Persistence Patterns and Intensity of Leaf Rust Disease in Chrysanthemum Production Systems

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Abstract. This study aims to determine the conditions of chrysanthemum cultivation, the pattern of distribution of chrysanthemum leaf rust disease (persistence), the development of disease symptoms, and the intensity of chrysanthemum leaf rust disease at the cut flower production center in the Special Region of Yogyakarta (Sleman and Kulonprogo). The results showed that chrysanthemum farming in DI Yogyakarta is cultivated on a flat to hilly topography, and the cultivation method is simple and conventional in a plastic house (gauze). Rust disease caused by *Puccinia horiana* is found in Sleman and Kulonprogo Regency with varying degrees of severity. Chrysanthemum rust disease has random disease distribution which means that the cause of the disease is dispersed by the wind or by seeds. *P. horiana* spores are dispersed by the wind and can be caught with Kiyosawa-type spore traps at an altitude of 0.5-1.5 m from the soil surface. The highest intensity of chrysanthemum leaf rust disease is found in dense/lush plantings in susceptible varieties in Pakem Sleman at an elevation of 900 m above sea level by 85% and Samigaluh Kulonprogo at an elevation of 650 m above sea level by 58%.

1 Introduction

The chrysanthemum is one of the flowers that is very popular among the wider community because of the many types, shapes, and colors of attractive flowers. Chrysanthemums are also known as daisies or *seruni*. Today, there are more than 1,000 species of chrysanthemums growing around the world. The types of chrysanthemums grown in Indonesia are mostly the result of introductions from abroad such as from the Netherlands, the United States, and Japan. Florists name chrysanthemums as flowers of a thousand colors because current conditions are found in many kinds of chrysanthemum colors which are the result of plant breeding[1].

The economic value of chrysanthemum flowers is quite high [2]. This is evidenced by the sales value of each bunch of Rp. 25,000, - (twenty-five thousand rupiahs), higher than other ornamental plants (roses Rp. 2,000, - per stalk; gerbera Rp. 1.500, - per stalk; and nightly Rp. 1.500, - per stalk), as well as the high market demand for chrysanthemums. The data from the Directorate General of Horticulture [3] showed that the production of chrysanthemum cut flowers tends to increase, in line with increasing demand. In 2005, 2006,

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2007, 2008, and 2009, chrysanthemum production in Indonesia was 47,465,794, 63,716,256, 66,979,260, 99,158,942, and 107,847,072 stalks, respectively. The production of cut chrysanthemums occupies the first position in comparison with other commodities of cut flowers (roses, night tasty, and orchids). In 2010, the production of chrysanthemum cut flowers reached 185,232,970 stalks, with market demand increasing by an average of 10% per year. The high production of chrysanthemums compared to other cut flowers has implications for the need for seeds, cultivation technology, and types of cultivars that are quite high.

Some of the obstacles faced in producing chrysanthemums include the low adaptability of introduced chrysanthemums to the conditions of the physical environment in Indonesia, limitations in the type and color of local chrysanthemum flowers, the lack of availability of quality seeds, limited knowledge of cultivation techniques, and the threat of pest and disease disorders. A good agroclimatic for the year-round growth of chrysanthemums in tropical regions allows plant-disturbing organisms (pests) to develop, among them mealybug pests, caterpillars, leaf-scraping flies, and diseases such as leaf rust and flower rot [4]. Losses from rust disease in chrysanthemums are also felt in different countries. Turkiye reports yield losses can reach 80% [5], while in the UK yield losses reach 100% [6]. Rust disease has great potential to affect chrysanthemum production because the initial attack of the pathogen is not easily detected. Diseased plant propagation materials or propagation materials often do not show symptoms. The propagation material can be carried over a considerable distance [7]. Propagation materials carrying pathogens constitute a potential initial inoculum (X0). This study aims to determine the condition of chrysanthemum cultivation land, the pattern of chrysanthemum leaf rust disease, the development of disease symptoms, and the magnitude of the intensity of leaf rust disease in chrysanthemum planting.

2 Basic Theory

Rust fungus is an obligate parasite that usually does not kill plants, but its infection will reduce the health and strength of the plant so that it affects the production and quality of flowers, as well as reducing the aesthetic value of chrysanthemums due to the presence of pustules (rust) [8]. Rust disease is the main disease in chrysanthemums caused by the fungus *Puccinia horiana* P. Henn (*P. horiana*). The decline in the quality of chrysanthemums is supported by the statement of Kristina et al. [9] that, rust disease can reduce the freshness of chrysanthemum flowers (vase-life) to only 5 days, whereas for healthy flowers without defects, the freshness can last up to 12 days at room temperature (27–29 °C). The loss of chrysanthemum yield due to rust disease has never been calculated precisely. Yield loss is estimated at 30% due to a decrease in selling value and a delay in harvest time [4].

2.1 Chrysanthemum Morphology

Chrysanthemum cultivation in Indonesia are classified as a type of *Dendrathema grandiflorum*, Tzvlev Syn. *Chrysanthemum morifolium* [Ramat.] Kitam belongs to the Asteraceae family and Chrysanthemum genus [10]. The height of chrysanthemum plants ranges from 0.5-1 m, with erect stems of spherical shape and slightly branched. The surface of the stem tends to be rough green. The position of the chrysanthemum leaves is single, with an alternating location, oval in shape with a tapered tip, rounded base, and inscribed leaf edges. The length of the leaves ranges from 7-13 cm, with a width of 3-6 cm. The bones of chrysanthemum leaves are pinnate and thick, with a rough surface, green in color. The arrangement of chrysanthemum flowers is compound, saucer-shaped, and located in the armpits of the leaves and or the tip of the stem [11]. The midline of chrysanthemum flowers is between 3-5 cm in size, with pointed and average green flower tips. The stamens and pistils

in chrysanthemums are finely textured, are in the middle position of the flower with an oblong crown, and easily come off. Stamens are between 3-8 mm long and yellow.

2.2 Chrysanthemum Rust Disease

On the upper surface of the leaves there are white spots, which are small to large about 0.1 to 0.5 mm, while on the lower surface, spots can form pustules or deep grooves of white or pale color. Diseases weaken the plant and inhibit the development of flowers.

Rust disease develops rapidly at high humidity mainly due to dense planting and can cause chrysanthemum leaf damage up to 100% [12]. The symptoms of rust disease are easily recognized on young infected leaves, namely pustules. On the underside of the leaves, there are white-brown to blackish nodules and on the upper part of the leaf surface, there are deep grooves that are pale white. When severe disturbances lead to the inhibition of flower growth. Pustules on the undersurface of leaves infected with rust disease progressively develop and can cause damage to the leaf epidermis and at that time spore release can occur [13]. Pustules can also be located on the upper part of the leaf surface and at large sizes can give rise to necrotic areas on the leaves. Severe infections can cause leaf fall and symptoms appear to spread to the stalks and stems of plants.

3 Methods

3.1 Sites

Research in the field was carried out from May 2021 to November 2022 at the chrysanthemum production center of DIY Province, precisely in Sleman Regency and Kulonprogo Regency. The research in gauze houses was carried out from January to March 2022 at greenhouses in plastic houses with insect screen walls, located in Hargobinangun Village, Pakem District, Sleman Regency (500-900 m asl) and Sidoharjo Village and Gerbosari Village, Samigaluh District, Kulonprogo Regency (350-900 m asl). Both were in the Special Region of Yogyakarta Province.

3.2 Data Analysis Method

The data on the persistence and intensity of disease at the chrysanthemum planting level were obtained by employing surveys or direct observations of chrysanthemum plantations and interviews with farmers. Chrysanthemum plantings were surveyed with indicators of differences in agroecosystems, then were selected systematically with the main sample withdrawal unit being one chrysanthemum planting bed, and then the second example withdrawal unit was carried out namely subplots. Subsections were specified diagonally in the plot of land so that 5 subsections were obtained. In each subsection of land, the number of plants used as an example was as many as 100 plants. The observation was repeated 3 times on different overlays. The observations for disease persistence were in the main plot, while disease intensity was in the subplot.

The observed variables were:

- Land conditions. Observed land conditions included the height of the place and the way of cultivation (pruning, applying fertilizers, and the use of pesticides).
- Persistence (distribution) of leaf rust disease. The pattern of leaf rust disease in chrysanthemums was observed by observing weather conditions, such as air temperature and air humidity.

Observation of disease in chrysanthemums was carried out on fields that have been known to have a high intensity of leaf rust disease based on the results of surveys at the location of chrysanthemum cultivation centers. The plots of observation land (main plot) were made in sketches in the observation book and both healthy and diseased plants were marked with symbols for healthy plants and ★ for diseased plants. Disease persistence patterns were determined by comparing them with plant disease persistence patterns according to Brown [14] (Figure 1).

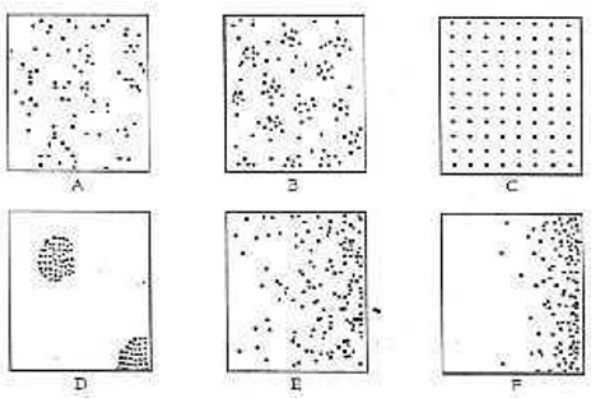

Fig. 1. The pattern of persistence of plant diseases in the field. A: random, B: aggregation, C: even or regular, D: grouping with a firm border (patch), E: flat gradient, F: sharp gradation (steep gradient)

The intensity of the disease. -- Based on the sporadic symptoms of rust disease, the intensity of the disease (I) or the percentage of infested plants was calculated by the formula according to Rahardjo and Suhardi [15] as follows.

$$I = \frac{a}{b} \times 100\% \quad (1)$$

Information:
I: Intensity of the disease.
a: the number of infested plants; and
B: Number of plants observed

To assess the severity of the intensity of the disease (in field management) a scale is used according to Hanudin *et al.* [16] as follows:

Mild attack : when the degree of disease intensity < 11%
Moderate attack : when the degree of intensity of the disease > 11% - < 36%
Severe attacks : when the degree of intensity of the disease > 36% - < 66%
Puso attack : when the degree of intensity of the disease > 66% - < 100%

The data obtained were tabulated and analyzed descriptively so that an overview of field conditions, disease persistence patterns, and the intensity of chrysanthemum leaf rust disease in the field were obtained.

4 Results and Discussion

4.1 Disease Persistence

The characteristics of the distribution of diseases in space or disease persistence in chrysanthemum planting can be seen from the spatial pattern of diseased plants at a certain time. The results of observations at several chrysanthemum planting sites showed that the symptoms of rust disease were evenly distributed on each plant. According to [17], disease persistence is the result of transmitting a number of pathogenic inoculums that come from various sources and last for a certain period of time. The spread of plant diseases on a spatial scale is a direct result of the targeting of pathogens that vary according to the type of pathogen and its space conditions. Understanding spatial patterns in disease epidemics is essential to know the role and potential sources of inoculum [18].

The results of the observation of the persistence (distribution) of chrysanthemum rust disease can be seen in Table 1.

Table 1. Results of the chrysanthemum rust disease survey (*Puccinia horiana*) at several locations.

No	Location and height of the place, m asl	Cultivars and plant age (days)	The presence of rust	Types of persistence	Disease intensity (%)	Assessment of attacks
1	Banjarsari, Pakem, Sleman, 500	Puspita Nusantara, 55	Exist	Random	15,8	Moderate
2	Wonokerso, Pakem, Sleman, 600	Fiji, 65	Exist	Random	44,5	Weight
3	Sidorejo, Pakem, Sleman, 650	Sheena, 58	Exist	Random	22,0	Moderate
4	Ngipiksari, Pakem, Sleman, 800	Kusumapatria, 40	Exist	Random	5,0	Low
5	Kaliurang, Pakem, Sleman, 900	Sakuntala, 72	Exist	Random	85,0	Died
6	Gorolangu, Samigaluh, Kulonprogo, 350	Puspita Nusantara, 35	Exist	Random	20,5	Moderate
7	Karang, Samigaluh, Kulonprogo, 650	Ratnahapsari, 85	Exist	Random	58,0	Weight
8	Karang II, Samigaluh, Kulonprogo, 700	Puspita Pelangi, 85	Exist	Random	10,0	Low
9	Clumprit, Samigaluh, Kulonprogo, 900	Mustika Kaniya, 70	Exist	Random	18,5	Moderate
10	Nglambur, Samigaluh, Kulonprogo, 1.000	Shamrock, 85	Exist	Random	30,0	Moderate

Source: research data (processed)

From the results of observations in Table 1, most cultivars of chrysanthemum plants can be attacked by rust disease with varying intensity of the attack. The spread of the disease begins in one or more plants which then extends to other plants. Viewed in the form of a plant population spatially, diseased chrysanthemum plants in one bed (bed) are random, with symptoms that appear can come from the middle, end of the bed, or plants planted near the insect screen wall (edge) (Figure 2 c). The characteristics of rust disease can be found at all research sites. This situation emphasizes that the cause of rust disease in chrysanthemums corresponds to the description according to Brown [14] and Martini *et al.*, [4].

In Table 1, chrysanthemum rust disease is found in all chrysanthemum farms with random persistence which means that the cause of rust disease (*P. horiana*) is dispersed through the wind or carried away by seeds as presented in Figure 2 [19]. The transmission of rust disease pathogens through the wind is the basis for spore capture.

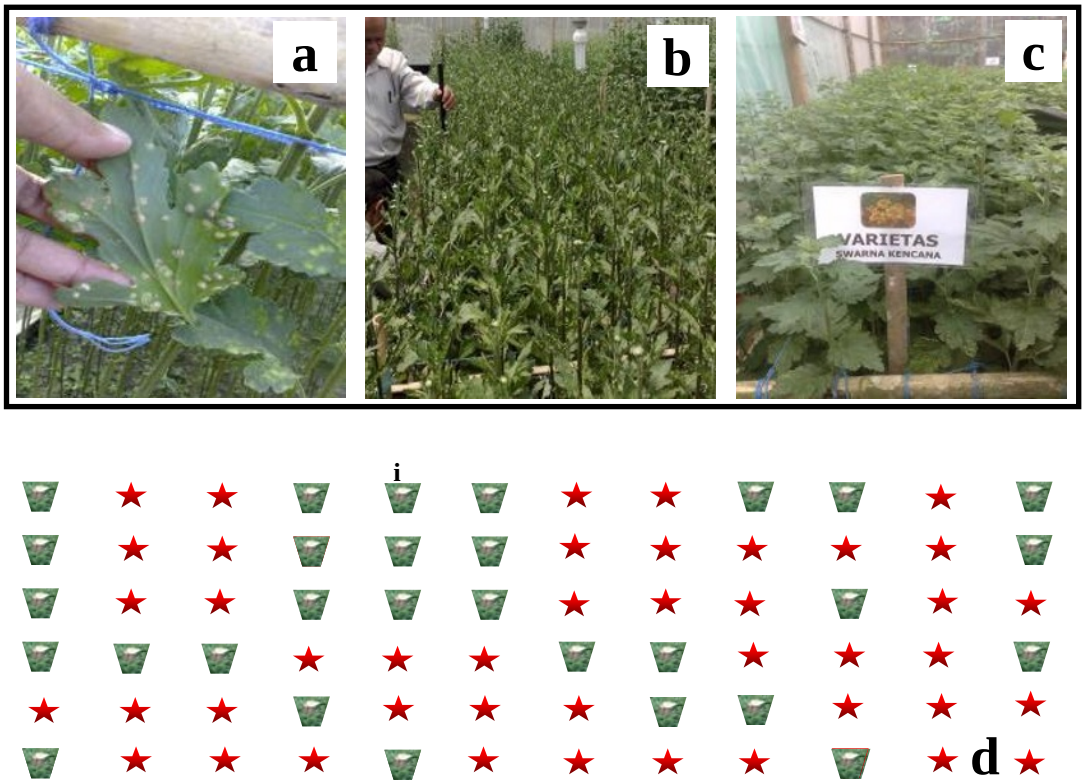

Fig. 2. Random persistence pattern of rust disease (*Puccinia horiana*) on chrysanthemums in the field (row spacing 10 cm x 10 cm): a. visible symptoms from the underside of the leaves; b. conditions in the field, c. var. Swarna Kencana (sensitive); d. Illustration of the agihan scheme, : healthy plants, : sick plants.

4.2 Spore Capture

Figure 3 shows a comparison between spore forms resulting from coarraignment from diseased tissue and spores resulting from capture. A sampling of rust symptoms on the

Puspita Nusantara cultivar chrysanthemum was carried out in January 2022 (rainy season) to coincide with the flowering phase of chrysanthemum plants, then repeated on Fijian cultivar chrysanthemums carried out in April 2022 (dry season).

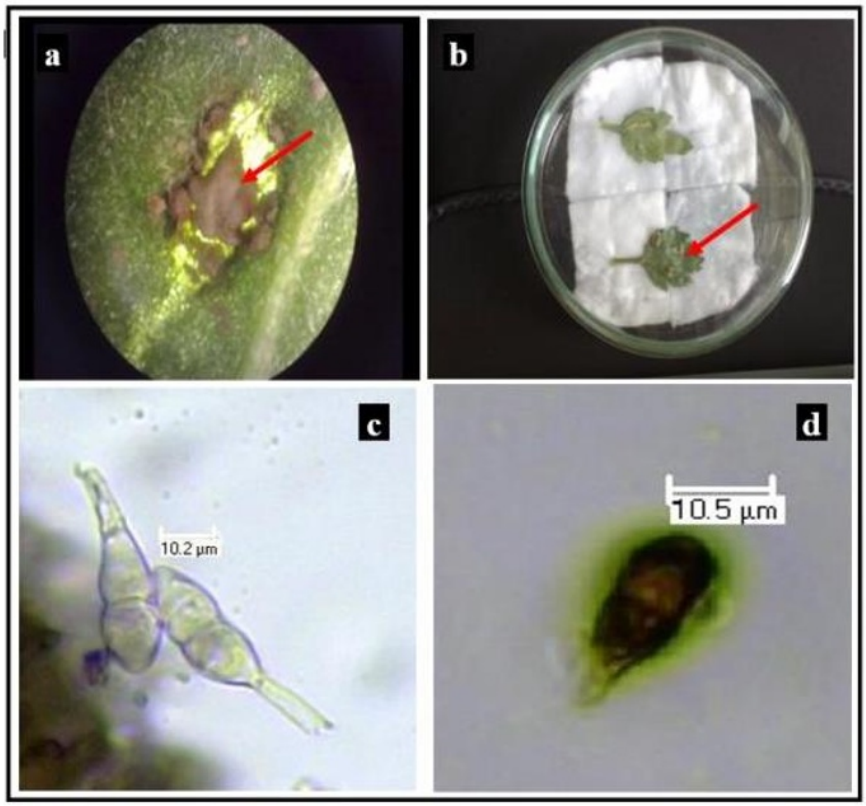

Fig. 3. Spore form *Puccinia horiana.*
a: Leaves symptomatic of rust pustules
b: Symptomatic leaves are stored on a wet cotton swab in petri dish
c: Spores corroded from diseased chrysanthemum leaves
d: Captured spores on the object's glass

From Figure 3, it appears that the spores captured are identical to the spores of *P. horiana* from the concisions, so it can be ascertained that the spores caught are the spores of P. horiana. This step is the first step to analyze the results of captured spores. Studies of rust disease in different fields and seasons were conducted to determine the relationship between the intensity of rust disease and the number of spores caught on chrysanthemums planted in different seasons.

The observation variables in this study include the intensity of the disease associated with weather factors, namely air temperature and air humidity. The data is shown in Table 2.

Table 2. The average intensity of rust disease (*Puccinia horiana*) in two chrysanthemum production centers (Puspita Nusantara variety) in DIY.

Location	Altitude of place (m asl)	Block (Hamlet)	Moisture (%)	Temperature (°C)	Average number of spores caught	Disease intensity (%)
Pakem, Sleman	500	1 (Jetisan)	74,20 a	27,64 a	8,33 a	17,45 a
	600	2 (Wonokerso)	75,86 a	26,40 a	19,00 a	17,82 a
Samigaluh, Kulonprogo	700	1 (Karang)	91,66 b	25,03 a	14,00 a	45,50 b
	900	2 (Nglambur)	92,66 b	22,53 a	20,00 a	53,55 b

Data followed by the same letter in the same column, showing no noticeable difference in the degree of confidence 95%.

The data in Table 2 were then analyzed with a t-test, to determine the difference in disease intensity between locations. In Table 2, it can be seen that the intensity of rust disease in Samigaluh, Kulonprogo is relatively higher than the intensity of rust disease in Pakem, Sleman in the same variety Puspita Nusantara. This variety is known to be a variety that falls into the category of *Phakopsora pachyrhizi* resistance to the pathogen *Puccinia horiana* [20]. The intensity of rust disease is influenced by different field conditions, temperatures, and humidity. This is in line with what was stated by Zadok and Schein [21], that the threshold of plant disease damage varies with the location, season, and scale of the farm.

The research site in Samigaluh District is an area in the Menoreh mountains that relatively has a colder (low) daily temperature compared to the Pakem District in Sleman Regency, which is at the foot of Mount Merapi. The volcanic material of Merapi, which spread over various elevations, has weathered and developed into soil rich in nutrient minerals such as andisols and inceptisols. The mineralogical composition of Merapi lavas consisted of feldspars and pyroxene minerals which are easily weathered and have a high potential as nutrient reserves in the soil [22]. The amount of variation in weather elements in Samigaluh District, Kulonprogo Regency is the air temperature of 22.53-25.03°C and the humidity of 91.66-91.66%. In the Pakem Subdistrict, Sleman Regency has successive amounts of air temperature and humidity of: 26.40-27.64°C and 74.20-75.86% (Table 2). In this study, the temperature range shown between the four locations was around 1-3°C. This suggests that there are noticeable differences in air temperature and humidity between locations. The difference in research locations can be seen from the data on the height of the place of each location (village). The highest temperature range between 900 m and 500 m is 5.11°C. Meanwhile, the humidity range between 900 and 500 m above sea level is 18.46%. According to Marwoto [10], chrysanthemums can grow at daily temperatures of 17-30°C and humidity above 60%. This shows that chrysanthemum rust disease is suspected to always be on the chrysanthemum farm, due to the growing requirements it requires. According to Afriani., *et al* [22], chrysanthemum plants generally require conditions of high air humidity. Young to adult plants generally grow well at an air humidity of 70-80%. According to the results of research by [25], the optimal air humidity requirement in chrysanthemum cultivation in DIY is at an altitude of 700 m with a humidity of 72.58%.

The intensity of rust disease is higher at high humidity in Samigaluh, Kulonprogo, which is 45.50-53.55% compared to the intensity of rust disease in chrysanthemums planted in

Pakem, Sleman by 17.45-17.82%. According to Ramlan & Nurjanani [26], the epidemic of rust disease in soybeans is supported by the length of wet leaves with temperatures less than 28ºC. Spore germination and spore penetration require free water and occur at a temperature of 20-28ºC. Long humid conditions and cold periods are needed to infect the leaves and sporulation. Chrysanthemum plantations in Pakem District and Samigaluh District are at an altitude of 350 to 900 m above sea level, with a temperature range between 19-31ºC, accompanied by long leaves wet both by fairly high dew due to morning fog and rain that splashes into the chrysanthemum plants. This condition provokes an epidemic of rust disease in chrysanthemums.

The intensity of the disease in Kulonprogo belongs to the severe category, while in Sleman it is mild. Thus, rust disease in Samigaluh district, Kulonprogo needs special attention and serious management because it has the potential to cause heavy damage and even puso. The seed source of chrysanthemum plants as a source of plant propagation needs to be studied because rust disease (*P. horiana*) is an obligate parasite. According to Martini [4], *P. horiana* basidiospores are very fragile, and easily spread by wind or water splashes, while their teliospores can last for 8 weeks when still in the substrate at a humidity of 50% or less. In humid conditions, teliospores will germinate to produce basidiospores. When the humidity is 81-90%, basidiospores can last for 60 minutes. Chrysanthemum development sites in Yogyakarta Province have weather conditions that correspond to the development of rust disease spores. Such a situation causes the pathogen to continue to survive and be able to develop so that the region is included in the endemic region [27]. The presence of a potential host, an infective pathogen, accompanied by a supportive environment, has a great influence on the presence and severity of the disease. Therefore, it is necessary to regularly monitor the presence of rust disease spores in the field. According to Martini [12] one of the very important things in disease epidemics is the presence of inoculum dispersed from infected plants. The results of spore capture from chrysanthemum planting sites in Sleman Regency and Kulonprogo Regency obtained several forms of spores caught in a glass of a vaseline object. All observed object cups have some sort of spore shape captured as shown in Figure 4.

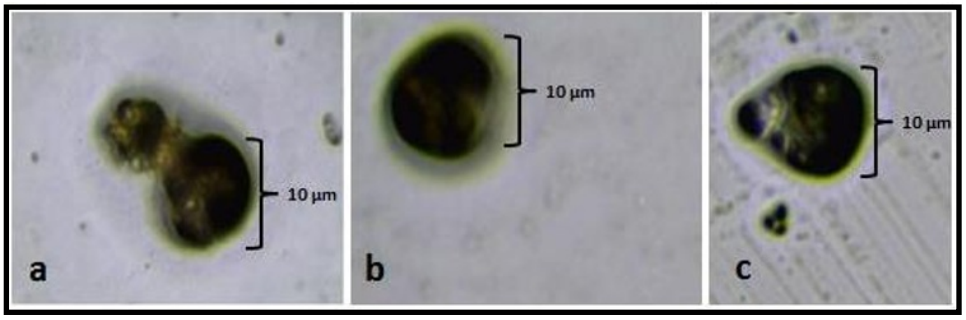

Fig. 4. Spore forms of *Puccinia horiana.*

5 Conclusion

Based on the results of the research and discussion that has been described, the following conclusions can be drawn:

1. Rust disease caused by *Puccinia horiana* is found in Sleman and Kulonprogo Regency with varying degrees of severity. Diseases are found from the time they arrive in the field.
2. Chrysanthemum rust disease has random disease distribution which means that the cause of the disease is dispersed by the wind or by seeds.
3. *P. horiana* spores are dispersed by the wind and can be caught with Kiyosawa-type spore traps at an altitude of 0.5-1.5 m from the soil surface. Spore dispersal occurs in the morning, afternoon, evening, and evening or at any time, either on the observation of the transition from the rainy season to the dry season or in the dry season to the rainy season.
4. Leaves in the lower third near the soil surface are the most pathogenic when compared to the upper leaves.

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