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Distribusi Penyakit Bulai Jagung (Peronosclerospora maydis) pada Lahan Pertanaman Jagung dengan Pendekatan Geostatistik

Distribution of Downy Mildew (Peronosclerospora maydis) on Maize Plots Based on Geospatial Approach

Hery Nirwanto[1*], Sutikno[2]

[1] Lecturer in Agrotechnology, Faculty of Agriculture, UPN "Veteran" East Java
[2] Lecturer in Statistics, Department of Statistics, ITS Surabaya
*Corresponding author e-mail: herry_n@upnjatim.ac.id

ABSTRACT

Downy mildew Peronosclerospora spp. is an important disease in corn (Zea mays L.). The damage of downy mildew caused by Peronosclerospora spp. is this pathogen can reach 90-100%, especially in corn varieties that are susceptible to downy mildew. So far, most research has only been limited to knowing the incidence of the disease, without being able to describe the spatial distribution pattern of downy mildew in the planting area. This research aims to determine the occurrence of disease and the spatial distribution patterns of downy mildew on a geospatial basis. Samples were taken from three corn fields affected by downy mildew on three fields planted with corn plants that were attacked by downy mildew. Data on the level of infestation, along with its coordinates, were used to create a theoretical semivariogram model, Gaussian, spherical, exponential. The distribution pattern is approached by interpolating attack level data using the kriging method. The research results show that the appropriate theoretical semivariogram model to describe the distribution of P. maydis in the observation area is the Gaussian model. The distribution of pathogens throughout the observation area began with a clustered pattern and evened out at the end of the observation. Foci had a clustered pattern in the first to fourth weeks of observation. Then each foci experienced development, so that the distribution pattern changed to become even after the fifth week of observation.

Keywords*: Zea mays L., spatial distribution, semivariogram, kriging*

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PENDAHULUAN

Corn (*Zea mays* L.) is one of the important crops that is widely cultivated in Indonesia because it plays a role (Saidah, 2015) (Purwidiani *et al.*, 2018). The Food and Agriculture Organization (FAO) noted that corn production in Indonesia reached 22.5 million tons in 2020. This number decreased by 0.38% compared to the previous year which was 22.58 million tons (Hasrizart *et al.*, 2023). The amount of production available to date has not been able to meet national corn needs(Salelua and Maryam, 2018). One of the caused by damage from the *downy mildew* disease *Peronosclerospora* spp. (Pakki, 2017). The damage caused by these pathogens varies widely can reach 90-100%, especially in corn varieties that are susceptible to downy mildew (Prasetyo *et al.*, 2021). Damage caused by pathogens is influenced by abiotic environmental factors, such as temperature and humidity (Muis *et al.*, 2022). One of the causes of downy mildew is that the combination of air temperature around 30°C and high humidity accompanied by dew can support the occurrence of downy mildew on corn plants. Wind plays a role in the release and dispersal of conidia (Arulselvi, Selvi and Pandiyan, 2018). Downy mildew, an airborne disease (Salcedo *et al.*, 2021), spreads through pathogenic conidia carried by the wind. Various management techniques have been used to reduce downy mildew attacks.

Downy mildew control techniques are still dominated by the application of synthetic fungicides and then The use of synthetic fungicides, though common, has drawbacks such as harming non-target organisms, promoting pathogen resistance, and causing environmental pollution. The application of synthetic fungicides has several negative impacts, such as killing non-target organisms, increasing pathogen resistance and environmental pollution (Sireesha and Velazhahan, 2016). For this reason, precise cultivation is needed by identifying locations to get optimal results and reduced environmental impact. Precision farming can reduce the environmental burden by implementing geospatial crop management practices (Belan *et al.*, 2018) and which implement advanced geospatial technologies for respecting soil heterogeneity (Řezník *et al.*, 2017) (Bongiovanni and Lowenberg-Deboer, 2004).

However, this impact can be minimized through monitoring activities (Bongiovanni and Lowenberg-Deboer, 2004). Regular monitoring of fields to identify the presence and spread of diseases is a key element of integrated disease management programs. Monitoring allows for the assessment of activities, identification of constraints and problems that arise during implementation, and serves as a fundamental step in plant protection (Dara, 2019).

Monitoring activities so far have only been limited to knowing the incidence of the disease, without being able to describe the spatial distribution pattern of downy mildew in the planting area. Nowadays, monitoring activities require geospatial-based information to support precision agriculture. In the field of pathology, geostatistics is used to estimate the threats posed by diseases, disease prevalence, and to identify areas vulnerable to location-specific diseases. Various methods of spatial disease distribution analysis are employed to characterize the spatial position of pathogens and the locations of disease-affected fields. By knowing the spatial position of pathogens, plant diseases can be controlled effectively and efficiently, thus avoiding excessive use of pesticides. Currently, spatial-based cultivation practices are part of the precision agriculture concept. Precision agriculture can reduce environmental burdens by applying crop management practices that utilize geospatial information (Balanagouda *et al.*, 2021; Anastasiou *et al.*, 2023; Limbo-Dizon *et al.*, 2023)

So it is necessary to conduct research on the spatial distribution patterns of downy mildew. One spatial method that has been widely used is using geostatistics to determine the occurrence of disease in Puri District, Mojokerto Regency.

METODE PENELITIAN

Sampling was carried out from December 2019 to January 2020 on corn planting land owned by farmers in Puri District, Mojokerto Regency, East Java. Mojokerto Regency is geographically located at 111°20'13”-111°40'47” East Longitude and 7°18'35”-7°47'0” South Latitude. Puri District, covering an area of 35,697 km^2, is situated 48 meters above sea level. Over the past five years, the average rainfall in the area was 2104.5 mm, spread over 93 rainy days.

Surveys. A survey was conducted to determine the location of corn plantations infected with downy mildew in the Mojokerto Regency area. Apart from surveys, observations and interviews were also carried out with farmers regarding the presence or absence of downy mildew attacks on their land.

The locations of corn plantations suspected of being affected by downy mildew are spread across Sumolawang and Sumbergirang villages, Puri District. A map detailing the locations and sampling methods for corn plants affected by downy mildew is provided.

Sampling Location. In Puri District, Mojokerto Regency, corn fields sampled for infection by *Peronosclerospora* spp. include one plot in Sumolawang Village and two plots in Sumbergirang Village. The sampling location can be seen in Figure 1.

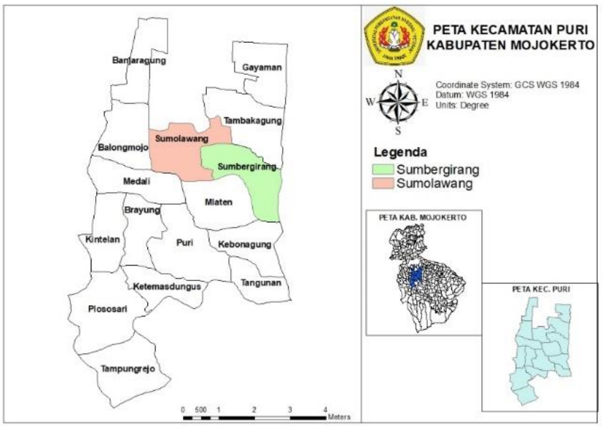


Figure 1. Map of sampling locations

Secondary Data Collection. The required secondary data includes climate data for Mojokerto Regency and farmers' cultivation techniques. Climate data will help ascertain the climate's impact on the downy mildew epidemic, while data on cultivation techniques will shed light on land use history.

Identification of the Pathogen that Causes Downy mildew

The fungus *Peronosclerospora* spp. was identified at the Mycology Laboratory of the Indonesia Agricultural Quarantine Agency (BBKP) in Surabaya.

Peronosclerospora spp. was identified morphologically and morphometrically, focusing on body shape and size. Observations were carried out under an Olympus CX 33 light microscope includes the shape and size of conidia, conidiophores, and sterigmata.

The fungal characteristics were compared with descriptions from previous researchers and reference books available at the Mycology Laboratory, Indonesia Agricultural Quarantine Agency in Surabaya.

Artificial sporulation induction was carried out to produce complete fungal morphology using the method(Talanca, Burhanuddin and Tenrirawe, 2011). Corn leaves from the field are washed with running water to remove dirt and other materials such as damaged conidiophores and then air-dried. The air-dried leaves are then soaked in a 2% sugar solution, with the base of the leaf positioned at the bottom and submerged 3 cm in the sugar solution. Next, cover the leaves using clear plastic, you can use PP (poly propellene) to maintain humidity for ± 6 hours. Next, the soaked leaves are placed in an open, dark area for one night. Conidia and conidiophores were harvested from leaves removed from the plastic cover at 3-4 in the morning.

Leaves that produce conidia and conidiophores are characterized by the presence of white, powdery-like propagules. The propagules were taken using clear adhesive plastic (tape) and then attached to a glass object that had been given one drop of 2% methylene blue dye. Next, all sides of the tape are given clear nail polish so that the preparation can be stored longer (Ekawati, Bande and H.S., 2018).

Determining the Research Sample. This research uses a survey method in the form of *purposive sampling* by calculating the occurrence of disease. Sampling was carried out using 20 quadrants measuring 1.5 x 1.5 m ^{2} in each observation plot (land). Each quadrant consists of 10-20 plants (Fig 2). The quadrant position is recorded following the Cartesian axis to obtain the coordinates of each sample point. Determination of the Cartesian axis is carried out using a coordinate system (X,Y) which consists of the horizontal axis as the X coordinate and the vertical axis as the Y axis (Belan *et al.*, 2018). One corner of the land is used as a starting point which is the distance point (0,0) and will be used for other distance measurements. Data on disease occurrence with position in XY coordinates is then made into a variogram model to be interpolated into a spatial map using geostatistical methods.

Disease incidence (%). Disease incidence was carried out during six weeks of observation by calculating each quadrant of the sample and then entering it into the disease incidence formula. The number of corn plants infected with downy mildew compared to the number of healthy corn plants according to (Purwanti, Wahyudi and Hamyana, 2023):

$$\text{Disease incidence} = \sum \frac{n}{N} \times 100\%$$

Information:

n : number of diseased plants;
N : number of plants observed

The incidence of disease in each field was then categorized based on the level of attack by the pathogen that causes downy mildew on the cultivated land using a research table conducted by (Matruti, Kalay and Uruilal, 2018)(Table 1).

Table 1. Downy mildew attack category

Disease Intensity (%)	Attack Category
0	Normal
$0 < x \leq 25$	Light
$25 < x \leq 50$	Currently
$50 < x \leq 75$	Heavy
$x > 75$	Very heavy

Statistic analysis. The observation data obtained was processed using Microsoft Excel 2016 to determine the development of disease incidence through descriptive statistics in the form of average values, mode, standard deviation, variance and coefficient of variance, as well as graphs of disease development.

Geostatistical analysis. Test using the Shapiro-Wilk method using SPSS 24. After obtaining information regarding the normality of the data, spatial analysis was carried out using the distance relationship and the semivariogram or variogram values. Semivariogram is a statistical tool that can be used to describe and model spatial relationships between regional variables (Myers and Armstrong, 2000; Brenner *et al.*, 1998).

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} (Z(u_i) - Z(u_i + h))^2$$

where:

$\gamma(h)$ = semi variogram value with distance h
$Z(u_i)$ = observation value at the pointu_i
$Z(u_i+h)$ = observation value at point u_i+h
$N(h)$ = the number of pairs of points that have a distance h

The models used are Gaussian, spherical and logarithmic. Matching is carried out visually, as is the method used by geostatisticians who mostly use visual methods for fitting variograms because the results are quite satisfactory (Afif and Octova, 2019). After matching the semivariogram model, data interpolation was carried out using kriging with the aim of getting a visualization of the spatial distribution pattern of disease over time. (Belan *et al.*, 2018). Visualization takes the form of a contour map by interpolating unsampled points using the ordinary kriging method.

Ordinary Kriging Estimator is expressed in a formula (Brenner *et al.*, 1998):

$$\tilde{Z}(X_0) = \sum_{i=1}^{n} \lambda_i Z(X_i)$$

where :

$\tilde{Z}(X_0)$ = Predicted value on variable X

λ_i = Weighting that determines the size of the distance between points

i = 1,2,, n, where n is the amount of data to be processed

$\tilde{Z}(X_i)$ = *Actual value* of variable X in data i

The semivariogram model approach was carried out using SGeMS (*Stanford Geostatistical Modeling Software*) software.

HASIL DAN PEMBAHASAN

Symptoms of Downy mildew. Symptoms of the disease appear on corn plants where there is a layer of water on the surface of the plant leaves. Corn plants in these three fields showed symptoms in the form of yellowish chlorotic leaves, stiff leaves, and signs of pathogen propagules on the lower surface of the leaves (Figure 2). This is in accordance with the symptoms of the disease found (Matruti, Kalay and Uruilal, 2018) and (Ekawati, Bande and H.S., 2018) in the form of leaves that have yellowish white lines, parallel to the leaf veins, the leaves are slightly upright and stiff. A white, flour-like substance is evident on the underside of the leaves, especially visible in the mornings. Infected plants become stunted (Ekawati, Bande and H.S., 2018), indicating that downy mildew is a disease that attacks corn plants during the vegetative to generative phases.

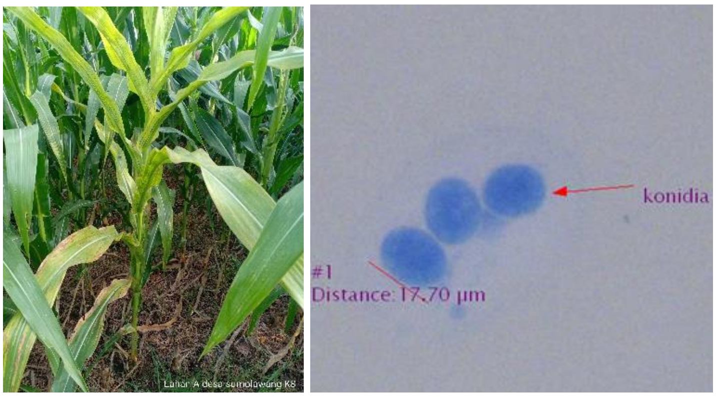


Figure 2. Symptoms of corn plants attacked by downy mildew in the research field and *Peronosclerospora* spp. at 40x10 magnification

Pathogens that cause downy mildew. The result of identifying the pathogen that causes downy mildew through sporulation induction is that the conidia of the pathogen grow on the lower surface of the leaves, indicated by white powder (Figure 4). Harvesting of pathogen spores is carried out at 04.00 or after 7 hours when the leaves are placed in the open room. The pathogen that causes downy mildew on corn plants can only be harvested after incubation for 7 hours, this is in accordance with (Ekawati, Bande and H.S., 2018) *in* (Putranto *et al.*, 2022) Germination of *Peronosclerospora conidia* that causes *maize downy mildew* from America requires a minimum of 4 hours over a wide temperature range, namely 10-33°C. The morphology and morphology of the conidia obtained were observed microscopically

The results of microscopic observations with a magnification of 40x10 showed that the morphology of the pathogen's conidia was slightly round to rounded with a diameter of 13.45–14 µm, a conidia area of 143.98 μm^2 , and a number of conidiophore branches of two (Figure 2). This is consistent with (Pakki *et al.*, 2019) that *Peronosclerospora maydis* has a conidiophore length of 78.20-228.00 µm. Conidia are *spherical* (round) to *subspherical* (slightly round) with a size of 7.62 – 25.10 x 5.43 – 19.31 µm. Conidiophores are bifurcated 3-4 times.

The *Peronosclerospora* species that generally attacks corn plantations in East Java, especially Mojokerto, is *Peronosclerospora maydis*. This is supported by (Nurhilal *et al.*, 2020) the downy mildew disease caused by *P. maydis* on corn plants on the island of Java.

Descriptive statistics. The first step in geospatial analysis is calculating descriptive statistics of observation data in the field. The results of calculating descriptive statistics for the Sumolawang land are shown in Table 2. The characteristics of data can be seen based on the mode, variance, range and variance coefficient values.

Table 2. Descriptive statistical values

Village	Sunday	Average	Standard error	Mode	Standard	Samples	Range	CV
	to				Deviation	Variance		
Sumolawang	1	49.14	3.69	33.33	16.51	272.67	61.82	0.34
	2	45.33	2.68	50.00	12.00	143.94	42.22	0.26
	3	59.59	2.52	61.54	11.28	127.23	35.75	0.19
	4	53.88	2.60	58.33	11.61	134.81	35.71	0.22
	5	71.80	1.85	60.00	8.26	68.16	26.67	0.12
	6	70.51	1.66	75.00	7.40	62.00	20.28	0.10
Sumbergiring 1	1	35.79	2.69	43.75	12.05	145.13	41.94	0.34
	2	45.58	1.79	50.00	8.00	64.07	33.64	0.18
	3	51.11	2.23	50.00	9.96	99.21	39.39	0.19
	4	50.44	2.06	46.15	9.23	85.28	33.33	0.18
	5	69.87	1.89	60.00	8.45	71.45	28.77	0.12
	6	67.40	2.08	61.54	9.07	45.00	31.82	0.13
Sumbergiring 2	1	40.84	2.33	53.33	10.43	108.86	36.25	0.26
	2	43.84	2.65	33.33	11.84	140.24	38.10	0.27
	3	46.32	2.79	46.67	12.47	155.42	40.59	0.27
	4	47.89	1.90	50.00	8.53	72.70	33.33	0.18
	5	75.36	1.30	80.00	5.80	33.62	17.95	0.08
	6	71.09	2.26	66.67	10,11	31.74	31.09	0.14

The mode values on all fields during the 6 weeks of observation showed an increasing trend. This indicates that the incidence of disease is increasing. The condition is caused by the development of diseases that spread through the air. All land tends to increase from time to time. The disease incidence value from the beginning of observation was classified as moderate. This is because observations do not start from the beginning of the appearance of symptoms and the affected corn plants are already at the end of the vegetative phase. The mode value provides information about the percentage dominance of disease events in each field, the variance and range values provide information about the heterogeneity of disease events in the field.

Variance and range values of Sumolawang land during 6 weeks of observation. All fields tend to have high variance and range values (heterogeneous) and decrease (homogeneous) with increasing time and plant age.

The average level of attack in the first to fourth weeks showed that Sumbergiring 2 land was the lowest with a value between 40.84 – 47.89 percent compared to other land. After the fifth week of observation, the relative increase was around 67-75 percent, this was also followed by an increase in disease homogeneity. This condition can be seen by the decreasing CV value on all land to less than 10 percent. These results indicate a uniform increase in attack rates (Pimentel-Gomes and Garcia, 2002).

This homogenization of the entire land indicates that the disease epidemic initially consisted of several foci with varying disease incidence values, then each foci experienced disease development. So that between one foci and another foci there are no clear (vague) boundaries. This condition is in accordance with the statement (Severns *et al.*, 2019) that epidemics caused by long-distance pathogens often start with one or several groups that are spatially different from infected individuals, then the disease spreads to the uninfected population and grows. This indicated that the epidemic began with a clustered pattern and over time it changed to become evenly distributed.

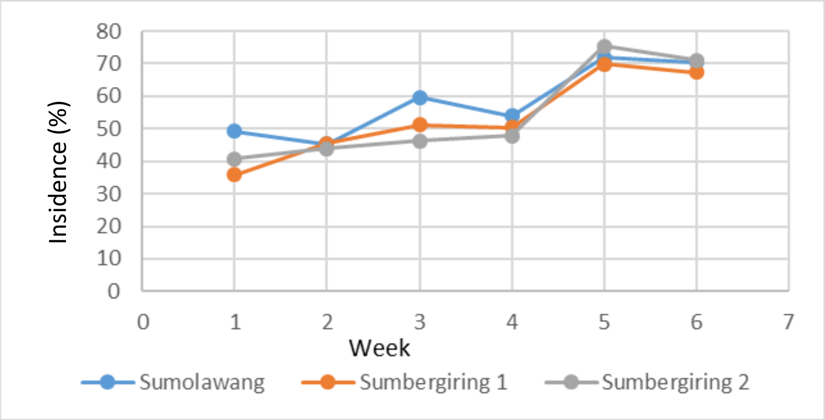


Figure 3. Development of downy mildew at several study

The development of the disease from week to week is shown in Figure 3 which shows that it increases with increasing plant age. In the vegetative phase during the first to fourth weeks of observation, development was relatively slow, but as the generative phase approached, development was relatively rapid. The three varieties planted showed almost the same development, however, when observing the four corn plants in the Sumbergiring 2 field, they developed quickly.

Geopatial Distribution of Downy mildew. Geospatial statistical methods or often called geostastic methods are used to determine theoretical semivariogram models that can represent experimental semivariograms. The results of the visual analysis show that the appropriate theoretical semivariogram model to represent the development and distribution *of P. maydis* in the observation area is the Gaussian model. After obtaining information about the accuracy of the theoretical semivariogram model, semivariogram analysis can be carried out.

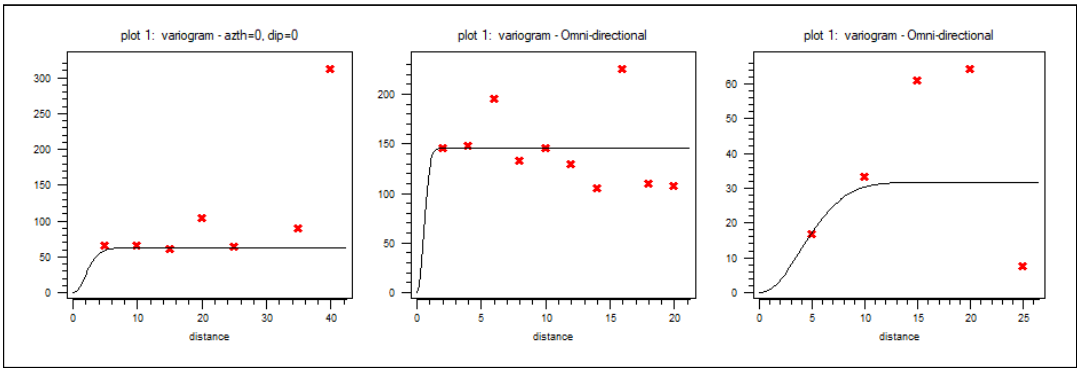
Table 3. Variogram of experimental results during six weeks of observation

Land	Model	Sill						Range					
		Week						Week					
		1	2	3	4	5	6	1	2	3	4	5	6
Sumbergiring 1	Gaussian	145	64	101	88	70	45	10.5	10.05	3.5	3.2	8	5.1
Sumbergiring 2	Gaussian	102	142	156	72	35	31	6	17	7	3	17	9.8
Sumolawang	Gaussian	272	143	128	132	69	62	19	55	11	5.6	4.9	4.9

Table 3 shows the results of semivariogram analysis on all experimental fields which have fluctuating and decreasing sill values. Comparison of semivariograms to see how disease spreads in the field (Severns *et al.*, 2019). This shows that with increasing plant age the level of disease attacks is higher and spreads homogeneously. The range values in all observations also show fluctuations, but in the Sumolawang field the range values are the highest, until the fourth observation at around 56 HST, the high range indicates a strong spatial influence from the inoculum source, however, after the fourth week of observation the range values The highest is in Sumbergiring 2 land. This means that the disease can spread widely because the plants are more susceptible.

The relationship between range and scatter power pathogen, the longer the range value, the further the pathogen can spread to infect plants. The high and low range values indicate the pathogen's dispersing ability to cause new foci at a certain distance (Figure 7).

Pathogen dispersion power is related to plant resistance, because dispersion power indicates the ability of pathogen conidia to infect a number of plants over a certain distance. The wider the range of infection caused by one foci, the plant can be said to be of a susceptible variety. Because with the influence of one foci, a number of plants up to a certain distance can be infected.



a b c

Figure 4. Results of experimental semivariogram analysis on land a) Sumolawang, b) Sumbergiring 1, c) Sumbergiring 2 at the end of the observation

The results of the semivariogram model on the Sumolawang land tend to have shorter ranges and distances than other observation lands. This indicates the small spatial influence of a plant in causing infection in plant populations over a certain distance. This low influence can be caused by several factors, one of which is the use of seed varieties. The seeds used by farmers on the Sumbergirang 2 land are P35 with moderate downy mildew resistance. The seed varieties used on the Sumbergirang 2 land are less resistant than the varieties used on other land, so the plant resistance on the Sumbergirang 2 land is lower than on other land.

The Sumolawang and Sumbergirang 1 fields in Figure 4 show that the range and distance values tend to be shorter than the semivariogram range of the Sumbergirang 2 field. This indicates that the Sumolawang and Sumbergirang 1 fields use variety seeds. resistant, NK 6172, with the property of being resistant to downy mildew, so that the effect of an inoculum in causing disease over a certain distance is lower as the spread distance increases. In contrast to the Sumbergirang 2 land which requires a smaller number of foci to cause disease in the planting area, the number of foci needed on the Sumolawang and Sumbergirang 1 land is more than the Sumbergirang 2 land.

The reduced influence of inoculum in causing disease in resistant plants is in accordance with research results (Pakki, 2017) which state that resistant varieties can suppress conidia production, reduce the source of initial inoculum, and slow down the transmission of downy mildew. On the other hand, the influence of the inoculum (foci) is stronger on the extent of disease distribution in susceptible varieties, thus analogous to the fact that susceptible plants need a small amount of foci to form large groups of symptom sources in a stretch of land.

Distribution Patterns in Various Varieties. The results of kriging of the Gaussian theoretical sermivariogram model that have been obtained are maps of the distribution of downy mildew on the observation land, both spatially and temporally (Figure 4). Maps of disease distribution on Sumolawang land can be seen in Figure 5, Sumbergirang 1 land can be seen in Figure 6, and Sumbergirang 2 land can be seen in Figure 7.

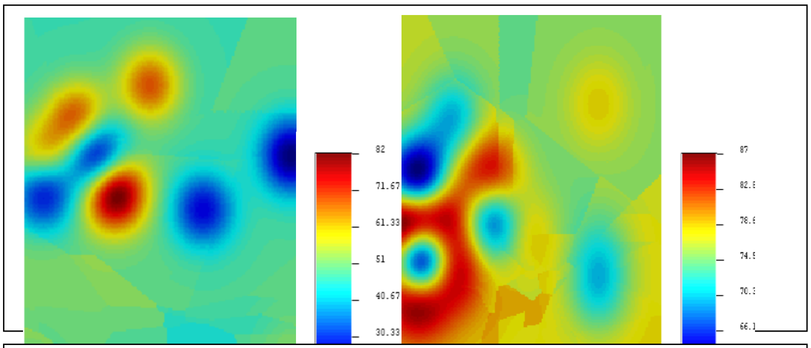


Figure 5. Map of disease distribution in corn var. NK 6172 (Sumolawang) at week 5 (left) and week 10 (right)

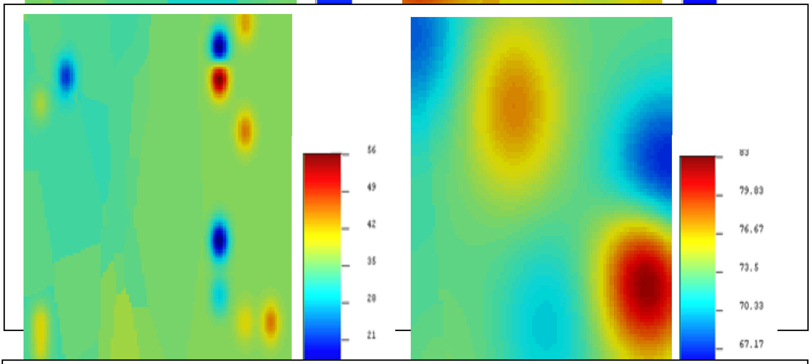


Figure 6. Map of distribution of downy mildew on var. NK 6172 Sumbergirang 1 at week 5 (left) and week 10 (right)

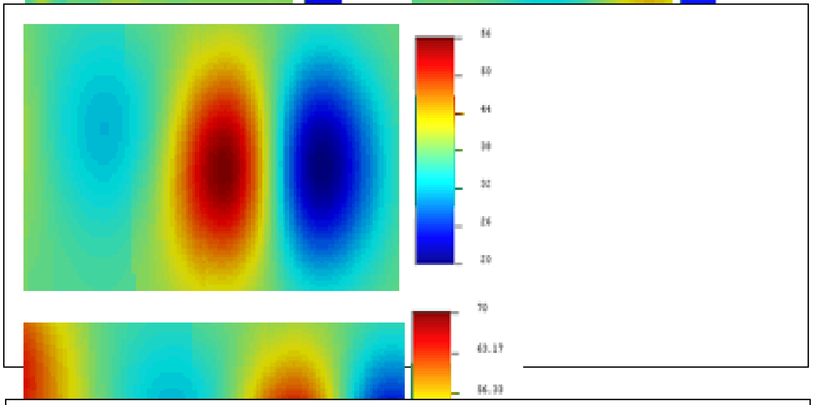


Figure 7. Map of distribution of downy mildew on var. P35 (Sumbergirang 2) at week 5 (left) and week 10 (right)

Attack Category

🟦 Very Light 🟨 Medium 🟥 Very Heavy

🟦 🟧

The spread of disease in the planting area begins with the presence of a focus of infection (foci) or *foci* (*focus of infection*) which can form a pattern of disease distribution. The focus of infection is a location that contains plant disease epidemic factors, both abiotic and biotic factors necessary for the spread of infection. Each focus of infection has an inoculum and other general characteristics such as plant population, plant cultivation and environmental characteristics that support the spread of infection. Foci found on

Sumolawang, Sumbergirang 1 and Sumbergirang 2 fields have characteristics that can be seen on the disease distribution map.

The map of the distribution of downy mildew throughout the observation area tends to have a lot of foci in the 1st to 4th week of observation, then the boundaries between foci become blurry in the 5th and 6th week of observation.

The Sumolawang land disease distribution map shown in Figure 5 shows that attacks by the pathogen that causes downy mildew in the first week of observation were still dominated by the very light attack category (dominated in blue). The highest attack in the first week reached 82%, then increased to 87% in the sixth week of observation and the map color was dominated by yellowish green to yellow likewise on the Sumbergirang 1 land.

The distribution of the Sumbergirang 1 land disease is shown in Figure 6, where the foci in the 1st week were dominated by blue, indicating that the attack was still in the very light category and the highest attack reached 56%. Then, as time increases, each foci has developed until it changes color from yellow to red. The lowest attack in the 6th week was 64% from the first week of observation, namely 14%. However, the disease distribution map is still dominated by green to yellowish green, indicating that the pathogen attack is still in the moderate category. Meanwhile, the distribution of disease on the Sumbergirang 2 land is dominated by orange to red colors.

The distribution of the Sumbergirang 2 land disease is shown in Figure 7, that the downy mildew epidemic at the beginning of the observation had a wide range of foci with various attack categories, ranging from very mild, moderate to severe. The lowest and highest attacks in the first week of observation respectively had a percentage of 20% and 56%, then each foci experienced development until they reached the highest attack in the sixth week of observation at 83%. The foci-foci on the Sumbergirang 2 land are wider than other fields so that infections on the Sumbergirang 2 land develop more easily. This was shown in the 5th and 6th weeks of observation, each foci experienced a development from initially being dominated by blue to orange to red at the end of the observation.

The foci-foci in all observation fields had a clustered pattern in the first week to the fourth week of observation. Then each foci experienced development, so that the distribution pattern changed to become even in the 5th and 6th weeks of observation. This is in line with the results of the spatial analysis in Table 2 that the distribution of pathogens throughout the observation area began with a clustered pattern until the 4th week of observation and had an even pattern in the 5th and 6th week of observation. The relationship between the development or epidemic of plant diseases the initial inoculum that spreads randomly has also been reported by previous researchers (Belan *et al.*, 2018).

The foci found on Sumolawang and Sumbergirang 1 land (Figures 5 and 6) tend to be smaller in size than the foci on Sumbergirang 2 land (Figure 7). This is in accordance with the results of the semivariogram analysis in figures 7, 8, and 9. The small size of the foci and the large number can be seen from the short range of the results of the semivariogram analysis. Meanwhile, foci which have a larger size can be seen in the wide range of semivariogram analysis results. This is in accordance with research results (Musoli *et al.*, 2008) that the effective range obtained from semivariance analysis of the host shows that diseased coffee trees can infect coffee trees up to a distance of about three adjacent trees. This distance is initially shorter, increasing as disease incidence increases

The range value in the semivariogram is very important in determining the limits of spatial dependence and can also be an indication of the interval value between sample units in mapping. The range value is also important for optimizing sampling in future mapping with precision (Pizzato *et al.*, 2014)

The size and number of foci in each observation field in this study were only based on differences in the resistance of the seed varieties used. Foci which are large in size and few in number indicate that the seed variety used in the observation field is a susceptible variety. The more susceptible the seed variety used, the easier it is for the pathogen to cause infection in plants up to a certain distance. Meanwhile, the small and large size of the foci indicates that the seed variety used in the planting area comes from a resistant variety, so it requires a certain amount of inoculum to cause a disease epidemic. The seed variety used in the Sumolawang and Sumbergirang 1 fields is a downy mildew resistant variety (NK 6172), so it requires a greater number of plants to cause a disease epidemic than in the Sumbergirang 2 field which uses the moderate downy mildew resistant P35 variety. This is in accordance with research results which state that disease development can increase if the environment is supportive and the host plant is susceptible to infection (Belan *et al.*, 2018).

By obtaining *P. maydis* aggregation map, it is possible to determine the control strategy to be applied to corn infected with downy mildew. The use of corn varieties that are resistant to downy mildew infection and the destruction of infected plants should be carried out using precision farming techniques to control damage caused by *P. maydis*. .

This research is useful for evaluating the resistance of corn varieties to downy mildew based on their distribution patterns, however, for use in other locations it is still necessary to pay attention to factors that are conducive to the development of the disease.

CONCLUSION

The Sumolawang and Sumbergirang 1 fields show that the range and distance values tend to be shorter than the semivariogram range of the Sumbergirang 2 field. This indicates that the Sumolawang and Sumbergirang 1 fields use seeds of the more vulnerable category variety, NK 6172. In contrast to the Sumbergirang 2 land which requires a greater number of foci to cause disease in the planting area, the number of foci needed on the Sumolawang and Sumbergirang 1 land is less than on the Sumbergirang 2 land. The foci in all observation fields have a clustered pattern at the start of the observation. Then each foci experienced development, so that the distribution pattern changed to become even at the end of the observation.

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