Chemical control of mango anthracnose disease in Ghana

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

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

Corresponding author's email: johonger@yahoo.co

ABSTRACT

Seven different fungicides were evaluated *in-vitro* and in the field for their efficacy against the causal agent and incidence and severity of mango anthracnose disease in Ghana. The recommended rates of Bendazim, (Carbendazim), Funguran (Copper hydroxide), Ivory (Mancozeb), Agriette +Ivory (Fosetyl-Al +Mancozeb), Sundomil (Mancozeb+Metalaxyl), Top Cop (Copper +flowable sulphur), Mirage (Prochloraz), Bendazim+Ivory and Funguran+Ivory were mixed with potato dextrose agar (PDA) and the radial mycelial growth of the pathogen was determined on these amended media. The fungicides were applied on fruit bearing trees in a commercial farm in the Yilo Krobo District after which the disease incidence, severity and percentage of exportable fruits were determined. The results showed that the pathogen was not able to grow on PDA amended with the fungicides. In the field, Bendazim and Funguran fungicides were able to suppress the disease to a large extent resulting in the highest percentage of exportable fruits. Prochloraz solution at both ambient temperature and 53 °C were able to completely eradicate the pathogen, and prevented development of postharvest anthracnose disease symptoms.

Original scientific paper. Received 30 Apr 14; revised 23 Sept 14.

Introduction

Mango (*Mangifera indica* L.) is one of the most important fruit crops in the tropics, and approximately makes up 50 per cent of tropical fruits produced in the world (Jedele *et al*., 2003). The world's largest producer of mango is India followed by China and Thailand. The largest producer of the crop in Africa is Nigeria followed by Egypt, while countries such as Ghana and Burkina Faso produce modest amounts (FAOSTAT, 2010)

Mango is a speciality crop in most of the international markets and, hence, is an important source of foreign exchange for most developing countries including Ghana. Currently, Mexico is the world's largest exporter of the mango followed by India and Brazil. In Africa, none of the producer countries is considered as one of the top 10 exporting countries (FAOSTAT, 2010) although South Africa, Kenya, Mali, Burkina Faso and Cote d'Ivoire export modest quantities. Ghana has also been exporting the crop for the past 20 years, but the amounts exported each year are so modest that the country cannot be considered as an important exporter of the crop.

Ghana is made up of six major agro-ecological zones comprising the coastal savanna, the wet equatorial forest, semi-deciduous forest, transitional zone, Guinea savanna and Sudan savanna. Commercial mango farms are heavily concentrated in the coastal savanna, where the bulk of Ghana's mangoes for the export markets are produced. Due to increasing profitability of the crop, new areas such as the transitional and Guinea savanna zones are now being cultivated to the crop. It is believed that if the major problems related to the production of the crop are properly handled, mango has a potential of becoming a major export crop of the country.

One of the major problems confronting the production of mango is the incidence of pests and diseases (Ploetz, 1998). Currently, mango anthracnose caused by *Colletotrichum gloeosporioides* has been identified as the most important fungal disease affecting the production of the crop in Ghana (Oduro, 2000). The disease can blight flowers, thereby preventing fruit set. However, the causal agent produces latent infections which develop symptoms on the fruits that are in transit or storage. This postharvest stage of the disease has been reported as the most destructive nature of the disease (Freeman *et al*., 1998).

Several methods have been proposed for the control of mango anthracnose in different mango growing areas. However, the use of fungicides, both at the pre and postharvest stages of the fruits has been found to be the most effective method of controlling the disease (Dodd *et al*., 1991). In Ghana, several fungicides such as Mancozeb, Funguran and Carbendazim are available on the market, and have been labeled for the control of mango anthracnose in the field. These fungicides have been found to be very effective in controlling the disease in most mango growing areas (Arauz, 2000; Akem, 2006). Also available is Prochloraz, which is permitted to be used for postharvest treatment of mango fruits that are destined for the European market (Arauz, 2000), where a bulk of Ghana's mango exports are sent

Despite the huge fungicide resources available locally for the control of the disease, not much information is available to guide farmers on the choice and mode of application of fungicides for effective control of the disease. In such a situation, there is a likelihood of these fungicides being misused. Apart from wastages due to wrong application methods, it would also lead to poor control of the disease. Such poor results are most often thought to be as a result of reduced potency of the fungicide (Odzeyem, verbal communication). In some cases, farmers tended to question whether the causal agent has developed resistance to these fungicides.

To be able to formulate a good control measure against the disease, there will be the need for a proper assessment of the fungicides available in the country, to ensure that the most effective ones are recommended to farmers. In the study, therefore, some of the common fungicides available on the Ghanaian market were assessed for their efficacy against the causal agent of the mango anthracnose disease and the disease incidence and severity in the field.

Materials and methods

Selection and in vitro *evaluation of fungicides*

Based on rapid appraisal method of interviewing 82 mango farmers, the types of fungicides they use to control diseases in their farms were selected. The selected fungicides (Table 1) were tested on 7-day old culture of the *Colletotrichum gloeosporioides*. The fungus was isolated from diseased mango fruits showing anthracnose disease symptoms that were collected from different mango farms in Ghana. The assessment was carried out *in vitro*, by determining the radial mycelia growth of the fungus on potato dextrose agar (PDA) amended with recommended rates of the fungicides after Peres *et al*. (2002).

The required amount of each fungicide was measured and mixed thoroughly with 100 ml of autoclaved molten PDA (39 g l^{-1}) and dispensed into three Petri dishes, each containing about 30 ml of the fungicide-amended media and allowed to set. Plugs of each isolate taken from the periphery of a 7-day old culture, using a sterile cock borer, were placed in the middle of each plate at one plug per plate. Three replications of each isolate were used. Control plates contained PDA without fungicide amendment. The Petri dishes were placed in polythene bags and incubated in the laboratory at temperature of 23 – 25 ºC and relative humidity of 60 per cent to 65 per cent using the completely randomised design. Radial mycelial growth of the colonies were measured daily, by measuring the diameter of the colonies along diagonal lines drawn at the reverse side of the Petri dishes with a ruler. Measurement of mycelia growth started from the 3rd day after incubation when significant growth was recorded on the control plates to the 8th day when the growth in the control had covered the entire plate. Per cent inhibition in radial growth over control was calculated using the formula:

$$I = \frac{C-T}{C} \times 100$$

where I = per cent inhibition of growth of test fungi, C = radial growth (mm) in control and T = radial growth (mm) in treatment.

Experimental site

The field trial to assess the efficacy of the different fungicides against the anthracnose disease was carried out in a commercial mango farm located in the Yilo Krobo District of Eastern Region of Ghana. The area is characterised by the coastal savanna agroecological zone and has the highest density of mango farms in Ghana. The selected farm had a history of postharvest losses of fruits due to infection by the anthracnose disease. Weather conditions in the area where the farm was located were obtained from the Ghana Meteorological Services Department (Table 2).

Field layout and application of treatments

The experiment was carried out in the minor season of 2010, between September and December and again in the major season of 2011, between January and May.

Ten-year old mango trees of the Keitt variety were selected for the experiment. The trees selected were pruned to ensure the removal of excess foliage, and all plant debris were removed from the field. This was carried out immediately the previous seasons harvest was over in both seasons' trials. Early pruning of trees was necessary to ensure that the trees had enough time to

Table 1

Fungicides Evaluated for Effect on the Radial Mycelial Growth and Incidence and Severity of Mango Anthracnose Disease in Ghana

Product name	*Manufacturer*	*Active ingredient*	*Nature*	*Application rate*
Bendazim	Iprochem	Carbendazim	Systemic	2.0 g l^{-1}
Funguran	Makhteshim	Copper hydroxide	Contact	2.0 l^{-1}
Ivory	Calliope	Mancozeb	Contact	4.0 l^{-1}
Agriette+Ivory	-	Fosetyl-Al+Mancozeb	Contact/Systemic	2.0l^{-1}+2.0 l^{-1}
Sundomil	-	Mancozeb+Metalaxy	Contact	4.0 l^{-1}
Top Cop	Stoller	Copper+Flowable sulphur	Contact/Systemic	30.0 ml^{-1}
Mirage	Makhteshim	Prochloraz	Systemic	1.5 ml^{-1}
Bendazim+Ivory*	-	Carbendazim+Mancozeb	Systemic/Contact	1.0 l^{-1}+2.0l^{-1}
Funguran+Ivory	-	Copper hydroxide+Mancozeb	Contact	1.0 l^{-1}+2.0l^{-1}

Table 2

Weather Data Obtained at the Research Area During the Period of the Study

Year	*Month*	*Rainy days*	*Rainfall amount (mm)*	*Temperature (°C)*	*Humidity (%)*
2010	September	15	11.5	27.6	85.5
	October	13	12.3	28.4	83.0
	November	13	9.2	28.9	83.0
	December	3	16.1	29.3	80.0
2011	January	0	0	27.6	79.5
	February	4	19.4	28.4	79.5
	March	6	9.3	28.9	79.5
	April	6	9.9	29.3	80.5
	May	7	7.2	29.0	80.0

Source; Ghana Meteorological Services Department, Accra.

recover from the shock before flower initiation. Flower initiation was carried out by dissolving Potassium nitrate in water at a rate of 16.6 g l^{-1} and spraying the mixture on the trees. This was done at bi-weekly intervals for two consecutive times. After flower initiation, trees with uniform flowering were selected for the trial. Nine treatments made up of the five fungicides and three combinations of different fungicides (Table 1) and a non treatment control were arranged in a randomized complete block design with four replicates. The treatments were applied with a calibrated solo mistblower with a volume rate of application of 200*l* ha^{-1}. Treatments were applied at bi-weekly intervals commencing on 10th September, 2010 and 15th January, 2011in the minor and major season trials, respectively. In each season, the applications continued until 2 weeks before harvesting. In all, there were a total of eight treatments per season. Trees were protected against stone weevils and fruit flies with cypermethrin at a rate of 4 ml l^{-1}. At approximately 114 days after flowering, fruits were harvested, and 100 fruits per tree were selected at random and used for the assessment of disease incidence and severity. The disease incidence (DI) was determined using the formula:

$$DI = \frac{\text{number of fruits with disease symptoms}}{\text{Number of fruits inspected}} \times 100$$

Disease severity index was determined by estimating the percentage of the fruit surface area diseased and rating the percentage using a scale of 0-5 after Lakshmi *et al*.,

(2011) (Table 3). After that all fruits from each replicate were graded into exportable fruits (without anthracnose lesions), non-exportable fruits (with disease lesions) and those that cannot be utilised in any way (discarded fruits).

TABLE 3

Disease Severity Rating Scale Used for the Assessment of Disease Severity in Different 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

Post harvest treatments

Eighty clean and healthy mango fruits, without any skin blemishes were selected at random from each of the nine treatments evaluated on the field, and were divided into four lots of 20 fruits each, and each lot was subjected to one of the following postharvest dips:

1) Mirage solution at ambient temperature of 25 ºC,
2) mirage solution at 53 ºC,
3) hot water at 55 ºC
4) water at ambient temperature to serve as control.

Fruits were dipped in treatments for 10 min after which they were air-dried and packed tightly in cardboard boxes. Fruits were then stored between 25 – 28 °C and RH of 60 per cent to 65 per cent using a complete randomized block design with four replicates of five fruits per replicate. After 15 days in storage, the disease incidence was assessed by expressing the number of fruits showing disease symptoms as a percentage of the number of fruits incubated. The disease severity was determined by estimating the percentage of the surface of fruits diseased and rating it using the scale of 0 – 5 after Lakshmi *et al*., (2011) (Table 3).

Data analysis

Percentage inhibition of mycelia growth of the pathogen, disease incidence, percentage of exportable and non-exportable fruits were all arcsine transformed and subjected to analysis of variance (ANOVA). ANOVA was performed directly on the disease severity indices, using GENSTAT 9th edition. Means were separated using LSD at five per cent.

Results

Effect of selected fungicides on the mycelia growth of C. gloeosporioides

Each of the six fungicides (Bendazim, Funguran, Ivory, Mirage, Sundomil and Top Cop) and the combination of Agriette and Ivory, was able to suppress the growth of the pathogen throughout the period of the experiment. The pathogen failed to grow in the PDA amended with the fungicides from the 3rd day of incubation to the 8th day resulting in a 100 per cent suppression of radial growth each day (Table 4). The observations, therefore, showed that all the fungicides evaluated at their recommended rates in the study were very effective against the pathogen.

Effect of preharvesting applications of fungicides on disease incidence and severity of minor season's mango production.

There was significant difference in disease incidence (P < 0.05) among the different

TABLE 4

Effect of Different Fungicides on Radial Growth of C. gloeosporioides *Obtained from Mango on Amended PDA*

Type of fungicide	*Incubation period (Days)* 3	4	5	6	7	8
Agriette+Ivory	100	100	100	100	100	100
Bendazim	100	100	100	100	100	100
Funguran	100	100	100	100	100	100
Ivory	100	100	100	100	100	100
Mirage	100	100	100	100	100	100
Sundomil	100	100	100	100	100	100
Top Cop	100	100	100	100	100	100

Values are percentage reduction in radial growth compared to the control

treatments. The highest disease incidence of 49.1 per cent was recorded on control trees followed by 38.6 per cent on trees treated with Top Cop fungicide. The lowest incidence was recorded on trees treated with Bendazim (Table 5). Disease incidence recorded on trees treated with Sundomil and Agriette plus Ivory and Top Cop was not significantly different ($P > 0.05$). Also, disease incidence on trees treated with either Ivory only or Ivory in combination with Bendazim or Funguran was not significantly different ($P > 0.05$).

There was significant difference ($P < 0.05$) in disease severity among treatments. The highest severity index (1.8) was recorded on control plots, whilst the lowest was recorded on trees treated with Bendazim (0.8). Disease severity among the rest of the treatments, i.e. Agriette plus Ivory, Sundomil, Ivory, Top Cop and the Ivory plus Bendazim treatments was not significantly different. Also, severity index on Funguran-treated trees was not significantly different from what was obtained on the Bendazim treated trees (Table 5).

Significant difference ($P < 0.05$) in percentage exportable fruits was recorded among treatments. The highest (70.2%) total production was recorded on trees treated with Bendazim, whilst the lowest (46.8%) was recorded on control trees (Table 5). The percentage of exportable fruits recorded on Funguran-treated trees was not significantly different from what was recorded on the trees treated with Bendazim. Percentage exportable fruits obtained after treatment with the rest of the fungicides did not vary significantly from each other (Table 5).

Effect of pre and postharvest treatments on the incidence and severity index of mango anthracnose disease on the Keitt variety of mango in the minor season

In the minor season, there was significant difference in incidence of postharvest anthracnose disease ($P < 0.05$) among fruits that received the different postharvest treatments. The lowest disease incidence (0) was obtained on fruits treated with Mirage dip at both ambient and at 53 ºC, whilst the highest disease incidence (97.8%) was recorded on the control fruits (treated with water at ambient temperature). The difference in the disease incidence on fruits treated with hot water and the control fruits was not significant (Table 6).

There was significant interaction between the preharvest and postharvest treatments on the severity index of postharvest anthracnose disease. The lowest disease severity index (0) was recorded on fruits that were dipped in the Mirage solution at both am-

TABLE 5

Effect of Fungicide Applications on the Incidence and Severity of Mango Anthracnose and on the Percentage of Exportable Fruits Produced in the Minor Season of 2010

Treatment (Fungicide/concentration)	[1]*Disease incidence (%)*	[2]*Severity index*	[3]*Exportable fruits (%)*	[4]*Discarded fruit (%)*
Agriette+Ivory (2 g l^{-1}+2 g l^{-1})	37.1	1.5	59.7	1.4
Bendazim (2 g l^{-1})	19.3	0.8	70.2	1.6
Funguran (2 g l^{-1})	26.1	1.0	65.8	0.8
Ivory+Funguran (2 g l^{-1}+1 g l^{-1})	32.9	1.6	58.4	1.4
Ivory+Bendazim (2 g l^{-1}+1 g l^{-1})	33.9	1.3	60.4	1.1
Ivory (4 g l^{-1})	32.4	1.3	62.9	2.2
Sundomil (4 g l^{-1})	37.8	1.5	62.3	1.2
Top Cop (20 ml l^{-1})	38.6	1.5	57.8	1.9
Control	49.1	1.8	46.8	1.8
Lsd (5%)	3.5	0.2	6.4	NS

[1] Incidence: Percentage of fruits showing the disease syptoms on the field. [2]Severity index based on a scale of 0-5 where 0 = no disease symptoms and 5 = more than 50 per cent of fruit surface diseased. [3]Exportable fruits are fruits without disease symptoms and could be sold on international markets. [4]Discarded fruits are those that had the disease lesions such that they could not be sold on both the international and local markets.

bient temperature and at 53 ºC, respectively, of the type of preharvest treatment that the fruits received. The control performed the same as the hot water when fruits were treated with either Bendazim or Funguran in the field. Otherwise, hot water was superior to the control when the fruits were treated in the field with the other fungicides (Table 7).

Effect of preharvesting applications of fungicides on disease incidence and severity of major season's mango production

The disease incidence ranged from zero on fruits from trees treated with Bendazim to one per cent in control trees. However, disease incidence among the different treatments was not significantly different (Table 8). Similarly, disease severity was low with the severity index ranging from zero to 0.13. Among the different treatments, the difference in disease severity index was not significant (Table 8). The percentage of fruits that were exportable also ranged from 97.9 per cent to 98.7 per cent among treatments, with the highest percentage being recorded on trees that were treated with Bendazim, whilst the lowest was recorded on trees treated with a combination of Ivory and Funguran. However, the difference in percentage of the exportable fruits among treatments was not significant (Table 8).

Effect of pre- and postharvest treatments on the incidence and severity index of mango anthracnose on the Keitt variety of mango in the major season

In the major season, there was significant difference in incidence of postharvest anthracnose disease ($P < 0.05$) among fruits that received the different postharvest treatments (Table 9). The lowest disease incidence (0) was obtained on fruits treated

TABLE 6

Effect of Pre and Postharvest Treatments on the Incidence of Postharvest Anthracnose on Fruits of the Keitt Variety of Mango in the Minor Season of 2010

Preharvest treatments	*Postharvest treatments/Disease incidence (%)*				
	Water at ambient temperature	*Hot water at 55 °C*	*Mirage at ambient temperature*	*Mirage at 53 °C*	*Mean*
Agriette+Ivory (2 g l^{-1}+2g l^{-1})	100.0	100.0	0.0	0.0	50.0
Bendazim (2 l^{-1})	80.0	65.0	0.0	0.0	36.3
Funguran (2 l^{-1})	100.0	100.0	0.0	0.0	50.0
Ivory (4 l^{-1})	100.0	100.0	0.0	0.0	50.0
Sundomil (4 l^{-1})	100.0	100.0	0.0	0.0	50.0
Top Cop (20 ml l^{-1})	100.0	100.0	0.0	0.0	50.0
Ivory+Bendazim (2 l^{-1}+1l^{-1})	100.0	100.0	0.0	0.0	50.0
Ivory+Funguran (2 l^{-1}+1 l^{-1})	100.0	100.0	0.0	0.0	50.0
Control	100.0	100.0	0.0	0.0	50.0
Mean	97.8	96.1	0.0	0.0	

LSD (5%): Preharvest = NS; Postharvest = 3.9; Preharvest* postharvest = NS

TABLE 7

Effect of Pre and Postharvest Treatments on the Severity Index of Postharvest Anthracnose on Fruits of the Keitt Variety of Mango in the Minor Season of 2010

Preharvest treatments	*Postharvest treatments/*Disease severity index*				
	Water at ambient temperature	*Hot water at 55 °C*	*Mirage at ambient tem,perature*	*Mirage at 53 °C*	*Mean*
Agriette+Ivory (2 g l^{-1}+2l^{-1})	3.3	2.7	0.0	0.0	1.5
Bendazim (2 g l^{-1})	1.4	0.8	0.0	0.0	0.6
Funguran (2 g l^{-1})	2.4	2.1	0.0	0.0	1.1
Ivory (4 g l^{-1})	3.1	2.8	0.0	0.0	1.5
Sundomil (4 g l^{-1})	3.3	2.9	0.0	0.0	1.6
Top Cop (20 ml l^{-1})	2.5	1.9	0.0	0.0	1.2
Ivory+Bendazim (2 g l^{-1} +1 g l^{-1})	2.3	1.9	0.0	0.0	1.0
Ivory+Funguran (2 g l^{-1} +1 g l^{-1})	3.3	1.95	0.0	0.0	1.3
Control	3.4	2.65	0.0	0.0	1.5
Mean	3.3	2.8	0.0	0.0	

*Based on a scale of 0-5 where 0 = no symptoms and 5 = more than 50% of fruit area covered.
LSD = 0.05: Preharvest = 0.2; Postharvest = 0.1; Preharvest* postharvest = 0.3.

with Mirage dip at both ambient and at 53 ºC whilst the highest disease incidence of 38 per cent was recorded on the control fruits (treated with water at ambient temperature). The difference in the disease incidence on fruits treated with hot water and the control

TABLE 8

Effect of Fungicide Applications on the Incidence and Severity of Mango Anthracnose Disease and on the Percentage of Exportable Fruits Produced in the Major Season of 2011

Treatment	*1Disease incidence (%)*	*2Severity index*	*3Exportable fruits (%)*	*4Discarded (%)*
Agriette+Ivory (2g l^{-1}+2g l^{-1})	0.3	0.01	98.4	0.9
Bendazim (2 g l^{-1})	0.0	0.0	98.7	0.8
Funguran (2 g l^{-1})	1.0	0.1	98.0	1.4
Ivory+Funguran (2 g l^{-1}+1 g l^{-1})	0.3	0.0	97.9	1.5
Ivory+Bendazim (2 g l^{-1}+1 g l^{-1})	0.0	0.01	98.3	1.2
Ivory (4 g l^{-1})	0.3	0.02	98.6	0.7
Sundomil (4 g l^{-1})	0.5	0.0	98.0	0.7
Top Cop (20 ml l^{-1})	0.5	0.02	98.2	0.8
Control	1.0	0.13	98.2	0.6
L.S.D (5%)	NS	NS	NS	NS

[1]Incidence: Percentage of fruits showing the disease symptoms on the field; [2]Severity index based on a scale of 0-5 where 0= no disease symptoms and 5 = more than 50 per cent of fruit surface disease; [3]Exportable fruits are fruits without disease symptoms and could be sold on international markets; [4]Discarded fruits are those had the disease lesions such that they could not be sold on both the international and local markets.

fruits was not significantly different (Table 9).

There was significant interaction between the preharvest and postharvest treatments on the severity index of postharvest anthracnose disease on the mango fruits (Table 10). The lowest disease severity index (0) was recorded on all fruits that were dipped in the Mirage solution at both ambient temperature and at 53 ºC, respectively, of the type of preharvest treatment that the fruits received in the field (Table 10). Hot water was superior to the control only when the fruits were treated with Agriette plus ivory, Ivory, Sundomil, Top Cop, Ivory and Bendazim, Ivory and Funguran or not treated (control) on the field. However, hot water treatment and the control performed similarly on fruits that were treated with either Funguran or Bendazim on the field (Table 10).

Discussion

In Ghana, mango farmers continue to report that fungicides currently available for the control of mango anthracnose are ineffective, raising questions as to whether the causal agent had developed resistance to these fungicides. An *in-vitro* study of the growth of the pathogen on PDA amended with seven different fungicides showed that the pathogen has not developed resistance to any of these fungicides. This technique has been used by several authors elsewhere and found to be very reliable in assessing resistance of pathogens to fungicides (Sariah, 1989; Sanders *et al*., 2000; Peres *et al*., 2002). The pathogen was found to be susceptible to all the fungicides tested. If these fungicides are ineffective in farmer's fields, it may be due to other reasons rather than the development of resistance strains of the pathogen.

TABLE 9

Effect of Pre and Postharvest Treatments on the Incidence of Mango Anthracnose Disease on Fruits of the Keitt Variety of Mango in the Major Season

Preharvest treatments.	*Postharvest treatments/Disease incidence (%)*				
	Water at ambient temperature	*Hot water at 55 ºC*	*Mirage at ambient temperature*	*Mirage at 53 ºC*	*Mean*
Agriette+Ivory (2 gl^{-1}+2 gl^{-1})	40.0	35.0	0.0	0.0	18.7
Bendazim (2 gl^{-1})	30.0	10.0	0.0	0.0	10.0
Funguran (2 gl^{-1})	35.0	35.0	0.0	0.0	17.5
Ivory (4 gl^{-1})	35.0	30.0	0.0	0.0	16.3
Sundomil (4 gl^{-1})	40.0	30.0	0.0	0.0	17.5
Top Cop (20 mll^{-1})	40.0	40.0	0.0	0.0	20.0
Ivory+Bendazim (2 gl^{-1}+1gl^{-1})	35.0	30.0	0.0	0.0	11.2
Ivory+Funguran (2 gl^{-1}+1 gl^{-1})	40.0	35.0	0.0	0.0	18.7
Control	50.0	45.0	0.0	0.0	23.7
Mean	38	30	0.0	0.0	

*Based on a scale of 0 - 5 where 0 = no symptoms and 5 = more than 50 per cent of fruit area covered.
LSD (5%); Preharvest = NS, Postharvest = 10.7, Preharvest*postharvest = 32.8.

TABLE 10

Effect of Pre and Postharvest Treatments on the Severity Index of Mango Anthracnose on Fruits of the Keitt Variety of Mango in the Major Season

Preharvest treatments.	*Postharvest treatments/Severity index**				
	Water at ambient temperature	*Hot water at 55 ºC*	*Mirage at ambient temperature*	*Mirage at 53 ºC*	*Mean*
Agriette+Ivory (2 gl^{-1}+2gl^{-1})	0.8	0.4	0.0	0.0	0.3
Bendazim (2 gl^{-1})	0.3	0.1	0.0	0.0	0.1
Funguran (2 gl^{-1})	0.7	0.4	0.0	0.0	0.3
Ivory (4 gl^{-1})	0.7	0.3	0.0	0.0	0.3
Sundomil (4 gl^{-1})	0.7	0.3	0.0	0.0	0.3
Top Cop 920 mll^{-1})	0.8	0.4	0.0	0.0	0.3
Ivory+Bendazim (2 gl^{-1}+1 gl^{-1})	0.8	0.1	0.0	0.0	0.2
Ivory+Funguran (2 gl^{-1}+1 gl^{-1})	0.8	0.4	0.0	0.0	0.3
Control	0.9	0.6	0.0	0.0	0.4
Mean	0.3	1.18	0.0	0.0	

*Based on a scale of 0 - 5 where 0=no symptoms and 5 = more than 50 per cent of fruit area covered.
L.S.D (5%); Preharvest = 0.2, Postharvest = 0.1, Preharvest*postharvest = 0.3.

To assess the efficacy of the fungicides against the mango anthracnose disease for the production of exportable quality mango fruits, the field study was carried out in both the minor and major mango growing seasons on a farm located in the coastal savanna zone, where the bulk of Ghana's exportable mangoes are produced. The farm selected was a commercial mango farm producing as an out-grower for many exporters to Europe and Middle East, and had a history of persistent anthracnose infections all year round.

In the minor season of 2010, the incidence and severity of anthracnose disease in the experimental field were quite high, with the incidence ranging from 19.3 per cent to 49.1 per cent and the severity index also ranging from 0.8 to 1.8 (Table 4). This could be attributed partly to the type of weather which pertained at the experimental field during the period when a lot of rainy days and high temperatures were recorded (Table 2). According to Nelson (2008), anthracnose disease is favoured by wet, humid and warm weather. The results of the experiment also showed that all fungicidal treatments were effective in reducing the incidence and severity of the disease resulting in a higher percentage of exportable fruits compared to the control (non-treatment) (Table 5). This confirms that the chemicals used in the study were effective against the pathogen and corroborates the results of the *in-vitro* studies.

During the major season trial, the disease incidence and severity recorded from the different treatments were very low, with the incidence ranging from zero to one per cent and severity ranging from zero to 0.13. This could also be attributed partly to the fewer number of rainy days at the early fruiting stages, which may have resulted in a lower dispersal of conidia resulting in low disease incidence and severity. During the period, there was no significant difference in the disease incidence, severity and percentage of exportable fruits (Table 8). This showed that the control was as effective as any of the fungicides applied, and that the application of fungicides during the period was not necessary. This is consistent with the reports that when fruits are produced in the dry season, good control of the disease can be achieved without the application of any fungicides (Arauz, 2000). In most of the mango production seasons within the coastal savanna, the transitional and the Guinea savanna zones, very few rains are recorded during the major mango production seasons, which sometimes begin in December or January and ends in April or May. Therefore, good control of the disease in the major season in these areas could be achieved without the application of fungicides. Indeed, this is mostly the case in the Guinea savanna where mangoes earmarked for the international organic markets are produced in Ghana.

When conditions favoured the development of the disease in the field (in the minor season), Bendazim was found to perform better than all treatments (except Funguran), reducing the disease incidence and severity, thereby increasing the number of exportable fruits. Bendazim (Carbendazim) together with Benomyl has been reported as being very effective against the disease before resistance to the latter developed in the field elsewhere (Arauz, 2000; Akem, 2006). One reason that may have accounted for superior performance of Bendazim was its systemic nature, which enabled it to remain in the tree system whilst the contact fungicides such as Ivory may be washed away or have their concentrations diluted by the rains. Again, being a systemic fungicide, it may be more effective being applied at bi-weekly intervals than the other fungicides which are mainly contact (Ullasa, 1989). Other fungicides such as Agriette plus Ivory and Sundomil also contain some active ingredients which are systemic in nature, but are not known to be effective against the pathogen (Ascomycete) (Agrios, 2005). These make Bendazim one of the most preferred among the different fungicides used in the study.

Mancozeb is a dithiocarbamate fungicide which is highly effective for the control of anthracnose (Arauz, 2000). In study, it was found to perform better than the control but was inferior to Bendazim. Mancozeb is a contact fungicide, and fungicides of such nature are required to be applied at shorter intervals to achieve the same results as systemic fungicides which are applied at bi-weekly intervals (MacMillan, 1984). In Ghana, weekly application of fungicides of any type is considered too expensive by farmers and, hence, Mancozeb, if applied would be done at bi-weekly intervals. In such a case, good control is not likely to be achieved especially, when conditions favoured the development of the disease in the field. However, though the performance of the fungicide was not as effective as the systemic one (Bendazim), its better performance as compared to the control is an indication that the fungicide was effective and could produce better results when applied at weekly intervals.

Funguran, a copper based fungicide was found to be as effective as Bendazim (in the minor season), and provided a better control of the disease than Mancozeb (Table 4). It has been reported that copper based fungicides (especially the oxides of copper) are usually less effective than the dithiocarbamates especially under high disease pressure (Arauz, 2000). However, despite the reports of lower potency of copper based fungicides, the hydroxide of copper (active ingredient of Funguran) was found to be very effective in the study. Funguran is a contact fungicide which was applied at bi-weekly intervals in the study, however, it performed very well. This could be attributed partly to the nature of its active ingredient which is copper. Copper compounds are not easily washed from leaves by rain since they are relatively insoluble in water. They, therefore, give longer protection against diseases than other organic materials (Ware, 1991). The performance of Funguran in the study may be similar to what some farmers may be experiencing on their farm. This is because Funguran was being used on most commercial mango farms in Ghana that were producing the fruits for export, an indication that they also were achieving good results with the fungicide.

Latent infections of the fruits in the field could be very damaging, as they develop lesions on already harvested fruits destined for the market which then will render the fruits unmarketable. Mirage (Prochloraz) either at ambient temperature (25 ºC) or at 53 ºC was able to totally control the disease on the mango fruits at the postharvest stage, irrespective of the preharvest treatment that the fruits had received. The high performance of the fungicide has been reported by several authors and has also been identified as an effective alternative to Benomyl (Dodd *et al*., 1991), which was the most potent fungicide until resistance was developed in the field (Akem, 2006). In Thailand, postharvest dip of mangoes in Prochloraz was found to be more effective in controlling the disease than Benomyl (Visaprathanonth & Puagmee, 1989). Therefore, the effective control obtained with dipping of fruits in Prochloraz was consistent with earlier reports. Prochloraz is allowed to be used as postharvest treatment on fruits destined for the European market (Arauz, 2000). The fungicide is, therefore, the best option for the postharvest treatment of mango fruits against anthracnose.

Fungicide dips of Prochloraz at both ambient and 53 °C yielded the same level of control of the disease. In terms of cost, ambient temperature treatment is preferable since costs may be incurred in the provision of energy to maintain water at a higher temperature. Also, dipping in Prochloraz at ambient temperature may not require any complex structures to handle the large number of fruits destined for the market and, hence, can be practiced by most farmers. On the other hand, though moderately hot water was able to reduce the disease severity compared to the water control, the levels of the disease on the surface of the fruits after storage still reduces the aesthetic value of the crop.

Conclusion

It can be concluded that the best option for the control of mango anthracnose is the use of Carbendazim (when the disease incidence is expected to be high), Funguran or Mancozeb in the field after which the fruits would be dipped in Prochloraz solution after harvest. These fungicides have been duly registered to be used on fruit crops in Ghana for the control of plant disease and, therefore, pose no problem for their use for the control of anthracnose disease of mango in the country, if used responsibly.

REFERENCES

Agrios, G. M. (2005) *Plant Pathology*. 5th edn. Academic Press, New York. 952 pp.

Akem, C.P. (2006) Mango anthracnose disease; present status and future research priorities. *Plant Pathology Journal* **5**, 266 – 273.

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

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

FAOSTAT (2010) World mango production. *www.novagrim.com.pages/2000-2001_mango-statistics-EN.aspx.*

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

Jedele, S., Hau, M. A. & **von Oppen, M.** (2003) An analysis of the world market for mangoes and its importance for developing countries. *Paper presented at the Conference on International Agricultural Research for Development. Gottingen, Germany. October 8-10.*

Lakshmi, B. K. M., Reddy, P. N. & **Prasad, R. D.** (2001) Cross infection potential of *Colletotrichum gloeosporioides* Penz, isolates causing anthracnose in sub-tropical crops. *Tropical Agricultural Research* **2**, 183 – 193.

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.*

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.

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. 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.

Sanders, G. M., Korsten, L. & **Wehner, F. C.** (2000). Survey of fungicide sensitivity in *C. gloeosporioides* from different avocado and mango production areas in South Africa. *European Journal of Plant Pathology* **106**, 745 – 752.

Sariah, M. (1989) Detection of Benomyl resistance in the anthracnose pathogen, *C. capsici. Journal of Islamic Academy of Science* **2** (3), 168 – 171.

Ullasa, B. A. (1989) *Effect of Pre-harvest fungicidal sprays for the control of anthracnose of mango*. Abstracts of the third International Mango Symposium. Daron, Northern Australia. 55 pp.

Visaprathanonth, N. & **Puagmee, A.** (1989) *Efficacy of four fungicides against postharvest diseases of mango*. Abstracts of the 3rd International Mango Symposium. Northern Territory, Australia. 1989 pp.

Ware, G. W. (1991) *Fundamentals of Pesticides-A Self Instruction Guide*. Thompson Publications. California. 307 pp.