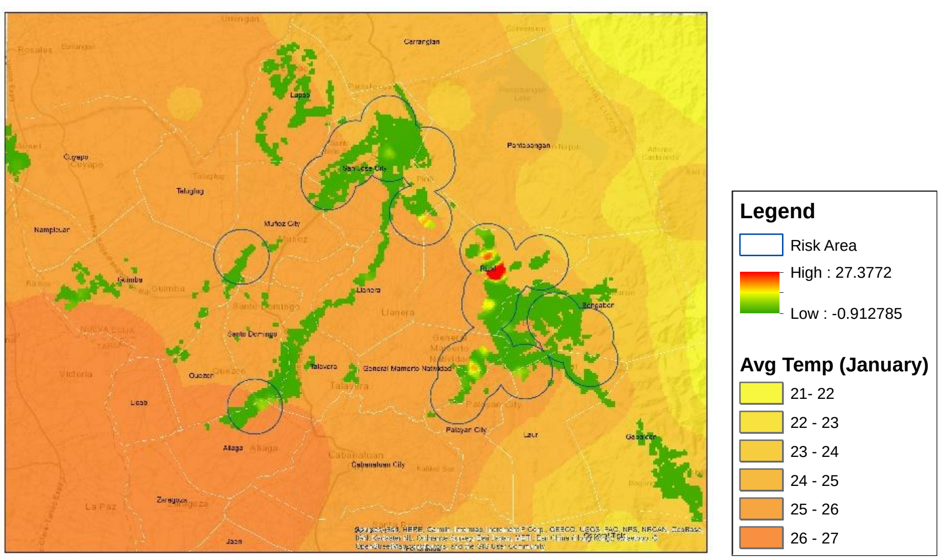


Figure 3. Spatial distribution of leafminer during the month of January

Figure 4 shows the distribution of leafminer (*L. trifolii*) in onion growing areas in Nueva Ecija during the month of February. During this month, the region experienced much lower temperature than January. Regression analysis was carried out to validate the relationship between the spread of leafminer using the values from the hotspot analysis and raster image of temperature. The coefficient determination (R^2) shows a positive relationship between the spread of leafminer infestation and the relative prevailing temperature during the month of February with R^2 of 51.52. However, the analysis was observed to be poor due to the range of the temperature during this month, which is very favorable for the life cycle *L. trifolii* to continue.

Moreover, the map shows that there was an increase of infested areas observed, thus, the lower temperature gives better survivorship for the (*L. trifolii*). Based on the works of Leibee (1984), the constant temperature requirement for the life cycle of *L. trifolii* is at 25°C, while the eggs were observed to have less mortality rate at 20°C (Libee, 1984) (Parella, 1987). Thus, during the month of January and February 2019, the *L. trifolii* was able to mass produced and spread throughout the onion areas at prevailing temperature of 25°C.

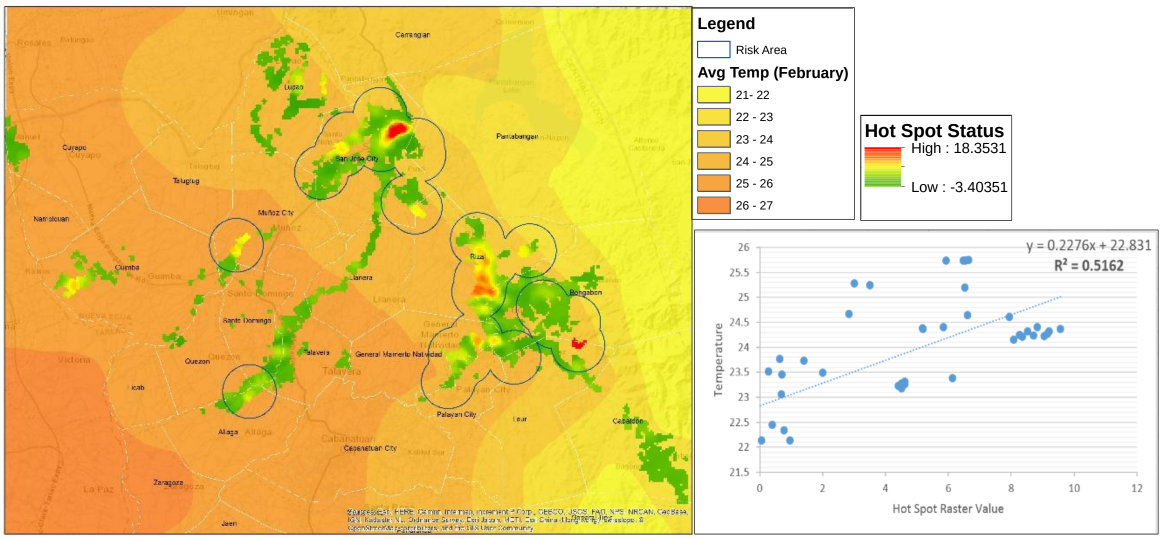


Figure 4. Spatial distribution of leafminer during the month of February

Figure 5 shows the map of distribution of *L. trifolii* in the onion areas during the month of March 2019, wherein a gradual increase of temperature up to 31°C was experienced. Based on the hotspot map, low incidence of *L. trifolii* was observed in the onion areas that experienced high temperature of 30°C which was actually experienced in the municipalites of Guimba and Cuyapo. From the study of Mickenberg (1988), temperatures above 30°C are usually unfavorable resulting to high larval mortality rate. Thus, onion areas with this condition might not experienced high severity level of damage due to high mortality of larvae which is the most damaging stage of many leafminer species. On the other hand, spread of *L. trifolii* was observed in San Jose City when the temperature ranged from (26°C-28°C) an optimum range for survival. In addition, the coefficient determination (R^2) to evaluate the relationship of the two variables gives an R^2 of 60.84, which shows a good relationship. The result of the analysis showed that an increase of temperature in the region is associated with high distibution of *L. trifolii* in the area and vice versa.

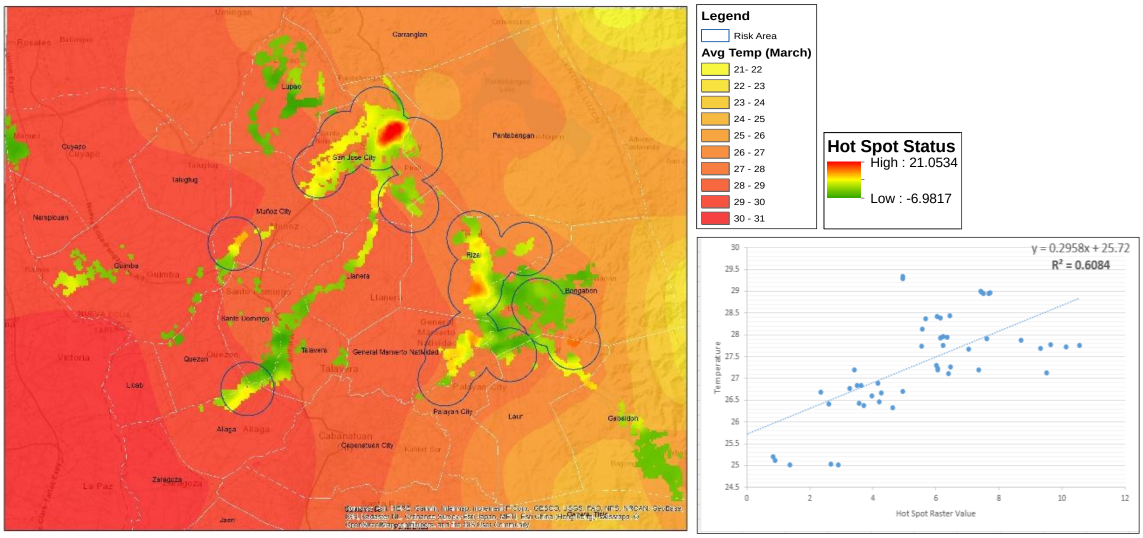


Figure 5. Spatial distribution of leafminer during the month of March

4. SUMMARY AND CONCLUSION

Spatial distribution of Leafminer in the onion areas was conducted by analyzing the relationship of the infested alternate hosts and leafminer infestation in the onion fields, and the effect of temperature on the spread of infestation. During field surveys, *Lyriomyzae trifolii* species was observed to be the major pest which was also commonly observed from the infested alternate hosts. To generate distribution maps based on the infestation level and severity of damage caused by *L. trifolii* for the month of January to March, 2019, hot spot analysis and Kriging were used. First observations of hot spot areas of *L. trifolii* was observed in Rizal, San Jose City, and General Natividad, where infested alternate hosts were present.

The study also shows that during the month of January to February, 2019, *L. trifolii* was able to mass produced and spread throughout the onion areas, due to suitable temperature condition ranging from 21°C to 27°C. To determine the effect of temperature on the spread of *L. trifolii* during the month of February and March, 2019, regression analysis showed good relationship. In addition, the presence of optimum and maximum range for the survivorship of *L. trifolii* gives better result, which was observed during the month of March, 2019. Moreover, the GIS tools was proven to be effective in analyzing the distribution patterns of *L. trifolii* given with locations of alternate hosts and available temperature data.

5. ACKNOWLEDGEMENT

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