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THE IMPACT OF TARO LEAF BLIGHT (*PHYTOPTHERA COLOCASIA*) IN THE MALDIVES

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Abstract: Taro had been selected and vegetative propagated as a staple food in many parts of the world including the Maldives. In Maldives taro had been used as a staple food, even though its' production has comparatively slowed down since the early 2000's. Taro remain an underutilized crop due to the little attention attached to it and due to scarcity of land available for production. Also the susceptibility to many diseases including Taro Leaf Blight (TLB) caused by the fungus *Phytopthera colocasia*; it poses a potential economic impact of food security to many taro growing regions. This paper provides an overview of TLB in the Maldives, its origin, distribution, biology, management and its impact on the community. The paper will largely focus on a field study which was conducted in Hithadhoo of Addu City, with the aim of finding the prevalence of TLB; and also the impact TLB on the growth and yield of taro. Incidence and severity of disease was found by selecting taro plants randomly from the study site. The plants were observed, photographed and analyzed using MATLAB disease grading software. The diseased grade of taro is 0.56. The percentage incidence of the disease in this area was recorded to be 36.7%. This study revealed the presence and low incidence of taro leaf blight in the study site. The disease severity was found to be low. The research concludes that with proper care and management of disease at the early stages, taro leaf blight in this area could be effectively controlled.

Keywords: Colocasia esculena, *Phytopthera colocasiae*, taro, taro leaf blight

INTRODUCTION

In the Maldives, agriculture industry is small in comparison to other countries of the world, but it produces significant amount for the local consumers. It has not been able to perform to its full potential, due to scarce land, poor soils and prevalence of pest and diseases. Also the capacity to exploit the full potential of traditional food crops such as breadfruit, cassava, plantain and taro is also lacking. Furthermore, the country does not have adequate resources for research and development of traditional crops and commercially grown fruits and vegetables.

Taro (*Colocasia esculenta* (L.) Schott) is one of the world's oldest root crops (Ubalua, Ewa, & Okeahgu, 2016) and considered to be of edible aroids and an important food crop in the family Aracea. It is of economic and cultural significance to many countries in the Asia, Pacific, and Africa. Taro is known as cocoyam in Africa, dasheen, eddoe, malanga in Asian countries, kalo in Hawaii, and dalo in Fijji. Global taro production reached 10.1 million tonnes harvested from 1.6 million hectares in 2016, resulting in an average yield of 6.1 tonnes per hectare. In 2017, 10.1 million tons harvested from 1.5 million hectares, resulting in an average yield of 6.945 tons per hectare. Nigeria is the largest producer with a global share of 32.4%, followed by China, Cameroon, Ghana, and Papua New Guinea (PNG).

Taro is a culturally significant, ethnic commodity having traditional uses in main meals and is prized by many Maldivian households. In 2016 Maldives taro production was at 103 tonnes with an average yield of 58.5 hectograms per hectares (he/ha) (FAOSTAT, 2018). TLB can reduce yield of the corm by up to

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50% and leaf yield by up to 95%. Additionally, the consequences of leaf area reduction by onset of TLB leads to corm rots which develops rapidly after harvest (Singh *et al*., 2012). This leads to heavy losses of taro.

Despite the many challenges, as a locally grown food crop, it has great potential to survive and it has the potential to supplement other foods in daily household use. With the world's population projected to increase by 2050, there is a demand in increased food production and greater diversification of crops. Taro belonging to roots and tuber crops and is an important root crop providing energy for over 500 million people worldwide mostly in the tropics (Tarla, Bikomo, Takumbo, Voufo, & Fontem, 2016; Ubalua *et al*., 2016).

Taro is an herbaceous plant consisting of a central corm from which leaves grows upwards and roots grown downwards and cormels (small corms) grow laterally. Leaves arise from the apex of the corm. Each leaf consists of a long erect petiole and a large lamina. The attachment of the lamina is peltate meaning that the petiole is attached at the middle of the lamina which is a characteristic of the taro (Garedew & Ayiza, 2017). The inflorescence in taro is occasional and is made up of a spathe (Onwueme, 1999).

Taro is susceptible to a number of pests and diseases including TLB, leaf hoppers, mite and root rot disease (Ubalua *et al*., 2016). Leaf blight of taro, caused by *Phytophthora colocasiae* is a water mold (oomycete pathogen) whose origins are thought to be in South East Asia (Singh *et al*., 2012). TLB is mainly a foliar pathogen, although postharvest storage rots also occur (Nelson, Brooks, & Teves, 2011). In the tropic due to the favorable temperatures and regular periods of wetness promotes the disease by favoring dispersal, infection and disease development (Singh *et al*., 2012). It is a major disease that threatens the sustainability of taro production (Miyasaka, McCulloch, & Nelson, 2012). The disease significantly reduces the number of functional leaves by reducing photosynthesis and can lead to corm yield reductions of the magnitude of 50% (Nelson *et al*., 2011). The yield losses can range from 50 to 60% under severe conditions and susceptible varieties are destroyed (Brooks, 2008).

Outbreak of TLB, is now one of the major cause of destruction to taro. Taro is vegetative propagated, hence, it is vulnerable to TLB and the eradication of this blight is very difficult as it thrives in the taro growing conditions and impacts whole of the fields where taro is being grown (Brooks, 2008). TLB has been a destructive disease in the Pacific and South East Asia over many decades and has reached many taro growing areas. Food security has been threatened in these regions where TLB outbreaks have occurred and more so as the disease is difficult to manage through conventional means (Tom *et al*., 2012).

In order to make calculating and grading disease severity, a single-leaf disease severity automatic grading system dependent on image processing was created by using MATLAB GUIDE platform. Using this system, it would require little effort and time to grade leaf samples. This system uses techniques such as image segmentation and processing technologies and algorithms on a diseased plant leaf to automatically calculate and grade it (Li, Ma, & Wang, 2013).

There is little to be done to prevent a severe epidemic of TLB if the pathogen is present, as the environmental conditions are favorable for the disease development (Nelson *et al*., 2011). Maldives environment is favorable to TLB and hence the severity of the crop loss is considered to be huge. Several measures to address the TLB outbreak has been organized by MoFMRA in the past few years. This study, therefore, sought to identify the detrimental effects of TLB while addressing the diversity of the taro species in Maldives, its relation to the Maldivian community, and ways it can be conserved in an already deteriorating habitat.

METHODOLOGY

The study area

The study was a regional study that covered the southern region of Maldives including Seenu atoll, Gnaiviyani atoll and Gaafu Dhaalu atoll. The main focus of this study using field survey was in Hithadhoo of Seenu atoll.

Hithadhoo is located within longitude 73° 04′ 59.99″ E and latitude 0° 36′ 0.00″ N at the southernmost atoll of the country. Field observations for taro samples were conducted in taro fields from *Odassau*, Hithadhoo. Maldives Meteorological Center reports that during the last quarter of the year 2020, the southern-most atolls received an average rainfall of 90% - 110% but moderately higher rainfall than central and northern atolls. Average rainfall was at 222 mm with a highest mean temperature of 30°C and lowest mean temperature of 26°C (Maldives Meterological Service, 2020). The major vegetation types in Hithadhoo are the mangroves and tropical vegetation.

Field survey and data collection

The data was obtained from the site during the harvesting period of the taro crops. The harvesting period was six months after planting.

Figure 1: Study site (Odassau, Hithadhoo, Addu)

From the study site, thirty taro plants were selected randomly and were assessed for the presence or absence of taro leaf blight. Leaves showing early stage of infection (water-soaked lesions and yellowing of leaves as shown in figure 2A) and leaves showing late-stage infections (large brown patches with completely yellowed and wilted leaves as shown in figure 2B) were observed and confirmed and then counted as diseased leaves. If the plant contains no diseased leaves, it was not counted as an infected plant. Computation of disease incidence was determined according to the formula of Van der Puije, Ackah, & Moses, 2015 as:

Percentage disease incidence (%) = (Number of Infected plants / Total number of plants) × 100

The occurrence was evaluated on a 0 – 100% incidence of taro leaf blight scale.

Determining taro leaf blight severity

From the same study site, another thirty plants with infected leaves were randomly selected and symptoms such as patches on leaves with light brown and dark brown color were observed. From those thirty plants one leaf with disease symptoms was photographed using a Canon DSLR camera. The disease severity index was calculated using software MATLAB, Graphical user interface (GUI) leaf disease severity grading software.

The software comprises disease severity scale developed by Horsfall and Heuberger. (Bechem & Mbella, 2019). The software automatically calculates the total area of the leaf and the disease area of the leaf. Then, it grades according to the scale.

Table 1: Disease severity scale developed by Horsfall and Heuberge (1942) adapted from(Bechem & Mbella, 2019).

Category	Severity
0	Apparently infection-free;
1	Trace-25% leaf area infected;
2	26-50% leaf area infected
3	51-75% leaf area infected
4	>75% leaf area infected

Since the data collected were limited, they were subjected to analysis to obtain descriptive statistics (percentage, mean, minimum and maximum) only using the statistical package in Microsoft Excel 2013. Therefore, the validity and reliability were only checked through the descriptive statistics that were obtained.

RESULTS

Field observations

From the study, several symptoms of the disease were identified on the leaves and petioles of the plants (figure 2A). Some of the leaves had extensive damages and were perished and collapsed onto the ground as shown in figure 2B. Signs of the disease detected from the study area include small brown dots with water lesions, dark brown patches on the upper side of the leaf (figure 2C). The spots were not just on one part of the leaf, but they had been detected on several parts of the large leaves of taro plants (Figure 2C).

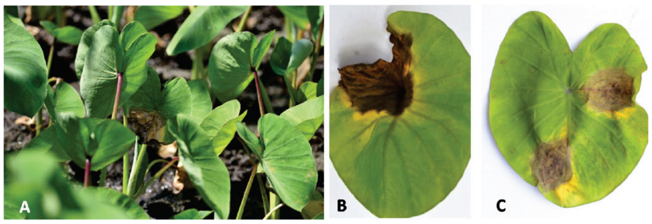

Figure 2 : Symptoms of taro leaf blight observed from field

Taro leaf blight disease incidence The results of taro leaf blight disease in *Odassau* area are tabulated as shown on table 1. The percentage disease incidence was recorded to be 36.7%.

Table 2: Percentage TLB disease incidence

Number of plants with symptoms	*Total number of plants*	*Percentage incidence (%)*
11	30	36.7

Taro leaf blight disease severity

The result of disease severity in Hithadhoo is shown on table 2. The highest percentage disease area and disease grade was observed for sample 22, with 11.58% diseased area and disease grade of 0.91. The least percentage of diseased area was detected for sample 27, with a percentage diseased area of 0.21% and disease grade of 0.34. Statistical evidence indicated that the mean percentage of diseased area was 3.34% and the mean disease severity was 0.56.

DISCUSSION

In this study, several symptoms of TLB were observed during field observations. Leaves as well as petioles of some of the plants were damaged due to TLB. According to Singh *et.al* (2012) infections in petioles are rare. When petioles are infected, they will also display yellowish brown spots in the same manner as on the leaves of taro plants. These spots enlarge and expand during rainy days. As the spots enlarge the petiole becomes weak, it softens and bends. After few days the petiole will not be able to bear the weight of the leaf and it will be broken and collapsed to the ground (Singh *et al*., 2012).

Taro leaf blight disease incidence

Results of the study conducted indicates the presence of taro leaf blight. The disease incidence was found to be 36.7%. The incidence of TLB in this study area was low. In research conducted in other countries, disease incidence level higher than 50% is considered as higher incidence level (Chiejina & Ugwuja, 2013). Therefore, those areas are labeled as areas with high occurrence of disease. Since the incidence level in the study area was lower than 50%, the area can be described as an area with low occurrence of taro leaf blight disease.

The lower disease incidence in the area could be due to various reasons. One of the reasons could be the genetic properties developed by the accession to reduce the effect of the pathogen. A study to evaluate the incidence of TLB from fields of Kenya and Pacific Caribbean had displayed lower disease incidence in Pacific Caribbean due to the above-mentioned reason(Otieno, 2020). *P. colocasiae* is a diploid heterothallic oomycete. It is identified that heterothallic of *Phytophthora* produced oospores rapidly evolve and recombine to form different strains. The extent of genetic properties and variability are not studied well but, the isozyme variation studies are ongoing (Singh *et al*., 2012). In a RAMS analysis done in India, the results had indicated substantial intra specific diversity presence among *P. colocasiae.* A great intensity of genetic diversity was apparent with 100% polymorphism amid the isolates (Nath, Basheer, Jeeva, & Veena, 2016). Therefore, due to the genetic diversity of the fungus oomycete, the pathogen dispersal and disease developments will vary and this will have an effect on how the presence of the indications and signs of the disease.

Another reason for the low incidence level in the study area could be due to the irregularity in the TLB infection pattern. According to Singh and his colleagues, the distribution of infection in an area and the severity of symptoms on plants are irregular. The disease pattern is not predictable and even if a severely diseased plant is present among other plants, immediately those adjacent may have little to no disease(Singh *et al*., 2012). Although the primary reproductive unit of *P. colocasiae* the sporangium requires rainfall to germinate, during rainy days the sporangia present on the leaves can get washed from the leaves onto the ground(Singh *et al*., 2012). According to the statistics from Maldives Meteorological Center Addu city experienced highest rainfall during the last quarter of the year (Maldives Meterological Service, 2020). Therefore, during the study period, even if the sporangia were present on the nearby leaves of the infected plants, it could have been washed from the leaves to the ground and prevented it from germinating on the leaves of the neighboring plants.

Taro leaf blight disease severity

The mean disease severity recorded in this study was low. It was found to be 0.56 which according to the disease severity scale in figure 11 means the disease severity is nearly very low. From the descriptive analysis the minimum disease severity detected was 0.340 and the maximum disease severity value was 0.905. The 95% confidence level for disease severity was 0.06. The disease severity can be low for this area as the rain can wash away the pathogen on leaves before it germinates. Also the weather condition in study site may not be favoring the growth of the pathogen. During the October month the daily average maximum temperature was recorded to be 30.8 °C during sunny days while average low temperature of 24.8 °C was observed. Also, the relative average humidity was recorded to be 83%. Even with favorable temperature, the pathogen could not germinate well due to the heavy rains during this period. The heavy rain will obstruct the *P. colocasiae* trying to germinate(Van der Puije, Ackah, & Moses, 2015).

Another reason for the low disease severity in this field could be due to the good cultivar used in the field. In researches where decent and improved cultivars of taro were used, both disease incidence and severity had been detected to be very low (Admoako, Kwoseh, Emmanuel, & Stephen, 2016).

When a plant is infected with the pathogen *P. colocasiae* the symptoms can be detected both on the upper surface of the leaf and the lower surface of the leaf. On the upper surface usually the water-soaked areas with small white powdery speckles and brown dots and patches are observed. On the lower surface area also water-soaked lesions are present(Singh *et al*., 2012). Severe infection symptoms include the entire leaf and petiole getting rot leading to complete defoliation. In very severe conditions, an entire taro field will have 100% of infected plants with no corms formed(Mbong, Fokunang, Lum A, Bambot, & Tembe, 2013). The general observations from the study field are validating the disease grade found in this taro growing area. Symptoms such as large brown patches were observed but they were very low and few. Frequently, only a few dots and minor infection areas were observed on the leaves of the plant and hence the disease severity grade was very low.

Prevalence of TLB

The results of the investigation conducted in Hithadhoo indicate low prevalence of TLB. However, this study is confirming that taro leaf blight disease is present in this neighborhood of Hithadhoo. The region's weather conditions are quite similar to the factors (rainfall, temperature and humidity) of disease development. According to Brooks (2005) favorable conditions of TLB include temperatures of 28-30 °C, relative humidity of 90% - 100% (Brooks, 2005). Therefore, it is an indication that the taro leaf blight disease could worsen in the upcoming days and month in this area. In another research also it was detected that taro plants growing in extremely hot and humid environments displayed higher susceptibility to blight disease than those growing under cold and dry conditions.

From the general observations of the taro field, it was detected that the space or the distance between each taro plant in the farm was less (between 6-12 inches). This is a concerning matter, as the disease can spread from one plant to another through splashing rain and by wind (Onwueme, 1999). Therefore, it is wise to leave enough spacing between each plant so that during windy and rainy days, the pathogen cannot be dispersed from one plant to another.

Since, the prevalence of TLB is low it is possible that the pathogen *P. colocasiae* was recently introduced to this district. Disease spreading pathogen can be transmitted during transportation of planting material and use of diseased planting materials from a diseased region (Admoako *et al*., 2016). Therefore, it is vital to check the source of the planting materials before planting.

The limitations of this research identify the areas and topics to be addressed in future research. In Maldives taro growing regions, the TLB disease incidence and severity should be studied further considering the factors that aid in the progress of the disease. Maldives is a hot and humid country which could deteriorate the current condition of the disease.

Based on the current results, the *Colocasia esculenta var esculenta* cultivar should be tested and checked for the resistance of the disease. Also, those plants with no symptoms of TLB should be separated and planted in an area away from those plants that are infected. Since, the disease incidence and severity are low, removing diseased plants at early stages will minimize the spreading of disease from one plant to another during rainy seasons.

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