Nature of mango anthracnose in Ghana: Implications for the control of the disease

J. O. HONGER*, S. K. OFFEI, K. A. ODURO & G. T. ODAMTTEN

(J.O.H.: Soil and Irrigation Research Centre, University of Ghana, Legon,Ghana; S. K. O. & K.A.O.: Crop Science Department, University of Ghana, Legon, Ghana; G.T.O.: Botany Department, University of Ghana, Legon, Ghana

**Corresponding author's email: johonger@yahoo.com;*

ABSTRACT

Mango anthracnose is a major disease hampering the production of quality fruits for export in Ghana. The nature of the disease and its spread were studied in 82 mango farms in the Greater Accra, Eastern, Volta, Ashanti, Brong Ahafo and Northern regions of Ghana in 2010 and 2011. Field visits were undertaken to mango farms, and the types of the disease symptoms and sources of inoculum were determined. A survey was also carried out to measure the disease incidence and severity at the preharvesting stage, whilst the incidence of the latent infection was also determined. Two types of symptoms were attributed to the disease. Leaves, dried panicles and mummified fruits were found to be the major sources of inoculum. The disease was not found in five of the districts surveyed. Comparatively, more of the disease was found at the postharvest stage than at the preharvest stage. The implications of the findings are discussed.

Original scientific paper. Received 30 Apr 14; revised 17 Oct 14.

Introduction

Mango anthracnose is reported to be the most important fungal disease affecting mango worldwide (Nelson, 2008; Crane & Campbell, 1991; Jeffries *et al*., 1990). It is a major pre and postharvest disease of the crop throughout the tropics (Jeffries *et al*., 1990). The disease is believed to co-exist with mango cultivation worldwide (Fitzell, 1981), and is a major constraint to fruit production and marketing (Ilag, 1992). The disease affects both leaves, twigs, petioles, panicles and fruits (Nelson, 2008). It also causes blossom blight of flowers and results in poor fruit set (Estrada, Dodd & Jeffries, 2000). Anthracnose disease also causes latent infection on developing fruits which generally remain quiescent until the fruit ripens (Estrada, 2000; Dodd, Jeffries & Jeger, 1989) except on young fruits (Dodd *et al*., 1991). Symptoms develop on fruits in transit or storage and reduce their marketability (Freeman, Katan & Shabi, 1998).

Anthracnose disease is caused by *Colletotrichum gloeosporioides, Glomerella cingulata* or *Colletotrichum acutatum* (teleomorph) (Peres *et al*., 2002; Freeman, Katan & Shabi, 1998). In Ghana, the disease is reportedly caused by *C. gloeosporioides* (Offei *et al*., 2008; Oduro, 2000). The pathogen produces abundant conidia in the tree canopy and these are considered the primary inoculum (Arauz, 2000). The disease is favoured by wet, humid and hot weather (Nelson, 2008), and the pathogen is relatively inactive in dry weather (Arauz, 2000). Symptoms of the disease is characterised by dark sunken lesions which may or may not be accompanied by bright orange coloured acervuli of the causal agent (Agrios, 2005).

In Ghana, mango production is concentrated around the coastal savanna, transitional zone and the Guinea savanna. Few farms are scattered in the semi-deciduous forest zone where humidities are relatively higher. To control the disease and achieve higher yields, most mango farmers apply different types of fungicides, some of which have been shown to be very effective against the disease in many places including the Philippines (Dodd *et al*., 1991). However, farmers in Ghana complain that most fungicides available were not able to control the disease satisfactorily (Odzeyem, verbal communication).

According to Honger (2013), poor control of the disease may be due to improper application of fungicides, which could also be blamed on poor knowledge of the nature and epidemiology of the disease rather than the development of resistance of the pathogen to fungicides. Mango anthracnose disease has recently attracted the attention of researchers in Ghana, because mango has become one of the important non-traditional export crops of Ghana. However, not much work has been done to elucidate the nature of the disease. It is strongly believed that a better understanding of the nature of the disease in Ghana would facilitate the development of better control measures against the disease. In view of this, the study was carried out to identify the types of disease symptoms attributed to mango anthracnose in Ghana, evaluate different plant parts as possible sources of infective propagules, and determine the disease incidence and severity on fruits from different mango production areas in Ghana at the pre- and postharvest stages.

Materials and methods

Field survey of commercial mango farms

Study area

The study was carried out in 12 selected Metropolis/Municipals/Districts of Ghana from the Greater Accra, Eastern, Volta, Ashanti, Brong Ahafo and Northern regions. The areas were distributed among the four major agro-ecological zones of Ghana namely the coastal savanna, the semi-deciduous forest, transition and the Guinea savanna (Table 1). A 10-year average weather conditions in the selected areas are shown in Fig. 1.

Field visits

Field visits were made to a total of 82 farms found in the selected mango growing areas to study the nature of the mango anthracnose disease through observations in the field, and collect samples of both diseased and healthy plant parts for further studies.

Observation of disease symptoms

Field visits to determine the nature of the mango anthracnose disease were carried out in 30 selected farms in the Yilo Krobo District of the Eastern Region in the minor

TABLE 1

Administrative Areas of Ghana Selected for the Study

Area	*Administrative division*	*Region*	*Agroecological zone*
Ga West	District	Greater Accra	Coastal savanna
Dangme West	District	Greater Accra	Coastal savanna
Manya Krobo	District	Eastern	Coastal savanna
Yilo Krobo	District	Eastern	Coastal savanna
North Tongu	District	Volta	Coastal savanna
Hohoe	Municipal	Volta	Semi-deciduous
Kwaebibirem	District	Eastern	Semi-deciduous
Kumasi	Metropolis	Ashanti	Semi-deciduous
Berekum	Municipal	Brong Ahafo	Transitional
Kintampo	Municipal	Brong Ahafo	Transitional
Savelugu/Nanton	District	Northern	Guinea savanna
Tolon/Kumbugu	District	Northern	Guinea savanna

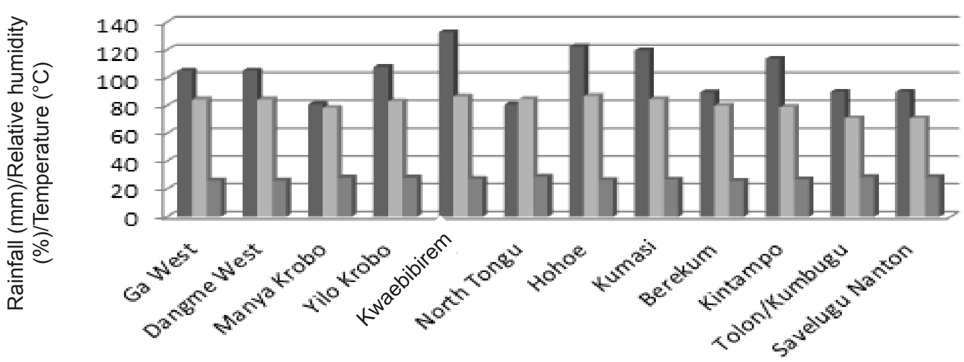

Fig. 1 Mean 10 year weather data of the areas where the study was carried out

mango production season of 2009. Except for one farm that was selected for detailed studies, each of the selected farms was visited once during which leaves, inflorescences and fruits developing on the trees were inspected for the presence of the mango anthracnose disease symptoms which were recorded. Fruits showing atypical anthracnose disease symptoms were harvested, bagged and sent to the Plant Pathology Laboratory of the Crop Science Department of the University of Ghana for the isolation and identification of the causal agents.

To obtain more information about the nature of the disease, one of the mango farms was selected and five trees located at different parts of the farm were selected at random. Five inflorescences per tree were tagged prior to fruit set. After fruit set, the trees were visited regularly to observe the development of the anthracnose disease symptoms on both the fruit stalks and the fruits. Any of the fruits that dropped were collected and inspected for the symptoms of the disease. The observations of the selected trees were carried out till all the fruits were harvested by the farmer. During the period, the farmer was allowed to carry out his routine disease control measures of fungicide applications at 2 weeks intervals.

Isolation and identification of the causal agent of diseases with atypical anthracnose symptoms collected from the mango farms

Samples of the mango fruits showing atypical anthracnose disease lesions were washed with soap and water and were air dried. They were then placed in clean black polyethene bags containing moistened paper towels to increase the humidity. The mouths of the bags were tied and placed in a dark cupboard for 7 days. The signs of pathogens that grew on the surfaces of the fruits were scrapped on a slide containing a drop of water. The slides were covered with a cover slip and the fungi observed under the compound microscope. With the aid of standard reference materials, the isolated fungi were identified. The type of fungus and the nature of the disease symptoms were used to identify the diseases observed.

Evaluation of leaves, panicles and dropped fruits as important sources of inoculum

Farm visits to collect plant samples to determine if leaves, panicles and dropped fruits are major sources of inoculum were carried out in all the 82 selected farms in the 2010 major mango production season. During the visit to each farm, 10 leaves without any visible disease symptoms and of all ages were collected at random from five trees found in the middle of each farm. Harvested leaves from farms within the same Metropolis, Municipal or District were bulked together, and 100 of these were sampled at random and sent to the Plant Pathology laboratory of the Crop Science Department, University of Ghana. The 100 leaves from each location were divided into four parts of 25 leaves each, representing four replications. These were placed in black polyethene bags containing moistened tissue paper. The open end of the bags were tied and incubated in a dark cupboard using the completely randomized design (CRD). Two weeks after incubation, the leaves were retrieved and their surfaces inspected for the presence or absence of acervuli, using a hand held lense. The number of leaves showing the signs of the pathogen was expressed as a percentage of the total number of leaves incubated. Dry panicles and mummified fruits from the previous season's production were also collected and subjected to the same treatment.

Field survey for the assessment of anthracnose incidence and severity

The survey for the determination of the disease incidence and severity of mango anthracnose disease in the field was carried out during the major mango growing season of 2010 and 2011. In each year, the survey was carried out between February and March, 2 - 3 weeks after fruit set in the selected mango farms. Mango farms with sizes ranging between a quarter of a hectare to 10 hectares were selected at random in each of the selected areas and used for the survey. On each farm, ten trees of the Keitt variety (the only variety common to all farms selected) were sampled at random, and disease incidence (DI) was calculated by the equation (Madden *et al*., 2007)

$$DI = \frac{\text{Number of trees showing disease symptoms}}{\text{Total number of trees inspected}} \times 100$$

Ten other trees were selected at random and each tree was circled at walking pace.

Stops were made at regular (approximately at 4-5 m) intervals, and the inflorescence found at the head level was selected and fruits found were harvested. Two hundred fruits per farm were picked at random, and the percentage of the fruit area covered by the disease lesion was visually estimated and rated on a scale of 0-5 using the criteria of All India Co-ordinate Research Project on Sub-tropical Fruit Crops (Table 2). The disease severity index per tree was estimated using the formula:

$$DSI = \frac{\sum fX}{\sum x}$$

where DSI = disease severity index, f = number of fruits with a particular rating, x = a particular rate based on the percentage of fruit surface area covered by disease lesion.

TABLE 2

Disease Severity Rating Scale Used for the Assessment of Disease Severity Index in Selected Mango Farms in Ghana

Rating	*Meaning*
0	No infection
1	Up to 5% of fruit surface area covered
2	6 – 10% of fruit area affected
3	between 11 and 20% of fruit area covered
4	21 – 50% of fruit area affected
5	more than 50% of the fruit surface area covered

Source: Lakshmi *et al*., (2011)

Determination of latent infections of mango anthracnose on mature fruits

At fruit maturity (between 110 and 120 days after flowering) within the different areas, 50 fruits without visible disease symptoms were harvested from each farm, and all fruits collected from farms within the same area were bulked and 100 fruits were sampled. The selected 100 fruits were washed with soap and thoroughly rinsed three times with tap water and air-dried. After that they were divided into lots of four with each lot of 25 fruits representing a replicate of area. Fruits were packed into plastic baskets with holes for ventilation and covered with jute sacks, and left on benches in the laboratory at the prevailing relative humidity of 60 per cent to 65 per cent and temperature of 25 to 27 °C for 2 weeks. The fruits were then inspected for symptoms of mango anthracnose disease and the incidence of the disease calculated.

Data analysis

Data on percentage of leaves, panicles and fruits developing acervuli after incubation, disease incidence at both the pre and postharvest stages and disease severity index (DSI) were subjected to analysis of variance. With the exception of DSI, all data were arcsine transformed prior to analysis. The analysis was performed using the 9th edn of Genstat statistical analysis software. Means were separated using LSD at five per cent.

Results

Types of disease symptoms associated with mango anthracnose

Two types of disease symptoms on fruits hanging on trees were found. The first type was dark-brown sunken spots which ranged from pin point sizes to large chlorotic areas on the diseased fruit surface. In some instances, the dark brown spots were accompanied by bright yellow acervuli of the causal agent of the disease. This disease symptom was also found to occur on the fruit peduncle resulting in dead and dried peduncles which eventually break leading to fruit drop. Fruit drop due to the disease was found to occur on young fruits between the ages of 1 – 3 weeks after fruit set.

The second type of symptom was slightly raised spots, which in most cases coalesce together to make the fruit surface rough in a characteristic 'alligator skin-like'. Surfaces of such fruits appear cracked and rough to touch. When incubated for some time, the characteristic anthracnose dark-brown sunken lesions emanated from the raised spots, confirming the symptom as another form of mango anthracnose disease symptom. Compared to the dark-brown sunken lesion, this type of symptom was restricted to the fruits surface and, hence, was not found as a form of the disease that could lead to fruit drop.

Apart from the disease symptom being shown on young fruits between the ages of 1–3 weeks after fruit set, very few older fruits were found with the disease symptom. Such older fruits were all found with some form of wounds. On such fruits, the disease lesions appear to be emanating from the edge of the wounds. Also, some of the few fruits that were not harvested and had began to ripe on the trees also showed the disease symptom.

Diseases identified with similar symptoms as mango anthracnose

Two other diseases with symptoms similar to that of mango anthracnose were encountered, and these could be easily confused with the mango anthracnose Young fruits between the ages of 1–3 weeks after fruit set were found to be infected with a disease whose symptom was characterised by black greasy spots that were not sunken. When such fruits were incubated in the black polyethene bags, the spots spread rapidly, coalesced and covered the entire fruit surfaces. No fungus was isolated from the diseased symptom. However, the symptom which was also found on leaves were similar to what has been associated with bacterial black spot.

The second disease symptom was characterised by a dark-brown lesion which initially was colourless. This lesion in most cases originated from the stem end portion of the diseased fruits, and could cover the whole fruit while the fruit was still hanging on the tree. When the diseased fruits were incubated in the black polyethene bags, mycelium of a fungus made up of both hyaline and dark hyphae which were septated was observed. The symptoms and the nature of the signs suggested that the disease was stem end rot caused by *Lasiodiplodia theobromae.*

Evaluation of leaves, fruits and dried panicles as important sources of inoculum

The symptomless mango leaves collected from the different mango growing areas were found to develop large masses of acervuli on their surfaces particularly, in the middle portion along the mid-rib after incubation. Similarly, the mummified fruits and dried panicles were also found with signs of the pathogen developing on their surface after incubation. Since these fruiting bodies contained the infective propagules of the pathogen, the leaves, panicles and fruits were considered as important sources of inoculum.

There was a significant difference in percentage of leaves developing the acervuli on their surface among the leaves from the different mango growing areas. The highest percentage (77%) was obtained on leaves from Kumasi Metropolis, whilst the lowest percentage (14%) was obtained on leaves from Savelungu-Nanton District (Table 3). The percentage recorded on leaves from Hohoe, Kintampo, Berekum, Savelugu-Nanton and Tolon-Kumbugu was not significantly different.

The percentage of fruits showing the acervuli after incubation also varied significantly among the different locations. The highest percentage (61%) was recorded on fruits from Kumasi Metropolis, whilst the lowest (8%) was recorded on fruits from Tolon- Kumbugu (Table 3). The percentage recorded on fruits from Hohoe, Kintampo, Berekum, Savelugu-Nanton and Tolon-Kumbugu was not significantly different (Table 3).

The percentage of panicles developing the acervuli was highest in the Ga West District whilst it was lowest in the Savelugu-Nanton District (Table 3). The percentage recorded from the Ga West District was not significantly different from what was recorded in Kintampo, Savelugu-Nanton and Tolon-Kumbugu districts. Also, the percentage of panicles from Savelugu-Nanton developing acervuli was not significantly different from those collected from Berekum, Kintampo and Tolon-Kumbugu (Table 3)

In general, more leaves were found developing the acervuli of the pathogen followed by fruits and the dried panicles from the various mango growing areas (Table 3).

TABLE 3

Occurrence of Acervuli of Colletotrichum gloeosporioides *in the Indicated Plant Parts in Mango Farms in Ghana*

Location	**Occurrence of acervuli of* C. gloeosporioides *(%)/ Plant parts*		
	Leaves	*Fruits*	*Panicles*
Ga West District	60.0 (50.9)	37.0 (37.7)	25.0 (29.5)
Dangme West District	61.0 (51.5)	33.0 (35.3)	18.0 (25.0)
Manya Krobo District	59.0 (50.3)	34.0 (35.9)	18.0 (25.0)
Yilo Krobo District	65.0 (53.8)	36.0 (37.1)	15.0 (20.7)
Kwaebibirem District	75.0 (61.9)	59.0 (50.7)	22.0 (27.5)
Kumasi Metropolis	77.0 (62. 2)	61.0 (51.9)	20.0 (26.5)
North Tongu District	66.0 (54.4)	29.0 (32.5)	16.0 (22.8)
Hohoe Municipal	16.0 (23.5)	12.0 (20.2)	9.0 (15.9)
Berekum Municipal	18.0 (25.0)	11.0 (17.9)	10.0 (18.5)
Kintampo Municipal	17.0 (24.2)	13.0 (21.3)	6.0 (13.1)
Savelugu-Nanton District	14.0 (21.7)	10.0 (18.5)	5.0 (12.6)
Tolon-Kumbugu District	14.0 (21.9)	8.0 (16.4)	3.0 (9.3)
LSD (5%)	(9.5)	(9.1)	(12.2)

Means with arcsine transformed in parenthesis.

Incidence and severity of mango anthracnose disease in selected Metropolis/Municipal/Districts of Ghana

The disease incidence in 2010 ranged from 0.0 to 100.0 per cent. The highest incidence of 100.0 per cent was recorded in both the Kumasi Metropolis and Kwaebibirem District, whilst the lowest was recorded at Hohoe Municipal, Berekum, Kintampo, Tolon-Kumbungu and Savelugu-Nanton districts (Table 4). The incidence among Ga West, Manya Krobo, North Tongu, Dangme West and Yilo Krobo districts ranged from 42.0 per cent to 67.5 per cent(Table 4). Similar results were obtained in 2011 with highest incidence (100.0%) being recorded in the Kwaebibirem District and Kumasi Metropolis, whilst the disease was not found in the Hohoe Municipal, Berekum, Kintampo, Tolon-Kumbungu and Savelungu-Nanton districts. During the period, the disease incidence ranged from 54.0 per cent to 67.5 per cent among Ga West, Manya Krobo, North Tongu, Dangme West and Yilo Krobo Districts (Table 4).

The DSI in 2010 ranged from 0.0 to 3.8, with the highest being recorded in both Kwaebibirem District and Kumasi Metropolis. The disease was absent in the Hohoe Municipal, Berekum, Kintampo, Tolon-Kumbungu and Savelungu-Nanton districts. In 2011, a similar trend was observed. The severity index ranged from 0.0 in the Hohoe Municipal, Berekum, Kintampo and Savelugu-Nanton districts to 3.8 in the Kwaebibirem District. In Ga West, Manya Krobo, North Tongu, Dangme West and Yilo Krobo districts, the severity index ranged from 0.4 to 0.7 (Table 4).

Incidence of latent infection on mature fruits collected from mango farms

In 2010, the incidence of the postharvest symptom development on fruits ranged from 0.0 per cent to 99.0 per cent. The lowest was recorded on fruits from Hohoe Municipal followed by Savelugu-Nanton and Tolon-Kumbungu districts, whilst the highest (99.0 %) was recorded on fruits from Kumasi Metropolis. The DI recorded on fruits from Ga West, Dangme West districts, Berekum and Kintampo Municipals was not significantly different (Table 5). Similarly, the DI on fruits collected from Manya Krobo, Yilo Krobo and North Tongu was not significantly different.

In 2011, the lowest DI (2.0%) was recorded on fruits from Hohoe Municipal, whilst the highest (93.0 %) was recorded on fruits from Kwaebibirem District. There was no significant difference in the DI on fruits from Ga West, Dangme West and Yilo Krobo. Also, the difference in DI on fruits from Manya Krobo and North Tongu was not significant (Table 5).

Discussion

The mango anthracnose disease produced dark-sunken lesions on leaves, inflorescence and fruits. This type of the disease symptom accompanied by acervuli formation by the

TABLE 4

Disease Incidence and Severity Index of Mango Anthracnose in Mango Orchards in 2010 and 2011

Location	*No. of farms*	*Disease incidence (%)*		*Disease severity index*	
		2010		*2011*	
Ga West District	10	47.0 ± 3.0	54 ± 2.7	0.4 ± 0.02	0.4 ± 0.02
Dangme West District	10	69.5 ± 7.6	65 ± 7.5	0.6 ± 0.1	0.7 ± 0.2
Manya Krobo District	5	42.0 ± 8.6	58 ± 9.7	0.4 ± 0.1	0.5 ± 0.1
Yilo Krobo District	30	57.3 ± 3.9	55 ± 3.7	0.6 ± 0.1	0.5 ± 0.03
Kwaebibrem District	1	100.0	100.0	3.8	3.8
North Tongu District	4	67.5 ± 8.5	67.5 ± 8.5	0.5 ± 0.02	0.6 ± 0.1
Hohoe Municipal	6	0.0	0.0	0.0	0.0
Kumasi Metropolis	1	100.0	100.0	3.8	3.7
Berekum Municipal	4	0.0	0.0	0.0	0.0
Kintampo Municipal	3	0.0	0.0	0.0	0.0
Savelugu-Nanton District	5	0.0	0.0	0.0	0.0
Tolon- Kumbungu District	3	0.0	0.0	0.0	0.0

causal agent has been described as a characteristic symptom of the disease, and is mostly used as a diagnostic feature of the disease (Agrios, 2005; Arauz, 2000; Ploetz, 1998). In the study, another disease symptom, described as the alligator skin, is being reported for the first time as an additional different symptom elicited by the same anthracnose pathogen. This confirms the report by Nelson (2008) that some strains of the pathogen are able to cause cracks in the epidermis resulting in the alligator skin effect. Prior to this work, only the dark sunken lesion symptoms have been reported in Ghana (Offei *et al*., 2008; Oduro, 2000). It is, therefore, important that this type of symptom is taken into consideration in future studies of the disease in Ghana.

TABLE 5

Incidence of Postharvest Anthracnose in Various Mango Growing Areas of Ghana

Location	Disease incidence (%) 2010	2011	Mean
Ga West District	40.0 (39.5)	41.0 (40.10	40.5
Dangme West District	40.0 (39.5)	39.0 (38.9)	40.5
Manya Krobo District	60.0 (51.1)	58.0 (49.9)	59.0
Yilo Krobo District	49.0 (44.1)	47.0 (43.1)	48.0
Kwaebibrem District	98.0 (84.6)	93.0 (75.4)	95.5
Kumasi Metropolis	99.0 (87.3)	90.0 (72.1)	94.5
North Tongu District	60.0 (51.2)	59.0 (50.5)	59.0
Hohoe Municipal	0.0 (4.1)	2.0 (8.2)	1.0
Berekum Municipal	25.0 (30.2)	24.0 (29.5)	24.5
Kintampo Municipal	25.0 (30.2)	27.0 (31.5)	26.0
Savelugu-Nanton District	8.0 (16.7)	11.0 (19.6)	9.5
Tolon-Kumbungu District	8.0 (16.7)	9.0 (15.7)	8.5
LSD (5%)	(8.5)	(8.6)	

Means with arcsine transformed in parenthesis

The disease was found to infect the peduncle of young fruits aged 1–3 weeks after fruit set, leading to the abscission of young fruits. Nelson (2008) has reported that the causal agent of mango anthracnose was capable of causing infected fruits of mango to drop. However, the mechanism involved was not elucidated. Therefore, apart from giving credence to the report that the disease can cause fruit drop, current data from the study showed that infection and subsequent withering of the fruit peduncle by the disease is the major cause of fruit drop associated with the disease. It means early protection of the young fruits (between the ages of 1–3 weeks after fruit set) against the disease can prevent losses associated with the disease.

Prior to the flowering and fruiting period of the mango trees, it was observed that leaves and panicles had a high concentration of acervuli, which are the sources of infective propagules of the causal agent. Although no experiment was carried out to determine whether inoculum emanates from other sources onto the infection courts of trees, the leaves and panicles contained enough inoculum to trigger epidemics. This observation is consistent with that of Arauz (2000) that there may be enough inoculum in the tree canopy to trigger epidemics. Though both leaves and panicles were found to be potential sources of inoculum on trees, the higher number of infective leaves on the trees compared to the panicles indicated that between the two, the leaves were of more importance in terms of harbouring of potential inoculum.

Mummified fruits were also found to contain a high level of inoculum, which agrees with a report by Arauz (2000) that the pathogen sporulates abundantly on mummified fruits. The findings of the study showed that when mango trees are pruned of excess leaves, dried panicles and mummified fruits, the number of inoculum sources and, hence, the concentration of inoculum in the tree canopy are reduced.. Therefore, good farm sanitation which includes the complete removal of pruned plant parts such as leaves, panicles and mummified fruits is necessary for a good control of the mango anthracnose disease on mango farms.

Two other diseases associated with mango namely bacterial black spot, caused by *Xanthomonas* sp*. pv. mangiferae indicae* (Gagnevin & Pruvost, 2001), and stem end rot caused by *Lasiodiplodia theobromae* (Sakalidis, Hardy & Burgess, 2011; Johnson, 1998) were identified on some of the diseased mango fruits collected from the various farms in the study. These diseases were identified as factors that could mask the correct diagnosis of the mango anthracnose disease. The nature of both the stem end rot and bacterial black spot disease symptoms were such that they were not easily distinguishable from the mango anthracnose disease symptoms. Their symptoms on the fruits may inadvertently be attributed to mango anthracnose. Farmers have consistently reported that the fungicides available on the Ghanaian market were not very effective against the causal agent of the mango anthracnose disease (Odzeyem, verbal communication). However, the similarity in disease symptoms caused by the target pathogen and those of other pathogens implies that, it would not be easy to determine whether the fungicide spray had been effective in reducing incidence of the mango anthracnose disease until a proper assessment is made. Training of farmers to be able to distinguish between the different disease symptoms could be very useful.

Variations in incidence and severity of mango anthracnose were observed in the different farms spread across the different mango growing areas of Ghana. In general, variations in incidence and severity of plant diseases could be attributed to differences in cultural practices which include soil cultivation and removal of crop residues, host genotypes, planting times and the growing environment (Marley, 2004; Neya & Normand, 1998). In the mango anthracnose host-pathogen relationship, where the pathogen is known to survive in fallen plant parts, removal of crop residues play an important role in reduction of the inoculum on the farm. This may be one of the reasons accounting for the variation in the disease incidence and severity in farms within the same agro-ecological zone. For example, in the Kwaebibirem District and Kumasi Metropolis, where the highest disease incidence and severity were recorded, the farms selected had been set up purposely for research activities. However, there was no evidence of any research work on-going during the period of the study. There was also no evidence of removal of crop residues in the farms. This contrasted with the farms in the Hohoe District where plant debris were removed and farms were found to be well maintained during the period of the survey. Consequently, the disease was not detected in farms surveyed in the Hohoe District which was located in the same agro-ecological zone as the Kumasi Metropolis and the Kwaebibirem District, where all farms surveyed had the disease. This underscores the importance of maintaining clean farms as a means of controlling the disease.

The survey was carried out on the same crop genotype, namely the Keitt variety of mango, across the different farms in the study. However, great variations were found in the size of the mango trees. Trees in the Hohoe, Kintampo, Berekum, Savelugu-Nanton and Tolon-Kumbungu districts were shorter and smaller in girth than those in the other remaining areas. Incidentally, the lowest disease incidence and severity were also found in the same areas namely Hohoe, Kintampo, Berekum, Savelugu-Nanton and Tolon-Kumbungu districts. This must be expected since smaller trees are characterised by less dense foliage and lower humidity within the canopy. Also, fungicide application, when necessary would be more efficient on smaller trees than huge and tall trees. Furthermore, since leaves serve as one of the major sources of inoculum in the tree canopy (Arauz, 2000), there may be a direct relationship between the number of leaves and the inoculum concentration.

In the coastal savanna zone, most trees were tall with larger canopies compared to the Guinea savanna zone. Due to the short interval between the two mango production seasons in the coastal savanna zone, farmers within the area find it almost impossible to carry out effective pruning. The trees, therefore, grow luxuriously. Consequently, the disease was severer in the coastal savanna than in Guinea savanna. Therefore, apart from facilitating the entrance of sunshine into the tree canopy and reducing the inoculum level on farms, tree pruning might also reduce the general size of the trees and, hence, the disease incidence and severity.

The prevailing weather condition is another important factor that influences the incidence and severity of plant diseases (Agrios, 2005; Kranz & Rotem, 1987). Of major importance is rainfall which influences distribution and spread of mango anthracnose, by serving as a major vehicle for the dispersal of conidia within the tree canopy. It also provides free moisture for the germination of conidia (Arauz, 2000; Jeffries *et al*., 1990). Therefore, the variations in rainfall patterns across the various regions may be another factor influencing the distribution of the mango anthracnose disease in Ghana.

The two farms that recorded the highest disease incidence and severity in the Eastern and Ashanti regions all lie within the semi-deciduous forest agro-ecological zone. The zone is characterised by high amounts of rainfall during most parts of the year (Fig. 1). In addition, temperatures are also high all year round, and this is known to increase relative humidity (Chala, Burberg & Tronso, 2010) that exacerbates the anthracnose disease (Nelson, 2008). Under such environmental condition, the production of good quality fruits will depend on the rigid institution of good disease control practices including the frequent application of fungicides (Arauz, 2000). Generally, farmers avoid these areas for the establishment of mango farms. However, certain benefits to be derived such as availability of land and rainfall and ability of trees to flower at certain desirable periods entice some farmers to site farms in such areas.

There was evidence during the study that most of the farms that were practicing heavy pruning and heavy fungicide applications were found in the Hohoe District in the semi-deciduous forest. These farms were able to supply good quality fruits to the international markets by adhering to rigid disease control regimes. This contrasted sharply with the farms in the Kwaebibirem District and Kumasi Metropolis in the same agro-ecological zone, where fruits produced during the period were of poor quality due to the absence of rigid disease control.

The fact that rainfall pattern in the agroecological zones played a role in the disease incidence and severity was supported by the absence of the disease symptoms in the Savelungu-Nanton and Tolon-Kumbugu districts. Leaves and dried panicles from previous season's production from the farms in both districts were found to harbour the pathogen's acervuli (which contained the infective conidia of the pathogen). Despite this evidence of infective propagules, the disease was not detected in the field. This means the fruits were either not infected at all or the infections were quiescent, and prevailing environmental conditions to promote the development of disease symptoms was not condusive during the production period. The first explanation is not plausible because development of postharvest symptoms from fruits from the region showed that some of the fruits were infected. Presumably, the absence of the disease in the field could be attributed either to the absence of the requisite amounts of rainfall necessary to disseminate infective propagules during the early fruit development stage (when infected fruits develop symptoms), or the unavailability of successive rainy days that promote the development of the cracked skin lesions attributed to the disease (Nelson, 2008). The Savelugu-Nanton and Tolon-Kumbugu districts are in the Guinea savanna agro-ecological zone, where the lowest amount of total rainfall in a year is recorded in Ghana (Fig. 1). Furthermore, the high all year round temperatures and low relative humidity resulted in the low disease incidence and severity.

The rainfall pattern in the Northern Region is seasonal with a dry spell recorded in November to March. This period also coincides with the flowering and early fruit set, the most susceptible stage of the fruit. The continuous rainy-days without a dry spell which leads to development of disease symptoms are virtually non-existent in the region. This unique rainfall pattern within the area may have contributed to the absence of fruits with visible symptoms at the preharvesting stage. This presumably makes the Northern Region very conducive and less expensive for the cultivation of mango. Consequently, many mango farms are currently being set up in the area and if the trend continues, the area may overtake the coastal savanna in terms of density of mango farms.

The disease incidence and severity in Berekum and Kintampo were low, similar to what was recorded in the Savelugu-Nanton and Tolon-Kumbugu districts. Berekum and Kintampo Municipals are both located in the transition zone, and their climatic conditions are closer to that of the Guinea savanna zone. Hence, the disease incidence and severity were also lower. In contrast, Ga West, Dangbe West, Yilo and Manya Krobo districts have high humidities all year round. Consequently, disease incidence and severity were higher than those from the Guinea savanna zones. However, Ga West, Dangme West, Yilo and Manya Krobo districts have an advantage of two production seasons per calendar year, compared to the other districts. To produce fruits of good quality, farms sited in these districts must practice regular tree pruning and removal of plant debris from the farms. These must be complemented with intense fungicide application which must commence long before flowering and continued till fruit maturity (Honger, 2013).

Postharvest anthracnose was prevalent in all the major mango growing districts of the country. Comparatively, more fruits were infected at the postharvest stage than the preharvesting stage in all the districts, making the postharvest stage more destructive. This confirms the report that symptoms developed on the mango fruits after harvest is the most destructive nature of the disease (Freeman, Katan & Shabi, 1998). It may also confirm why in most mango growing areas, it was believed that the disease is only important at the postharvest stage, and most control measures are aimed at preventing disease development at that stage (Arauz, 2000). Unlike the preharvest stage where some of the diseased fruits were marketable at least on the local market, the dark sunken lesions that developed on fruits after postharvest render those fruits unmarketable, showing that the disease at that stage is a major constraint on fruit production and marketing. This implies that effective control measures to prevent development of postharvest anthracnose disease symptoms on harvested fruits is critical for profit making in the mango industry.

Conclusion

The findings of the study have shown that without proper training, farmers would find it difficult to distinguish between anthracnose disease symptoms and other fruit spot symptoms on mango fruits. In such a case, any report regarding the disease from the farmers would need thorough assessment before decisions are made.

The results further showed that leaves, panicles and mummified fruits are major sources of inoculum on mango farms. The practice where farmers use these as mulch must be discouraged as much as possible.

The disease incidence and severity were found to be low in the transitional and Guinea savanna zones of Ghana. These places in Ghana are not very favourable for the development of the anthracnose disease symptoms. Therefore, mango farms must as much as possible be sited in these areas. However, when farms must necessarily be set up in the coastal and semi-deciduous forest, where conditions favoured the development of the disease, very riguourous control practices, such as constant removal of excess plant parts and debris must be combined with application of fungicides, to control the disease in these areas.

It was also very evident, that irrespective of the environmental conditions, latent forms of the disease would be encountered. Therefore, treatment of mango fruit after harvest, such as dipping in any acceptable fungicide, must be encouraged in Ghana to prolong the shelf life of the fruits.

The disease incidence recorded on the fruits at the postharvest stage were comparatively higher than what was recorded at the preharvest stage in almost all the Metropolis/Municipals/Districts. This means that the control of the disease at the postharvest stage must be of major concern to growers and exporters than at the preharvest stage.

REFERENCES

Agrios, G. M. (2005) *Plant Pathology* 5th edn.

Academic Press, New York. 952 pp.

Arauz, L. F. (2000) Mango Anthracnose: Economic impact and current options for integrated management. *Plant Diseases* **84** (6), 600 – 611.

Chala, A., Burberg, M. B. & **Tronso, A. M.** (2010). Incidence and severity of Sorghum anthracnose in Ethiopia. *Plant Pathology Journal* **9**(1), 23 – 30.

Crane, J. H. & **Campbell, C. W.** (1991) *The Mango*. Florida Cooperation Extension Service, Institute of Food and Agricultural Science, University of Florida.

Dodd, J. C., Jeffries, P. & **Jeger, M. J.** (1989) Management strategies to control latent infection in tropical crops. *Aspects of Applied Biology* **20,** 49 – 56.

Dodd, J. C., Bugante, R., Kromen, I., Jeffries, P. & **Jeger, M. J.** (1991) Pre and post harvest control of mango anthracnose in the Philippines. *Plant Pathology* **40**, 576 – 583.

Estrada, A. B., Dodd, J. C. & **Jeffries, P.** (2000). Effect of humidity and temperature on conidial germination and appressorium development of two phillipine isolates of the mango anthracnose pathogen *Colletotrichum gloeosporioides. Plant Pathology* **49**, 608 – 618.

Fitzell, R.D. (1981) Regular application of Benomyl on the population of *Colletotrichum* on mango leaves. *Transaction of the British Mycological Society* **98**, 65 – 77.

Freeman, S., Katan, T. & **Shabi, E.** (1998) Characterization of *Colletotrichum* species responsible for anthracnose disease of various fruits. *Plant Diseases* **82**, 596 – 605.

Gagnevim, L. & **Pruvost, O.** (2001) Epidemiology and control of mango bacterial black spot. *Plant Diseases* **85**(9), 928 – 935.

Honger, J. O. (2013) *Characterisation of the causal agent of mango anthracnose disease in Ghana*. (PhD Thesis). University of Ghana, Legon.

Ilag, L. I. (1992) Diseases of mango and their control. *Paper presented during the first national symposium workshop on Mango diseases in The Philippines. Bureau of Plant Industry, March 19-20.*

Jeffries, A, Dodd, J. C., Jeger, M. J. & **Plumbley, R. A.** (1990) The biology and control of *Colletotrichum* species on tropical fruit crops. *Plant Pathology* **39**, 343 – 366.

Johnson, G. I. (1998) Stem end rot. In *Compendium of tropical fruit diseases*. (R.C Ploetz, G.A Zetmeyer, W.T.Nishijima, K.G. Rohrbach and H.D.Ohr, eds.) pp. 39 – 40. The American Phytopathological Society, Minnesota, USA.

Kranz, J. & **Rotem, J.** (1987) *Experimental techniques in plant disease epidemiology.* Springer-Verlag, Berlin. 229 pp.

Lakshmi, B. K. M, Reddy, P. N. & **Prasad, R. D.** (2011) Cross infection potential of *Colletotrichum gloeosporioides* Penz, isolates causing anthracnose in sub-tropical crops. *Tropical Agricultural Research* **2**, 183–193.

Madden, L. V., Hughes, G. & **van den Bosch, F.** (2007) *The study of plant disease epidemics.* The Americal Phytopathological Society, Minnesota, USA.

Manicom, B. Q. & **Pruvost, O. P.** (1998) Bacterial black spot. In *Compendium of tropical fruit diseases*. (R.C. Ploetz, G. A. Zentmeyer, W.T. Nishijima, K.G. Rohrbach and H. D. Ohr, eds.) pp. 41-42. The American Phytopathological Society, Minnesota, USA.

Marley, P. S. (2004) Effects of integrating host plant resistance with time of planting and fungicides on anthracnose, grain mold and yield of sorghum (*Sorghum bicolor*) in the Nigerian northern Guinea savanna. *Journal of Agricultural Science* **142**, 345 – 350.

McMillan, R. T. (1984) Control of mango anthracnose with foliar sprays. *Proceedings of the Florida State Horticultural Society* **97**, 344–345.

Nelson, S. C. (2008) *Mango anthracnose (Colletotrichum gloeosporioides*). College of Tropical Agriculture and Human Resource. Publication PD-48. Hawaii, USA.

Neya, A. & **Normand, M. L.** (1998) Response of sorghum genotypes to leaf anthracnose (*Colletotrichum graminicola*) under field conditions in Bourkina Fasso. *Crop Protection* **17**, 47 – 53.

Oduro, K. A. (2000) *Checklist of plant pests in Ghana. Volume 1. Diseases*. Plant Protection and Regulatory Service Directorate , Ministry of Food and Agriculture. Accra, Ghana. 105 pp.

Offei, S.K., Cornelius, E. W. & **Sakyi-Dawson, O.** (2008) *Crop Diseases in Ghana and their Management*. Smartline Publishing Limited. 104 pp.

Peres, N. A. R., Kuramae, E. E., Dias, M. S. C. & **De Souzza, N. L.** (2002) Identification and characterisation of *Colletotrichum* species affecting fruit after harvest in Brazil. *Journal of Phytopathology* **150**, 128 – 134.

Ploetz, R. C. (1998) Anthracnose. In *compendium of tropical fruit diseases.* (R.C. Ploetz, G. A. Zetmeyer, W.T. Nishijima, K.G. Rohrbach and H.D. Ohr, eds) pp. 35 – 36. The American Phytopathological Society, Minnesota, USA.

Sakalidis, M. L., Hardy, G. E. & **Burgess, T. I.** (2011) Pathogenic Botryosphaeriaceae associated with *Mangifera indica* in the Kimberley region Of western Australia. *European Journal of Plant Pathology* **130**, 379 – 391.