https://dx.doi.org/10.4314/gjas.v57i1.1

Pathogenicity of *Colletotrichum coccodes* causing anthracnose disease and its effect on growth and yield of sweet potato [*Ipomoea batatas* (L.) Lam]

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ABSTRACT

The disease causing ability of Colletotrichum coccodes and the effect of anthracnose on growth and yield of sweet potato accessions were evaluated in a two-year field trial. Field layout was a randomized complete block design with 16 sweet potato accessions replicated thrice. Young leaves of sweet potato accessions were sprayed with an inoculum concentration of 2.1×10^7 in a two-split application in the field with growth, yield, and disease indices recorded. Pathogenicity of C. coccodes was significantly highest among four accessions; OW4, SE10, SE12 and SPK-004 with abundant necrosis on leaves and stems of inoculated plants. Disease incidence varied between 2.48% - 52.83%, and 2.77% - 50.73%, during the 2018 and 2019 planting seasons respectively, with host response ranging from being susceptible to resistant. Accessions OW5 and OS15 had significantly lower disease incidence and severity than other treatments (p = 0.031 and 0.28 respectively) and also produced the highest yield ranging between 15.84-17.29 and 14.88-15.72 t/ha^{-1}, in 2018 and 2019, respectively. This study has shown that anthracnose causes significant reduction in expected yield in sweet potato cultivation and also identified two resistant sweet potato accessions that can be useful sources in breeding for resistance to the disease.

Keywords: Disease incidence; inoculum, necrosis; pathogenicity; sweet potato
Original scientific paper. Received 03 Jun 2021; revised 05 Feb 2022

Introduction

Sweet potato [*Ipomoea batatas* (L.) Lam] is an important root tuber that is commonly cultivated in the rain forest and Guinea savanna agro-ecological zones in West Africa. Nigeria is the leading producer of sweet potato in the African continent with an annual production of 3.93 metric tons, but with a projected yield of 10 metric tons (NBS, 2017). The starchy underground roots contain substantial amounts of carbohydrate, minerals and B-vitamins (Ward *et al.*, 2006). It thrives well on various types of soil including marginal lands with low fertility. It is a fast growing creeper which has the ability to suppress weeds, after the first weeding and helps in soil conservation. It is cultivated for its fresh roots and leaves which are used for human consumption, animal feeding (Pasche *et al.*, 2010) and ethanol production (Ramesh *et al.*, 2008).

Diseases caused by plant pathogens constitute major constraints to sweet potato production worldwide and they lead to huge crop losses. Field diseases of sweet potato are very important because they affect the quantity and quality of the cultivated crop and ultimately

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the harvested produce. More importantly, the causative agents are often transferred from the field to store. Pathogens that attack sweet potato in the field include bacteria, fungi, viruses and nematodes. However, fungi account for over 60% of sweet potato diseases globally (Dania and Thomas, 2019). Sweet potato is attacked by root and foliar diseases which are responsible for substantial economic yield losses among peasant farmers and reduction in foreign earnings of producing countries. Anthracnose is one of the most important diseases attacking the roots, leaves and vines of sweet potato in Nigeria (Njoku *et al.*, 2009). It limits the photosynthetic ability of the crop which leads to reduction in the expected yield of harvested tubers.

Anthracnose disease is caused by *Colletotrichum* species, which are devastating pathogens that attack various cultivated crops worldwide (Biyan *et al.*, 2016; Aragaw *et al.*, 2019). These pathogens are characterised by typical sunken necrotic lesions with concentric rings, and in some cases, presence of acervuli (Nitzan *et al.*, 2009). *Colletotrichum capsici* has been reported to cause about 50% postharvest losses in chili pepper (Pakdeevaraporn *et al.*, 2005). Nitzan *et al.* (2005, 2009) reported that *Colletotrichum coccodes* (Wallr.) S. J. Hughes causes black dot disease of potato (*Solanum tuberosum* L.). It is soil-borne, and sporulates on roots, vines, and leaves of infected plants (Ingram & Johnson, 2010). It produces sclerotia which aids its survival in the off-season and when environmental conditions become unfavourable (Nitzan *et al.*, 2005; Padder *et al.*, 2011). The pathogen is polyphagous with a wide host range and also causes anthracnose disease in tomato, pepper in the solanaceae family and other crops including coffee with significant losses at harvest (Dean *et al.*, 2012; Alemu *et al.*, 2018). It has been reported to form synergistic interaction with the wilt-causing pathogen, *Verticillium dahliae*, leading to reduction in harvested potato (Pasche *et al.*, 2010). Although *C. gloeosporioides* is characteristically identical to *C. coccodes*, the later can be differentiated by spores that are slightly constricted and tapering at each end (Liu *et al.*, 2011; Alindia & Magnobba, 2020).

About 50 varieties of cultivated plants are attacked by *C. coccodes* globally, especially potato and tomato (Farr & Rossman, 2011). The fungus produces acervuli, consisting of aerial hyphae with conidiophores containing asexual spores and sclerotia that could survive in potato fields for up to seven years. It occurs in ageing tissues of infected plants and weeds such as *Euphorbia* species which serve as alternative host in the epidemiology of the disease (Rodríguez-Salamanca & Hausbeck, 2018). The severity of anthracnose disease is often influenced by prevailing environmental conditions. A positive interaction among the host, pathogen and conducive environment often encourages disease infection and development in plants (Agrios, 2005). Elevated temperatures and high relative humidity enhance leaf wetness which provides ideal conditions for infection, spore germination, multiplication of the pathogen and disease spread in the tropical climate (Than *et al.*, 2008).

The prevalence of anthracnose disease on sweet potato farms within the Nigerian farmlands stimulated interest in this research. Although *C. coccodes* had been linked to black dot disease in potato tubers, there is inadequate information on its ability to cause anthracnose disease in sweet potato fields which could assist researchers in breeding for resistance and management of the disease. Therefore, this study evaluated pathogenicity of *C. coccodes* and its effect on growth and yield of sweet potato.

Materials and Methods

Source of inoculum

An isolate of *Colletotrichum coccodes* was obtained from the mycological herbarium in the Pathology laboratory of the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria. The pathogen was initially isolated and identified from infected sweet potato showing anthracnose disease symptoms in a previous experiment in 2017 (Dania, 2019). This was further sub-cultured on quarter-strength potato dextrose agar (PDA) to facilitate spore production, purified and incubated at 27±2°C for 10 days at alternating cycles of 12 h light and 12 h darkness according to Kim *et al.* (2001). The PDA was amended with ampicillin at a dosage of 50 µg/ml to eliminate bacterial contaminants according to Nitzan *et al.* (2005). Eight liters of inoculum was prepared and spore concentration was adjusted to 2.1×10^7 conidia per ml using a haemocytometer (Rodríguez-Salamanca *et al.*, 2018).

The research design of the study

Although the *C. coccodes* isolate used in this experiment was identified from an earlier research as previously stated, its pathogenicity status had not been established. Therefore, prior to the field experiment, vines of a susceptible sweet potato variety, SPK-004, obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were planted in a mini pot experiment in the screen house to establish the pathogenic potential of the isolate. Inoculum was prepared from a 10-day quarter-strength PDA, which is a non-selective medium used to induce production of spores in fungi that do not sporulate well on nutrient- rich PDA medium.

The inoculum concentration was then adjusted to 2.1×10^7 conidia per ml. The first four young leaves of the susceptible variety were inoculated with a 15 ml inoculum using hand sprayer, while control plants were sprayed with sterile distilled water. The inoculated plants were covered with transparent white polyethylene sheets for 24 h to create the ambient temperature and relative humidity required for infection. Temperature and relative humidity readings were taken using a thermometer and psychrometer, respectively. The values varied between 28°C - 30°C, and 77% - 92% under the polyethylene sheets, respectively. The experiment consisted of three replicates in a completely randomized design.

Sampling procedure

Inoculated plants were incubated in the growth chamber for 14 days under 12 h cycle of light and darkness and examined for lesion development that were typical of anthracnose disease. Minimum and maximum temperature during this period varied between 28°C and 31°C, while relative humidity was between 69% and 92%. Re-isolation was made from infected loci for culturing on PDA to ensure that the growth characteristics of isolates conformed with those of *C. coccodes* in order to confirm Koch's postulation. Three symptomatic plants per treatment were randomly selected for re-isolation of *C. coccodes* from infected leaves.

Cut sections were again plated on quarter-strength PDA amended with 50µg/ml ampicillin and incubated in an incubator at 27±2°C for 10 days. Fungal colonies were examined for typical morphological characteristics of *C. coccodes* such as colony characteristics, shape and size of conidia, acervuli, appressoria, setae and sclerotia under a binocular compound microscope (Kim *et al*., 2001; Robert *et al.*, 2001; Rodríguez-Salamanca & Hausbeck, 2018). Pathogenicity was evaluated as: No infection (-), Mild infection (+), Moderate infection (++) and Severe infection (+++).

Data collection and analysis

The experiment was conducted at the University of Ibadan Teaching and Research Farm, Ibadan, with a bimodal rainfall pattern between May and September in 2018 in the rainy season, and with a repeated trial during the same period in 2019. The treatments consisted of sixteen yellow-fleshed sweet potato accessions. Three accessions were collected from each of five Local Government Areas (LGAs) that are notable producers of the crop in Oyo state, Nigeria i.e. Oyo East (OE), Oyo West (OW), Atiba (AT), Saki East (SE) and Ogbomoso South (OS). A susceptible check, SPK-004 was also obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Table 1). The experiment was a randomized complete block design consisting of 16 treatments and replicated thrice. The land was cleared and ridges were made at one meter interval. Vine cuttings measuring 20 cm with four nodes were planted at a spacing of 1 m × 0.3 m with a plant population of 33,333 per hectare. Each plot size was 4.5 m × 1 m which consisted of 15 plants per plot.

Planting was done on land that had been under fallow for eight years hence no fertilizer was applied. Soil test was carried out prior to planting to ensure that *C. coccodes* was not already present in the experimental soil. First weeding was done manually at four weeks after planting (WAP) with a second weeding at 8WAP. Inoculum preparation was done as previously described and field application was carried out by spraying using a calibrated 16-liter Knapsack Sprayer Model: KF-13 Chennai, India, two times during each year of trial. The first inoculation was carried out on 5th June, 2018 at 4WAP with a second application two weeks later at 6WAP during the peak of the rainy season when environmental conditions favoured successful infection. During this period, temperature and relative humidity under field conditions ranged between 27°C and 33°C, while relative humidity was between 74% and 96%, respectively. Young leaves were sprayed with 2.1×10^7 conidia per ml concentration which had earlier proved to be effective in the pathogenicity test at five days post emergence. Pathogenicity of *C. coccodes* was also evaluated on all the 16 sweet potato accessions under field conditions as previously described in the screen house experiment.

TABLE 1

List of sweet potato accessions used in the study and their origin

Accession	LGA	Location	Coordinates
OE1	Oyo East	Owode	8.5777°N, 3.5610°E
OE2	Oyo East	Araromi	6.5651°N, 3.4708°E
OE3	Oyo East	Ajagba	7.8254°N, 3.9301°E
OW4	Oyo West	Isokun	7.8500°N, 3.9123°E
OW5	Oyo West	Akeetan	7.8397°N, 3.9235°E
OW6	Oyo West	Fasola	7.8994°N, 3.7782°E
AT7	Atiba	Abolupe	8.23485°N, 8.2345°E
AT8	Atiba	Olugbile	8.0333°N, 4.0500°E
AT9	Atiba	Afonja	8.23485°N, 3.9038°E
SE 10	Saki East	Sepeteri	8.6267°N, 3.6066°E
SE 11	Saki East	Agbonle	8.8754°N, 3.5254°E
SE 12	Saki East	Ogborro	8.7668°N, 3.6091°E
OS13	Ogbomoso South	Kajola.	8.1127°N, 4.2261°E
OS14	Ogbomoso South	Adeoye	7.9847°N, 3.5616°E
OS15	Ogbomoso South	Ijeku	8.10822°N, 4.2495°E

Data were collected on growth parameters including number of vines, vine length, number of leaves and vine girth. The number of vines and leaves were obtained by counting the vines and leaves from four randomly selected plants per plot and the mean calculated. The length of the vines were determined by measuring the distance between the point of attachment to the base of the plant and the terminal bud using a meter rule for each of the four selected plants per plot and the mean value recorded. Stem girth was measured using a Vernier caliper. Weeding was done manually and harvesting was done at 120 days after planting at physiological maturity. Yield data collected included number of tubers, tuber length, tuber width and yield (t/ha). Yield per hectare was calculated as:

Yield (Kg/ha^{-1}) = Area of hectare (m^2) × Root weight per plot

Area occupied by one plant

Yield in kg/ha^{-1} was converted to tonnes/ha^{-1} by dividing values by 1000

Disease incidence was assessed by counting the number of symptomatic plants and expressed as percentage of total plant population per treatment, while disease severity and reaction of the sweet potato accessions to anthracnose were assessed by estimating the proportion of the plant parts that showed characteristic symptoms. Disease reaction was rated on a 1-9 scale using the modified method of Than *et al*. (2008):1 = highly resistant (No infection); 2 = resistant (1% to 2% of the leaf surface with necrotic lesion surrounding the infection site); 3 = moderately resistant (3% to 10% of the leaf showing necrotic lesion, with likely presence of acervuli on the leaf surface); 5 = moderately susceptible (11% to 29% of the leaf surface showing sunken necrotic lesion, with likely presence of acervuli); 7 = susceptible (30% to 50% of the leaf surface covered with necrotic lesion with presence of acervuli and isolated symptoms on the vines); and 9 = highly susceptible (>50% of the leaf surface showing necrosis, numerous lesion on the vines and many acervuli and sclerotia).

Data on incidence and severity of anthracnose among the sweet potato accessions were collected bi-weekly beginning at two weeks after inoculation (WAI), which was equivalent to 6WAP up till 10 WAI (16WAP). All trials were repeated and data obtained from the experiments were subjected to one way statistical analysis of variance (ANOVA) at $p < 0.05$ using General Statistics software package, Gen Stat 10 edition. If interactions were significant, means were separated with Tukey's HSD post-hoc test.

Results and Discussion

Effect of anthracnose disease on growth of sweet potato inoculated with C. coccodes

The number of vines per sweet potato plant varied between 4.36 – 8.30, and 4.25 – 7.01, in 2018 and 2019 growing seasons, respectively (Table 2). There was no significant difference ($p > 0.05$) in vine number among the sweet potato accessions, including the susceptible check SPK-004 which served as control in both years of trial. Similarly, vine girth did not differ significantly among the treatments in both growing seasons.

Accessions AT9 obtained from Atiba Local Government Area (LGA) had the highest vine length measuring 315.54 cm in 2018, while AT7 from same LGA reached the highest length of 311.20 cm in the repeated trial in 2019. Vine length differed significantly ($p < 0.05$) among the accessions in both growing seasons. Vine length among accessions OE3, OW4, AT9 and SE10 was not significantly higher than the susceptible check but similar in the repeated experiment in 2019.

Pathogenicity of *C. coccodes* and incidence of anthracnose disease on sweet potato accessions: The *C. coccodes* isolate caused infection on most of the sweet potato accessions evaluated in the study (Table 3). However, its pathogenicity rating varied from very few necrotic lesion (+), moderate lesion (++) to abundant necrosis on leaves and vines. On re-isolation, *C. coccodes* grew rapidly on full strength PDA. The colonies were dark brown at the centre with whitish creamy periphery and dark gray reverse side. Colonies had reduced growth on quarter-strength PDA, and were creamy white at the centre with emerging sclerotia on the concentric rings at the centre with a dark brown periphery. The disease-causing ability of *C. coccodes* was very low in two of the accessions, OW5 and OS15, obtained from Oyo West and Oyo south LGAs, respectively.

Conversely, pathogenicity of *C. coccodes* was significantly highest among three accessions, OW4, SE10 and SE12 obtained from Oyo West and Saki East LGAs, respectively, and SPK-004 which served as the control treatment. Anthracnose incidence was significantly ($p < 0.05$) lower at 2WAI, which was equivalent to 6WAP. However, disease incidence increased steadily as duration after inoculation progressed. Although there was significant difference among treatments at 2WAI, anthracnose incidence was significantly higher among control plants than other treatments in the two-year trial. Disease incidence reached its peak at 10WAI, which was equivalent to 16WAP with values ranging between 2.48% – 52.83%, and 2.77% – 50.73%, during 2018 and 2019 planting seasons, respectively (Table 3).

Accessions OW4, SE10 and SE12 and the control treatment that recorded the highest rate of pathogenicity also had corresponding higher percentages of anthracnose incidence. However, anthracnose incidence was significantly higher ($p < 0.05$) in the control treatment than other accessions. Accession OW5 had a relatively lower incidence of 2.48% during the first trial in 2018 with a slight increment to 3.37% in the repeated planting season in 2019. Similarly, OS15 had significantly lower incidences of 2.77% and 3.08% at the end of the planting seasons in 2018 and 2019, respectively (Table 3).

TABLE 2

Growth parameters of sweet potato accessions inoculated with Colletotrichum coccodes

	2018 Planting season				2019 Planting season			
Accession	**No. of vines**	**Vine length (cm)**	**No. of leaves**	**Vine girth (mm)**	**No. of vines**	**Vine length (cm)**	**No. of leaves**	**Vine girth (mm)**
OE1	5.73a	272.42d	201.33cd	4.20a	4.88a	288.71c	194.10d	6.62a
OE2	6.28a	281.18cd	188.48de	4.72a	5.15a	301.30b	200.62d	5.18a
OE3	5.31a	276.30d	214.72bc	5.50a	5.70a	292.34bc	221.15a	4.40a
OW4	7.86a	300.18b	177.11ef	6.38a	5.57a	296.50bc	187.36de	5.21a
OW5	5.35a	309.74ab	218.65b	4.51a	6.12a	300.21b	197.06d	4.85a
OW6	4.36a	278.15cd	220.23b	5.25a	4.90a	284.83cd	211.16bc	3.73a
AT7	6.10a	308.51ab	196.80d	4.90a	5.66a	311.20a	206.38c	5.32a
AT8	5.11a	314.31a	219.40b	4.12a	4.25a	306.65ab	214.21b	4.08a

AT9	4.72a	315.54a	208.17c	5.41a	5.34a	293.51bc	207.72c	5.51a
SE10	7.09a	277.99d	183.31e	6.08a	7.01a	290.31bc	189.25de	6.38a
SE11	8.30a	284.67c	229.74a	6.82a	6.88a	279.26d	215.04b	5.42a
SE12	5.33a	293.44bc	186.90de	4.51a	6.83a	301.14b	203.50cd	4.33a
OS13	6.77a	307.62ab	200.83cd	5.33a	4.43a	283.80cd	211.77bc	5.50a
OS14	7.22a	302.71b	186.41de	4.60a	5.91a	280.52cd	217.83ab	4.65a
OS15	8.06a	313.80a	203de.75	6.64a	6.10a	303.21b	183.70e	4.12a
SPK-004	5.81a	286.20c	224.32ab	5.82a	5.32a	293.68bc	199.49d	6.17a
CV (%)	1.58	6.80	7.29	1.03	1.22	9.22	10.63	1.08
P-value	0.073	0.041	0.025	0.093	0.68	0.129	0.33	0.61

Means followed by different letter along a column are significantly different using Tukey's HSD post-hoc test at $p < 0.05$. OE = Oyo East Local Government Area (LGA), OW = Oyo West LGA, AT = Atiba LGA, SE = Saki East LGA, OS = Ogbomoso South LGA

TABLE 3

Pathogenicity of Colletotrichum coccodes and incidence of anthracnose disease on sweet potato accessions

		2018 Planting season					2019 Planting season				
Accession	**Pathoge-nicity**	**2WAI**	**4WAI**	**6WAI**	**8WAI**	**10WAI**	**2WAI**	**4WAI**	**6WAI**	**8WAI**	**10WAI**
OE1	++	2.20b	4.15b	8.46bc	11.50c	20.27cd	1.78b	3.67bc	10.82bc	17.28bc	24.33c
OE2	++	1.77b	3.40b	7.75bc	10.04c	18.94d	2.52b	6.60b	13.47bc	16.90bc	24.28c
OE3	++	4.19ab	9.42ab	15.38b	26.73bc	19.23cd	2.80b	6.32b	12.23c	15.71c	17.01d
OW4	+++	0.70b	2.85b	6.60c	17.22bc	33.81b	2.31b	5.08b	15.67b	23.93b	43.54ab
OW5	+	0.0bc	0.60bc	1.82d	2.03d	2.48e	0.0c	0.0c	2.10cd	2.91d	3.37ef
OW6	++	1.59b	3.31b	5.71c	11.25c	14.90de	0.79b	6.15b	10.30bc	13.45c	17.01d
AT7	++	2.70b	6.11ab	15.85b	17.40bc	21.83cd	1.27b	5.82b	13.42bc	15.16c	18.23d
AT8	++	1.80b	3.10b	10.23bc	17.37bc	25.60c	2.11b	6.66b	11.53bc	14.70c	28.14b
AT9	++	1.87b	4.46b	13.31b	20.86b	34.73b	2.30b	8.83ab	19.55ab	23.63b	26.77bc
SE10	+++	0.52b	2.66b	9.91bc	23.78ab	37.46ab	1.35b	8.12ab	17.30b	21.81b	38.50b
SE11	++	1.66b	4.43b	10.09bc	18.41bc	27.82bc	2.08b	5.17b	12.06bc	18.84bc	26.23bc
SE12	+++	4.81ab	10.51ab	14.78b	23.80ab	30.10bc	4.02ab	10.53ab	21.17ab	28.45ab	42.75ab
OS13	++	5.20ab	9.68ab	17.30ab	22.63ab	29.83bc	4.19ab	8.22ab	16.50b	23.65b	26.38bc
OS14	++	0.87b	3.15b	12.64b	20.95b	26.14c	1.77b	3.68bc	11.33bc	17.73bc	21.37cd
OS15	+	0.0b	0.0ab	0.62cd	1.30cd	2.77de	0.0bc	0.0ab	1.05cd	2.50cd	3.08e
SPK-004	+++	8.78a	17.44a	22.50a	31.99a	52.83a	9.40a	15.35a	27.67a	38.55a	50.73a
CV (%)		1.02	1.38	3.33	5.01	6.02	1. 44	1.77	2.03	4.61	6.07
P-value		0.030	0.029	0.038	0.027	0.042	0.019	0.024	0.0161	0.044	0.026

Means followed by different letter along a column are significantly different using Tukey's HSD post-hoc test at $p < 0.05$. WAI = Weeks after inoculation. OE= Oyo East Local Government Area (LGA), OW = Oyo West LGA, AT = Atiba LGA, SE = Saki East LGA, OS = Ogbomoso South LGA. + = very few necrotic lesion on leaves, ++ = moderate necrotic lesion on leaves, +++ = abundant necrotic lesion on leaves and vines.

Disease severity rating on sweet potato accessions inoculated with C. coccodes

Anthracnose severity was comparatively low at 2WAI with no significant difference among the accessions ($p > 0.05$) (Table 4). However, disease severity was significantly ($p < 0.05$) lower in two of the accessions, OW5 and OS15 than other treatments including the control. Accessions OW4, SE10, SE12 and control treatment had the highest severity rating ranging between 7.04 – 7.66, and 7.13 – 7.51 in 2018 and 2019, respectively. Accessions OW5 and OS15 had significantly low disease severity than other treatments at 10WAI. Four of the accessions OE1, OE2, AT8 and AT9 sourced from Oyo East and Atiba LGAs were moderately susceptible to anthracnose disease. Accessions OW4, SE10 and SE12 obtained from Oyo West and Saki East LGAs, and SPK-004, which served as control were susceptible to the disease with severity values that were significantly ($p < 0.05$) higher than other treatments. Six of the accessions obtained from five LGAs i.e. Oyo East, Oyo West, Atiba, Saki East and Oyo South were moderately resistant to anthracnose disease, while two accessions, OW5 and OS15 from Oyo West and Ogbomoso South LGAs showed resistance to the disease with severity values that were significantly lower than other accessions. Although there was no significant difference ($p > 0.05$) in the reaction of the sweet potato accessions to anthracnose disease between the first and second planting seasons, severity scores were more prevalent in the repeated trial in 2019 (Table 4).

TABLE 4

Disease severity rating on sweet potato accessions inoculated with Colletotrichum coccodes

	2018 Planting season					2019 Planting season					
Accession	**2WAI**	**4WAI**	**6WAI**	**8WAI**	**10WAI**	**2WAI**	**4WAI**	**6WAI**	**8WAI**	**10WAI**	**Host reaction**
OE1	2.33a	2.67b	2.88b	3.07b	3.18b	1.65ab	2.21a	2.79b	3.88b	5.42ab	MS
OE2	1.89a	2.33b	2.17b	2.38b	5.77ab	2.01a	2.43a	2.66b	4.73ab	5.21b	MS
OE3	2.17a	2.62b	2.79b	3.13b	3.18b	1.33ab	2.14a	2.50b	2.83bc	3.01b	MR
OW4	1.20a	1.78b	2.04b	2.42b	7.66a	2.17a	2.33a	3.64a	5.74a	7.18a	S
OW5	0.0ab	0.0c	0.67c	1.81b	1.68bc	0.0b	0.0ab	0.71c	1.56b	1.93bc	R
OW6	2.33a	2.58b	2.83b	2.89b	3.07b	1.48ab	1.87a	2.09b	2.48bc	3.02b	MR
AT7	1.35a	1.61b	1.84b	2.32b	3.18b	1.11ab	2.02a	2.55b	2.64bc	3.68b	MR
AT8	2.18a	2.38b	2.55b	2.86b	5.22b	2.51a	2.68a	2.81b	4.31ab	5.02ab	MS
AT9	2.04a	2.58b	2.80b	3.81ab	5.29ab	2.18a	2.33a	2.42b	2.77bc	5.51ab	MS
SE10	1.62a	2.02b	2.33b	2.67b	7.04a	1.36ab	1.85a	2.12b	4.33ab	7.32a	S
SE11	2.08a	2.41b	2.72b	2.84b	2.97bc	1.28ab	2.22a	2.34b	2.67bc	3.40b	MR
SE12	2.17a	2.45b	2.63b	3.01b	7.35b	1.17ab	2.08a	2.23b	2.54bc	7.13b	S
OS13	2.11a	2.60b	2.89b	2.91b	3.01b	2.01a	2.32a	2.51b	2.78bc	3.75b	MR
OS14	1.98a	2.27b	2.44b	2.77b	3.05b	2.04a	2.28a	2.31b	2.51bc	3.80b	MR
OS15	0.0ab	0.0c	0.51c	1.28b	1.53bc	0.0b	0.2ab	1.04c	1.33b	1.88bc	R
SPK-004	2.77a	3.179a	4.18a	5.02a	7.38a	2.77a	2.81a	4.01a	6.28a	7.51a	S
CV (%)	1.06	1.73	1.09	1.33	2.80	1.27	1.029	1.05	3.01	2.77	
P-value	0.058	0.031	0.024	0.042	0.039	0.018	0.070	0.017	0.020	0.011	

Means followed by different letter along a column are significantly different using Tukey's HSD post-hoc test at $p < 0.05$. WAI= Weeks after inoculation. OE= Oyo East Local Government Area (LGA), OW=Oyo West LGA, AT=Atiba LGA, SE=Saki East LGA, OS= Ogbomoso South LGA.

Effect of anthracnose disease on yield of sweet potato accessions inoculated with C. coccodes

The number of tubers per plant ranged between 3.28 – 7.83, and 3.97 – 7.75, in 2018 and 2019 planting seasons, respectively. Accession OS14 from Ogbomoso south LGA had the highest number of 7.83 tubers per plant in 2018, while OE3 from Oyo East recorded the highest in 2019 (Table 5). The number of tubers per plant differed significantly (p < 0.05) among the treatments. Similarly, there was significant (p < 0.05) difference in tuber length and width per plant among the sweet potato accessions in both years of trial. Yield per hectare ranged between 8.28 – 17.29 t/ha^{-1}, and 8.15 – 15.72 t/ha$^{-1,}$ in 2018 and 2019, respectively. Accessions OW5 and OS15 had the highest yield per hectare of 17.29 t/ha^{-1} and 15.72 t/ha^{-1}, respectively in 2018.

Accession OW5 recorded the highest yield of 15.84 t/ha^{-1} in 2019. Conversely, the lowest yield of 8.28 t/ha^{-1} obtained in accession AT7 from Atiba LGA was not significantly higher than the control in 2018, while in 2019, accession SE11 had the lowest yield of 8.15 t/ha^{-1}. Two of the moderately resistant accessions, OE3 and OS13 produced a comparatively higher yield of 14.80 t/ha^{-1} and 15.68 t/ha^{-1} in 2018 and were not significantly different from values obtained for resistant accessions OW5 and OS15 in 2019. Similarly, accessions OE3 and OS13 produced yields of 14.80 t/ha^{-1} and 13.01 t/ha^{-1} next to the resistant accessions. Overall yield per hectare among the accessions was generally higher during the first experimental trial than the second farming season.

TABLE 5

Yield parameters of sweet potato accessions inoculated with Colletotrichum coccodes

	2018 Planting season				2019 Planting season			
Accession	**Tubers/ Plant**	**Tuber length (cm)**	**Tuber width (cm)**	**Yield (t/ha-1)**	**Tubers/ plant**	**Tuber length (cm)**	**Tuber width (cm)**	**Yield (t/ha^{-1}**
OE1	3.54ab	13.57ab	7.40b	10.51ab	5.29ab	15.16ab	8.62ab	9.10ab
OE2	4.77ab	13.89ab	10.82ab	11.26ab	4.41ab	14.51ab	9.79ab	10.66ab
OE3	3.28ab	15.60a	8.10b	14.80a	7.75a	13.52ab	10.23ab	13.31ab
OW4	3.82ab	16.24a	11.67ab	7.98b	4.58ab	14.26ab	9.20ab	12.52a
OW5	6.30a	12.76ab	9.34ab	17.29a	5.23ab	13.14ab	7.75b	15.84a
OW6	5.55a	13.83ab	13.07a	10.35ab	5.85ab	13.25ab	12.08a	9.43ab
AT7	6.30a	17.39a	10.16ab	8.28b	5.12ab	13.31ab	9.12ab	9.57ab
AT8	4.21ab	15.52a	9.52ab	10.33ab	5.07ab	17.81a	8.45ab	12.80a
AT9	6.86a	13.78ab	7.48b	12.51ab	4.45ab	15.38ab	9.33ab	10.62ab
SE10	3.82ab	16.40a	8.91b	8.72b	3.97ab	14.79ab	8.77ab	9.36ab
SE11	6.25a	17.13a	10.34ab	8.52b	4.11ab	17.60a	10.75ab	8.15ab
SE12	5.35a	13.98ab	8.47b	11.17ab	5.23ab	14.64ab	12.90a	10.30ab
OS13	4.37ab	13.33ab	7.23b	15.68a	7.40a	13.92ab	8.64ab	13.01ab
OS14	7.83a	12.37ab	9.38ab	13.90ab	5.12ab	14.27ab	8.83ab	11.01ab
OS15	6.77a	15.65a	8.65b	15.72a	5.82ab	14.15ab	9.39ab	14.85ab
SPK-004	4.89ab	16.60a	10.75ab	8.64b	4.56ab	13.63ab	8.72ab	9.36ab
CV (%)	3.75	6.30	2.66	5.70	2.08	3.81	5.01	7.3
P-value	0.069	0.077	0.013	0.25	0.064	0.084.4	0. 441	0.83

Means followed by different letter along a column are significantly different using Tukey's HSD post-hoc test at p < 0.05. OE= Oyo East Local Government Area (LGA), OW=Oyo West LGA, AT=Atiba LGA, SE=Saki East LGA, OS= Ogbomoso South LGA

Colletotrichum species are ubiquitous and destructive pathogens causing anthracnose disease with a wide host range including root and tuber crops, fruits, vegetables, legumes amongst others (Kim *et al*., 2000; Farr *et al*., 2016). This study has confirmed *C. coccodes* as the causative agent of anthracnose disease in sweet potato. The pathogen has been reported to infect over 50 different host plants worldwide (Farr & Rossman, 2011; Saxena *et al*., 2016). Liu *et al.* (2011) reported *C. coccodes* as the causal agent of black dot disease of potato and anthracnose in tomato. The pathogen grew rapidly on full strength PDA, but had reduced growth on quarter-strength PDA. Reduced strength enhances spore production for inoculum preparation and improves the identification process. While in addition to the phenotypic and genotypic changes that may occur on high nutrient media like PDA, there is impact of nutrition on metabolite production (Leslie & Summerell, 2006).

The sweet potato accessions differed significantly in vine length and number of leaves per treatment. Three accessions, AT8, AT9 and OS15 had very fast growth habit with widest land area coverage in 2018 and were not significantly different in the repeated trial. This result is consistent with the findings of Koriocha (2009) and Nwankwo *et al*. (2012) that reported significant variability in growth habit of sweet potato varieties cultivated in open fields under natural conditions. Growth habit has direct effect on ecological indices such as erosion, weed growth and soil structure. The fast growing accessions in this study had the ability of spreading rapidly and uniformly on the surface of the soil, thereby preventing weed growth due to their inability to have direct access to sunlight for photosynthesis. Sweet potato varieties with spreading habit suppress weeds and encourage better root formation and varieties with this attribute are better suited to intercropping due to their ability to harness sunlight under maize canopy than the erect cultivars (Nwankwo *et al*. (2012).

C. coccodes was pathogenic to all the sweet potato accessions, suggesting that it was a virulent strain of the fungus and the environmental conditions were favourable for disease development. However, pathogenicity varied from very few necrotic lesions on inoculated leaves to abundant necrosis on leaves and stems of the plants. Kim *et al*. (2001) reported significant variability in the pathogenicity of *Colletotrichum* species on perilla plants. Although it has been reported that the teleomorph stage of *C. coccodes* has weaker pathogenicity than its anamorph (Kim *et al*., 2000; Alvarez *et al*., 2014), this pathological variation between both stages of the fungus could not be established in this study because the anamorphic stage was evaluated.

Incidence of anthracnose disease was low at 2WAI, but increased steadily with duration over 10 WAI. Ingram *et al*. (2011) reported the incidence of *C. coccodes* causing black dot disease of potato (*Solanum tuberosum*) and showed that the conidia of the fungus could successfully infect the potato stems during a 21 hour mist period using plant inoculation assay and survive subsequent fungicide application under field conditions. The authors submitted that the pathogen has the capacity to infect roots and tubers of potato if planted from infected seeds or tubers. However, this could not be confirmed in this study since there was no evidence that the seeds or tubers were infected and comparison could not be made since the planting materials were different. Seeds and tubers may habour resident seed-borne inocula prior to planting which may serve as sources of infection.

Anthracnose symptoms were pronounced on the leaves and vines of the sweet potato plants but not tubers. It has been reported that delayed harvesting of sweet potato predisposes tubers to pathogen attack (Dania & Thomas, 2019). *C. coccodes* often infects the above ground parts of sweet potato, especially stems and leaves. However, the expression of symptoms such as sunken necrotic lesion and chlorosis may not be visible until late in the cropping season (Pasche *et al*., 2010; Amin *et al*., 2014). *C. coccodes* has been associated with latent infection in potato tubers (Garg *et al*., 2014; Admasu *et al*., 2014), which implies that there is a possibility of asymptomatic sweet potato tubers harvested in this study.

Disease severity varied among the sweet potato accessions with host response ranging from being susceptible to resistant. This may have been enhanced by the prevailing environmental conditions during the experiment, which was conducted at the peak of the rainy season. High relative humidity greater than 70% and temperatures higher than 20°C have been reported to favour the severity of onion leaf and neck anthracnose disease (Rodríguez-Salamanca *et al*., 2018). Liu *et al*. (2011) attributed severe disease incited by *C. coccodes* to high rainfall and the use of overhead irrigation during the cropping season. The resistance of crops to disease significantly influences the degree of damage by plant pathogens and thus reduces disease severity.

Resistance to disease in biological system is not absolute and it connotes the ability of the plant to overcome disease either completely or partially to a very high degree (Agrios, 2005). Hence, the two resistant accessions in this study still showed very mild anthracnose disease symptoms. Evaluating sweet potato accessions for susceptibility to *C. coccodes* will help to identify existing germplasm with resistance to anthracnose. The severity of anthracnose disease was lower in 2018 than the repeated trial. The higher severity in the second year may be attributed to the existence of residual inoculum in the soil following the first harvest (Ngeve, 2001). Rodríguez-Salamanca & Hausbeck (2018) reported that the survival and persistence of *C. coccodes* in onion rhizosphere may be influenced by residue location and presence of micro sclerotia in the soil.

Colletotrichum coccodes is particularly difficult to manage because infection takes place throughout the cropping season and this is usually favoured in a moist environment in the rhizosphere and vegetative parts. Continuous cropping, especially of the same crop has the tendency to increase the incidence and severity of plant diseases, hence crop rotation is always preferred to break the secondary cycles of plant pathogens (Zhao *et al*., 2016). Yield is an important factor that determines farmers' choice of sweet potato varieties (Njoku *et al*., 2009). The high yielding accessions could be incorporated into breeding programmes to increase field performance of the susceptible types. Although effect of flesh colour on tuber yield was not evaluated in this study, it is a vital factor in determining the choice of sweet potato by consumers. The carotenoid content of orange-fleshed types is high in vitamin A and thus preferred by many consumers (Rees *et al*., 2001).

Conclusion and Recommendation

This study confirmed *Colletotrichum coccodes* as the causative agent of anthracnose disease in sweet potato. It also identified two sweet potato accessions, OW5 and OS15 as being resistant to anthracnose disease, though subject to further experimentation and validation. These could be good sources of resistance in upgrading susceptible varieties and breeding for higher yield by plant breeders. Integration of host resistance genes and cultural practices such as planting of disease-free vines, crop rotation, weed control and adherence to plant spacing is, therefore, recommended in the management of anthracnose of sweet potato.

REFERENCES

Agrios, G. N. (2005) Plant Pathology, 5th Edition. Academic Press, Inc., San Diego, USA. 922.

Admasu, W., Sahile, S. & Kibret, M. (2014) Assessment of potential antagonists for anthracnose (*Colletotrichum gloeosporioides*) disease of mango (*Mangifera indica* L.) in North Western Ethiopia (Pawe). Archives of Phytopatholology and Plant Protection 47: 2176–2186.

Alemu, K., Adugna, G., Lemessa, F. & Muleta, D. (2018) Induction of systemic resistance in arabica coffee (*Coffea arabica* L.) against coffee berry disease (*Colletotrichum kahawae* Waller & Bridge) mediated through plant defense activator. International Journal of Pest Management 65, 1 – 11.

Álvarez, E., Gañán, L., Rojas-Triviño, A., Mejía, J. F., Llano, G. A. & González, A. (2014) Diversity and pathogenicity of *Colletotrichum* species isolated from sour sop in Colombia. European Journal of Plant Pathology 139, 325 – 338.

Alvindia, D. G. & Mangoba, M. A. N. (2020) Biological activities of *Moringa oleifera* Lam. against anthracnose of mango caused by *Colletotrichum gloeosporioides* Penz. Archives of Phytopatholology and Plant Protection 53, 1 – 14.

Amin, M., Teshele, J. & Tesfay, A. (2014) Evaluation of bio-agents seed treatment against *Colletotrichum lindemuthianum* in haricot bean anthracnose under field condition. Research in Plant Sciences 2, 22 – 26.

Aragaw, G., Chala, A. & Terefe, H. (2019) Spatial distribution and association of factors influencing sorghum anthracnose (*Colletotrichum sublineolum*) epidemics in eastern Ethiopia. International Journal of Pest Management 66(3), 1 – 15.

Binyam, T., Girma, A. & Fikre, L. (2016) Distribution and importance of sorghum anthracnose (*Colletotrichum sublineolum*) in Southwestern and Western Ethiopia. Plant Pathology Journal 15, 75 – 85.

Dania, V. O. (2019) Bio-efficacy of *Trichoderma* species against important fungal pathogens causing post-harvest rot in sweet potato [*Ipomoea batatas* (L.) Lam]. Journal of Bangladesh Agricultural University 17(4), 446 – 453.

Dania, V. O. & Thomas, A. S. (2019) Bioactivity and phytochemical composition of *Moringa oleifera* in the management of fungal rot disease of orange-fleshed sweet potato. Nigerian Journal of Mycology 11, 26 – 45.

Dean, R., van Kan, J. A. L., Pretorius, Z. A., Hammond-Kosack, K. E., Di Pietro, A., Spanu, P. D., Rudd, J. J., Dickman, M., Kahmann, R., Ellis, J. & Foster, G. D. (2012) The top 10 fungal pathogens in molecular plant pathology. Molecular Plant Pathology 13, 414 – 430.

Farr, D. F. & Rossman, A. Y. (2011) Fungal databases, systematic mycology and microbiology laboratory. USDA, ARS. Accessed online 6 Jan. 2011 at: http://nt.ars-grin.gov/fungal databases/.

Farr, D. F., Rossman, A. Y. & Palm M. E. B. (2016) Fungal databases, systematic botany and mycology laboratory. USDA, ARS. Accessed online 12 Sept at: http://nt.ars-grin.gov/fungal databases/.

Garg, R., Loganathan, M., Saha, S. & Roy, B. K. (2014) Chilli anthracnose: A review of causal organism, resistance sources and mapping of gene. In: Microbial diversity and biotechnology in food security. In: Kharwar, R. N., Upadhyay, R., Dubey, N. & Raguwanshi, R. (Eds) Springer, 589 – 610.

Ingram, J. & Johnson, D. A. (2010) Colonization of potato roots and stolons by *Colletotrichum coccodes* from tuber-borne inoculum. American Journal of Potato Research 87, 382 – 387.

Ingram, J., Cummings, T. F. & Johnson, D. A. (2011) Response of *Colletotrichum coccodes* to selected fungicides using a plant inoculation assay and efficacy of azoxystrobin applied by chemigation. American Journal of Potato Research 88, 144 – 153.

Kim, W. G., Lee, D., Cho, W. & Shin D. B. (2000) Identification and pathogenicity of *Colletotrichum* species isolated from Perilla leaves. Plant Pathology Journal 16,166 – 176.

Kim, W. G., Lee, D., Cho, W. & Shin, D. B. (2001) Anthracnose of perilla caused by *Colletotrichum* spp. and *Glomerella cingulata*. Plant Pathology Journal 17(4), 236 – 241.

Korieocha, D. S., Ogbonna, M. C., Nwokocha, C. C,, Echendu, G. O. & Okorocha E. O. A. (2009) Effect of time of herbicide application and sweet potato morpho-types on the effectiveness of herbicide on weeds. Proceedings of the 43rd Annual Conference of Agricultural Society of Nigeria, 124 – 127.

Leslie, J. F. & Summerell, B. A. (2006) *Fusarium* laboratory workshops. A Recent History. Mycotoxin Research 22(2), 73 – 74.

Liu, F., Hydeb, K. D. & Cai, L. (2011) Neotypification of *Colletotrichum coccodes*, the causal agent of potato black dot disease and tomato anthracnose. Mycology 2 (4), 248 – 254.

National Bureau of Statistics (2017) Social Statistics in Nigeria. Pp. 15.

Ngeve, J. M. (2001) Field performance and reaction to weevils of improved and local sweet potato genotypes in Cameroon. In: Akoroda, M. O, and Ngeve, J.M. (Eds.), Root crops in the 21st century (Pp. 290-297). Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root Crops – African Branch, 11-17 October. Pp. 77 – 83.

Nitzan, N., Cummings, T. F. & Johnson, D. A. (2005) Effect of seed tuber generation, soil-borne inoculum, and azoxystrobin application on development of potato black dot caused by *Colletotrichum coccodes*. Plant Disease 89, 1181 – 1185.

Nitzan, N., Evans, M. A., Cummings, T. F., Johnson, D. A., Batchelor, D. L., Olsen, C., Haynes, K. G. & Brown, C. R. (2009) Field resistance to potato stem colonization by the black dot pathogen, *Colletotrichum coccodes*. Plant Disease 93, 1116 – 1122.

Njoku, J. C., Muoneke, C. O., Okocha, P. I. & Ekeleme, F. (2009) Effect of propagule size and intra-row spacing on the growth and yield of sweet potato in a humid agro-ecological zone. Nigerian Agricultural Journal 40(1), 115 – 124.

Nwankwo, I. I. M., Bassey, E. E., Afuape, A. O., Njoku, J., Korieocha, D. S., Nwaigwe, G. & Echendu, T. N. C. (2012) Morpho-agronomic characterization and evaluation of in-country sweet potato accessions in southeastern Nigeria. Journal of Agricultural Sciences 4 (11), 281 – 288.

Padder, B. A. & Sharma, P. N. (2011) *In vitro* and *In vivo* antagonism of biocontrol agents against *Colletotrichum lindemuthianum* causing bean anthracnose. Archives of Phytopathology and Plant Protection 44, 961 – 969.

Pakdeevaraporn, P., Wasee, S., Taylor, P. W. J., & Mongkolporn, O. (2005) Inheritance of resistance to anthracnose caused by *Colletotrichum capsici* in *Capsicum*. Plant Breeding 124, 206 – 208.

Pasche, J. S., Taylor, R. J. & Gudmestad, N. C. (2010) Colonisation of potato by *Colletotrichum coccodes*: Effect of soil infestation and seed tuber and foliar inoculation. Plant Disease 94, 905 – 914.

Ray, R. C. & Naskar, S. K . (2008) Bioethanol production from sweet potato [*Ipomoea batatas* (L.) Lam] by enzymatic liquefaction and simultaneous saccharification and fermentation (SSF) process. Dynamic biochemistry, process biotechnology and molecular biology. Global Science Books 2(1), 47 – 49.

Rees, D., Kapinga, R., Jeremiah, S. & Rwiza, E. (2001) Preferences and selection criteria of sweet potato varieties in rural and urban areas of Tanzania. In: Akoroda, M.O, and Ngeve, J.M. (Eds), Root Crops in the 21st Century pp. 417-423 Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root Crops-African Branch, held at the Centre International des Conferences, Cotonou, Republic of Benin, 11 – 17 October, 1998.

Roberts, P. D., Pernezny, K. & Kucharek, T. A. (2001) Anthracnose caused by *Colletotrichum* sp. on pepper. University of Florida - Institute of Food and Agricultural Sciences, Accessed online 14th September 2019 at: http://edis.ifas.ufl.edu/PP104.

Rodríguez-Salamanca, L. M. & Hauberk, M. K. (2018) Evaluating host resistance to limit *Colletotrichum coccodes* on onion. Horticultural Sciences 53(7), 916 – 919.

Saxena, A., Raghuwanshi, R., Gupta, V. K. & Singh, H. B. (2016) Chilli anthracnose: The epidemiology and management. Frontiers in Microbiology **7**, 15 – 27.

Than, P. P., Jeewon, R. & Hyde , K. D., Pongsupasamit, S., Mongkolporn, O., & Taylor, P. W. J. (2008) Characterization and pathogenicity of *Colletotrichum* species associated with anthracnose disease on chilli (*Capsicum* spp.) in Thailand. Plant Pathology 57, 562 – 572.

Ward, O. P., Singh, A. & Ray, R. C. (2006) Production of renewable energy from agricultural and horticultural substrates and wastes. In: Ray, R. C. & Ward, O. P. (Eds), Microbial Biotechnology in Horticulture 1, 517 – 558.

Zhao, W., Wang, T., Chen, Q. Q., Chi, Y. K., Sew, T. M. & Qi, R. D. (2016) First report of *Colletotrichum scovillei* causing anthracnose fruit rot on pepper in Anhui Province, China. Plant Disease 100, 21 – 68.