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The Distribution and Analysis of Spatial Autocorrelation of Fruit Fly on Red Chili Cultivation in Cirebon, West Java, Indonesia

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ABSTRACT

The information of fruit fly spatial distribution and its correlation with the environment is a key to their population control including sampling and an effective analysis procedure as a basis for population estimation. This study aims to analyze spatial dispersion and autocorrelation of fruit fly on red chili cultivation in Cirebon. The distribution of fruit fly from attractant Metil Eugenol trap and cue lure analyzed by using various dispersion index and regression models namely: ratio (s^2/x), |d| Elliot value, Llyod index, Green coefficient, Morisita dispersion index, k dispersion parameter, Iwao regression analysis, and Taylor regression analysis. The analysis result of various dispersion index and regression models such as ratio value (s^2/x) > 1, value |d|>1, value x*>1, coefficient GI> 0-1, and value (1/k)>0 shows that fruit fly population at both locations have clumped dispersion pattern. This is supported by the result of Taylor and Iwao regression analysis with slope value > 1 showing clumped dispersion pattern. Further analysis for fruit fly use Morisita dispersion index revealing clumped dispersion pattern for *Bactrocera papayae* and *Bactrocera cucurbitae*; *Bactrocera carambolae* has homogenous dispersion pattern that tends to clump; *Bactrocrea tau* and *Bactrocera albistrigata* has homogenous dispersion pattern. Spatial autocorrelation analysis based on Moran index value interpretation is I > -0,05 with p-value < 0,05 showing positive spatial autocorrelation between the traps that are located close together (0-10 m) and even far apart (70-75 m and 80-85 m).

Keywords: *Bactrocera* sp. Dispersion Index. Moran Index. Spatial Autocorrelation. Dispersion Pattern.

INTRODUCTION

Information about the presence of types of fruit flies in an area needs to be known and reported as an anticipatory step to conduct Bactrocera species fruit fly control on fruit and vegetables cultivation. This is urgent because certain fruit fly species has preference towards specific type of host (HASYIM; MURYATI; DE KOGEL, 2006). Moreover, by finding out the data about the types of fruit flies in an area along with its distribution will facilitate the use of attractants for control in the field because the use of attractants can be adjusted to the population of many fruit flies found in an area.

The understanding of fruit fly bioecology is no less important in Bactrocera species of fruit fly control program. Two considerable scopes that have to be aware of in ecology concept are the distribution and abundance of organisms along with one of its important aspects, namely spatial distribution. Understanding the spatial distribution associated with insects become urgent as it is a result of interactions between one type of individual with their habitat. Having knowledge of fruit fly dispersion pattern enables us to get a better comprehension in determining the correlation between fruit fly and their environment as the basis of an effective sampling program and analytical procedure. It aims to establish an integrated population estimation and population control of fruit flies along with providing basic information to determine the dynamics of spatial distribution of organism and a population model development (SOEMARGONO et al., 2011). In addition, spatial dispersion patterns, insects' movement patterns, analysis of insects' population dynamics, variety and time of population change are essential elements in the development of integrated pest management.

According to Morris et al. (1992) and Taylor; Woiwod; Perry (1978, 1980) the dispersion patterns of most insect population is spatially aggregated (aggregrated or clumped). However, the aggregation level varies between insect species and populations. General approach conducted to find out characteristic of certain insect spatial distribution is the approach based on variance and sample averages (MAHENDRA, 2011)). Hence, this study will also analyze dispersion patterns by using geostatistics method that provides information on correlation between sample points separated by a certain distance using spatial autocorrelation analysis. The purpose of this analysis is to obtain an understanding of dispersion patterns and the close relationship between locations of fruit fly traps will be obtained through autocorrelation analysis.

METHODOLOGY

This research used quantitative research design to analyse significant spatial autocorrelation at a distance of 0-20 m for *B. papayae* and 0-20 m as well as 30-40 m for *B. Carambolae.* Quantitative research is a research pointed out on data measurements by statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating pre-existing statistical data using computational techniques (MUIJS, 2011)

The sample of this analysis was conducted in red chili cultivation in Cirebon, Indonesia. The tools needed in sampling and identification of fruit fly in field consist of trapped bottles equipped with attractants, sample bottles, surgical instruments, microscope slide glass, cover glass, microscope stereo, microscope inverted and Program Tool A. The ingredients used are attractants metil eugenol, attractants cue lure, alcohol. Fruit flies in Red chili cultivation trapped by metil eugenol, and fruit flies attracted by cue-lure traps.

After the interpretation of Moran index values being carried out through Microsoft Excel as the additional program, further analysis then being conducted namely spatial autocorrelation analysis (hypothesis test whether there is autocorrelation or not) in order to see how significant or matter the value of Moran index. This analysis also functions to see whether Moran index value at certain distances show significant spatial autocorrelation or not. Hypothesis test done in this analysis is as follows:

Ho: there is no spatial autocorrelation (insignificant autocorrelation)

H1: there is spatial autocorrelation (significant autocorrelation)

Making decision whether there is autocorrelation based on p-value score, namely the smallest significance so that the observed test statistic value is still significant. If p-value > α then Ho accepted, which means there is no spatial autocorrelation (not significant) at that distance. Otherwise, if p-value < α then Ho rejected. Significance level (α) used is 5%.

Research Procedure

Collection and Identification of fruit fly

The collection of fruit flies caught using bottle traps with attractant like methyl eugenol and cue lure. The identification of fruit flies *Bactrocera* sp. conducted by determining fruit fly species belong to complex *Bactrocera dorsalis* member and which is not based on the observation of morphology characters, namely color patterns on the wings, thorax, and abdomen refer to identification key of (DREW & HANCOCK, 1994). More

identification used measurement of genital organs of male (aedeagus) and female (aculeus). According to Iwaizumi, Kaneda, Iwahasi (1997) The measurement of genital organs of male and female fruit flies carried out by making microscope slide of genital organ. Male genital organ (aedeagus) and female (aculeus) obtained through abdominal surgery that has been preserved in 70% alcohol.

Determination of fruit fly dispersion patterns

The spatial distribution of fruit flies examined by using some dispersion parameteres namely through the ratio of variance and average (s^2/x). The use of variance and average ratio is to determine distribution trends by looking at the dispersion index. This is the simplest and the most fundamental way (MYERS et al. 1978). This ratio is able to show the types of dispersion. Type of dispersion is random when ratio value = 1, type of dispersion is homogenous when ratio value < 1, and the dispersion is clumped when ratio value >1 (CHIARALUCE et al., 2018). In order to determine the significance of the 1 value, chi-square test done by using the following formula:

$$d = \sqrt{2\chi^2} - \sqrt{2(N-1)-1} \qquad (1)$$

$$\chi = \left(\frac{s^2}{x}\right)(N-1) \qquad (2)$$

d is statistical test score and N is the total number of sample units. If the value is $|d|<$ 1,96, so that the random dispersion type accepted. If the value of d < -1,96, the type of dispersion allegedly homogenous. Then if the value of d > 1,96, the type of dispersion is clumped (ELLIOTT, 1977).

Besides using variance and average ratio, the determination of dispersion index carried out by calculating Llyod index. The calculation of Lloyd index is important because it doesn't depend on sample size or the population average (HURLBERT, 1990). Llyod index calculated as ratio of crowding average (x^*) tŏwards population average (x). Crowding average (x^*) calculated based on the formula (SOUTHWOOD, 1978) has described as follows: $x^* = x + (\frac{s^2}{x} - 1)$, where x is population average and s^2 is variance. If the value of Lloyd index equals one, it shows random dispersion. If the value is more than one, it shows clumped dispersion. Then if the value is less than one, it shows homogenous dispersion.

Morisita dispersion index (BROWER & ZAR, 1989) used as the confirmation in determining dispersion pattern of fruit fly species from the previous dispersion index. This Morisita index is relatively independent on the type of distribution, the number of sample and

average size (KAO, 1984). The calculation of Morisita dispersion index carried out by using the following formula:

$$ID = n\left(\frac{(\sum X\,2)-N}{N(N-1)}\right) \qquad (3)$$

With ID = Morisita dispersion index, n = number of sampling trap, N = the number of individual in n trap, and X = the number of individual in each trap. If ID has value < 1, it shows homogenous dispersion pattern, ID = 1 shows random dispersion pattern and ID> 1 shows clumped dispersion pattern.

The validation of that Morisita dispersion index value then tested through statistical test by using *chi-square* distribution with applicable equation as follows:

$$X^2 = \frac{n\sum_{i-1}^{s} x^2}{N} - N \qquad (4)$$

The value of *chi-square* from the above calculation compared to *chi-square* value of statistical table by using confidence interval 95%. Testing criteria are if the value of $X^2_{\text{count}} < X^2_{\text{table}}$, then H_0 accepted (ID=1), which means there is no significant difference with random spread. If the of value X^2 count > X^2 table, then H_0 rejected (ID=1), which means there is significant difference with random spread.

Next, by using a basis of average values and variance, the calculation of dispersion index and other statistical tests carried out as a confirmation of distribution pattern of fruit fly population.

In order to measure aggregation level, some dispersion index such as Green Gl coefficient (Green, 1966), *Taylor`s power law* (TAYLOR; WOIWOD; PERRY, 1978), Iwao regretion (IWAO & KUNO, 1968), and parameter k for negative binomial, are commonly used. The measurement using other dispersion index need to be done because the measurement using only one dispersion index cannot be confirmed valid (MYERS et al., 1978). In the measurement of insects population dispersion index, it is better to use some dispersion index models before drawing conclusions about the dispersion patterns (SOEMARGONO et al., 2011).

Green Gl coefficient determined based on the following formula (GREEN, 1966):

$$Gl = \frac{\left(\frac{s^2}{x}\right)-1}{\sum x-1} \qquad (5)$$

Where s^2 = variance, x = average number of *Bactrocera* in each trap, ∑x = total number of

Bactrocera caught in the trap. Green coefficient shows random dispersion type when Gl = 0 and clumped dispersion type when Gl ≥ 0 – 1.

The determination of dispersion index using *Taylor`s power law* stated that variance (s^2) is directly proportional to *fractional power* of arithmetic mean where $s^2 = a\ x^b$. Coefficient a and b calculated based on regression model: $\log s^2 = \log a + b \log x$, where *slope* b is aggregation index showing random dispersion type if b=1, homogenous if b < 1, and clumped if the value of b > 1.

Iwao regression is a regression of *crowding* mean (x^*) on the average population with linear model: $x^* = \alpha + ßx$, where x^* value gained from previous *crowding* mean formula. Value of α is a basis of index calculation and value of ß gained from the result of b value from the previous Taylor regression. Dispersion parameter (k) for negative binomial determined through the following formula: $= \frac{(x^2 - \frac{s^2}{n})}{(s^2 - x)}$, which will correspond to a binomial negative distribution.

Spatial Analysis of Fruit Fly

The steps taken in this analysis section are to calculate Moran index value and carry out spatial autocorrelation analysis based on the Moran index value that is followed by significance hypothesis test based on *p-value* with 5% level of significance. Moran index value calculated using Microsoft Excel as an additional program. This program is able to calculate *Moran's I* (indeks Moran), p-value *Morans's I*, and present *Moran's I* value in graphical form (corelogram). This program was obtained from *Statistical Modelling Tools for Design and Analysis of Conservation Monitoring Data* with the name of the program *Tool A.*

Testing and Planning for Spatial Autocorrelation.

The use of Moran index in calculating special autocorrelation of attractants trap points for fruit flies carried out because the placement or setting of traps done systematically with the same distance of 5m away. The calculation of this Moran index is only conducted at sampling location on red chili cultivation, Pabedilan Wetan District, Cirebon.

RESULTS AND DISCUSSION

Collection and Identification of Fruit Fly

Based on the identification of fruit fly sample from metal eugenol trap in Cirebon, 3 species of fruit flies found as well as in the attractant cue lure trap (Table 1).

Table 1. The result of fruit fly identification caught from metil eugenol trap.

Location	Identification Result		
	Trap	Types of fruit flies	Total
Red chili cultivation, Pabedilan Wetan,Cirebon	Metil eugenol	*B. papayae*	682
		B. carambolae	128
		B. cucurbitae	16
	Cue lure		
		B. cucurbitae	858
		B. tau	33
		B. albistrigata	1

The *aedeagus* length of *B. carambolae* and *B. papayae* fruit fly (Table 2) as the result of identification from metil eugenol trap based on morphology character. It is done to support the identification result based on observation of morphology character conducted previously.

Table 2. The result of *aedeagus* measurement of fruit fly sampel from the trap.

Measurement	Aedeagus length (µm)	
	B. carambolae	*B. papayae*
Average	3248,6	3499,005
Deviation Standard	204,5	266,9

The data gained from the measurement result of 100 *aedeagus* samples for each fruit fly species *B. carambolae* and *B. papayae* (Table 2) compare to the study conducted by (IWAIZUMI et al., 1997; DURAHMAN, 1999; ARIEF, 2009) also refer to the identification key of (DREW & HANCOCK, 1994), it can be concluded that caught fruit flies by metil eugenol trap on red chili cultivation Cirebon are *B. papayae* dan *B. carambolae*.

According to Arief (2009), *B. papayae* has nearly 1,9 – 2,19 mm long aculeus with an average of 2,02 ± 0,09 mm, and has nearly 3219-3853µm long aedeagus with an average of 3534,7 ± 192,9 µm. In line with the identification key of (DREW & HANCOCK, 1994), the aculeus length of *B. carambolae* is 1,4-1,6 mm. Further, study result of (DURAHMAN, 1999) shows that the size of *aedeagus B. carambolae* in the range of 2800-4200 µm with an

aedeagus average length of 3224,5283 ± 204,153 µm. The study conducted by (IWAIZUMI et al., 1997) explains that *B. carambolae* has 2,46 ± 0,07 mm long *aedeagus* and 1,40 ± 0,07 mm long *aculeus*, while *B. papayae* has 2,95 ± 0,13 long *aedeagus* as well as 1,99 ± 0,09 mm long *aculeus*.

Dispersion pattern of fruit fly Bactrocera sp.

Dispersion pattern of fruit fly determined by some index based on the comparison between average and variance. Dispersion index used are the calculation of d Elliot value, Llyod index (x*), Green coefficient (GI). Besides, the analysis of Iwao regression and the analysis of Taylor regression along with dispersion k parameter (Table 3) are carried out as well.

Table 3. Dispersion parameter of fruit fly *Bactrocera* sp.

Location	Disperse Indeks Average						
	x	**s^2**	**s^2/x**	**D**	**x***	**GI**	**k**
Cirebon	43,425	208,08	4,79	11,291	46,61	0,0518	129,61

The result of some spatial distribution parameter of fruit fly shows that they have clumped dispersion pattern. From the fruit fly collection through trap, the average ratio and variance shows the result is > 1 of 4,79. Even d Elliot value in most traps shows clumped result (d value > 1,96 shows clumped dispersion pattern). Green Coefficient (GI) obtained also has value of > 0 – 1 which stated that GI value of > 0 – 1 included in the clumped dispersion pattern (GREEN, 1966). From the calculation of 1/k value, 1/k > 0 value was gained of 0,0073 that shows clumped dispersion pattern (ELLIOTT, 1977). Southwood (1978) also reported that k > 8 value show clumped type where the smaller the value of k, the greater indicates the clumped dispersion pattern. Elliott (1977) said that the stability of k value indirectly affects the level of population distribution of an insect that is relatively constant in a certain period in addition to the sample variance. The lack of this approach is that the lack of attention on the characteristics of sampling spatial location whereas in the spatial distribution analysis of insects population is strongly influenced by the characteristics of the sampling location.

The result of Taylor linear regression and Iwao regression also show clumped dispersion pattern of fruit fly. The value of *slope* gained for fruit fly is b = 1,291 and because

b = 1,291 > 1 based on the result of Taylor regression analysis (Figure 1), dispersion pattern of fruit fly belongs to the clumped type (TAYLOR; WOIWOD; PERRY, 1978).

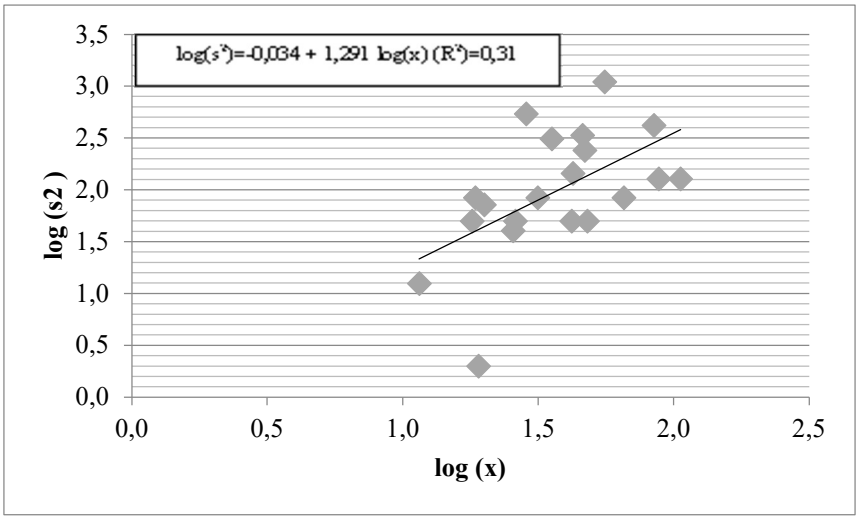

Figure 1. Taylor regression, log (s^2) = log(a) + b log(x) for fruit fly in Cirebon red chili cultivation.

The result of Iwao regression analysis shows the clumped population of fruit fly. The value of Iwao regression slope is ß = 1,003 (Figure 2).

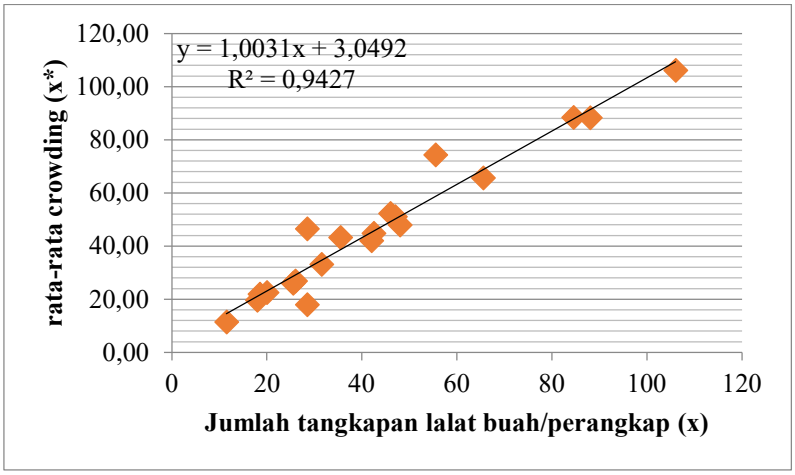

Figure 2. Iwao regression, x* = 3,049 + 1,003x (R^2) = 0,94 for fruit fly population in Cirebon red chili cultivation.

The result of Taylor regression analysis and Iwao regression analysis does show the same dispersion pattern. However, by noticing the value of R^2, it can be concluded that the result of Iwao regression analysis is more in line with fruit fly population than the result of Taylor regression analysis. R^2 value of Iwao regression analysis (R^2 = 0,94 and R^2 = 0,98)

(Figure 2) is higher than the value R^2 of Taylor regression analysis (R^2 = 0,31 dan R^2 = 0,77) (Figure 1). In addition, Iwao regression analysis presents a more prevalent data of distribution along the trendline lines than Taylor regression analysis.

Besides using various dispersion index based on the comparison between variance and average, the determination of each fruit fly species dispersion pattern of fruit carried out through the calculation of Morisita dispersion index with the result of clumped and homogenous dispersion pattern (Table 4). This Morisita index is relatively independent towards the type of distribution, the number of sample and the average size (KAO, 1984). It is also used as a confirmation of fruit fly species dispersion pattern from the calculation of previous dispersion index.

Table 4. Value of Morisita dispersion index in Cirebon red chili cultivation.

Species	ID	X^2 **count**	X^2 **table**	Dispersion
B. papayae	17.188	1127.473	30.144	Group
B. carambolae	0.736	8.269	30.144	Homogen
B. cucurbitae	12.528	66.001	30.144	Group
B. tau	0.081	88.312	30.144	Homogen
B. albistrigata	0.00	96.794	30.144	Homogen

The result of Morisita dispersion index continued with *chi-square* test showing fruit fly species namely *B. papayae* and *B. cucurbitae* having clumped dispersion pattern (ID Morisita > 1) and significantly different X^2_{count} (1127.473) > X^2_{table} (30.144) whereas *B. carambolae* has homogenous dispersion pattern (ID Morisita < 1) yet not significantly different X^2_{count} (8.269) < X^2_{table} (30.144). Thus, *B. carambolae* has homogenous dispersion pattern that tends to clump. *B.tau* and *B. albistrigata* has homogenous dispersion pattern (ID Morisita < 1),

Clumped dispersion pattern seen at *B. papayae* and *B. cucurbitae* in Cirebon red chili cultivation. This relates to the availability of hosts such as red chili for *B. papayae* and bitter melon for *B. cucurbitae* that is only in one particular stretch of land or cultivation area. Meanwhile, homogenous dispersion pattern on *B. albistrigata* same as *B. carambolae* in which has a host that tends to be evenly distributed because it is widely available outside the cultivation area of trapping specifically in each house of many residents with guava trees that are the main host for both type of fruit flies.

Spatial autocorrelation

In the previous section, we studied the spatial dispersion of fruit fly using an index based on variance anad average ratio namely variance coefficient and sample variance without paying attention to the characteristic of spatial location where the sample was taken. Therefore, another spatial dispersion pattern analysis is also studied by looking at the dependence of spatially connected data using spatial autocorrelation analysis. This spatial autocorrelation analysis used when there is a value of particular variable at one location depending on the other location nearby. Correlation or relationship of data might be hidden if the investigation of the correlation between the two using simple analysis such as linear regression so that the more specific test need to be carried out whether there is correlation among the installation points of fruit fly traps using spatial autocorrelation analysis. The method used to analyze spatial autocorrelation is by calculating Moran index value. Moran index compares geographical proximity in the form of deviations from mean of the whole experiments. Moran index used in counting spatial autocorrelation of fruit fly trap points because the placement or installation of traps done systematically with the same distance of 5 m away.

Moran index value calculated based on input in coordinates of each station and the value of the fruit flies catch in the trap, while the output is in the form of Moran index value for distance between pair of points in table and graphic (corelogram). The presentation of Moran index value can be seen in Figure 3.

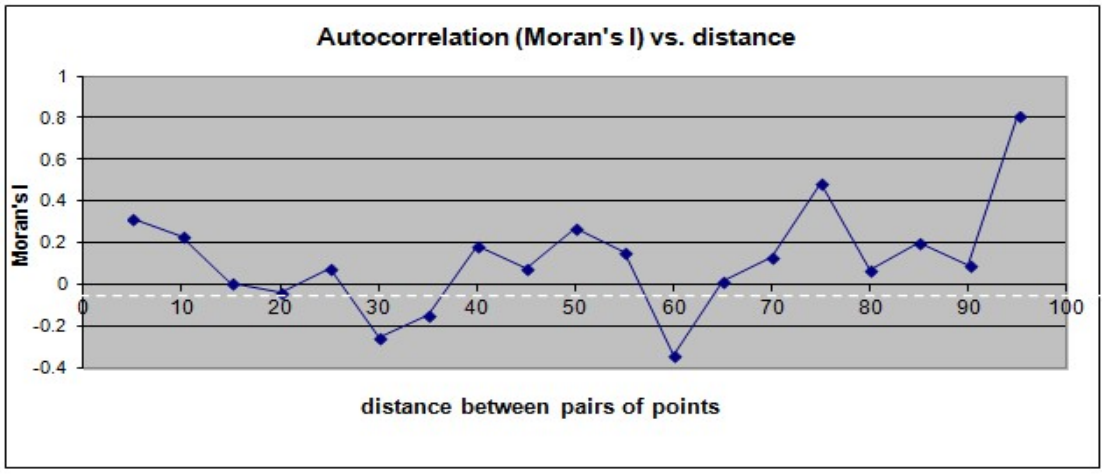

Figure 3. Moran index for each pair of distance in Cirebon chili red cultivation.

Based on Moran index value and the interpretation of Moran index, $\boldsymbol{I > -\frac{1}{(n-1)}}$ (I > -0,05) for positive spatial autocorrelation and $\boldsymbol{I < -\frac{1}{(n-1)}}$ (I < -0,05) for negative spatial autocorrelation where n is the number of traps (n=20). Thus, it can be concluded that in most range of trap installation points show positive spatial autocorrelation. It means the number of fruit flies caught at that range of distance, the value of interaction on the attractants tend to be the same or similar.

After hypothesis test being carried out, it is known that in the close range of 0-10 m the number of insects trapped in this range tends to be in the same or similar interactions. It is because in the range of distance shows positive spatial autocorrelation which means significant as well as for long distances over 70-75 m and 80—85 m. It shows significant positive spatial autocorrelation (I > -0,05, p-value < 0,05). In the range of 25-30 m and 35-40 m, significant negative spatial autocorrelation results were obtained, which means the number of fruit flies caught in the range of distance the interaction value on the attractants trap tends to be different. Furthermore, the calculation of *p-value* to test significance level of Moran index value almost all showed insignificant spatial autocorrelation at 5% level of significance (p-value > 0,05; H_0 accepted). The small number of trapped fruit flies usually results in insignificant spatial patterns. This comes from the inability of statistics to see spatial pattern based on the small number of catch (PAPADOPOULOS; KATSOYANNOS; NESTLE, 2003).

Corelogram profile and Moran index value in natural population show that positive autocorrelation found at relatively short or close pairing distances, while negative correlation found at relatively long distances (PAPADOPOULOS; KATSOYANNOS; NESTLE, 2003). In fact, the result of the study obtained does not match the natural population corelogram profile. This is perhaps due to environmental changes that form spatial pattern. One of environmental changes is the border effect such as in Cirebon red chili cultivation whose area is bordered by other plants such as bitter melon, corn and beans. The study area of Cirebon red chili cultivation is not too large (1000 m^2), the border effect in this area might cause the minimization of planting environment to form spatial pattern of fruit flies. Moreover, the red chili planting environment is quite homogenous in terms of vegetation composition. (In 1000 m^2 the area is only planted with red chili), allowing fruit fly population to be in similar environment. As the result, positive spatial autocorrelation result obtained even at aconsiderable distance (produce a circular gradient) (PAPADOPOULOS; KATSOYANNOS; NESTLE, 2003).

CONCLUSION

The dispersion pattern of fruit fly generally based on variety of dispersion index showing the clumped dispersion pattern. Dispersion pattern for each type of fruit flies based on Morisita dispersion index showing clumped dispersion pattern for *B. Papayae* and *B. cucurbitae* while *B. carambolae* has homogenous dispersion pattern that tends to clump. *B. tau*, and *B. albistrigata* has homogenous dispersion pattern. The dispersion pattern based on spatial autocorrelation analysis for *B. papayae* is homogenous while *B. carambolae* show clumped dispersion pattern. The correlation between trapping points of each type of fruit flies based on spatial autocorrelation show significant positive spatial autocorrelation at a distance of 0-20 m for *B. papayae* and 0-20 m as well as 30-40 m for *B. carambolae.* Through these results it can be ascertained that fruit flies have certain dispersion patterns that affect the location of the trap installation points. Through spatial autocorrelation analysis data explain that the installation of traps need to pay attention to the range of installation points because of the number of fruit flies trapped in the distance range the interaction value to the practical trap tends to be the same or different depending on the distance of the trap. This can be used as a basis for installing trap points on an agricultural or plantation land so that trap installation is more effective.

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