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Research Article

Occurrence and Distribution of Papaya Dieback Disease in Peninsular Malaysia

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Keywords

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Distribution,
Dieback,
Climate change,
Cultural factors

Abstract

In this research, a one way Analysis of Variance (ANOVA) with Duncan Multiple Range Test (DMRT) showed that the disease was mostly found in Johor state, with mean of Disease Incidence (DI) and Disease Severity (DS), 63.8$\pm$ 3.1and 39.6$\pm$ 2.25, respectively; whereas the lowest disease occurrence was recorded from Malacca state, with mean of DI and DS, 36.3$\pm$ 6.25 and 31.6$\pm$ 0.20, respectively. There was significant difference between Johor with Negeri Sembilan, and Selangor, Pahang and Melaka. Pearson coefficient correlations showed the positive correlations between disease severity with rainfall and relative humidity (r= 0.620150, r= 0.72629) and age of crop (r= 0.84708) besides able to cause papaya dieback might be due to higher rainfall and humidity and also closely related each other. The relationship between disease severity and age of farm is (r = 0.84708). Our results on relationship between DI and DS explained that DI increasingly affected the level of DS. The highest DI occurred in Johor due to the unfavorable environmental condition for crops. Besides, weather data showed that this area had the highest rainfall and relative humidity. We assumed that the most severe disease in this area likely due to unwell-drainage and unwell-sanitation farm.

Introduction

Many records of diseases on papaya crop have been reported. However, the papaya industry is currently facing a major threat from papaya dieback disease. Dieback disease has been spread to many of the major papaya growing countries of the world (Trujillo and Schroth, 1982; Webb, 1985). In the late 1960's the disease appeared in the West Indies and destroyed the papaya fields in the area where the cultivar 'Solo' was grown for its high yields and fruit quality (Ollitrault *et al*., 2005). Thus, understanding the potential effects of changes in agriculture and diseases on plants is an important issue. Dieback disease transmission is preferred by rain-splash with the bacteria entering neighbouring host plants via natural openings and wounds (Obrero, 1980).

In Malaysia, papaya is grown in commercial plantations. Papaya is an important tropical fruit in the international market and the global production was reported to be 11.22 million metric tonnes in 2010 (Wee *et al*., 2014). Malaysia plays a major role in contributing to the global papaya production and becomes one of the major exporters of papaya. However, attacks by dieback disease on papaya plants have been identified as a major cause reduces yield and quality papaya production besides causing economic losses to planters. Besides, there is no information of the distribution and incidence of papaya dieback has been reported in Malaysia.

Disease assessment is important to assess their potential to cause economic loss to papaya plants by comparing their incidence and severity on papaya trees. Thus, this study was carry out to study the distribution and occurrence of papaya dieback in Peninsular Malaysia, to determine disease incidence, severity and to relate disease severity to temperature, rainfall, relative humidity, wind speed, tree age and size of farms. Therefore a study on the distribution, occurrence, and intensity of dieback disease would be of much advantage to be used in the planning of disease management practices and for awareness to planters.

Materials and Methods

Samples Collection

Ten locations in five states namely Melaka, Pahang, Selangor, Johor and Negeri Sembilan selected to collect symptomatic plants samples such as leaves, petioles, stems and fruit of papaya farms from May 2011 until June 2012. A total of 40 papaya trees from each sampling location were randomly selected for disease assessment. Diseased samples from surveyed farms were taken, labeled, stored in plastic bags and brought to the Microbiology Laboratory at the Department of Plant Protection, Universiti Putra Malaysia. Disease incidence was determined by using a zigzag pattern technique. For each study site, the assessment was conducted only one time. Weather data including rainfall and relative humidity (RH), temperature and wind speed were obtained from the nearest Malaysian Meteorological Department (from the period of 2008 to 2012) from each state

Table - 1 Locations covered during papaya dieback disease surveys regarding to cultural data and cultivar in Peninsular Malaysia

Location	State	Size of farm (ha)	Papaya Cultivar	Age (Years)	Planting System
Tanjung Minyak	Melaka	0.4	Sekaki, Eksotika	1.0	Monocropping
Hutan Percha	Melaka	0.36	Sekaki	0.8	Monocropping
Temerloh	Pahang	200	Paiola, Sekaki	2.0	Intercropping
Kuantan	Pahang	1.17	Solo	1.5	Monocropping
Serdang	Selangor	0.97	Sekaki, Eksotika	0.6	Intercropping
Hulu Selangor	Selangor	1.42	Sekaki, Eksotika	1.5	Intercropping
Batu Pahat	Johor	2.07	Solo, Sekaki	2.5	Monocropping
Kluang	Johor	1.13	Sekaki, Eksotika	2.0	Monocropping
Rembau	Negeri Sembilan	1.30	Sekaki, Eksotika	1.5	Monocropping
Kuala Pilah	Negeri Sembilan	1.22	Sekaki	1.0	Monocropping

Field Disease Incidence Assessment

Papaya dieback symptoms, number of healthy and symptomatic plants, types of cultivated papaya cultivar were recorded. Disease incidence (%) was valued based on symptoms recorded for the samples collected from each farm surveyed. Disease incidence (DI), was computed by the following formula (Cooke, 2006):

$$DI\ (\%) = \frac{\text{Number of diseased plant}}{\text{Total number of plant assessed}} \times 100$$

Disease Severity Assessment

The disease severity are also been assessed according to disease rating scale and conditions of papaya dieback disease in Peninsular Malaysia. Disease severity (DS, in percentage) was measured using the equation as proposed by Horsfall and Barrat (1945) and scored according to rating scale (Kim *et al*., 2000) as shown in Table 2.

$$DSI\ (\%) = \frac{\Sigma\,(a \times b)}{N.Z} \times 100$$

$\Sigma\,(a \times b)$ = Sum of the symptomatic plant and their corresponding score scale
N = Total number of sampled plant
Z = Highest score scale

Table - 2 Symptoms of papaya dieback were scored based on scale 0–5

Scale	Percentage of severity level on infected plants	Description of Symptom
0	0	No symptoms.
1	0 – 20%	A few black spots on leaves and fruits.
2	20 – 40%,	**Slightly**: Water-soaked spots on petioles and stems. Brown lesion on fruits, canker on stems and yellowing on leaves.
3	40 – 60%,	**Moderate**: Water-soaked and greasy on all plants part Rotting odor on fruits and necrosis on leaves.
4	60 – 80%	**Heavy**: Leading to dieback. Only a few leaves/leafstalks on papaya trees
5	80 – 100%	Stems and all plants part become rotten as well as death of papaya trees

(Kim *et al*., 2000)

Results and Discussion

Field Symptoms of Dieback Disease

Surveyed data revealed that the cultivars affected were Eksotika, Solo, Sekaki and Paiola. General, field observation on papaya farms during monitoring and collecting time showed that the initial symptoms for dieback disease are a mottling of the upper leaves. Affected plants also develop yellowing and necrosis along leaf edges followed by water-soaked areas on leafstalks and crowns as has been reported by Noriha *et al*. (2011). Subsequently, fruit on affected tree becomes rotten, dark spots on the skin and become water-soaked flesh. These symptoms were also explained by Nishijima (1994).

Later, necrotic and water-soaked areas developed on stems and spread to the internal tissues, followed by bacterial infections (Fullerton *et al*., 2011). With the end of apical growth, failure of plant vigor and more stunted leaves at the top. Thus, the final stage, bending of water-soaked leafstalks appears, leading to dieback, and death of papaya trees (Maktar *et al*., 2008). The entire crown and the stem gradually dies back from the top (Gibb *et al*., 1996). However, the bacterium has been shown to survive for unlimited periods in the cankers and leaf lesions of affected papaya and will survive for at least 14 days on the leaves.

Disease Occurrence of Dieback Disease

The present study found that overall mean disease incidence and disease severity of dieback in infected papaya orchards in five states in Peninsular Malaysia were 45.25% and 34.25%, respectively. Disease severity was relatively low when compared with disease incidence. On the basis of specific location, the highest papaya dieback incidence was 67.5% as recorded in Batu Pahat, while the lowest incidence was observed in Hutan Percha (30%). While, on the basis of disease occurrence of papaya cultivars, the highest disease incidence was recorded on Solo in Batu Pahat (75%) while the lowest disease incidence was Sekaki in Hutan Percha (30%). Relatively, high disease severity was observed on Sekaki in Hutan Percha at Melaka. Very low severity was observed on Eksotika in Serdang. However, the highest disease severity among cultivars was recorded on Sekaki, followed by Eksotika, Solo and Paiola (Table 3). The lowest severity was recorded at Hulu Selangor and Serdang.

This might be due to intercropping system. Sayed and Hamdollah (2011) explained that intercropping is its ability to reduce disease damage. Fujita *et al*. (1992) also noted that, although intercropping does not always reduce pathogen, but most reports have pointed to reduced populations of diseases in the intercropping. However, intercropping system also needs less chemical to control disease than monocropping (Singh and Adjeigbe, 2002). Papaya dieback occurrence in surveyed areas in Peninsular Malaysia varied from location to location. During the survey, low disease incidence was observed in isolated fields as noted in Melaka. The reasons for the absence of the disease on known susceptible cultivars during the survey in Peninsular Malaysia are not clear but, might be attributed to absence of favorable environmental factors especially rainfall and relative humidity, required for development of dieback disease. The environment may affect the availability, plant pathogen and growth stage to diseases of plants (Agrios, 2005; Su *et al*., 2004).

Table – 3 The occurrence of dieback disease based on cultivar in different locations in Peninsular Malaysia

Location	State	Cultivar	Disease Occurrence (%)	
			Disease Incidence	Disease Severity
Tanjung Minyak	Melaka	Sekaki Eksotika	45 40	32.5 31.1
Hutan Percha	Melaka	Sekaki	30	31.4
Temerloh	Pahang	Paiola	40	34.0
Kuantan	Pahang	Sekaki Solo	40 35	37.1 32.5
Serdang	Selangor	Sekaki Eksotika	50 45	40.0 24.0
Hulu Selangor	Selangor	Sekaki Eksotika	45 50	38.0 35.6
Batu Pahat	Johor	Solo Sekaki	75 60	38.7 45.0
Kluang	Johor	Sekaki Eksotika	65 55	33.8 41.0
Rembau	Negeri Sembilan	Sekaki Eksotika	50 40	35.6 31.4
Kuala Pilah	Negeri Sembilan	Sekaki	35	28.9
Mean			**45.25**	**34.25**
Std.Dev			**11.3**	**3.7**

Interaction Disease Occurrence between Location, Weather and Cultural Factors

One way ANOVA with DMRT test highlighted that, the disease occurrences of papaya dieback were maximum in Johor with incidence and severity level of 63.8±3.1% and 39.6±2.25%, respectively. Meanwhile, the lowest occurrence was observed in Melaka with incidence and severity level of 36.3±6.25% and 31.6±0.20%, respectively (Table 4). According to statistical analysis, the incidence of dieback disease in Johor was significantly difference with other states. Disease severity was also relatively lower when compared with disease incidence.

Table - 4 Occurrence of dieback disease on papaya based on location in Peninsular Malaysia

	Disease occurrence (mean ± SE)			
Location	**Disease Incidence (DI)**		**Disease Severity (DS)**	
Melaka	36.3 ± 6.25b		31.6 ± 0.20b	
Pahang	38.8 ± 1.25b		34.4 ± 0.40ab	
Selangor	47.5 ± 1.85b		34.4 ± 2.40ab	
Johor	63.8 ± 3.1a		39.6 ± 2.25a	
Negeri Sembilan	40.0 ± 5.0b		31.2 ± 2.30b	
Mean	45.75		34.56	
Std. Dev	11.06		3.78	
CV	12.34		7.383	
	F value	**Pr > F**	**F value**	**Pr > F**
	7.38*	0.0250	3.68^{ns}	0.0928

*Means followed with same letter are not significantly different on 95% confidence interval (α = 0.05) analyzed with one-way ANOVA with DMRT test.

The results of the analysis were presented in Figure 1. The 4-years average (2008-2012) of weather data of Peninsular Malaysia which could influence the establishment of current surveyed of disease occurrences. The average annual rainfalls were 211.56 mm & 213.72 mm. The average highest rainfall was obtained in Johor (212.64 mm). Overall, the average temperature is about 26.59°C & 25.63°C. The average highest temperature was recorded in Negeri Sembilan (26.94°C) and the lowest in Johor (26.11°C). The maximum relative humidity was observed in Johor with a value 84.14% when the rainfall is significantly high. Otherwise, the minimum relative humidity was recorded in Melaka (78.34 %). The graph showed that, the temperature decreases to its minimum when the amount of rainfall and relative humidity are both at their maximum.

In previous study, Gwani *et al*. (2013) explained that, the amount of rainfall is directly proportional to relative humidity and inversely proportional to the temperature. The previous study conducted by Obrero (1980) showed rainfall was the most important weather factor influencing bacterial crown rot as it provided conditions essential for the penetration and distribution of the pathogen.

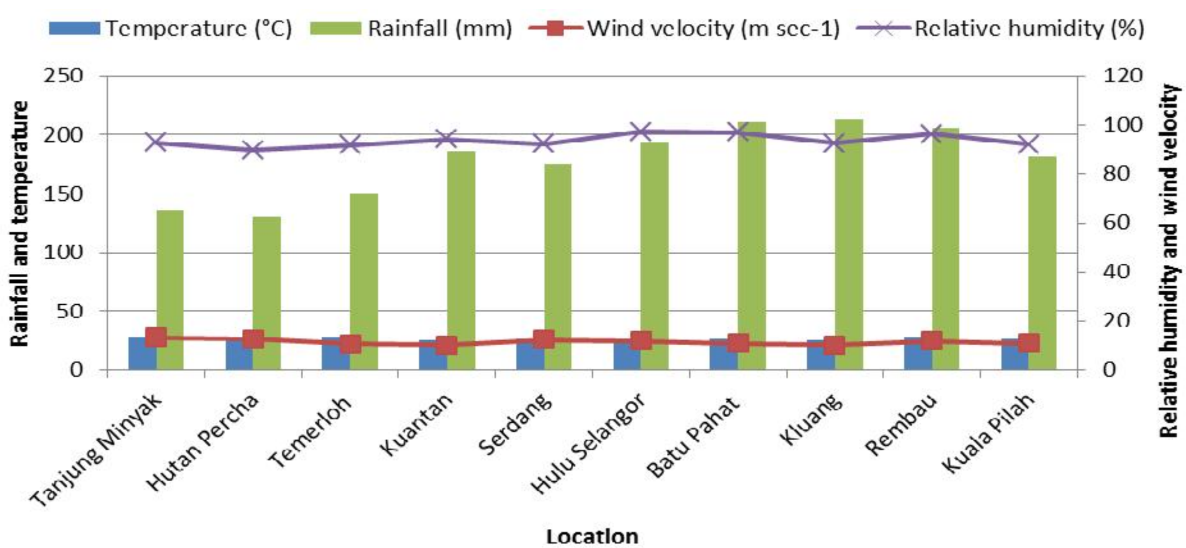

Figure - 1 The 4-years (2008-2012) of weather data in Peninsular Malaysia obtained from Department of Meteorological Malaysia

Coakley *et al*. (1999) noted that, weather is predicted to have a direct impact on the incidence and severity of diseases in papaya crops whereas it can change resistance and rates of pathogen development. Besides, weather also will significantly affect the presence of diseases (Rosenzweig and Tubiello, 2007). The risk of production losses due by diseases is likely to increase due to climate change; however, production losses are rarely considered in weather assessments (Anderson *et al*., 2004). The weather also influences the incidence as well as temporal and spatial distribution of plant diseases (Yáñez-López *et al*., 2012).

Changes in temperature, rain, relative humidity, etc. could all affect the disease occurrence and disease development. Agrios (2005) explained that, weather also affects all life stages of the pathogen and host. Nevertheless, little research on the effects of climate change on plant diseases has been conducted (Garrett *et al*., 2006). Weather is one of the most important factors affecting the occurrence of diseases. Aquilizan (1995) and O'Hare (1995) noted that dieback was often associated with long periods of heavy rainfall. In addition, study conducted by Obrero (1980) found there was no evidence of insect transmission. There was non-significant correlation was observed association between disease severity and rainfall (r =0.6202), disease severity and temperature (r = -0.2939) (Figure 2). In most surveyed areas in Peninsular Malaysia high rainfall was accompanied with high temperature and relative humidity. Since high rainfall and temperature appear to be the main factors distinguishing Peninsular Malaysia, the probability of dieback disease to occur in where susceptible papaya cultivars are grown seems to be very high.Temperature is one of the main factors in conjunction with the rain to determine the incidence and severity of disease, but the effect could be positive and negative. A change in temperature could directly affect the spread of infectious disease. In general, high moisture and temperature must be favorable and act together in development of plant diseases (Agrios, 2005). Moisture, in the high humidity, is essential for infection and spread in many plant pathogens. Typically, the two most important environmental factors in the development of plant disease epidemics are temperature and moisture (Agrios 1997). Much of this literature focuses on diseases of agricultural crops and includes discussion of the influence of temperature on plant disease (Coakley *et al*., 1999). Extreme weather conditions will plant disease depending on their amount and duration in the rain or the temperature. Disease often occurs when temperatures are more stressful for the plant than for the pathogen. The main factors that development of diseases is temperature, similarly these factors affect type and condition of host crop (Rosenzweig *et al*., 2001; Agrios, 2005). Changes in rainfall patterns and temperature can induce severe epidemics in plants (Coakley *et al*., 1999).

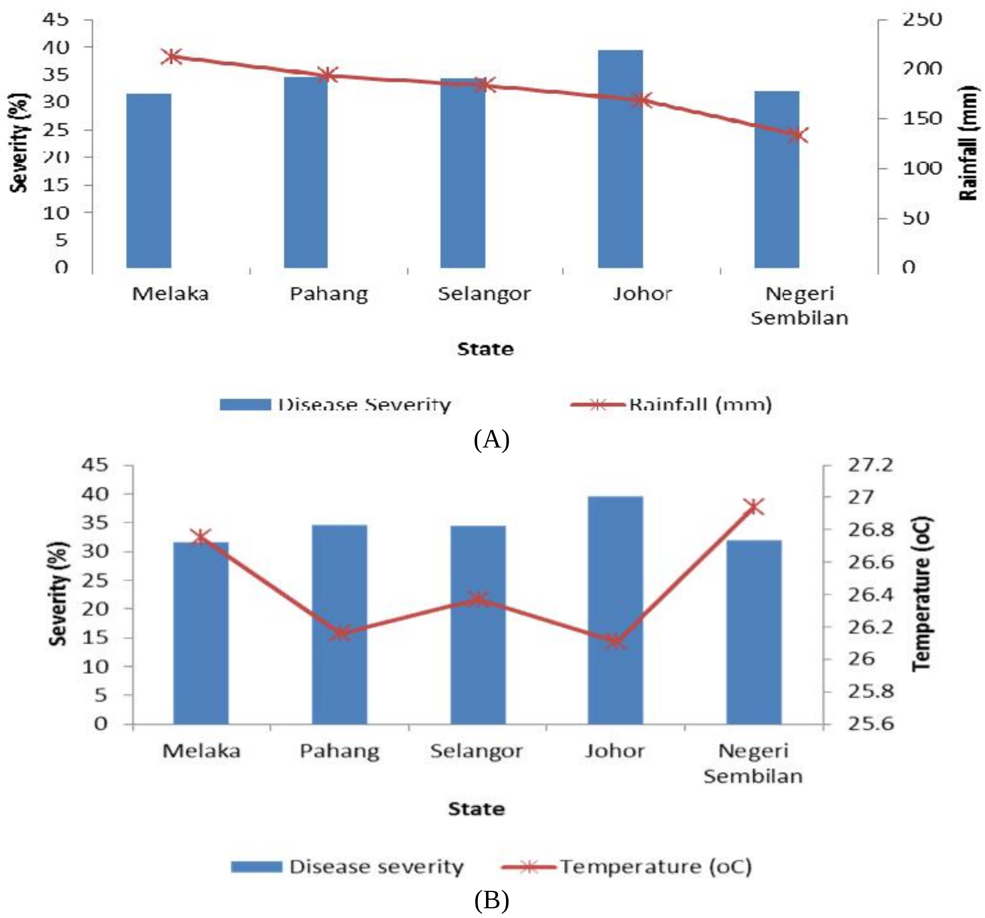

Figure - 2 Relationship between (A) disease severity and rainfall (B) disease severity and temperature in different states in Peninsular Malaysia (2008-2012)

Relationship of weather and cultural factors with was summarized in Table 5. Based on the Pearson's correlation analysis, disease severity and had positive correlations with rainfall, relative humidity and also with age of crop with range of r value around 0.6202-0.84708. However, according to data analysis, disease severity was found to be significantly with relative humidity (r = 0.7263). A positive correlation was obtained between relative humidity and rainfall (Gwani *et al*., 2013). There were significant differences between disease severity and age of crop (r = 0.847080). In addition, Agrios (2005) reported that crop age, is important in disease infection. There was no significant difference observed between disease severity and wind speed (r = -0.4163). The role of wind velocity is less important in affecting disease progress. There was not significantly among disease severity and size of field (r =-0.0181). There was no significant variation on disease severity with rainfalls (r = 0.6202) and disease severity with temperatures (r = -0.2939). The rainfall and temperature did not play any role in variability of disease severity. On the other hand, there was significant correlation between rainfall and relative humidity (r = 0.83419). There was insignificant between rainfall and temperature (Abdulhamid, 2011).

Table - 5 Correlation between disease severity, weather and cultural factors in surveyed areas in Peninsular Malaysia

	Disease Severity	Rainfall (mm)	Relative Humidity (%)	Temp (°C)	Wind Speed (m/s)	Size of field (Ha)	Age of crop (Yr)
Disease Severity	1.0	0.6202^{ns}	0.7263*	-0.2939^{ns}	-0.4163^{ns}	-0.0181^{ns}	0.84708*
Rainfall		1.0	0.83419*	-0.2872^{ns}	-0.6052^{ns}	-0.3108^{ns}	0.5729^{ns}
Relative Humidity			1.0	-0.1693^{ns}	-0.5043^{ns}	-0.1180^{ns}	0.6881*
Temp (°C)				1.0	0.5877^{ns}	0.2371^{ns}	-0.1566^{ns}
Wind Speed					1.0	-0.2540^{ns}	-0.6455*
Size of field						1.0	0.3324^{ns}
Age of crop							1.0

*Correlation is significant at the 0.05 level, ns= non-significant

It means the percentage of relative humidity must change by changing the temperature of the air. Nevertheless, according to Davis (1987), relationship environmental parameters and diseases occurrence was difficult to identify. However, the importance of air temperature to moisture is apparent. Thus, we assumed that the development of dieback disease on papaya in Peninsular Malaysia was influenced by weather and cultural factors. Stressed plants are often become more susceptible to disease. In addition, pathogens that cause crop diseases will be influenced directly by changes in climate, positively or negatively, depending on the environmental conditions that they require to cause disease. The climate is becoming unpredictable (Paul *et al*., 2009). The effect of climate change also disturbs and changes the distribution diseases (Rosenzweig *et al*., 2000).

Conclusion

The occurrence and distribution of papaya dieback disease varied from location to location in Peninsular Malaysia. Based on our results, we can concluded papaya dieback disease was severe in Johor. Although assessment of incidence are more easily than measures of severity but severity is more helpful than incidence. During the survey was conducted, low disease incidence has been identified in Melaka due to small farm production of the papaya. Moreover, the occurrence of dieback disease on papaya in Peninsular Malaysia was more influenced by environmental conditions and agricultural practices.

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