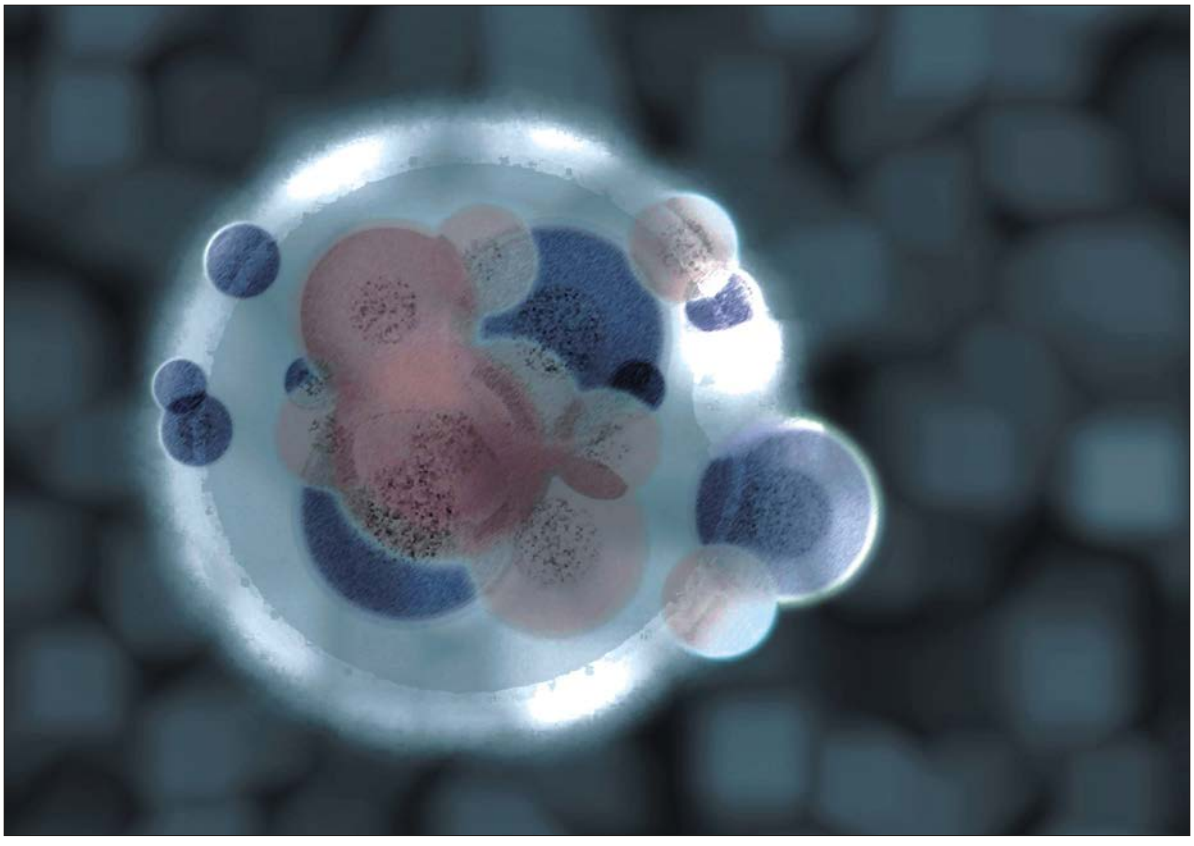

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Survival and Over-seasoning of *Colletotrichum gloeosporioides* F. sp. *Manihotis*, on Post-harvest Cassava (*Manihot esculenta* Crantz) Plant Materials and Soils

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Abstract: The aim of this study was to establish the importance of post-harvest survival and over-seasoning of *Colletotrichum gloeosporioides* f.sp. *manihotis* on planting materials and in soil. Infected stem cuttings from twelve cassava clones, harvested from two plot sites ES 24 and BSI, then incubated at 25±2°C for 8 months showed a significant decrease (P=0.05) in fungal survival amongst cassava clones. The lowest fungal recovery of 15% after 8 months incubation was recorded for cassava clones 88/0002336 and 30572. Cassava stakes, stored under shade and high relative humid conditions for 16 months showed a gradual monthly decrease in fungal survival, up to the 10th month. A gradual increase in fungal recovery was recorded from the 11th month up to the 16th month when maximum recovery was attained, due to re-infectivity of newly developed twigs by CAD pathogens from parent plants. Survival of fungus on soil gradually reduced with time and at the 6th month of sampling, there was no recovery recorded for 80% of the field plot sites. Burial of infected materials for 150 days below 30 cm depth significantly reduced the survival of *C. gloeosporioides* f.sp. *manihotis* on infected materials. These studies have shown that *C. gloeosporioides* f.sp. *manihotis* could survive on infected cuttings for more than 8 months, but less likely to survive in soil for more than 4 months.

Key words: Cassava (*Manihot esculenta*), *Colletotrichum gloeosporioides*, over-seasoning, post-harvest, survival

INTRODUCTION

Cassava anthracnose disease (CAD) caused by a host-specific fungus *Colletotrichum gloeosporioides* f.sp. *manihotis*, is considered to be a major economic disease in the tropics due to its potential for causing stem damage in cassava[1-3]. Cassava is a starchy root crop, which is among the most important food crops in the tropics, constituting a principal carbohydrate source for more than 800 million people in developing countries[4,5]. CAD reduces the quality of planting materials, leading to low germination and reduced leaf retention. Total crop failure has been reported in severe infection conditions[3,6,7]. CAD on young plants causes stem tip die back, wilt, defoliation and stem deformation [8,9].

Large cankers produced by CAD also serve as entry points for other pathogens such as *Agrobacterium manihotis* Chev, which is known to cause crown gall disease in South America[1,10]. These secondary infections could lead to total yield loss and shortage of planting materials for the next crop season.

The dissemination of CAD from plant to plant and the geographical distribution depends much upon climatic factors such as rainfall, relative humidity, temperature and wind action[4,10,11]. CAD is transmitted through infected plant cuttings during vegetative propagation[12] and by insect vector *Pseudotheraptus devastans*[13,14]. Seed survival of *C. gloeosporioides* f.sp. *manihotis,* the CAD causal agent and seed transmission has also been reported[15].

Cultural control measure has been described to a lesser extend as a possible control measure for anthracnose diseases of legumes and tropical fruits[16]. There is however, an information gap on the survival and possible over-seasoning of CAD on cassava post harvest materials. Information on the survival and recovery of CAD fungus on post harvest materials is also important for the adoption of effective post-harvest control measures under an effective farming practice within the intensive cassava cultivation regions, where season to season planting of cassava on the same piece of land is widely practice. It is possible that by reducing CAD inoculum pressure in the field, the chances of CAD transmission can be controlled.

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The small holder farming population in sub-Saharan are faced with problem of limited farm land and the constraints of pest and diseases. The high cost of pesticides had initiated increased interest in the investigation of cultural control options in managing diseases such as CAD which has become a major economic disease of cassava, causing total crop failures under severe infection conditions.

The aim of this study was to investigate post-harvest survival and over seasoning of cassava anthracnose disease on infected materials and soil. Investigate the potential of burial of infected post harvest materials in the reduction of CAD field inoculum pressure.

MATERIALS AND METHODS

Experimental sites: The studies were conducted in the field, greenhouse, nursery and laboratories of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. IITA is located to the North of Ibadan at latitude 7°30'N and longitude 3°45'E. The altitude of the Institute is 210 m above sea level[17].

Collection, isolation and identification of the fungus: Cassava stems showing CAD symptoms (dark brown lesions, deep cankers) were collected from infected field plots. The diseased stems were washed with running tap water and small pieces of infected material were cut from the edges of the cankers, surface-sterilized for 3 min in 10% sodium hypochlorite solution and rinsed five times in sterile distilled water. The stem pieces were dried on sterilized filter paper and placed on solidified Potato Dextrose Agar (PDA) containing 100 mg L^{-1} sodium novobiocin (antibiotics) to inhibit bacterial growth. The material was incubated at 25±2°C for 7 days. Observation was made daily for any mycelial growth. Identification of the fungus was done under the microscope and confirmation made using the procedure of Barnett and Hunter[18]. Pure cultures were obtained by sub-culturing onto fresh plates. Stock cultures were maintained on agar slants in McCartney bottles.

Role of post-harvest materials as a potential source of inoculum for C. *gloeosporioides* f. sp. *manihotis* in CAD establishment: Stem cuttings from twelve infected cassava clones (TME1, 88/01336, 91/00396, 91/00344, 89/00033, 91/00072, 88/01084, 88/00695/88/01983, 91/00684, 30572, 91/00317), were collected from two sites ES24 and BS1, at the IITA field plots after harvest and incubated at 25±2°C, 80% relative humidity conditions. Samples of infected pieces were cultured on PDA monthly to investigate the survival of *C. gloeosporioides* f. sp. *manihotis*. Each cassava clone consisted of 30 infected stem cuttings and 10 replicate plates were prepared for each clone treatment.

Investigation of the survival of *C. gloeosporioides* f. sp. *manihotis* on cassava stakes under shade: Harvested stems each containing five large CAD cankers from twelve cassava cultivars mentioned above, were tied into bundles (stakes) and stored upright under a well-developed tree, providing a good shade. The oldest ends of the stems were inserted into the soil and watered regularly to keep it moist and humid, thus enhancing twig germination and creating favourable conditions for the fungi to survive for longer periods. The stems were stored for 16 months, up to a stage where most of the old stems collapsed given rise to twig development with large leaf canopies. Sampling for fungal survival was done every 2 months by examination of infected plant parts for the presence of *C. gloeosporioides* f. sp. *manihotis*.

The diseased stems were washed with running tap water and small pieces of infected material were cut from the edges of the cankers, surface-sterilized for 3 min in 10% sodium hypochlorite solution and rinsed five times in sterile distilled water. The stems pieces were dried on sterilized filter paper and placed on solidified Potato Dextrose Agar (PDA) containing 100 mg L^{-1} sodium novobiocin (antibiotics) to inhibit bacterial growth. The material was incubated at 25±2°C for 7 days. Observation was made daily for any mycelial growth. Identification of the fungus was done under the microscope and confirmation made using the procedure of Barnett and Hunter[18]. Pure cultures were obtained by subculturing onto fresh plates. Stock cultures were maintained on agar slants in McCartney bottles.

Role of post-harvest materials as a potential source of inoculum for C. *gloeosporioides* f. sp. *manihotis* in CAD establishment: Stem cuttings from twelve infected cassava clones (TME1, 88/01336, 91/00396, 91/00344, 89/00033, 91/00072, 88/01084, 88/00695/88/01983, 91/00684, 30572, 91/00317), were collected from two sites ES24 and BS1, at the IITA field plots after harvest and incubated at 25±2°C, 80% relative humidity conditions. Samples of infected pieces were cultured on PDA monthly to investigate the survival of *C. gloeosporioides* f. sp. *manihotis* following procedures earlier described. Each cassava clone consisted of 30 infected stem

Post-harvest soil sampling for fungal survival: Soil samples were collected shortly after cassava harvest on five planting field sites (ES24, C1, BS1, BS17 and B3), at IITA. These plots all have four years continuous

intensive cassava monocropping cultivation. The soils were screened for the survival of *C. gloeosporioides* f.sp.*manihotis*. Freshly collected soil samples from these plots were first analyzed for soil properties (Table 1) before investigation for fungal survival. Soil were covered with infected debris accumulated from post-harvest leaves and stem fragments serving as fungal baits. The soil mounts were watered regularly to keep the soil moist and humid, a conditions favourable for fungal growth. Bulk soils samples covered with debris were collected on a monthly interval and placed in labeled paper bags and taken to the laboratory. The soils were air-dried then crushed to remove the fungal spores/hyphae from heavier soil particles of the residues. The fine soil particle were mixed thoroughly in distilled water and allowed to sediment for 1 h. The supernatant was filtered through 2 layers of sterile Whatman No 1 filter papers. The sterile filters trapped spores and were aseptically removed and plated on PDA media which was colonized by the spores after germination. PDA media was incorporated with 100 mg L^{-1} of sodium novobiocin to inhibit bacterial growth and observed for any growth of fungi. The fungus was identified following the procedure earlier described. Soil screening for fungal survival was terminated when there was no major recovery of fungi from the field plot soils.

Effect of burial of infected cassava material on the survival of *C. gloeosporioides* f.sp. *manihotis*: Infected stem cuttings (30 cm long) from 5 cassava clones (88/01084, 88/01983, 91/00395, 91/00317, 91/00052), were collected from field plots with at least 3 large cankers. Wooden rectangular boxes (60 cm long by 40 cm depth) were filled with steam-sterilized soils. Stem cuttings from each cultivar were placed on the surface of the soil or buried at 10, 20 and 30 cm depth, in the wooden boxes. Cuttings were collected from each box treatments at 30, 60, 90, 120 and 150 days of storage. The cuttings were washed with running tap water to remove soil particles, then air dried in filter papers, after which thin sections from the cankered portions were teased out with a sharp table knife and surface-sterilized with 10% sodium hypochlorite for 3 min and rinsed in five changes of sterile distilled water. The stem pieces were aseptically transferred with a forceps to sterile filter papers for drying, followed by placing the tissues on PDA in Petri dishes containing 0.10 g L^{-1} of streptomycin sulphate to inhibit bacterial growth. Tissue pieces were incubated at 20-25°C under white fluorescent lights (12 h/day). Observation was made daily for any mycelial growth. Identification of the fungus was done under the microscope and confirmation made using the procedure of Barnett and Hunter[18]. Pure cultures were obtained by subculturing onto fresh plates. Stock cultures were maintained on agar slants in McCartney bottles.

Preparation of spore suspension: Spore suspensions were prepared from 8-day-old cultures of the isolated fungus by flooding with sterile distilled water and dislodging the spores with small brush. The suspension was clarified by centrifugation at 2000 rpm for 3 min and the supernatant was filtered through 2 layers of sterile muslin cheesecloth. The spore concentration was determined with a haemocytometer and adjusted to $2.0x10^6$ spores/ml of distilled water.

Pathogenicity assessment: To confirm the fungus that survived from buried CAD infected cassava cuttings was host specific to cassava and not from other soil saprophytic *Colletotrichum,* spore suspension isolated from infected soils and buried materials were used to inoculate greenhouse 2 months old healthy potted cassava plants. Inoculation was carried out using stem puncture technique Muimba[8] at the internodal regions, followed by foliar spray of fungal suspension, using a hand sprayer until runoff. The plants were observed for characteristic CAD symptoms (necrotic lesion, wilt and defoliation).

Statistical analysis: Data collected for fungal survival on infected stem cutting, soil plot sites, buried materials and cassava stakes were analyzed according to the general linear model procedures of the Statistical Analysis System[19]. Fischer-protected least significant difference (LSD) test and the Duncan Multiple Range test of mean separation were performed when the ANOVA showed significance.

RESULTS

Evaluation of the variability in soil properties: Analysis of the soils from different plot sites prior to this study showed no significant variation in soil (pH, total nitrogen organic matter, exchangeable bases and others), in the four plot sites ES24, C1, BS1, BS17 and B3 (Table 1). This result showed that there was no variation in soil properties among the plot sites to influence the survival variability of *C. gloeosporioides* f.sp. *manihotis* in soils and infected materials.

Survival of *C. gloeosporioides* f.sp. *manihotis* on post-harvest infected stem cuttings from two plot sites: There was a decrease in fungal viability on infected plant

Table 1: Soil properties of experimental plots at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

	Plot locations				
Soil characteristics	ES24	C1	BS1	BS17	B3
pH	6.80	6.50	6.70	6.90	6.60
Organic matter (%)	2.60	2.80	2.50	2.40	2.70
Total nitrogen (%)	0.05	0.09	0.06	0.07	0.08
Available phosphorus (ppm)	10.25	10.30	12.71	11.51	12.30
Exchangeable bases (Meq/100 g)	3.03	3.01	2.96	2.86	3.05
Calcium (Ca)	0.70	0.72	1.10	0.91	0.83
Potassium (K)	0.25	0.23	0.30	0.27	0.26
Sodium (Na)	0.26	0.28	0.32	0.30	0.24
Exchangeable acidity (Meq/100 g)	0.23	0.20	0.20	0.20	0.25
Base saturation	95.64	95.61	95.26	95.38	95.57
Texture					
Sand (%)	80.30	80.50	82.40	81.30	82.60
Silt (%)	14.00	14.20	11.50	12.80	13.20
Clay (%)	5.90	5.70	6.10	5.50	6.30

Table 2: Survival incidence of *C. gloeosporioides* f.sp. *manihotis* on infected stem cuttings at plot site ES24

	Mean % fungal incidence of infected stem cuttings at monthly intervals*							
Cassava clones	1	2	3	4	5	6	7	8
TME1	98.50a	85.00a	83.80a	77.70a	70.50a	61.60a	40.40b	22.00cd
88/01336	96.00ab	87.70a	80.50b	74.50a	54.50d	35.50ef	26.70e	15.50e
91/00396	95.00b	88.50a	82.30ab	75.80a	64.80b	51.50b	43.80a	31.20a
91/00344	90.50c	85.30b	72.50c	63.70b	48.00fg	38.30de	27.50e	17.30e
89/00033	90.30c	84.00b	70.50cd	61.80b	52.00de	42.50cd	33.60c	24.50c
91/00072	86.50d	80.50c	72.50c	63.00cd	50.50ef	38.70de	30.50d	21.60d
88/01084	85.80d	78.70d	69.30de	62.70cd	59.50c	52.00b	38.40b	27.90b
88/00695	85.80d	77.20d	70.80cd	57.80bc	47.30g	36.50de	28.30de	20.10d
88/01983	84.00d	75.30e	64.50gh	60.75e	54.70d	38.50de	31.00d	22.50cd
91/00684	81.20e	74.60e	65.60fg	53.80e	41.00h	31.00f	25.20ef	18.60de
30572	80.50e	74.00e	67.80ef	63.00fg	48.30fg	38.50de	22.80f	15.40e
91/00317	70.50f	65.50f	62.00h	56.20f	49.50e-g	44.80c	32.10c	24.80c
Mean	87.00	80.50	71.79	64.22	53.40	42.60	31.66	21.78
CV	20.14	22.95	21.51	23.85	23.98	17.47	25.40	18.66

*= Each value is a mean of 4 replications; CV= Coefficient of variation.

Table 3: Survival incidence of *C. gloeosporioides* f.sp. *manihotis* on infected stem cuttings incubated at plot site BS1

	Mean % fungal incidence of infected stem cuttings at monthly intervals*							
Cassava clones	1	2	3	4	5	6	7	8
TME1	100.00a	94.20a	88.00a	80.70a	72.50a	65.00a	51.50b	36.00b
88/01336	98.30a	93.50a	86.40b	81.20a	66.90b	46.80cd	38.00d	22.80e
91/00396	96.80ab	91.60ab	88.50a	82.50a	70.10a	63.20a	54.90a	43.70a
91/00344	94.00b	88.70b	81.70c	68.40c	55.30d	49.40c	35.40de	24.50d
89/00033	92.70b	86.00b	75.30d	66.40cd	58.80cd	50.10b	41.60c	30.60c
91/00072	91.40b	83.50bc	76.10d	70.60b	63.50c	53.50b	43.00c	28.00cd
88/01084	87.00c	80.70c	68.20e	60.20e	56.20d	44.20d	33.70d	23.50e
88/00695	86.60cd	78.20cd	73.60de	62.90d	50.50ef	42.70de	35.00de	26.40d
88/01983	86.20d	76.80d	67.90e	63.50d	57.80cd	46.30cd	35.30de	28.60cd
91/00684	83.50de	73.50de	62.20f	56.80f	46.50f	35.60f	28.60f	21.00e
30572	82.20de	75.00d	64.50ef	59.50ef	52.00e	44.40d	30.50e	18.20f
91/00317	76.30e	68.40e	65.00ef	61.00e	54.50e	39.80e	28.00f	22.40e
Mean	89.33	82.51	74.78	67.80	58.72	48.42	37.96	27.14
CV	23.22	27.88	19.45	33.41	25.05	17.43	28.07	22.49

*= Each value is a mean of 4 replications; CV= Coefficient of variation.
Means in the same column followed by the same letter(s) are not significantly different (P=0.05)

cuttings with increase in incubation period collected from plots ES 24 and BS1 (Table 2 and 3). During the 1st month of screening, cassava clones (TME1, 88/01336, 91/00396, 91/00344 and 89/00033) showed fungal survival of above 90% recorded for plot ES24 (Table 2) and a similar survival trend was recorded on another plot site BS1. There was a gradual decrease in percentage viability of the fungus in all the post-harvest infected cuttings. The lowest fungal survival incidence of 15.4% was recorded at plot site ES24, on clone 30752, at 8 months incubation period (Table 2) and at plot site BS1 the lowest CAD fungal incidence was 18.2% recorded for clone 30752. The highest fungal recovery of 43.7% was recorded for clone 91/00396 (Table 3).

Table 4: Survival incidence of *C. gloeosporioides* f.sp. *manihotis* on cassava stakes under shades

	Mean % fungal incidence of infected stem cuttings at 2 monthly intervals*							
Cassava clones	2	4	6	8	10	12	14	16
TME1	83.50ab	80.20b	72.60c	60.00a	46.20bc	64.00a	72.50a	80.60b
88/01336	80.80b	76.60c	70.20d	57.40b	48.60b	58.40bc	66.60bc	75.10cd
91/00396	86.30a	83.50a	75.80a	63.50a	53.80a	60.50b	68.70b	78.40c
91/00344	80.60b	77.40c	70.40d	55.70bc	44.00c	52.00c	71.40ab	83.40a
89/00033	85.20a	81.80b	76.00a	61.00a	47.70b	58.60bc	73.90a	79.90b
91/00072	81.70b	75.30cd	68.90d	58.60ab	43.60c	53.20c	64.30c	76.20cd
88/01084	76.50c	70.00d	63.70e	50.20c	41.50c	48.70d	53.10e	64.40d
88/00695	73.30c	65.40e	56.00g	45.60d	37.60d	45.30de	50.60ef	57.60ef
88/01983	76.90bc	70.50d	65.30e	56.00b	40.70cd	46.00de	52.10e	59.30e
91/00684	70.10d	64.20e	58.50g	44.80d	34.10de	39.50e	47.80f	54.70f
30572	77.20bc	68.10de	61.20f	55.20bc	38.50d	45.50de	59.20d	66.00d
91/00317	68.10d	62.90f	57.00g	49.70c	33.90de	37.80e	46.00f	53.80f
Mean	78.35	73.00	66.30	54.80	42.52	50.79	60.52	69.12
CV	21.56	23.09	17.55	19.22	20.50	25.11	18.48	20.06

*= Each value is a mean of 4 replications; CV= Coefficient of variation.
Means in the same column followed by the same letter(s) are not significantly different (P=0.05)

Table 5: Survival of *C. gloeosporioides* f.sp. *manihotis* on soil samples sites at indicated months

	% Fungal recovery in soils at indicated months*					
Soil sampling sites	1 Month	2 Months	3 Months	4 Months	5 Months	6 Months
Site ES24	56.45c	30.80b	20.70c	10.30c	3.70b	0.00b
Site C1	35.80d	20.60c	12.40e	8.30cd	0.00c	0.00b
Site BS1	70.40a	43.30b	27.90a	19.20a	10.60a	3.50a
Site BS17	64.60b	32.20b	23.70b	14.10b	4.40b	0.00b
Site B3	52.20cd	23.60c	15.70d	6.60d	0.00c	0.00b
Mean	48.72	30.10	20.15	11.72	3.74	0.70
CV	17.33	21.14	15.08	18.66	21.00	18.25

Table 6: Survival of *C.gloeosporioides* f.sp.*manihotis* on infected cuttings buried at different depth

	% Fungi survival at indicated period of burial at different depth (cm)*											
	90 Days after burial				120 days after burial				150 days after burial			
Cassava clones	0 cm	10 cm	20 cm	30 cm	0 cm	10 cm	20 cm	30 cm	0 cm	10 cm	20 cm	30 cm
88/01084	76.80a	62.80bc	46.00a	29.60a	63.80a	52.80b	26.00a	9.80b	53.00a	43.40a	15.30a	10.20ab
88/01983	75.00a	64.60b	41.30b	25.70b	60.90b	47.30c	25.80ab	12.60ab	54.20a	37.00b	13.80b	8.40ab
91/00395	74.00b	67.20a	34.60c	26.20bc	63.40a	56.40a	28.40a	14.40a	50.60b	41.00a	10.00c	6.20b
91/00317	73.40b	48.00c	33.20c	23.60c	63.00a	38.00d	19.60bc	10.20bc	44.29d	28.50c	8.20d	4.60c
91/00052	70.50c	47.50c	35.40c	20.50c	62.50ab	36.20d	22.50b	12.6b	46.40c	25.30d	8.90d	5.50bc
Mean	73.84	58.02	38.10	25.12	62.72	46.15	24.46	11.92	49.70	35.05	11.23	6.80
CV	18.15	20.13	16.40	22.80	25.46	18.17	15.61	22.06	19.44	21.55	23.12	17.70

*Values are means of four replicates per treatment; CV= coefficient of variation.
Means in the same column followed by the same letter(s) are not significantly different (P=0.05)

Fungal recovery on post-harvest cassava stakes under shade: There was significant variation in fungal survival among the cassava clones at different screening periods (Table 4). Fungal survival on cassava stakes showed a general decrease among the clones, up to the 10th month of screening. Fungal survival increased steadily from 12-16th months after which the screening was terminated due invasion of parent plant by the increased leaf canopy population from developing twigs. The twigs at this stage were re-infected by the CAD pathogen from the parent plants, through vector feeding or from rain splashing of spores, which resulted to increased disease infection. At 16 month, the cassava stakes had attained maximum fungal survival incidence of above 80%, which was recorded for clones 91/00344 and TME1, respectively.

Fungal survival on post-harvest field plot soils: There were significant differences (P=0.05) in survival of *C. gloeosporioides* f.sp. *manihotis* on post-harvest field plot soils (Table 5). Fungal survival at the soil plot sites decreased with increase in the sampling period. At one month of soil sampling, maximum fungal survival was recorded for soils at plot sites BSI (70.40%) and BS17 (64.60%), respectively. Fungal recovery gradually reduced with sampling duration, until at the 6th month of sampling, there was no fungal recovery recorded on soils at four plot sites (C1, BS1, BS17 and B3).

Effect of burial depth and duration of buried infected cassava material on fungal survival: *C. gloeosporioides* f.sp. *manihotis* survival generally reduced with increased

depth and duration of burial of infected plant materials (Table 6). In all the five infected clonal materials used (88/01084, 88/01983, 91/00395, 91/00317, 91/00052), there was maximum reduction of fungal survival below 20% at 150 days of burial below 20 cm depth. Cassava clone 88/01084 recorded less than 10% fungal survival at 150 days of burial below 30 cm depth. The unburied plant materials (control) at 150 days, recorded fungal survival of 53% on clone 91/00317. At 30 cm depth, fungal survival was minimal, with the least survival of 4.60% recorded on cassava clone 91/00317.

DISCUSSION

There was a general decrease in fungal survival on post-harvest materials with increase in incubation period and on infected soils at field plot sites. The experiment for CAD fungal survival was terminated after the 8 months data collection due to total invasion of the cuttings by saprophytic fungi, thus making further isolation of C. *gloeosporioides* f.sp. *manihotis* extremely difficult. *C. gloeosporiodes* f.sp *manihotis* is an important disease of cassava causing significant crop failure and economic loss to cassava growers, who depend on this crop as their man source of income[1,3]. Despite the devastating effect of CAD, there has been no studies to assess the survival potential of the fungus on post harvest infected materials. The results obtained in this study have shown that the causal agent of CAD may reside on infected stem cuttings for at least 8 months and in soil for up to 4 months. This information is important to influence the management of post-harvest materials in the field.

Cassava is mostly propagated by cuttings and usually planting materials are derived from the last harvest. The stem cuttings after harvest are stored in stakes upright under shades or tips buried in the soil for maintaining freshness and humidity. With an understanding that the CAD fungus can survive on these stems during storage, it is important to advise farmers to separate infected cuttings from their planting stock during the storage process to minimize cross infection.

Studies on the viability of *C. gloeosporioides* f. sp. *manihotis* on cassava infected materials showed a gradual reduction in percentage viability of the fungus with increased period of incubation. However, observation of above 50% viability of the fungus in some cassava clones at 6 months of evaluation showed that abandoned infected cassava materials in the field could serve as a potential source of field inoculum during the next planting season. Eradication of infected materials through burial after harvest could reduce inoculum build-up in the field, before the new planting season[4,20] .

C. gloeosporioides f.sp. manihotis is host specific for cassava, this limits invasion and survival of the fungus on alternative host and thus creates a potential for control under good sanitation and cultural control practices. The presence of fresh cassava stakes also created a favourable conditions for *C. gloeosporioides* f.sp. *manihotis* survival. The development of twigs and leaf canopy at a later stage from the storage cassava stakes creates a potential post-harvest field-field CAD transmission.

Deep burial of infected materials significantly reduced *C. gloeosporioides* f.sp. *manihotis* inoculum under field conditions. Planting of cassava and other tuber crops is commonly done by the construction of ridges or mounts. The ridges are usually separated from each other by furrows which can attain depth of about 70 cm depending on the height of the ridges. This cultivation system makes it easier for farmers to effectively adapt deep burial system of infected material for CAD control under the crop rotation system. After cassava harvest, the infected materials are laid in the furrows and new ridges are constructed on these furrows thus burying the infected materials, while the land is used for planting new crop under the crop rotation system. This showed that burial of infected materials in furrows after harvest, in a crop rotation system could break the life cycle of *C. gloeosporioides* f. sp. *manihotis* and serve as a potential cultural control option to reduce inoculum pressure under field conditions.

Pre-and post harvest survival of anthracnose diseases on avocado and other tropical fruits has been reported[21,22]. CAD fungus are host specific to cassava and survive in warm wet conditions[23]. Although there was a decline of CAD pathogen with time under storage of post harvest material and during burial it is not known whether the decline in survival is related to weather conditions, host resistance or antagonistic activity of other soil invading fungi. There is the need for the investigation of the interactions of these factors on CAD control in order to make a conclusive statement about the factor influencing the decline in fungal population.

Other cultural practices such as crop rotation, fallow and burning of infected post-harvest plant have been proposed as control options for root and tuber crop diseases[1,24]. Complete control through crop rotation and burial is possible with pathogens that are soil invaders, that is survive only on living plants or only as long as the host residues persist as a substrate for their saprophytic existence[22,25]. Reducing the initial inoculum is very important for the control and effective management of pathogens such as *C. gloeosprioides* f.sp.*manihotis*. Information on the survival and over seasoning of CAD on post harvest materials is very important in order to adopt an effective cultural control practice in regions where season-to season cultivation of cassava crop are intense on the same piece of land. The adoption of host

resistance breeding and cultural control measures for cassava improvement, within the integrated pest and disease control strategies at the Tuber and Root Crop Improvement Program (TRIPP), at the International Institute of Tropical Agriculture (IITA), has led to increased productivity within the low-income subsistence farmers in cassava growing regions of Nigeria. The increased production level now ranks Nigeria as the leading producers of cassava and the prospect of achieving a sustainable food crop production within the region to meet the basic food supply to the over 100 million population has been enhanced[3].

The use of improved resistant cultivars and cultural control practices has been successfully applied in CAD management. These control options have significantly reduced the use of fungicides that are very expensive for the local poor farmers to purchase. The lack of training on the use of pesticides by the local farmers had in most occasions led to deleterious effects on the farmers as well as their crops and environments, because of poor application.

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