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Management of yam anthracnose and leaf spot diseases in seed yam production using fungicides

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Abstract

Yam anthracnose and leaf spot diseases are important diseases observed during seed production in Ghana. Management of these diseases with Bordeaux mixture, Carbendazim and Thiophanate methyl were evaluated at two locations (Ejura and Fumesua) and benefits of their applications established. When disease incidence was 3-5 Per cent, fungicides were applied in the field at respective dosages of 750, 292 and 413 g/ha of active ingredient using 15 L knapsack sprayers. Each fungicide was applied at bi-weekly (i.e. applied every two weeks) and four-weekly (i.e. applied every four weeks)for two months. Disease severity was assessed every two weeks using a scale of 0-11 and converted into percentage Disease progress curves were drawn, area under the disease progress curve (AUDPC) calculated and tuber yield determined. Partial budgeting was used to assess economic gains of each fungicide. Fungicides differed ($p<0.05$) in terms of disease severity and tuber yield. All fungicides significantly reduced AUDPCs compared with the control. Bordeaux mixture at bi-weekly interval resulted in tuber yield of 2,662.9 kg/ha which was higher than yield obtained as a result of application of Carbendazim (2,390.20 kg/ha), Thiophanate methyl (2,146.8 kg/ha) and control (2,085.8 kg/ha). Four-weekly application frequency showed similar trends for all treatments. The application of Bordeaux mixture and Carbendazim at four-weekly interval showed positive values of net income whereasThiophanate methyl did not. Thus, four-weekly application of Bordeaux mixture and Carbendazim applied at the onset of the diseases is recommended to seed yam farmers.

Keywords:AUDPC, Bordeaux mixture, Disease management, Economic benefit, Tuber yield

Introduction

Yam anthracnose caused by *Colletotrichum gloeosporioides* (Kwodaga et al., 2020) and foliar diseases notably leaf spot disease caused by *Curvularia eragrostidis* (Twumasi, 1981) have been reported as major threats to yam production in most yam producing areas in Ghana. Winch *et al*. (1984), reported yam anthracnose to be very damaging to yam plants especially in the West African sub region. The disease has also been reported in countries such as Nigeria (Akimbo and Opara, 2019), Ivory Coast (Nwadili et al., 2017) and Brazil (Green and Simons, 1994). In West Africa, an economic loss of up to 90 per cent has been reported due to the occurrence of yam anthracnose and leaf spot diseases (Winch et al., 1984).

Management of yam anthracnose and leaf spot disease has not been attempted by farmers despite their potential for causing significant crop loss. Farmers often consider the diseases as insignificant since some tuberization is obtained at harvest. However, the destruction of photosynthetic cells by the causal agents greatly affects the economic yield (Kutama et al., 2013) as the diseases adversely limit the ability of yam tubers to store food. Incidence of diseases prior to or during tuber development can

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have a negative effect on the yield. In the wet season, most fungal diseases like yam anthracnose and leaf spot diseases are common in yam fields due to the favourable environmental conditions accelerating the sporulation and spread of inocula of the pathogens (Muimba-Kankolongo, 2018). Management practices such as early planting, field sanitation, use of anthracnose resistant varieties and fungicide application have been reported to be effective in reducing yam anthracnose disease (Green and Simons, 1994).

The use of benomyl with weekly rotation with chlorothalomil was found to be effective in managing yam anthracnose disease when growers begun the spraying programmes at the onset of appearance of the first symptoms of the disease and they continued to spray on a weekly basis (Green and Simons, 1994). Twumasi (1987) also found Benlate, Dithane M-45 and Polyram-Combi to be effective against tar spot disease of water yam when sprayed at weekly or bi-weekly. The under-utilisation of fungicide application against yam anthracnose and leaf spot diseases could partly be due to the lack of information on the most effective and efficient application procedures to follow as well as the economic benefits from fungicide application. Since the application is done mostly during the wet season, protective fungicides get easily washed off from the treated surfaces after rains (Awuah, 1996).

Seed yam production in the tropics over the past two decades has seen a tremendous increase amongsmall-holder farmers (Otoo et al., 2001). This is evident from the rise in yam production globally from 32 million metric tonnes (MMT) in 1997 to 73 MMT in 2017 (FAO, 1997; FAO, 2017). According to Nweke et al. (1991), cost of planting materials constitute 50 per cent of the cost in yam production. The introduction of good agricultural practices and technologies such as yam minisett technique, ridging, trellis staking, seed treatment and positive selection technique have been adopted by most seed yam farmers in Ghana and Nigeria (Aighewi et al., 2017; Otoo et al., 2001; Osei et al., 2019).

Since seed yam production is done on relatively small land size compared to ware yam production, chemical control of yam anthracnose and leaf spot diseases would be feasible. The introduction of an appropriate and effective control for yam anthracnose and leaf spot diseases would undoubtedly improve seed yam production in Ghana. Currently, the demand for seed yams in Ghana cannot be met due to low yield resulting mainly from the above-mentioned diseases.

Bordeaux mixture (CaldoBordeles Valles 20 WP), Carbendazim (Bendazim 50 WP) and Thiophanate-methyl (Topsin-M 70% WP) are the three fungicides that have been introduced to the Ghanaian market. Studies on the significance of these fungicides in seed yam production in managing yam anthracnose and leaf spot diseases in Ghana have not been previously attempted even though their use on other crops are known (Honger et al., 2015; Mbi et al., 2021). Besides, fungicides are relatively expensive and evidence regarding their impact on disease management must be well established before being recommended to seed yam farmers. Successful management of these diseases in seed yam production would promote wide spread cultivation and substantial increase in overall production of seed yam to meet market demands. This study was undertaken to determine the benefits of the selected fungicides in managing yam anthracnose and leaf spot diseases during seed yam production.

Materials and methods

The experimental design was randomised block design (RBD) in a 4 x 2 factorial arrangement (i.e., three fungicides + control at two application frequencies) replicated three times. Fungicides tested in this study were Bordeaux mixture (CaldoBordeles Valles 20 WP), Carbendazim (Bendazim 50 WP) and Thiophanate-methyl (Topsin-M 70% WP). These fungicides were used

Table 1. Fungicides and recommended rates used in the trial

Fungicide trade name	a.i*	Mode of action	Amount of a.i (g/ha)**	Amount of product (g/ha)	Amount of product per plot (g/30m^2)
CaldoBordeles	Copper (Bordeaux mixture)	contact	750	3750.00	11.25
Bendazim	Carbendazim	systemic	292	583	1.75
Topsin-M	Thiophanate-methyl	systemic	413	590	1.77

*a.i.= active ingredient of fungicide**Includes allowance for 18% waste;

at the manufacturer's recommended application rates (Table 1). The control treatment was the use of sterile water. Application frequencies tested were bi-weekly and four-weekly intervals.

Land preparation and field layout

The study was undertaken at two research stations of CSIR-Crops Research Institute located at Ejura(lat. 7.3250° long. -1.4175°) and Fumesua (lat. 6.71458, long. -1.53542), Ghana. The weedicide, Glyphosate (trade name: Adwumawura) was applied in the field of 345 m^2 (15 m x 23 m) at the rate of 10mL/ L of water. After two weeks, the land was ploughed, harrowed and debris removed from the soil. Each plot consisted of three ridges (each 3 m long and 1 m wide) constructed across the slope of the land. Plots were arranged in a serpentine manner and replicated three times.

Yam minisett treatment, field establishment and management

Seed yams of the whiteyam (cultivar Kpamyo), were cut into minisetts (50 g) using ethanol-sterilised kitchen knife. The minisetts were immersed for 3 minin a mixture of 40 mL Karate (2.5 EC) insecticide and 10 g Dithane M-45 (80 WP) fungicide in 10 L water contained in a bucket and dried overnight (Osei et al., 2019). The minisetts were planted on ridges at a spacing of 30 cm between plants, firmed and watered. Each plot had 30 minisetts planted. Trellis staking of plants was done four weeks after planting. This was continued for all emerging plants within the planting season. Weeds were managed by hoeing regularly. For insect control, an insecticide, Emamectine Benzoate (trade name: ATAKA SUPER) was applied at a rate of 30 mL/15 L of water at three weeks after planting. Data on weather parameters during the study was obtained from Agrometeorology Division, Ghana Meteorological Agency, KNUST station (GPS: lat. 6.680413°, long. -1.558352°).

Fungicide application, disease and seed tuber yield assessment

Fungicides were applied on plants at the onset of disease. Each fungicide was applied with a non-motorised knapsack sprayer on plots (i.e., 30 plants per plot) considering the spraying intervals of two and four weeks for two months. A black polythene sheet was used during spraying to prevent drifts of fungicides onto other plots. Severity of yam anthracnose and leaf spot diseases on plants were assessed at every two weeks for all treatment plots, using the rating scale of 0-11 (Horsfall and Barratt, 1945) where, 0= 0%; 1= 0-3; 2= 3-6; 3= 6-12; 4= 12-25; 5=25-50; 6= 50-75; 7= 75-88; 8=88-94; 9=94-97; 10= 97-100 and 11= 100%. A conversion manual (Redman et al., 1962) was used to estimate the mean percentages in each plot. A disease progress curve was drawn for each fungicide treatment and the area under the disease progress curve (AUDPC) was calculated with Microsoft Excel (Microsoft Professional Plus 2016) using the following equation:

$$AUDPC = \sum_{i=1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i)$$

Where x_i is the cumulative disease severity expressed as the proportion at the ith observation, t_i is the time (weeks) at the ith observation and n is total number of observations (Van der Plank, 1963). Seed yam tubers on a plot were harvested at seven months after planting and weighed with a weighing balance (METTLER AE 200, S.N. L64937).

Economic analysis of fungicides

Partial budgeting (Lessley et al., 1991) was used to determine the effect of each of the proposed changes (i.e., fungicide applications) on net income. This was done by subtracting the sum of total additional costs and total reduced income from the sum of the total additional income and total reduced costs. A positive net value indicated an increase in net income resulting from the fungicide application which further indicated that the proposed yam anthracnose and leaf spot diseases control mechanism is economically feasible and vice versa. Costs of fungicides, labour and water as well as price of seed yam were estimated based on the existing values during the 2020 cropping season.

Statistical analysis

Data for disease severity and yield from both locations were pooled together using the average pooling method. They were then transformed using arcsine (√x/100) and square root transformations respectively, before being subjected to fixed-effects factorial analysis of variance (ANOVA) in Statistix 9.0 analytical software (Statistix, 2009). Means were compared with Tukey's Honesty Significant Difference (HSD) at a level of 5% probability. Back transformed data were presented. The correlation between disease severity and tuber yield was determined.

Results

Fungicides on disease severity and tuber yield

There were variations (F-value= 216.44, p= 0.0001) in disease severity on yam with regard to the fungicides tested. However, fungicide application frequencies employed in this study (i.e., bi-weekly and four weekly) showed no variation with respect to disease severity progress (Fig. 1) and AUDPC (Table 2). For bi-weekly application frequency, all the fungicides differed significantly from each other and with the untreated control. Bordeaux mixture had the lowest AUDPC value compared with the control which represented a 64.95 per cent reduction in disease severity (Table 2). Carbendazim reduced the disease severity by 50.70 per cent whilst

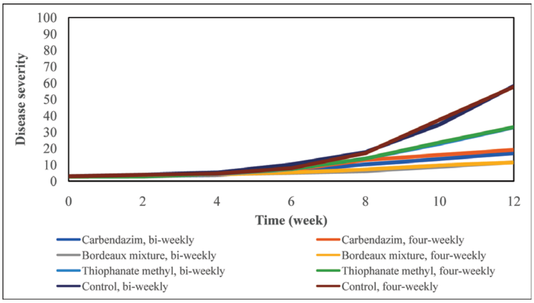

Fig 1. Progress of yam anthracnose and leaf spot diseases on plots receiving fungicides at two application frequencies

Table 2. AUDPCs and economic benefit of some fungicides sprayed to control yam anthracnose and leaf spot diseases in seed yam production

Fungicides Application*	AUDDPCs**	Tuber yield (kg/ha)	Partial budgeting (GH<)		
			Increased income due to change***[e]	Increased cost due to change****[f]	Net Change in income
Bordeaux mixture, 2-weekly	70.58	2,662.90	1,731.30	1,267.50	463.80
Bordeaux mixture, 4-weekly	70.33	2,635.20	1,621.80	633.75	988.05
Carbendazim, 2-weekly	99.28	2,390.20	913.20	647.88	265.32
Carbendazim, 4-weekly	103.67	2,414.10	958.50	323.94	634.56
Thiophanate methyl, 2-weekly	137.81	2,146.80	183.00	621.60	-438.60
Thiophanate methyl, 4-weekly	138.09	2,109.20	103.80	310.80	-207.00
Control, 2-weekly	201.39	2,085.80	0	0	0
Control, 4-weekly	200.44	2,094.60	0	0	0
HSD (5%)	26.13	81.54			

*Fungicides were sprayed 6 times (2-weekly) and 3 times (four-weekly).**AUDPCs = Area Under the Disease Progress Curve in percent weeks. Values with the same alphabet are not statistically different from each other.***Based on unit price of seed yam per 1 kg = GH<3, as at December, 2020. ****Based on costs of fungicides, labour and water in 2020.[e] = Total additional returns is equal to increased income since there is no reduced cost associated with the proposed fungicide applications[f]= Total additional cost is equal to increased cost since there is no reduced income associated the proposed fungicide application.

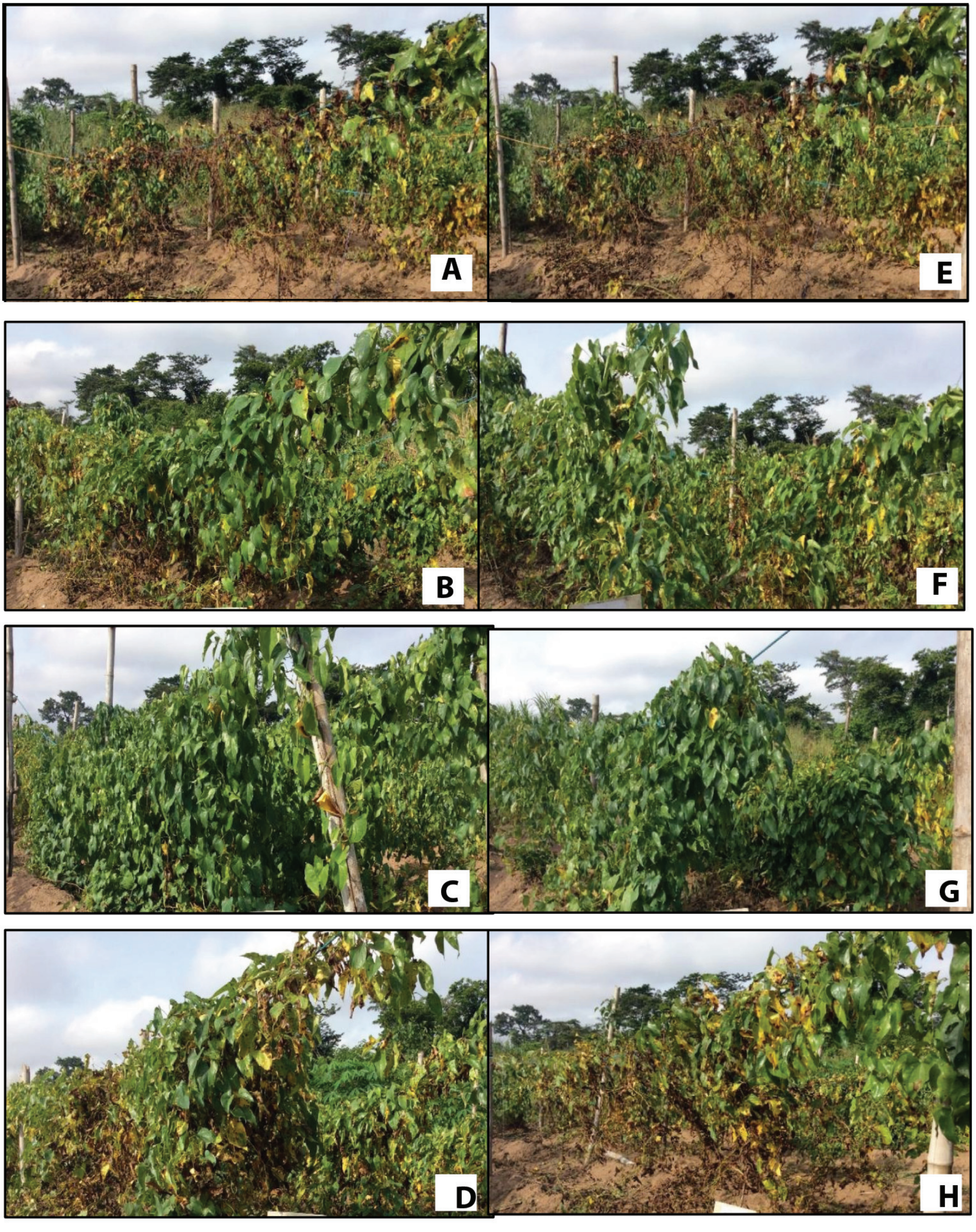

Plate 1.Severity of yam anthracnose/leaf spotting diseases on plots receiving fungicide applications. Left column = bi-weekly application frequency; Right column = four-weekly application frequency. A and E = Control; B and F = Carbendazim; C and G = Bordeaux mixture; D and H = Thiophanate methyl. Pictures were taken 1 week after last fungicide application

Thiophanate methyl had 31.57 per cent disease reduction. Similar trend was observed for four-weekly application frequency (Table 2).

Fungicide application frequencies employed in this study (i.e., bi-weekly and four-weekly) again showed no variation (F= 0.07, p= 0.7907) with respect to seed yam tuber yield. Plants which received Bordeaux mixture at bi-weekly application frequency had the significantly highest yield of 2,662.9 kg/ha tubers, followed by those treated with Carbendazim (2,390.20 kg/ha) and Thiophanate methyl (2,146.80 kg/ha) (Table 2). Tuber yields of Thiophanate methyl and the control treatment (2,085.80 kg/ha) had similar results (HSD=85.18). For four-weekly application frequency, Bordeaux mixture had a yield of 2,635.20 kg/ha, which was significantly higher than the yields of Carbendazim (2,414.10 kg/ha), Thiophanate methyl (2,109.20 kg/ha) and control (2,094.60 kg/ha) (HSD=81.54). Correlation analysis showed a strong negative relationship (i.e., -0.8126) between AUDPC and tuber yield.

There was a total of 24 rainy days between the initial application of fungicide and the last date for data collection. The average monthly rainfall during August, September, October and November were 6.8, 18.3, 21.6 and 14.3 mm respectively. The average minimum and maximum temperatures for this period respectively were 22.4 and 31.15 ^{o}C.

Economic benefit of fungicides

The bi-weekly application frequency showed positive values of net income for the application of Bordeaux mixture and Carbendazim, whilst Thiophanate methyl had a negative change (Table 2). Use of Bordeaux mixture and Carbendazim fungicides applied on a four-weekly basis gave appreciable net income values compared to the bi-weekly application. Thiophanate methyl, however showed a negative change in terms of the amount invested in the application of the fungicide (Table 2).

Result and Discussion

Use of fungicides to control yam anthracnose and leaf spot diseases in the field is rarely attempted by yam farmers in Ghana possibly due to the high costs involved as reported elsewhere (Kutama et al., 2013) and their ineffectiveness in controlling the disease during heavy rains (Green, 1994). The present study however revealed promising results in introducing the application of fungicides for the management of these diseases in seed yam production in Ghana. The cost of chemical fungicides, labour and equipment, heavy rain-washing fungicides from the applied leaf surfaces, the possible presence of fungicides-resistant strains of pathogens and intermittent or poorly timed applications are some other major limitations to the adoption of chemical control by yam producers (Kutama et al., 2013). High yields were obtained when fungicides were used to delay the onset of yam anthracnose until after root bulking (Sweetmore et al., 1994) which started normally at three months after planting.

Bordeaux mixture significantly reduced the disease severity. As a contact or protective fungicide, it protected the yam leaves from spread of the disease better than the systemic fungicides Carbendazim and Thiophanate methyl. Carbendazim also performed better than its counterpart Thiophanate methyl in reducing the disease severity. Thiophanate methyl at the application rate of 0.5 kg/ha was not effective against yam anthracnose and related diseases in the field. It is known to be effective in controlling most pathogenic members belonging to the Deuteromycetes (Awuah, 1996). Benomyl, which is similar to Thiophanate methyl has been reported to be effective against yam anthracnose when alternated with copper at weekly application interval (Kutama et al., 2013).

The fungicides tested also impacted positively on seed tuber yield. The fungicide products significantly varied from each other with Bordeaux mixture having the greatest yield, followed by Carbendazim. The control field showed a significantly lower tuber yield compared with the fields applied with the two fungicides. This confirms the report of Simkin et al. (2019) that the destruction of photosynthetic material affects the resultant crop yield. The period at which disease initially started and intensified is very critical as it coincides with tuberization period, which is three to seven months after planting (Chapman, 1965). There was a strong negative correlation between AUDPC and tuber yield. This suggested that as disease severity increases during tuberization period, there is a higher chance of getting a reduced tuber yield at harvest.

Fungal diseases have been controlled successfully by the use of fungicides in other crops. In a study done by Ekundayo and Daniel (1975), Benomyl was found to be effective in controlling soft rot of cassava caused by *Lasiodiplodia theobromae*. Use of metalaxyl containing fungicides sprayed at a weekly application rate of 4 g/L was found to be effective in controlling taro leaf blight caused by *Phytophthora colocasiae* (Mbi et al., 2021).

Most of these studies fail to establish the cost effectiveness of these fungicides by conducting economic studies. The partial budgets for Bordeaux mixture and Carbendazim sprayed at four-weekly application frequency indicated the benefits obtained from adopting fungicides to control fungal diseases and improve the yield of seed yams. From the results obtained, the cost of applying Bordeaux mixture and Carbendazim at the tested application rate and at a four-weekly application frequency for four times during the season would result in a strong positive change in net income. Application of Thiophanate methyl had a negative change in net income. Thus, it is practically not advisable for seed yam growers to adopt its usage at the experimented application rate. In Ghana, this study is the first experiment on the use of fungicides in seed yam production for which cost effectiveness in applying these fungicides was determined.

In conclusion, all fungicides tested performed effectively in managing yam anthracnose in seed yam production. However, Thiophanate methyl did not show a significant effect on the yield of seed yams. Therefore, based on the positive impact on disease severity and net income attainable, Bordeaux mixture and Carbendazim applied at four-weekly interval could be recommended to seed yam farmers to enhance their productivity.

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