Identified diseases would threaten on the expansion of Amorphophallus muellery Blume cultivation in Indonesia

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Abstract. As one of the important agribusiness crops, Amorphophallus muelleri Blume's cultivation areas, locally known as "porang", have significantly increased in the past recent years. The increase in cultivation area has been triggered by the significant rise of corm price and by the government program for enlargement of the porang cultivation. Consequently, farmers would eventually grow the porang on open agricultural land. As a result of cultivation expansion, an increase in corm production is required to meet export demand. Like other tuber crops, which have been cultivated on large and open areas in Indonesia, the porang plant would similarly experience severe damage and even a failure of harvest due to the diseases. The present field observation found infections caused by fungi (Phytophthora colocasia and Sclerotium rolfsii) and a plant virus significantly reduced the corm yield. The paper presented the first report of the diseases on the porang plant. Thus, the expansion of the porang cultivation area in Indonesia would be challenged by the infestation of these diseases.

1. Introduction
Amorphophallus muellery Blume, locally known as "porang" was considered an under-utilized tuber crop in Indonesia. Nowadays, however, porang has been one of the important commercial crops. The products of porang, e.g., chips and flour, are exported to some countries, such as Japan, China, Korea, and Australia [1 – 4]. Its value in maintaining human health and alleviating some human illness [5-10] might have driven an increasing demand for porang from importing countries. Consequently, the domestic price of porang fresh tuber (corm) is much higher than the price of sweet potato and fresh cassava tubers. Our field observation found the price of fresh porang corm at present was approximately IDR 10,000-12,000 kg⁻¹.

In Indonesia, porang plant has been naturally cultivated in the forest under some shading by trees. Under this farming management, the National production of porang corm has not met the market demand. Enlargement of porang cultivation areas could be one of the ways to increase porang national output significantly. The Indonesian Ministry of Agriculture has introduced a program supporting porang cultivation enlargement and increasing corm production in Indonesia [11]. This government endorsement and porang plant ability to grow generally on Alfisol soil without shading [12] would succeed in expanding porang cultivation on open-farming areas. As a result, a significant porang corm production would be achieved to meet the export demand.

However, sweet potato, cassava, and other crops cultivated on larger and open-farming areas have been deleteriously damaged by pests and diseases. Growth, yield, and economic reduction due to pests and diseases infestation have been well-documented [13–15]. Elephant foot and taro plants (Araceae
family) were also reported to be devastatingly infected by some diseases, like *Sclerotium rolfsii*, *Phytophthora colocasiae* and Dasheen mosaic virus, when grown on large and open areas [16–18].

Porang, belong to the same family as elephant foot yam, might also be challenged by significant disease infestation when cultivated on large and open farming areas. However, unlike on other tuberous crops, observation and studies of diseases on porang plants have not been extensively carried out. Some researchers observed diseases caused by nematode and fungi, infested porang plants and could potentially cause yield reduction and economic loss of porang [19–21]. Fungal disease on porang was reported to be effectively controlled by application of Fludioxonil (50% WP) and Boscalid (50% WG) [22]. The study aimed to identify a few diseases and damages on the porang plants grown in the glasshouse and on farmers field within forest trees stands.

2. Materials and methods

The present observation monitored the presence of diseases on porang (*Amorphophallus muelleri* Blume) at farmers field, Probolinggo–East Java and on porang plants at the Campus of Indonesian Legumes and Tuber crops Research Institute, Malang–East Java, Indonesia. The work was done during the growing season of porang, from December 2019 to April 2020. The disease observation in Probolinggo regency was done in 5 different fields. One farmer-owned each area. Porang plants were grown under *Albizia chinensis* trees in each field. The age of Albizia trees was reported by farmers to be 4 years. At the same time, porang plants in the observation area were in the third year of the growing season. The population of porang plants varied from 2,500 to 5,000 plants, depending on the farmer's field size. At the time of observation, organic matter derived from leaves and twigs of sengon trees was found on the field surface. Additionally, organic materials from weeds were sometimes gathered around porang.

The disease incidence at the Campus of Indonesian Legumes and Tuber crops Research Institute was monitored on porang plants grown on polyethylene bag containing growth medium of Vertisols and composted fecal organic materials cow (1: 1 by volume). Porang plants were kept in the glass-house and under mahogany (*Swietenia macrophylla*) trees. The number of porang was 100 plants in the glasshouse and 100 plants under mahogany trees.

The appearance and development of the disease on porang in the glass-house and in the farmers field were monitored every two weeks. The disease symptoms and damages due to the respected diseases were characterized and photographed as proof of the disease infestation. Whenever possible, the yield reduction of porang damaged by some disease was quantified from at least three plants for each porang sites. The yield reduction was measured by employing the Standard Deviation of three replicates. The diseases observed on porang plants were consulted with the plant pathologist to identify the diseases' names. Besides, disease names were identified on the basis of the symptoms as well as by *in vitro* evaluation.

3. Results and discussion

3.1. Taro leaf blight (*Phytophthora colocasiae*)

Taro leaf blight caused by *Phytophthora colocasiae* mainly infected plants belonging to Araceae, including *Colocasia esculenta* (taro) and *Alocasia macrorrhiza* (giant taro), and its infection was limited to the foliar part of the plants [23]. The rapid growth of the pathogen was observed at temperatures from 27 to 30°C. The disease symptoms cover the small, dark brown flecks or light brown spots on the upper leaf surface [23]. The symptoms often take place at the tips and margins of leaves and rapidly develop. Finally, holes are generated on the leaves.

Porang (*Amorphophallus muelleri* Blume), belonging to Araceae, naturally grows at temperatures 27 to 33°C in Indonesia. Thus, porang plant would also be prone to *Phytophthora colocasiae* infestation. The present observation showed that porang plants infected by a fungal disease, especially those planted in the glass-house, are considered an open farming environment (figures 1A, B, C). The symptoms exhibited by the infected porang plants were similar to the disease symptoms in taro infected by *Phytophthora colocasiae*. Figures 1A, B and C depicted the infection which occurred at the early growth
stage of porang. Initially, the symptom developed on the tips of leaves. The brown color began from the leaves' edge and expanded towards the leaves' inner side (figure 1A). The edge of leaves folded at further developed symptom (figure 1B) and subsequently, the whole leaves turned to brown color (figure 1C). The petiole of porang also died, suggesting that the disease also damaged petiole (figure 1C). Under this condition, the corms of porang were not produced, meaning the failure of the harvest. Interestingly, porang plants grown within trees' stand did not show such damage and looked healthy (figure 1D). Less sunlight and lower temperature within the stands of trees might lead to less occurrence of the disease.

![Figure 1. The disease symptoms on early growing stage of porang (Amorphophallus muelleri Blume). A). Early symptom, B). Further developed symptom, C). Porang plant was dead and D). Healthy porang plants.](image)

Figures 2A, B, C and D showed the symptom on an individual leaf of the 3 months porang plant. Initially, yellow color followed with brown color developed on the edge of the leaf (figure 2A). Further, the brown color developed larger and extended toward the leaf's inner side (figure 2B). Within the developed brown color symptom occurred the white spots, which finally formed holes (figure 2C). At the last stage of disease symptom development, mycelia and sclerotia were formed (figure 2D).

![Figure 2. The disease symptoms on porang at age of 3 months (Amorphophallus muelleri Blume). A). Early symptom, B). Further developed symptom and C). Leaf folded and holes generated and D). Mycelia and sclerotia of the pathogen.](image)

The fungal disease (*Phytophthora colocaciae*) infested porang plants grown in the glasshouse or farmers field without shading at a later stage, around 3 months after transplanting (figure 3). Interestingly, as shown in Figures 3A and B, the disease infected and damaged the first and the second shoots of porang grown in the glasshouse. The third and so forth showed the symptom infection even though they were on the same pot. This fungal disease's devastating infection caused porang plants to produce smaller corm (figure 3C left). The fresh weight of corm produced by healthy and damaged porang plants was 133g and 16g, respectively. Thus, the damage by *Phytophthora colocaciae* reduced
approximately 88% of corn yield. The degree of disease damage would indeed determine the degree of corn yield reduction. The result of this present investigation suggests that the disease caused by *Phytophthora colocacae* could be considered as a severe constraint to porang production in open fields.

![Image 1](image1.png)

**Figure 3.** The disease symptoms on later growing stage of porang (*Amorphophallus muelleri* Blume). A). Early symptom, B). Magnified symptom of A and C). Corm produced by the infected porang plant (left) and by healthy porang plant (right).

### 3.2. Collar rot (*Sclerotium rolfsii*)
*Sclerotium rolfsii* is a soilborne fungal plant pathogen that produces abundant white mycelium on infected plants and is known to attack various plants, such as tuber crops, vegetables, fruits, legumes [24–27]. Figures 4A, B, C, D, and E showed mycelium of pathogen densely colonized basal shoots of *Canavalia ensiformis* (L.), groundnut, tomato, sweet potato, and elephant foot yam [24–28]. Massive colonization resulted in the rottling of the basal shoot and caused shoots to lodge.

![Image 2](image2.png)

**Figure 4.** Densely colonization with mycelia of *Sclerotium rolfsii* on basal shoot of jack bean (*Canavalia ensiformis* (L.) (A), groundnut (B), tomato (C), sweet potato (D) and elephant foot yam (E).

#### 3.2.1. The damage of the above-ground porang plant by collar rot (*Sclerotium rolfsii*)
Figures 5B, C and D presented diseases found on porang grown at farmers’ field in Probolinggo were presented in. By comparing the colonizing mycelium in porang (figures 5 B, C and D) to the colonizing mycelia in jack bean, groundnut, tomato, and sweet potato and elephant foot yam (figures 4 A,B,C, D and E), the colonizing mycelium on porang was undoubtedly produced by *Sclerotium rolfsii* (figures 5B, C and D). The result of our observation assured that collar rot (*Sclerotium rolfsii*) infected and could severely damage porang plant. Quantitatively, the number of porang plants damaged in farmers’ fields due to this disease was approximately less than 25%. At the time of observation, the age of porang plants were about 4 months. The healthy plant (figure 5A) grew uprightly, and the color of the shoot and leaves
remained green. On the other hand, the heavily damaged plants lodged and showed yellowish to brownish color on petioles and leaves (figures 5B, C and D). The lesion due to abundant colonization of the fungal disease as observed on figures 5B, C and D caused porang plants lodging.

As mentioned above, the farmers’ field was heavily covered with tall grasses and short grasses. The weeding was done by pulling the grasses out. The grasses were then piled up near the basal shoot (petiole) of porang as farmers’ practice (see figures 5 B and C). Along with the rotting of grasses around the basal shoot of porang, the mycelium of *Sclerotium rolfsii* was growing and infecting the basal shoot of porang. The pile-up of grasses around the basal shoot of porang induces the humidity to increase and created a favorable condition for *Sclerotium rolfsii* to overgrow and infect the basal shoot porang. The porang basal shoots without covering with grasses did not result in infection by the disease (figure 5A). Therefore, the grasses after the weeding should not be put around the basal shoot of porang in order to minimize infection by *Sclerotium rolfsii*.

![Figure 5](image5.png)

**Figure 5.** A. Healthy porang (*Amorphophallus muelleri* Blume), B. Lodged porang due to disease at basal shoot, C) basal shoot of porang densely colonized with mycelia of *Sclerotium rolfsii* and D). badly lesion due to the attack of *Sclerotium rolfsii*.

![Figure 6](image6.png)

**Figures 6A, B, C and D** are organic materials in the soil colonized by mycelium of, corm left in the soil colonized by mycelium of *Sclerotium rolfsii*, porang corm damaged by and porang corm in the soil badly destructed by *Sclerotium rolfsii*, respectively.

3.2.2. The damage of porang corm in the soil by collar rot (*Sclerotium rolfsii*). The present fieldwork also observed the growth of mycelium of *Sclerotium rolfsii* and the pile-up of organic materials in the soil (figure 6A), suggesting that organic materials in the soil are sources of food for *Sclerotium rolfsii*. Porang corms left in the soil after the harvest are considered organic material and were subjected to fungal destruction. Figure 6 B depicted colonization of porang corm by mycelium of *Sclerotium rolfsii* in the soil. Due to massive destruction by mycelium of *Sclerotium rolfsii*, a big porang corm hole was generated (figure 6C). Figure 6D showed severe corm damaged in the soil. White mycelium was noticed next to the damaged corm. Such destructed corm would not germinate in the following growing season. Badly destroyed corms in the soil would eventually decrease the number of porang population in the next growing season. The information from farmers on the significant decrease of their porang population season by season is probably due to this fungal infestation on porang corm left in the soil.
3.2.3. The damage of porang corm and bulbil in the storage by collar rot (Sclerotium rolfsii). Bulbils and small corms of porang were used as planting materials. Before being used, bulbils and corms were usually stored at room temperature. During storing, fungal disease Sclerotium rolfsii was observed to infest these planting materials. Tiny amounts of soil debris attached to bulbils and corms could be a source of the disease and could cause the development of Sclerotium rolfsii during storing (figure 7). The appearance knew the infestation of mycelium coverage on bulbils and corms (see figures 7 B and D). Severe disease infection could result in serious destructed bulbils and corms of porang. The destroyed bulbils and corms lowered the quality of corms and bulbils as planting materials. As a result, the bulbils and corms could not be used as planting materials.

![Figure 7](image_url)

**Figure 7.** Effect of soil born Sclerotium rolfsii on the damages of bulbils and corm of porang (Amorphophallus muelleri Blume) during storing at room temperature. A= Healthy bulb, B= infected bulbil by Sclerotium rolfsii, C= Healthy corm and D= infected corm by Sclerotium rolfsii.

3.3. Viral disease

In the present observation, porang plants were kept close to the soybean plants in the glasshouse of ILeTRI. Soybean plants were densely populated with whiteflies, Bemisia tabaci. The severely infected soybean showed curly leaves and shorter plant height, indicating the symptoms related to viral infection (figure 8A). The virus could be transmitted by Bemisia tabaci that seriously infected soybean. After the harvest of soybean, whiteflies moved and infected some porang plants placed next to soybean plants. A high population of whiteflies caused curly leaves and shorter plant height (Figure 8B). The symptoms revealed by the whiteflies-infected porang were similar to the symptoms of the whiteflies-infected soybean. Some porang plants uninfected by the Bemisia tabaci looked healthy, normal leaves, and normal plant height (figure 8 C). The present observation result revealed the first information that the viral disease transmitted by Bemisia tabaci to porang plant could be the same as the viral disease transmitted by Bemisia tabaci to soybean.

Bemisia-viral-infected porang and healthy porang plants, as depicted in figure 8B and C, produced a corm of 24 g plant\(^{-1}\) and 190 g plant\(^{-1}\), respectively. Thus, corm yield was reduced by 87% due to damages by Bemisia-viral disease observed at the present work. Additionally, figure 8B also showed a reduction in porang plant growth, as indicated by the shorter plant height (dwarf plant). Viral diseases were previously reported to hamper the growth and yield of soybean [29]. Elephant foot yam, belonging to the same family to porang, was reported to be infected by viral diseases and showed various symptoms like mosaic, mottling, puckering, stunting, and filiform/shoestring in India [30]. Thus, the presence of whiteflies on porang plants must be observed periodically and sprayed by appropriate pesticides to prevent viral disease transmission. Besides, the planting of porang and soybean or other more sensitive crops to whiteflies infestation, e.g., in the intercropping system, needs to be avoided. Otherwise, the intensive measure by spraying with appropriate pesticides is vital to be employed.
Figures 8A, B, C and D are curly leaves of soybean severely infected with *Bemisia tabaci*, curly leaves of porang due to severely infected with *Bemisia tabaci*, healthy porang leaves and corm fresh weight of Bemisia-viral infected and healthy porang plants.

4. Conclusions

Fungal and viral diseases were commonly infected the porang plants. More appearance of viral and fungal diseases was found to be in an open farming area. Appropriate measures are essential to be applied to prevent severe damages from the diseases. The fungal identified was *Phytophthora colocasia* and *Sclerotium rolfsii*. *Phytophthora colocasia* was observed to damage leaves and petioles of porang during the growing period. *Sclerotium rolfsii* infested porang plants, corms left in the soil, corms, and bulbils stored under room temperature. Porang infested by *Bemisia*-transmitted viral disease showed similar symptoms to soybean infected by Bemisia-transmitted viral disease.

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