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The First Report of the Occurrence of Anthracnose Disease Caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. on Dragon Fruit (*Hylocereus* spp.) in Peninsular Malaysia

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Abstract: Problem statement: The increasing of dragon fruit (*Hylocereus* spp.) plantations in Malaysia enhances the researches on this crop, particularly focusing on its physico-chemical characteristics, great potential health benefits and nutritional value. However, its scientific report of disease is still lacking, primarily on anthracnose disease. This study was then conducted to investigate the distribution of anthracnose disease on dragon fruit and to correlate its occurrence with weather and cultural data. **Approach:** Survey and sampling were conducted on dragon fruit-growing areas in Peninsular Malaysia since December 2007 until August 2008 to measure the Disease Incidence (DI) and Disease Severity (DS). The diseased stem and fruit were sampled and brought to laboratory for isolation and identification. DI data were plotted with DS and then correlated using Pearson correlation with weather and cultural data. **Results:** Of the 43 surveyed-farms in 11 states, DI and DS were successfully recorded on three dragon fruit species from 36 farms (83.72%). The infected stem and fruit had reddish-brown lesions with chlorotic haloes symptoms. The lesion had brown centers and coalesced to rot. Based on its whitish-orange colony, septated hypae and capsule-like conidia and the pathogenicity test, the pathogen was identified as *Colletotrichum gloeosporioides*. One way ANOVA with DMRT test highlighted that the most disease occurrence was found in Malacca (mean of DI and DS, 57.30 and 21.20%), whereas the lowest in Kelantan state (mean of DI and DS, 6.70 and 4.30%). Pearson coefficient correlations were around 0.107-0.261 for relationships between disease occurrence and age of crops and acreage of farm, from-0.049 to-0.237 for disease prevalence with relative humidity and rainfall and around-0.012-0.173 for disease occurrence with monthly temperature, wind velocity and altitude. **Conclusion:** The occurrence of anthracnose on dragon fruit in Peninsular Malaysia was more influenced by environmental conditions and agricultural practices rather than climatic factors.

Keywords: disease incidence, disease severity, pitaya

INTRODUCTION

The dragon fruit (*Hylocereus* spp.) is a tropical climbing cactus which is also known as *pitaya* or *pitahaya* (Latin America), strawberry pear and night blooming cereus (English)[1-3] and *mata naga* (Malaysia). Currently, this plant has been commercially cultivating in Australia[4], Brazil[5], Colombia[6], Costa Rica[7], Egypt[8], Israel[9], Japan[10], Mauritius[11], Mexico[12], Nicaragua[13], Taiwan[14], the USA[15] and Vietnam[16]. In Malaysia, dragon fruit has been initially introduced on large scale at the end of 1990s by Golden Hope Company at Sungai Wangi Estate, Perak. Until 2006, Malaysia has around 927.4 ha (363.2 ha production areas) dragon fruit-growing areas with total production about 2,534.2 tons (production value around US$3.5 million) and Johor has the largest areas, 326.7 ha[17]. In addition to some abiotic disorders such as sunburn[17], very strong wind or hurricanes[2], high summer temperature[18], chilling injury, mechanical

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injury and water loss[3]; the cultivation of dragon fruit is also influenced by the infestation of pests and diseases.

Several diseases affecting white-fleshed dragon fruit (*Hylocereus undatus*) in many places have been scientifically reported, such as cactus virus X[19], stem rot and fruit rot in Taiwan[20] and Japan[21], stem spots in Mexico[22] and anthracnose disease in Japan[23] and the USA[24]. Anthracnose disease also infected yellow species of dragon fruit (*H. megalanthus* syn. *Selenicerus megalanthus*) in Brazil[25]. In Okinawa Perfecture, Japan, Taba *et al.*[23] not only observed anthracnose causing water-soaked lesion on *H. undatus* species but also found Salmon-colored conidial masses on diseased fruit. This disease has been successfully recorded in Miami-Dade County, Florida, the USA since December 2004 on the same crop as well[24]. Meanwhile, in the State of São Paulo, Brazil, *Colletotrichum* anthracnose has been reported causing a loss of up to 5% on yellow pitahaya[25]. Those three reports, however, neither correlated the anthracnose occurrence with environmental or cultural data.

Most of researches on dragon fruit in Malaysia more focused on its physico-chemical characteristics[26-28], great potential health benefits[29] and nutritional value[30-32]; whereas the scientific documentation particularly regarding diseases on dragon fruit in Malaysia is still lacking[33]. The recent report is *Fusarium* disease on red-fleshed dragon fruit (*H. polyrhizus*) in Malaysia[34] and there is no report of anthracnose disease on dragon fruit in this country. This study, therefore, was carried out to study the occurrence and distribution of anthracnose disease on dragon fruit in Peninsular Malaysia as well as to correlate its occurrence with weather and cultural data.

MATERIALS AND METHODS

Assessment of disease occurrence: Survey and sampling were concurrently carried out on dragon fruit-growing areas in Peninsular Malaysia since December 2007 until August 2008. Fifty posts of dragon fruit crops from each surveyed-orchard (at least with 0.4 ha in acreage) were randomly sampled to assess the disease occurrence. The Disease Incidence (DI) was measured using this following equation[35]:

$$DI = \frac{\text{Number of inf ected plant units}}{\text{Total number of plant units assessed}} \times 100\%$$

Meanwhile, the Disease Severity (DS) was determined according to alternative rating scale proposed by Bowen[36] in which scale 0 = no symptom, scale 1 = 0-20% disease severity range, scale 2 = 20-40%, scale 3 = 40-60%, scale 4 = 60-80% and scale 5 = 80-100%, respectively. DS was measured using the equation proposed by Kranz[37] as follows:

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

Σ (a×b) = Sum of the symptomatic plant and their corresponding score scale
N = Total number of sampled plant
Z = Highest score scale

Longitude and altitude data from surveyed area were recorded using GPS device (SILVA Multinav-Version 2.01). Cultural data including age of crops and acreage of farms were also noted.

Isolation and identification of pathogen: Infected samples of dragon fruit were collected and brought to laboratory for isolation on Potato Dextrose Agar (PDA) plates and for further identification morphological characteristics such as colony, mycelia as well as shape and size of conidia under light microscopy observation.

Pathogenicity test: This test was carried out in vitro on both healthy stem and fruit, according to method developed by Melanie and colleagues[38] with a slight modification. The isolated pathogen was cultured within Potato Dextrose Broth (PDB) medium and incubated for a week at 150 rpm rotary shaker. Conidia were harvested by filtering them through four layers of cheesecloth to remove mycelia. Conidia concentration was then determined using a hemacytometer and adjusted to 1×10^6 conidia per ml using Sterile Distilled Water (SDW).

The fresh and healthy organs were surface-disinfected for 2 min with 1% sodium hypochlorite (NaOCl). Artificial wounds approximately 2 mm deep on organ were aseptically made using sterile sharp-pointed tooth stick. Twenty microliters of conidia suspension was inoculated into the wounded site of the plant part using sterile fine-syringe needle. The inoculated organs were placed into the moisturized filter paper-layered trays and then wrapped with transparent wrapping plastic. They were incubated at room temperature in the laboratory for 2 weeks and the symptoms development was observed thrice a week.

Statistical data analysis: DI and DS data were first plotted and pooled together using Microsoft Excel 2003 Program. To achieve the best linear severity-incidence[39], test of normality was employed to determine whether data should be transformed or not prior to analysis. One way ANOVA with DMRT test was performed to obtain significant distribution of DI and DS amongst surveyed states by using SPSS Program, Version 15.0[40]. Regression analysis was also performed to correlate disease occurrence with weather factors (1998-2008 period) such as temperature, Relative Humidity (RH), rainfall and wind velocity-obtained from Malaysia Meteorological Department-as well as altitude, age of crops and acreage of farm.

RESULTS

Assessment of disease occurrence: During the surveys, the present study found that the red-fleshed species (*H. polyrhizus*) was planted nationwide in Peninsular Malaysia, i.e., 90.7% of the surveyed farms (Table 1). Both red-fleshed and white-fleshed species (*H. undatus*) were intercropped together in Ayer Hangat, Langkawi (Kedah) and Batang Merbau (Kelantan). The combination of red-fleshed and yellow species (*Selenicereus megalanthus*) was only found in Pokok Sena (Kedah); whilst these three species were cultivated in one farm in Mersing (Johor). Among those species, the anthracnose disease was more frequently found on red-fleshed one rather than on white-fleshed (in Ayer Hangat, Kedah and Mersing, Johor) and yellow species (in Mersing, Johor).

The occurrence of anthracnose disease was successfully recorded from 36 farms (83.72%) of the 43 farms surveyed from 11 states in Peninsular Malaysia. Despite of the highest incidence (80%) occurred in Pekan, Pahang; the most severe disease (32.0%) arose in Durian Tunggal, Malacca (Table 1).

Most of dragon fruit-growing areas in Peninsular Malaysia (37.20%), as shown in Table 1, were located nearby the rubber plantation from which the incidence of anthracnose disease could be recorded from 13 farms with such environmental condition (81.25%). The others were village situation, 25.58%; intercropped with other crops, 20.93%; experimental plot, 6.97%; village forest, 4.65%; and opened high hills and rice field, 2.32 and 2.32%, respectively.

Isolation and identification of pathogen: Anthracnose disease on dragon fruit was characterized with reddish-brown lesions and chlorotic haloes symptoms on stem as well as fruit (Fig. 1a and b). These lesions had brown centers and then coalesced to rot. On the fruit, symptoms could increasingly develop at post harvest condition in the moisturized store room. In the field, the aservuli were found as the dark concentric circle on the infected stem (Fig. 1c). The identification of isolated pathogen described that the fungus had whitish-orange colony (Fig. 1d), with septated hypae, circled aservuli bearing conidia on conidiogenous cells and capsule-like conidia (6-10×2-2.5 µm in size) containing one cell (Fig. 1e and f). According to Sutton[41], this pathogenic fungus was then characterized as *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.

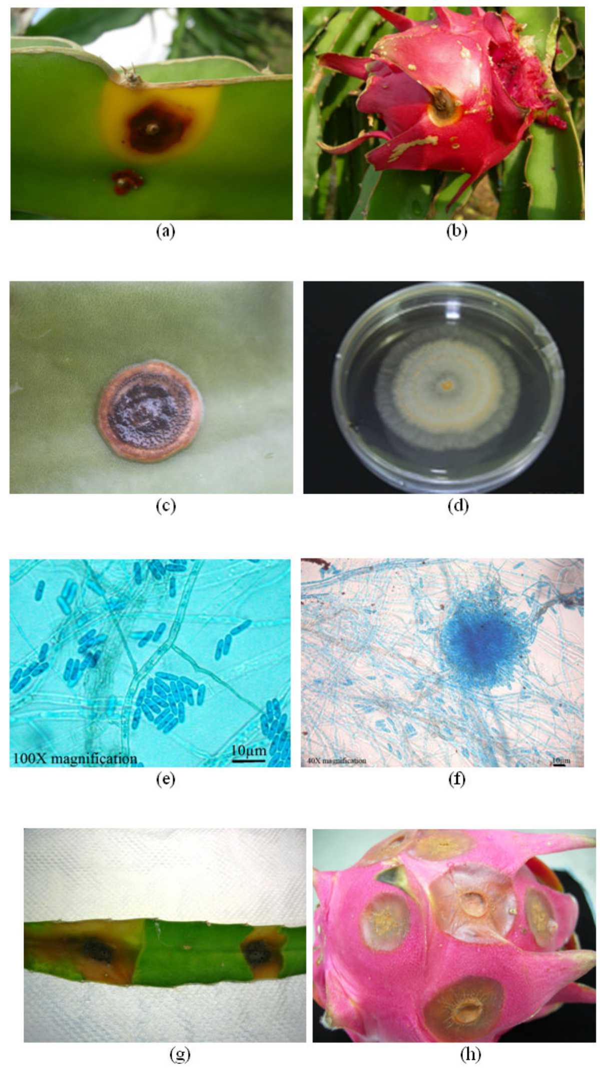

Fig. 1: (a): Disease symptom on infected stem (b): Symptoms on infected fruit; (c): Aservuli of *C. gloeosporioides* on infected stem; (d): Colony on PDA, (e): Conidia and hyphae; (f): Aservuli bearing conidia; (g): Disease symptoms on the inoculated stem and (h): Symptoms appearing on inoculated fruit for pathogenicity test

Table 1: Occurrence of anthracnose disease recorded from 43 of surveyed dragon fruit-growing areas in Peninsular Malaysia

Location[a]	Dragon fruit species	Farm environment	Altitude (m asl)	Age (years)[b]	Acreage (ha)[c]	Incidence (%)	Severity (%)
Johor							
Batu Pahat	Rf (Hp)	Rubber plantation	12.50	4.50	1.42	0 (0.00)[d]	0.0
Kluang	Rf (Hp)	Rubber plantation	81.38	4.00	1.42	60 (7.75)	18.4
Mersing	Rf (Hp), Wf (Hu), Ys (Sm)	Opened high hills	47.55	6.00	10.11	56 (7.48)	14.0
Malacca							
Durian Tunggal	Rf (Hp)	Rubber plantation	10.36	6.00	3.24	76 (8.72)	32.0
Machap Umboo	Rf (Hp)	Rubber plantation	61.26	5.00	2.43	46 (6.78)	15.2
Naning	Rf (Hp)	Rubber plantation	42.36	1.50	1.21	52 (7.21)	16.4
Negeri sembilan							
Rembau	Rf (Hp)	Village situtation	54.56	1.50	0.48	28 (5.29)	5.6
Kuala Pilah	Rf (Hp)	Rubber plantation	80.77	1.50	2.83	58 (7.62)	12.0
Pajam	Rf (Hp)	Rubber plantation	60.96	2.50	2.43	60 (7.75)	18.4
Selangor							
Sepang	Rf (Hp)	Village situation	51.20	3.00	0.65	0 (0.00)	0.0
Hulu Langat	Rf (Hp)	Rubber plantation	75.90	0.67	2.43	46 (6.78)	13.6
Sabak Bernam	Rf (Hp)	Village situation	13.41	3.00	1.21	54 (7.35)	14.8
Perak							
Slim River	Rf (Hp)	Rubber plantation	44.50	4.00	0.81	36 (6.00)	11.2
Teluk Intan	Rf (Hp)	Village situation	5.80	4.00	0.4	36 (6.00)	10.8
Tapah	Rf (Hp)	Rubber plantation	40.54	3.50	0.81	36 (6.00)	10.0
Batu Gajah	Rf (Hp)	Rubber plantation	42.36	2.50	0.61	36 (6.00)	11.2
Pantai Remis	Rf (Hp)	Intercropping	6.40	1.50	2.43	28 (5.29)	6.8
Taiping	Rf (Hp)	Intercropping	20.42	1.00	0.81	48 (6.93)	12.0
Pahang							
Pekan	Rf (Hp)	Village forest	11.88	3.00	4.45	80 (8.94)	28.8
Kuantan	Rf (Hp)	Urban situation	17.37	4.00	2.02	16 (4.00)	4.8
Raub	Rf (Hp)	Rubber plantation	146.91	4.00	3.64	38 (6.16)	11.2
Jerantut	Rf (Hp)	Rubber plantation	121.31	0.50	1.62	28 (5.29)	9.2
Terengganu							
Paka	Rf (Hp)	Intercropping	8.53	0.60	0.48	40 (6.32)	12.4
Merchang	Rf (Hp)	Village situation	6.09	3.00	1.01	32 (5.66)	9.2
Marang	Rf (Hp)	Intercropping	4.57	2.50	2.02	0 (0.00)	0.0
Setiu	Rf (Hp)	Intercropping	5.79	1.50	0.40	0 (0.00)	0.0
Kerteh	Rf (Hp)	Village situation	11.27	2.50	0.81	12 (3.46)	4.0
Kelantan							
Batang Merbau	Rf (Hp) and Wf (Hu)	Experimental plot	51.81	3.00	0.40	0 (0.00)	0.0
Kota Bharu	Rf (Hp)	Experimental plot	10.97	2.00	0.40	26 (5.10)	7.2
Gua Musang	Rf (Hp)	Rubber plantation	31.67	4.00	1.21	0 (0.00)	0.0
Kuala Krai	Rf (Hp)	Village forest	34.74	2.00	2.02	28 (5.29)	10.0
Pulau pinang							
Bukit Mertajam	Rf (Hp)	Village situation	30.78	3.00	2.02	48 (6.93)	12.8
Seberang Perai Tengah	Rf (Hp)	Village situation	22.55	1.50	0.81	28 (5.29)	7.6
Seberang Perai Utara	Rf (Hp)	Intercropping	9.44	5.00	5.95	28 (5.29)	9.6
Kedah							
Merbau Pulas	Rf (Hp)	Village situation	14.63	0.58	0.40	0 (0.00)	0.0
Pokok Sena	Rf (Hp) and Ys (Sm)	Rubber plantation	19.81	0.40	0.40	6 (2.45)	2.0
Gurun	Rf (Hp)	Intercropping	25.60	2.00	2.43	0 (0.00)	0.0
Yan	Rf (Hp)	Intercropping	3.96	2.00	0.40	18 (4.24)	5.2
Ayer Hitam	Rf (Hp)	Rice field	3.35	2.00	0.81	68 (8.25)	29.2
Mata Ayer	Rf (Hp)	Rubber plantation	28.95	3.50	2.02	0 (0.00)	0.0
Pantai Kok	Rf (Hp)	Village situation	27.43	1.50	0.40	58 (7.62)	21.2
Ayer Hangat	Rf (Hp) and Wf (Hu)	Experimental plot	3.96	4.00	0.81	48 (6.93)	15.2
Perlis							
Beseri	Rf (Hp)	Intercropping	25.60	2.00	0.61	32 (5.66)	8.4

[a]: Locations were arranged successively from the northern (Johor, Malacca and Negeri Sembilan), western (Selangor and Perak), eastern (Pahang, Terengganu and Kelantan) and southern (Pulau Pinang, Kedah and Perlis). [b]: Age of crops which were recorded until surveyed date; [c]: Generally, growers cultivated in acre acreage. 1 acre consists of approximately 449 posts in which 1 post has 4 plants. 1 acre = 0.4 ha; [d]: Square root transformation data; asl = above sea level; Rf = Red-fleshed species (Hp = *Hylocereus polyrhizus*); Wf = White-fleshed species (Hu = *Hylocereus undatus*); Ys = Yellow species (Sm = *Selenicereus megalanthus*)

Pathogenicity test: The *in vitro* pathogenicity test resulted in the appearance of the anthracnose symptoms on both inoculated stem and fruit that similar to those found in the field. These typical anthracnose symptoms occurred on the fruit and the stem on second and third day after inoculation, respectively (Fig. 1g and h).

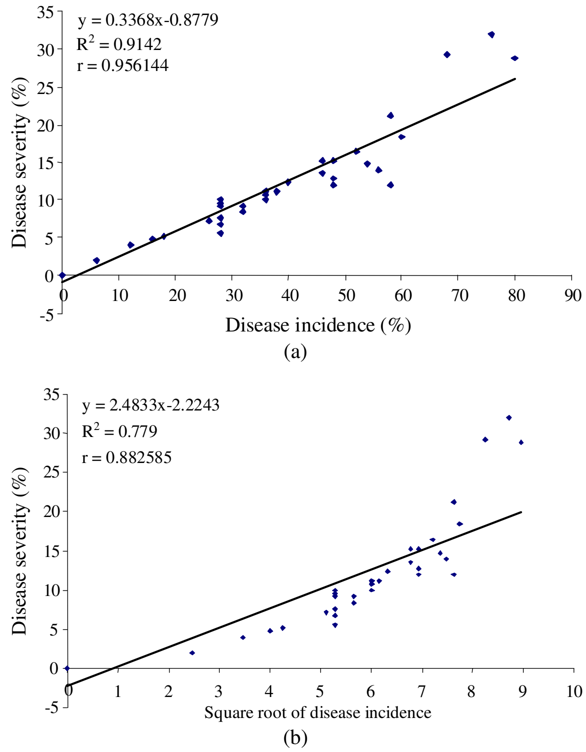

Fig. 2: Relationship between incidence and severity of anthracnose disease with (a): Untransformed and (b): Square root transformation of incidence data

The inoculated fruit became completely decaying on seventh day after inoculation, while the stem got severely rotting on tenth day after inoculation.

Statistical data analysis: The normality test of DI and DS data revealed that only DS data which was normally distributed, while DI data should be incorporated in square root transformation prior to further analysis. Relationship between DI and DS, either measured as untransformed or square root transformed data, positively revealed linear correlation with r = 0.956 and r = 0.882, respectively (Fig. 2). Meanwhile, one way ANOVA with DMRT test highlighted that the most disease prevalence was found in Malacca state, with mean of DI and DS, 57.30%±0.33 and 21.20%±5.41, respectively; whereas the lowest disease occurrence was recorded from Kelantan state, with mean of DI and DS, 6.70%±2.25 and 4.30%±2.54, respectively (Table 2). The positive Pearson coefficient correlations were successively showed between disease occurrence and age of crops and acreage of farm, with range of r value around 0.107-0.261. Conversely, relationship between disease prevalence and Relative Humidity (RH) and rainfall resulted in negative Pearson coefficient correlations, with range of r value from-0.049 to-0.237.

Table 2: The distribution of anthracnose disease in Peninsular Malaysia

	Disease occurrence	
State	Disease incidence (%)	Disease severity (%)
Johor	25.70±6.40ab*	10.80±5.54ab
Malacca	57.30±0.33a	21.20±5.41a
Negeri Sembilan	47.33±0.62ab	12.00±3.69ab
Selangor	22.18±5.71ab	9.460±4.74ab
Perak	36.36±0.04ab	10.33±0.75ab
Pahang	37.21±1.08ab	13.50±5.27ab
Terengganu	9.480±1.79ab	5.120±2.48b
Kelantan	6.700±2.25b	4.300±2.54b
Pulau Pinang	33.98±0.29ab	10.00±1.51ab
Kedah	13.54±1.58ab	9.100±4.01ab
Perlis	32.00±32.00ab	8.400±8.40ab

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

Table 3: Pearson correlation coefficient (r) between disease occurrence and weather and cultural data

	Weather conditions						
	Temperature	Relative humidity	Rainfall	Wind velocity	Altitude	Acreage of farm	Age of crops
DI	-0.012	-0.166	-0.237	0.078	0.173	0.261	0.107
DS	0.039	-0.154	-0.049	0.143	0.060	0.261	0.207

There were few nearly zero correlations between disease occurrence and monthly temperature, wind velocity and altitude of the surveyed localities, with range of r value around-0.012-0.173 (Table 3). We did not, however, found the significant correlation between disease occurrence and those factors, either at the 0.01 or at the 0.05 level.

DISCUSSION

This study could be likely considered as the first scientific report pertaining to the occurrence of *Colletotrichum* anthracnose disease on dragon fruit (*Hylocereus* spp.) in Peninsular Malaysia. Another disease note was reported by Masratul Hawa and her colleagues[34] who successfully proved *Fusarium proliferatum* as the pathogenic fungi causing brownish to reddish lesions on red-fleshed dragon fruit (*H. polyrhizus*). The three previous studies have noted the occurrence and the similar causal fungi of anthracnose disease on the white-fleshed species in Okinawa Prefecture, Japan[23] and Miami-Dade County, the USA[24] as well as on yellow species in Brazil[25]. This pathogen has been also reported infecting other cacti species in Korea, such as *Cereus peruvianus* (Peruvian apple cactus) and *C. tetragonus*[42], Indian fig cactus [*Opuntia ficus-indica* (L.) Mill.][43] as well as causing *Colletotrichum* stem rot on graft-cacti including, *H.*

trigonus (three-angled cactus), *Gymnocalycium mihanovichii* and *Chamaecereus silvestrii*[44].

Although this recent investigation highlighted that the pathogenic fungus, *Colletotrichum gloeosporioides*, produced similar symptoms and the same conidia shape, the size of conidia (6.0-10×2.0-2.5 µm) on PDA culture was slightly different compared to those previously found on white-fleshed species in Okinawa Prefecture, Japan and Miami-Dade County, the USA, i.e. 9.0-24×3.0-4.5 µm on PDA culture[23] and 12.5-17.5×3.8-7.5 µm on one-half strength acidified PDA culture[24], respectively; whereas the isolate infecting yellow species in Brazil had conidia 12.1-18.1×3.6-8.2 µm in size on PDA culture[25]. Unlike the isolated fungi from those three previous researches, our findings showed that the isolated fungus had whitish-orange colony.

Zero incidence of disease in 7 farms (16.27%) reported in this study mostly not only occurred in the farms which located far away from infected area, but also in the well-applicated sanitation farms; while low disease occurrences were found in farms in which copper based-fungicide was regularly treated. Statistically, however, the lowest disease occurrence (mean of DI and DS, 6.70%±2.25 and 4.30%±2.54, respectively) was found in Kelantan state in where dragon fruit crops were planted in experimental plot of state agricultural department and in farmer orchards which were intensively managed.

Our results on relationship between DI and DS explained that DI increasingly affected the level of DS. Seem[45] noted that the relationship between these two plant disease assessments, incidence and severity, created an epidemiologically significant concept. Although the coefficient correlations of this relationship were close to 1, namely 0.956 and 0.882 (Fig. 2), the survey data representing field condition described that the highest incidence was found in Pahang state, particularly in Pekan district; while the most severe disease was recorded in Malacca state, especially in Durian Tunggal district.

The highest DI occurred in Pekan (Pahang) probably due to the unfavorable environmental condition for crops. Weather data showed that this area had the highest monthly rainfall during 11-year period, i.e., 265.17 mm (Fig. 3). This condition might cause flood disaster on 2006 in this low land (11.88 m asl in altitude) so that enabled the pathogen to survive under such favorable environmental condition and then infect other healthy crops in the farm. Several under field studies found that the dispersal of those conidia was highly influenced by water, primarily rain splash[46-48].

This study, however, significantly found the highest disease occurrence in Malacca state (mean of DI and DS, 57.30%±0.33 and 21.20%±5.41, respectively), particularly in Durian Tunggal district. In fact the monthly rainfall in this state was very low, 77.5 mm (Fig. 3). We assumed that the most severe disease in this area likely due to unwell-sanitation farm. The farmer did not prune the damaged stems from infected plants and they tended to ignore debris of diseased stems around the farm. Some reports on other crops considered conidia produced from debris or dead leaves as the main source of of *C. gloeosporioides* inoculum which could rapidly initiate an epidemic once favorable conditions for dispersal and infection occurred[49,50]. Therefore, Le Bellec *et al*.[6] recommended pruning all the damaged stems and those that were entangled with one another at the first year after dragon fruit planting. In addition, the combination of pruning, weeding and spading has been reported increasing healthy fruit per plant and yield per hectare as well as reducing anthracnose occurrence on mango for two consecutive years[51].

The 81.25% of incidence of anthracnose disease in the farms located near rubber plantation probably occurred since the capability of inoculum to survive on dead leaves of rubber for long time. The occurrence of anthracnose disease on rubber had been documented since 1972[52]. Goyut *et al*.[48] reported that the conidia of *C. gloeosporioides* could disperse for several tens of meters in rubber tree. Rubber crops could provide canopies for dragon fruit farms as well, so that the micro climate in the farms could favor the disease development. This recent study, however, neither investigated those possibilities nor isolated pathogen from dead rubber leaves.

The relationship between disease occurrence and acreage of farm (DI and DS, r = 0.261) was constantly significant amongst the other weakly positive correlations in this recent research (Table 3.). It might be interpreted that disease occurrence would increase on larger farms due to requiring more intensive maintenance. Although there was a nearly zero correlation between DI and age of crops (r = 0.107), we obtained a little correlation between DS and this factor (r = 0.207). In the fields, we found that the disease occurred even on the youngest surveyed farm (5-month old) in Pokok Sena, Kedah.

The finding in this study also revealed a nearly no correlation between disease occurrence and wind velocity (DI, r = 0.078; DS, r = 0.143). As this pathogen has water-borne conidia, the role of wind velocity is less important in affecting disease progress, primarily increasing the dispersal of conidia.

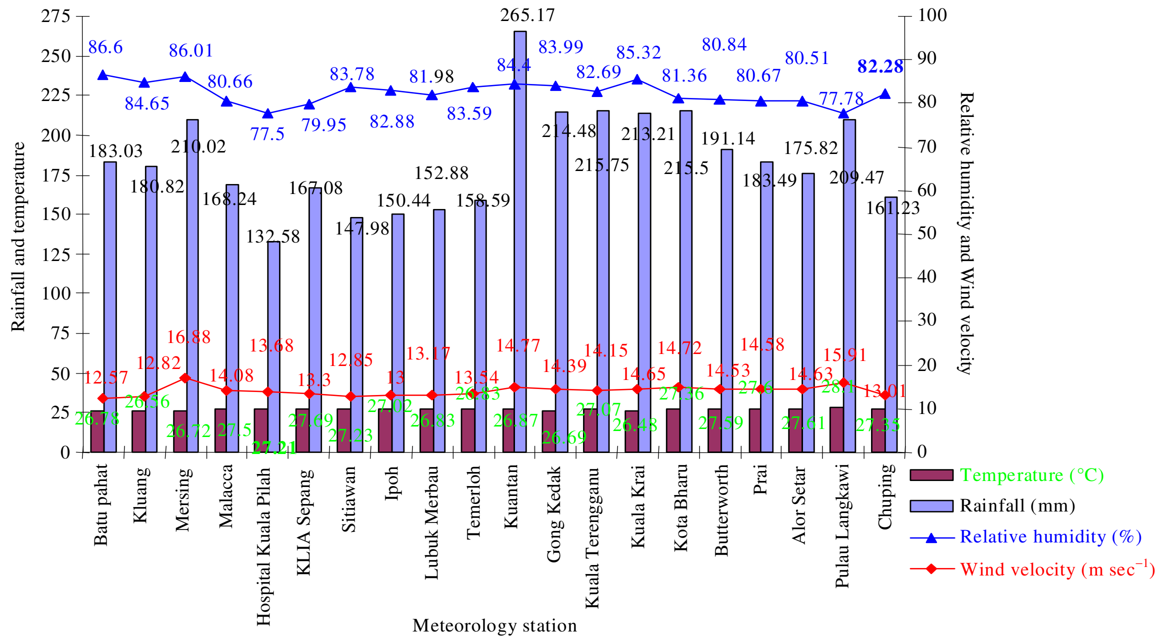

Fig. 3: The 11-year (1998-2008) of weather data in Peninsular Malaysia obtained from Department of Meteorological Malaysia

Agrios[53] noted that the wind could importantly influence the plant disease development by spreading inoculum of plant pathogen and accelerating the drying of wetness on the surfaces of plants surfaces and even become more important when it was assisted by rain.

In contrast with previous studies on *C. gloeosporioides* affecting cocoa[54], *Stylosanthes* spp.[55] and coconut palm[56], this study did not linearly highlighted correlation between disease occurrence and temperature. Those three experiments reported that the incidence of *C. gloeosporioides* was significantly inhibited by the increase of temperature. Meanwhile, our findings on a quite negative relationship between disease occurrence and RH and rainfall did not parallel that of other studies on rubber[52], citrus[57], *Stylosanthes* spp.[55] and coconut palm[56] which found strongly positive correlations. The uncertain correlations of disease development and RH and rainfall, however, were highlighted on other previous investigations on *Stylosanthes* spp.[58,59] and cocoa[54].

Our investigations found that the anthracnose disease widely occurred in dragon fruit-growing areas in Peninsular Malaysia with range of monthly temperature and RH, from 26.5-28.1°C and 77.5-86.6%, respectively. It was in line with several authors who reported range of 20-30°C as the optimum temperature for the lesion development on rubber leaves[52], in vitro disease development on *Stylosanthes* spp.[58] as well as germination and production of conidia[46], appressoria production[47], infection development[60] and growth and sporulation[59] of *C. gloeosporioides* on mango; but not similar with those who noted range of RH from 95-100% as the in vitro optimum RH for conidial production and germination as well as appressoria development of *C. gloeosporioides* on mango[46,47,60,62].

We can finally conclude that the occurrence of anthracnose on dragon fruit in Peninsular Malaysia was more influenced by environmental conditions and agricultural practices rather than climatic factors. In spite of the weather parameters change could affect the pathogen, the host as well as the interaction between pathogen and host[63,64], in some cases a relationship between environmental parameters and diseases occurrence was difficult to determine[59]. The climate change might be even less important compared with major technological, environmental and socioeconomic changes affecting agricultural production on the next century[64].

CONCLUSION

Although anthracnose disease on three different species of dragon fruit caused by *C. gloeosporioides* was distributed mostly in all surveyed dragon fruit-growing areas in Peninsular Malaysia, the highest occurrence was recorded from Malacca state; while the lowest prevalence was found in Kelantan state. This study also concluded that the occurrence and progress of disease were highly influenced by environmental conditions as well as agricultural practices.

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