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CAN THE INHERENT ANTIOXIDANT IN YELLOW-FLESHED CASSAVA VARIETIES (MANIHOT ESCULENTA CRANTZ) AND FERTILIZER APPLICATION SUPPRESS ROOT ROT?

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Abstract

Cassava root rot disease has been reported to cause huge losses of fresh root yield particularly when harvesting is delayed. The improved yellow-fleshed cassava varieties naturally contain antioxidant whereas antioxidant has been widely used to control plant root rot diseases in the tropics. The experiment was carried out at Federal University of Agriculture, Abeokuta, Nigeria in 2013/2014 and 2014/2015 cropping seasons to investigate: 1) the possibility of inherent antioxidant in yellow fleshed cassava root tuber to control root rot disease, 2) role of fertilizer application on tuber rot incidence and 3) delay harvesting of tubers on root rot incidence and, yield. The experiment was laid out in randomly completed block design arranged in a split-split plot and replicated three times. The main plot, subplot and sub-subplot treatments were four cassava varieties, 5 nitrogen levels, 4 potassium levels. Cassava harvested at 14th month produced the lowest root rot, longest tuber root and highest root yield in 2013/2014 and 2014/2015. TMS 98/505 (white-fleshed cassava) variety had the highest root rot. Cassava root yield had a positive correlation with tuber girth, number of tubers, tuber length and negative correlation with root rot at 14 and 16th months in 2013/2014 and 2014/2015, respectively. It was concluded that the white-flesh cassava varieties could not be delayed beyond 14 MAP, but the yellow varieties can further be delayed to 16 MAP. Besides, the study affirmed that white-fleshed cassava variety had the highest rot incidence suggesting that inherent antioxidant in yellow-fleshed cassava varieties can minimized rot incidence. However, fertilizer do not seem to influence tuber root.

Keywords: antioxidant, fertilizer, cassava varieties, delay harvesting, tuber rot

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) belongs to the family Euphobiaceae. It is a perennial woody shrub that is commonly grown as an annual. It is ranked as the sixth most important source of calories in the human diet worldwide (Alfredo *et al.*, 2000) for an estimated 800 million people around the world (Akparobi *et al.*, 1998; Lebot, 2009). Nigeria (49.18 million tonnes) is currently the world's largest producer of cassava followed by Thailand (30.04 million tonnes), Indonesia (24.06 million tonnes), Brazil (22.26 million tonnes) and Democratic Republic of Congo (16.25 million tonnes) in that order (FAOSTAT, 2021). Yellow fleshed cassava is rich in beta-carotene (Vitamin A or antioxidant) which is an important component of human nutrition (Maravalhas, 1964; McDowell and Oduro, 1983; SafoKantanka *et al.,* 1984).

Cassava root rot is a very important disease of cassava and was first discovered in West Africa by Mskita *et al.* (1998). It was reported to cause about 20 to 80% yield loss (Mskita *et al.,* 2005). Parasitic mushroom (*Polyporus sulphureus*) has been identified as one of the serious root rot pathogens in Ghana and is capable of causing 100% yield loss in susceptible cultivars (Moses *et al.,* 2005), 20 to 100% in Democratic Republic of Congo (Mwangi *et al*., 2004). Aigbe and Remison (2010) reported that the starch content and quality of garri decreased with increasing incidence or severity of root rot among assessed varieties of cassava. Mwangi *et al.* (2004) similarly reported that the root rots are an important constraint to cassava production in humid forest and forest transition of Central and West Africa and can impact negatively on food security to several millions people inhabiting the regions.

Rotting is known to increase significantly if mature plants are left in the soil for extended period of time (Oyekan, 2004). Mwangi *et al.* (2004) reported that harvesting immediately after the tubers mature is an effective management strategy adopted by farmers. However, lack of market coupled with the perishability of fresh tuber is major challenges faced by farmers. These challenges informed the farmer to practice delay harvesting by leaving the tuber in the soil until needed or availability of market. Reduced shelf life of cassava fresh storage roots limit marketing options and increases the likelihood of product losses and higher marketing costs (Ceballos *et al*., 2004; Sánchez *et al*., 2006; Zidenga *et al*., 2012).

Reported causes of cassava root rot diseases are water logged or flooded soils and microorganisms (fungi and bacteria) that are hydrophilic. Okigbo *et al.* (2009) isolated the percentage frequency of occurrence of following causal fungi of cassava root rot in Nigeria: *Fusarium solani* (15.10%), *F. oxysporum* (2.14%), *Candida spp* (1.73%), *Aspergillus niger* (16.25%), *A. tamari* (2.42%), *Mucor spp* (6.90%), *A. flavus* (8.92%), *Penicillium oxalicum* (6.80%), *P. digitatum* (1.71%), *P. chrysogenum* (3.56%), *Trichoderma viride* (8.62%), *Neurospora spp* (3.45%), *Botryodiplodia theobromae* (5.17%), *Geotrichum candidum* (6.90%) and *Rhizopus stolonifera* (10.34%).

Root rot diseases are serious but antioxidant has been reported to have been successfully used to control root and pod rot in peanut (Elwakil, 2003), Fusarium wilt in chickpea (Nighat-Sarwar *et al*., 2005), faba bean chocolate spot (Hassan *et al*., 2006), peanut root rot (Mahmoud *et al*., 2006), Fusarium wilt in tomato (Mohamed *et al*., 2007), root rot and leaf blight in lupine (Abdel-Monaim, 2008), damping-off in pepper (Rajkumar, 2008). Similarly, Mostasa (2006) reported that application of antioxidants, e.g. ascorbic, salicylic, coumaric, benzoic acids and propylgalate as either seed soaking or soil drenching proved sufficient protection against cumin caused by Fusarium oxysporum, F. sp. cumini or Acreromonium egyptiacum. Furthermore, antioxidant was used to control rot and wilt diseases of pepper caused by F. oxysporum, F. solani, and M. phaseolina (Abdel-monaim and Ismail, 2010). Hassan *et al*. (2014) used the following antioxidants ascorbic acid, salicylic acid, and EthyleneDiamineTetraacetic Acid (EDTA) to control Fusarium oxysporum, F. solani, and Macrophomina phaseolina on roselle under field conditions.

The primary mode of action of carotenoids as antioxidant is to quench singlet oxygen (a reactive type of oxygen (Rodriguez-Amaya, 2010). The antioxidant properties of carotenoids may help to inhibit the onset of other diseases that are believed to be initiated by free radicals such as atherosclerosis, age-related macular degeneration and multiple sclerosis (Edge *et al*., 1997). Furthermore, these properties are linked to the ability of carotenoids to quench singlet oxygen, eliminate deleterious effects of free radicals as well as playing a putative role of cancer prevention (Nassar *et al*., 2009; Akinwale *et al*., 2010; Priya and Siva, 2014; Uarrota *et al*., 2014).

The importance of antioxidants in controlling root rot cannot be overemphasized. Thus, the inherent antioxidant present in yellow fleshed cassava varieties may as well likely have the potential to suppress root rot compared to their white counterpart particularly in root rot endemic areas. High perishability of cassava coupled with poor market arrangement informed the farmer to harvest only the specific quantity of cassava tubers for any available market or home need while leaving the others unharvested in the soil. However, the root rot disease is a threat to this practice of delaying harvesting.

The role of plant nutrition is in two basic mechanisms of disease resistance: (1) formation of mechanical barriers (cell wall strengthening) and (2) synthesis of defense compounds that protect against pathogens (Spann and Schumann, 2010). However, provision of good nutritional level in crop production may not necessarily protect plants from many of the virulent pathogens that are capable of causing disease (Downer *et al*., 2013).

Nitrogen fertilization has been reported to produce succulent growth that will lead to exacerbation of diseases or may lead to other problems (Powell and Lindquist, 1997 as quoted by Fernandes *et al*. (2017)). This underscores the observation of Odedina *et al.* (2017) who evaluated 21 cultivars reported that considerable losses of cassava tuber to root rot was observed in cropping season when fertilizer was applied compared to those without fertilizer. However, Downer *et al.* (2013) found no effect of fertilizer source on disease development. Given the inconsistency in findings, there is the need to confirm or refute whether or not fertilizer application to cassava influences root rot in Nigeria.

Potassium is one of the most absorbed nutrients by cassava plants because it acts on the synthesis and starch accumulation in the storage roots (Fernandes *et al*., 2017). Besides, the application of 45–89 kg ha^{-1} dipotassium oxide (K_2O) increased the yield of storage roots and starch from 36–49% (Fernandes *et al*., 2017).

Therefore, this study intends to answer the following questions: Can the inherent antioxidant in yellow-fleshed cassava tuber suppress root rot? Can fertilizer exacerbate cassava root rot? What is the appropriate time to harvest with less damage to cassava tuber? The objectives of the study are to: 1) evaluate the inherent antioxidant in yellow fleshed cassava to the control of root rot 2) evaluate the effects of fertilizer on the tuber rot 3) determine the appropriate time of harvesting cassava tuber that will reduce root rot damage.

MATERIALS AND METHODS

The experiment was carried out at two different sites in 2013/2014 and 2014/2015 cropping season at Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) farm, Federal University of Agriculture, Abeokuta. Two separate sites were used for 2013/2014 and 2014/2015 cropping seasons because of the distance from the core research station coupled with security challenges of the site. The annual rainfall and mean air temperature of the experimental site were1314.4 mm per annual and 29 °C, respectively. The location has bimodal rainfall pattern with peaks at July and September. The latitudes for the two seasons are 7.291278 and 7.231683, respectively while the longitudes are 3.361224 and 3.391173, respectively. The altitudes above the sea level are 76 m and 115 m for the first and second season, respectively.

Soil samples (0–20 cm) were randomly taken on the field with the aid of soil auger. These were bulked together from which composite sample was taken for soil analysis. The soil was air-dried, ground and sieved with 2 mm mesh and then analyzed for physic-chemical properties. The textural class of the soil was loam in 2013/2014 while that of 2014/2015 was clay loam based on USDA soil textural calculator and triangle. The pH of the soil in 2013/2014 and 2015/2015 were neutral (7.3 and 7.0), respectively.

Treatment Details

The four improved cassava varieties with low cyanic acid which were developed in International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria were used. The three yellow-fleshed cultivars (TMS 01/1368, TMS 01/1372 and TMS 01/1412) used were registered and released in 2011 while the fourth (TMS 98/0505) (white-fleshed) cultivar was registered and released in 2005 (NACGRAB, 2014). The common outstanding characteristic of the four varieties is high yielding (NACGRAB, 2014). The two single fertilizer materials used as treatments were Urea (46% N) and potassium chloride (60% of KCl) while the 30 kg P ha^{-1} in the form of single super phosphate (18% P_2O_5) was applied to the entire plots.

The experiment was laid out in a split-split plot design replicated three times. The main plot was the cassava varieties while the sub-plot and sub sub-plot were nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) and potassium fertilizer (0, 15, 30 and 45 kg KCl ha^{-1}), respectively. Each of the sub-sub plot size was 10 m by 8 m. The discard between plots and those of replicates was 2 m each. The planting spacing of cassava cuttings was 1 × 1 m given a plant population 10,000.

Cropping history of the experimental: The two experimental sites were previously grown to maize-cassava intercropped for two consecutive years.

Crop Husbandry

The experimental area was ploughed, harrowed and ridged mechanically. Planting was done between 27th and 30th of July, 2013 and 26th and 29th July 2014 for 2013/2014 and 2014/2015 cropping seasons, respectively. Supplying of missing stands was done 3 Weeks After Planting (WAP).

Pre-planting treatment: The cassava cuttings were treated with ultimax Plus® fungicides (Copper Oxide + Metalaxyl) against fungal pathogens before planting. It is a combination of systemic and contact fungicides.

Pre-emergence herbicides [combined mixture of Xtraforce® (Atrazine 25%, metolachlor 25% a.i.) and Paraforce® (paraquat 20% SL)] were sprayed immediately after planting. Supplemented weedings were done with hoe weeding at 6, 9, 12 and 15 WAP when the plants were tender. Other weedings were done using spray guided contact herbicides [Paraforce® (paraquat 20% SL)] under the canopy of the cassava plants once a month using knap sack sprayer.

Harvesting

The tubers were harvested at 12, 14 and 16 Months After Planting (MAP). Each of the sub sub-plot was divided into three sub plots and was harvested between 27th and 31st of July (i.e. 12 MAP), 27th and 30th of September (14 MAP) and 27th and 30th of November (16 MAP) in 2014 and 2015 for the 2013/2014 and 2014/2015 cropping season, respectively.

Data Collection

Data were collected on 10 randomly selected plants per plot and uprooted for data on rot incidence and yield at 12, 14 and 16 MAP.

Number of tubers: It was taken from randomly selected 5 plants per plots.

Tuber weight (t ha^{-1}): It was taken by weighing 10 randomly selected plants per plot.

Disease Incidence: This is the rate of occurrence of disease symptoms in a given population of plants, usually calculated in percentage (Bansal *et al*., 1994):

Disease Incidence (%) =

$$= \frac{\text{Number of diseased tubers}}{\text{Total number of tubers}} \times 100. \quad [1]$$

Data Analysis

The data collected were subjected to Analysis of Variance (ANOVA) using GENSTAT 12 edition. Correlation analysis was also carried out. The significant means were separated using LSD (Least Significant Difference) at 5% level of probability.

RESULTS AND DISCUSSION

Influence of Weather Parameter on Cassava Root Rot

The rainfall amount, the relative humidity of the air, the number of sunshine hours and evaporation rate recorded during the two cropping seasons were generally lower than annual parameter (Tab. I). It is pertinent to note that weather parameters observed in 2013/2014 cropping season were higher than those of 2014/2015. The higher rainfall, relative humidity, lower evaporation and sunshine hours were expected to favour the activities of root rot organisms in 2013/2014.

Effects of Soil Physiochemical Properties on Cassava Root Rot

The soil textural classes (loam and clay loam) of the two sites (i.e. 2013/2014 and 2014/2015 cropping seasons, respectively) were well drained (Tab. II). The pH which is the measure of degree of acidity or alkalinity of the soil or hydrogen ion concentration indicated that the soil was neutral with a pH of 7.3 and 7.0 for the two locations used. This favoured the availability of the nutrient elements to the plants. The total nitrogen content (1.40 and 1.30) and K level (0.62 and 0.64 Cmol/kg) were above the critical level according to Abbet (2012) and Lege (2012). However, the soil of the experimental site was found to be low in organic matter (OM) based on the documentation of Ojeniyi and Akanni (2008) and Agbede *et al.* (2008) who reported that soils in south-west Nigeria were deficient in organic matter. The altitudes above the sea level of the two locations were 76 and 115 m for 2013/2014 and 2014/2015 cropping seasons, respectively (Tab. II).The textural class, altitudes and rainfall amount/pattern of the two locations cum seasons suggest that flooding was not likely and therefore the undoubtedly cause of root rot of cassava in the two locations or seasons could be attributed to root rot pathogens.

Effects of Time of Harvesting, Variety and Fertiizer on Number of Tuber, Rot Incidence and Tuber Yield in 2013/2014 and 2014/2015 Cropping Season

The number of tubers was significantly affected by time of harvest in both 2013/2014 and 2014/2015

I: *Weather parameters during the two cropping seasons*

Month	Total Rainfall (mm)		Relative humidity (%)		Sunshine hours		Evaporation (mm)		Mean temperature (°C)	
	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
July	202.6	90.7	76.3	68.8	3	3.8	1.2	1.9	25.6	29.1
August	35.2	92.7	71.7	70.4	3.1	2.3	2.6	2.8	24.3	25.6
September	136.0	160	69.7	71.1	4.3	3.2	3.0	2.0	25.6	26.3
October	94.4	205.9	67.2	70.2	5.0	5.3	2.4	2.7	27.0	26.3
November	15.6	17.6	60.0	67.3	6.5	5.3	4.2	3.8	28.3	27.5
December	16.5	0.0	58.5	56.9	6.2	6.5	4.1	3.6	27.2	28.5
January	8.2	0.0	59.4	33.1	6.1	6.1	4.2	3.3	28.9	27.9
February	15.5	17.1	53.4	49.4	5.8	2.1	4.5	1.7	29.3	28.9
March	149.1	35.3	59.1	51.2	6.0	5.6	3.1	3.4	28.8	30.2
April	87.2	11.5	65.7	51.0	5.7	6.1	3.7	3.8	28.2	28.9
May	113.8	15.1	67.7	71.1	5.8	6.7	2.9	3.8	27.8	28.5
June	116.5	14.5	64.4	62.1	5.9	4.2	2.3	2.5	27.5	26.9
Total	990.6	660.4	708.7	660.5	63.4	57.2	38.2	35.3	328.5	334.6
Average	82.6	55.0	64.4	60.2	5.3	4.8	3.18	2.94	27.4	27.9

Source: Department of Agro-meteorology and Water Resources Management, Federal University of Agriculture, Abeokuta (FUNAAB)

II: *The physiochemical properties of the two experimental sites*

Soil Physico-chemical properties	2013/2014	2014/2015
Sand (%)	44.49	35.72
Clay (%)	15.96	34.39
Silt (%)	39.55	29.89
Textural class	Loam	Clay loam
Altitude	76 m	115 m
Latitude	7.291278	7.231683
Longitude	3.361224	3.391173
pH	7.3	7.0
Mg (Cmol/kg)	24.2	27.18
Na (Cmol/kg)	0.52	0.51
K (Cmol/kg)	0.62	0.64
Organic C (%)	0.43	0.41
N (%)	0.14	0.13
Ca (C mol/kg)	41.4	38.99
Av. P (mg/kg)	25.7	30.64
Ex. Acidity (meq/100 kg)	0.25	0.38
Organic Matter (%)	0.71	0.71

cropping seasons (Tab. III). The numbers of cassava tubers harvested at 12 and 14 MAP were similar in 2013/2014 cropping season, but significantly higher than of those harvested at 16 MAP in 2013/2014. However, in 2014/2015 cropping season, the number of cassava tubers harvested at 16 MAP produced higher number of tubers than those harvested at 12 and 14 MAP.

The number of tubers produced by the cassava varieties were significantly different from each other in cropping season. The number of tubers obtained from TMS 98/0505 and TMS 01/1368 varieties were similar but significantly higher than the other varieties in 2013/2014. However, in 2014/2015, variety TMS 01/1412 had the lowest number of tubers while variety TMS 98/0505 had the highest. The consistently higher number of tubers of TMS 98/0505 variety observed in 2013/2014 and 2014/2015 cropping seasons could be attributed to genetically innate. This confirms the finding of Akoroda (2005) who reported that the number of roots which eventually form tubers as well as earliness of tuber bulking and maturity may depend on the genotype, assimilate supply, photoperiod, and temperature. The process of tuber formation and maturity may also depend on soil water supply, soil fertility and soil temperature (Ikpi *et al.*, 1986).

The response of number of tubers to nitrogen fertilizer was significantly different in 2014/2015 cropping season. The plot without fertilizer application had similar number of tubers with those that received 30 kg N ha^{-1} but was significantly lower than those plots treated with 60, 90 and 120 kg N ha^{-1}. This agrees with the work of Nair (1982) who reported that increase in number tubers was due to increase in dosage of nitrogen.

The time of harvest significantly influenced rot incidence in both cropping season but the damage was substantial in 2014/2015. Incidentally, weather parameter such as rainfall and humidity were higher suggesting favourable environment for root rot pathogen. This is a pointer to the fact that the second site could probably have more root rot inoculum than the first season. The rot incidences observed at 12 and 16 MAP were similar but had higher rot incidence than those of 14 MAP in 2013/2014 cropping season. In 2014/2015 cropping season, the time of harvest at 16 MAP had higher rot incidence compared to 12 and 14 MAP.

The varieties were significantly affected by rot incidence in both cropping season. Agbaje and Akinlosotu (2004), who tested varieties differing in cyanic content, similarly reported that incidence of tuber rot was influenced by varietal differences. The white-fleshed variety (TMS 98/0505) had consistently higher rot incidence compared to the three yellow-fleshed varieties. The higher rot incidence in TMS 98/0505, could not be unconnected to the absent of antioxidant (vitamin A or β-carotene content). The suppression of root rot incidence in yellow-fleshed cassava varieties compared to white-fleshed counterpart is an indication that the inherent antioxidant is playing a very key role in root rot disease control. This agree with the opinion of Edge *et al.* (1997) who documented that the antioxidant properties of carotenoids may help to inhibit the onset of diseases that are believed to be initiated by free radicals such as atherosclerosis, age-related macular degeneration and multiple sclerosis. This, perhaps, informed the use of antioxidant by several workers to reduce root rot in sweet pepper (*Capsicum annuum*) (Abdel-Monaim and Ismail, 2010) and roselle (*Hibiscus sabdariffa*) (Hassan *et al*., 2014) plants.

As the nitrogen level increases, more damages were caused by root rot in 2014/2015 cropping season (Tab. III). The nitrogen rate of 120 kg ha^{1} had similar root rot incidence with those of 60 and 90 kg ha^{1} but significantly higher than those of 0 and 30 kg ha^{1}. This result confirms the speculations of Odedina *et al.* (2017) but contradict the findings of Downer *et al.* (2013).

The time of harvesting significantly influenced fresh tuber yield in both cropping seasons. The tuber harvested at 14 MAP was reliably the highest in two cropping seasons. The harvesting done at 12 MAP gave the lowest fresh cassava tuber in 2013/2014 while those harvested at 16 MAP in 2014/2015 had the lowest. The wider gap observed in the tuber yield between the 12 and 14 MAP could be attributed to the accumulated addition of dry matter as the plant advances in age. However, the decline in tuber fresh yield observed at 16 MAP in

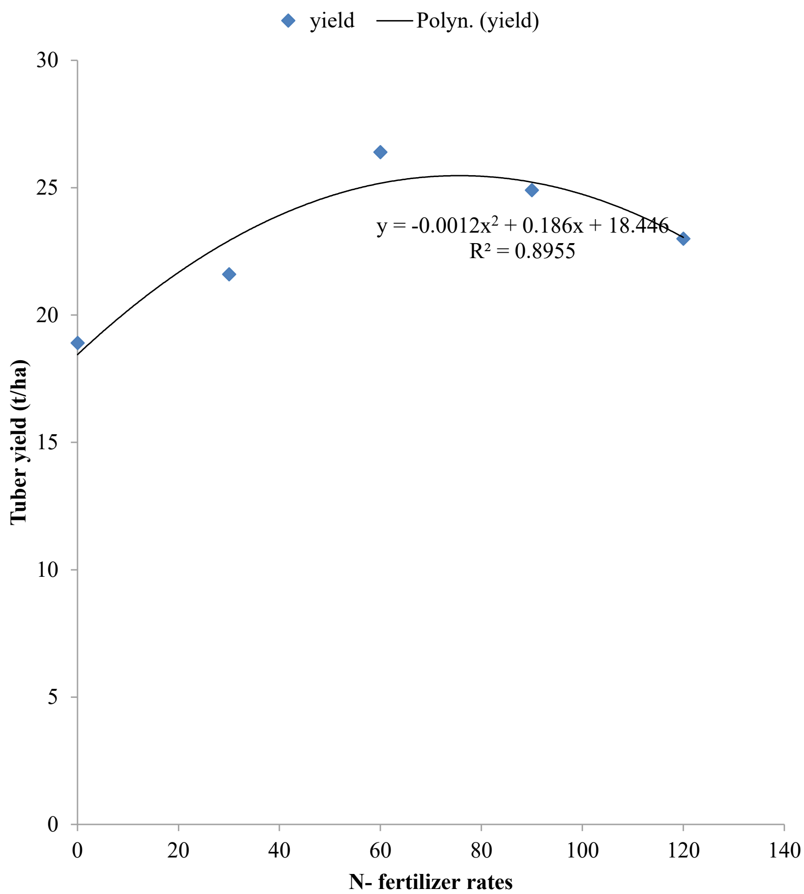
III: *Effect of time of harvesting, nitrogen and potassium sources on number of tuber, rot incidence and tuber yield in 2013/2014 and 2014/2015 cropping season*

Treatment	No of tubers		Rot incidence (%)		Yield (t ha^{-1})	
	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
Time of harvesting (T)						
12 months	6.03	6.37	0.47	1.77	26.0	26.1
14 months	5.99	6.48	0.27	1.94	37.2	31.3
16 months	5.46	6.99	0.47	5.50	33.2	14.6
LSD	0.29	0.35	0.11	0.54	2.30	0.29
Cassava varieties (V)						
01/1412	4.56	5.53	0.32	2.89	31.4	23.3
98/0505	7.11	7.99	0.62	4.34	36.3	19.6
01/1368	6.95	6.48	0.37	2.48	33.1	26.4
01/1371	4.69	6.46	0.30	2.57	27.6	24.2
LSD	0.33	0.41	0.12	0.62	NS	0.34
T x V	NS	NS	0.21	NS	4.59	NS
Nitrogen (N) (kg/ha)						
0	5.83	6.24	0.49	2.72	31.20	18.90
30	5.86	6.41	0.41	2.75	32.10	21.60
60	5.79	6.78	0.36	2.92	32.50	26.40
90	5.75	6.88	0.40	3.38	31.50	24.90
120	5.91	6.76	0.35	3.59	33.40	23.00
LSD	NS	0.46	NS	0.69	NS	0.38
N × V	NS	NS	NS	NS	NS	NS
T × N	NS	NS	NS	NS	NS	NS
Potassium (K) (kg/ha)						
0	5.77	6.52	0.38	3.15	31.20	21.90
15	5.63	6.69	0.42	3.02	32.20	23.70
30	5.98	6.52	0.40	2.87	32.10	24.50
45	5.98	6.72	0.41	3.25	33.10	23.00
LSD	NS	NS	NS	NS	NS	NS
V × K	NS	NS	NS	NS	5.30	NS
N × K	NS	NS	NS	NS	NS	NS
V × K × N	NS	NS	NS	NS	NS	NS
V × K × T	NS	NS	NS	NS	NS	NS
N × K × T	NS	NS	NS	NS	NS	NS
T × V × N	NS	NS	NS	NS	NS	NS

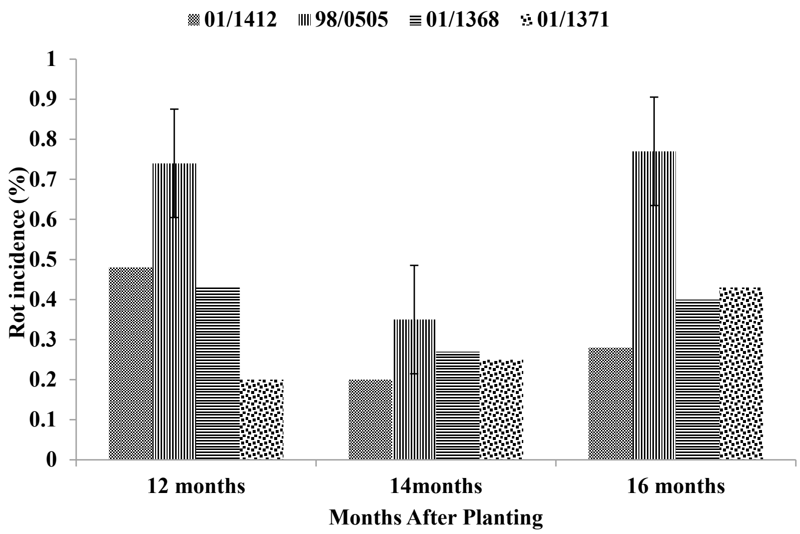
NS = not significant; LSD = least significant difference 5% level of probability

both cropping seasons corroborates the findings of Ebah-Djedji *et al.* (2012) who reported decline in cassava tuber at 17 months old. The sharper decline recorded on the harvest made at 16 MAP could be linked to root rot incidence as stated earlier. Hammer *et al.* (1987) did document similar results but was not specific on the number of months.

There was significant difference among cassava varieties in tuber yield in 2014/2015 cropping season. The highest tuber yield was obtained from TMS 01/1368 variety while the white-fleshed tuber variety (TMS 98/0505) had the lowest yield. The highest infection of root rot diseases observed on white-fleshed cassava accounted for the serious



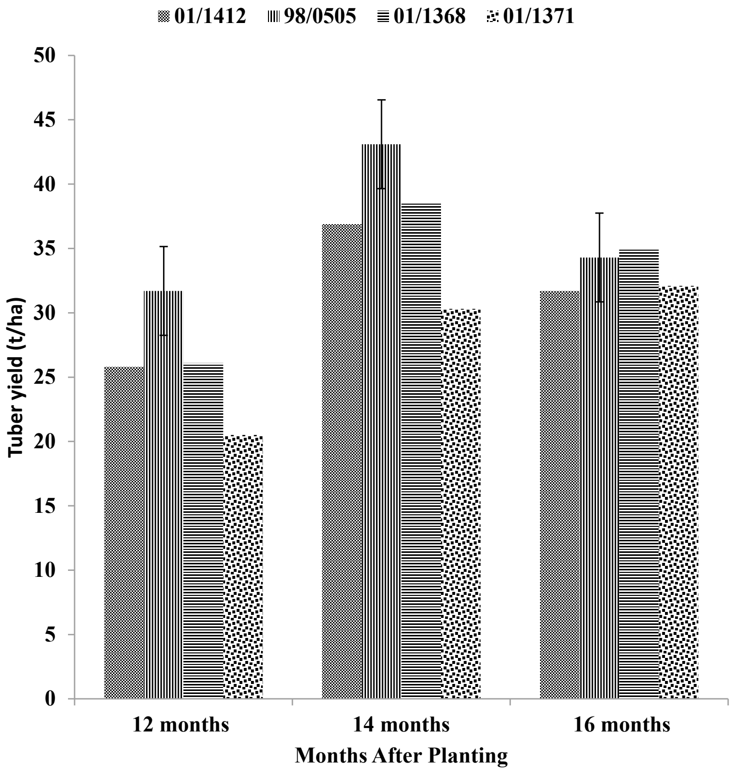
1: *Regression of nitrogen on tuber yield in 2014/2015 cropping season*



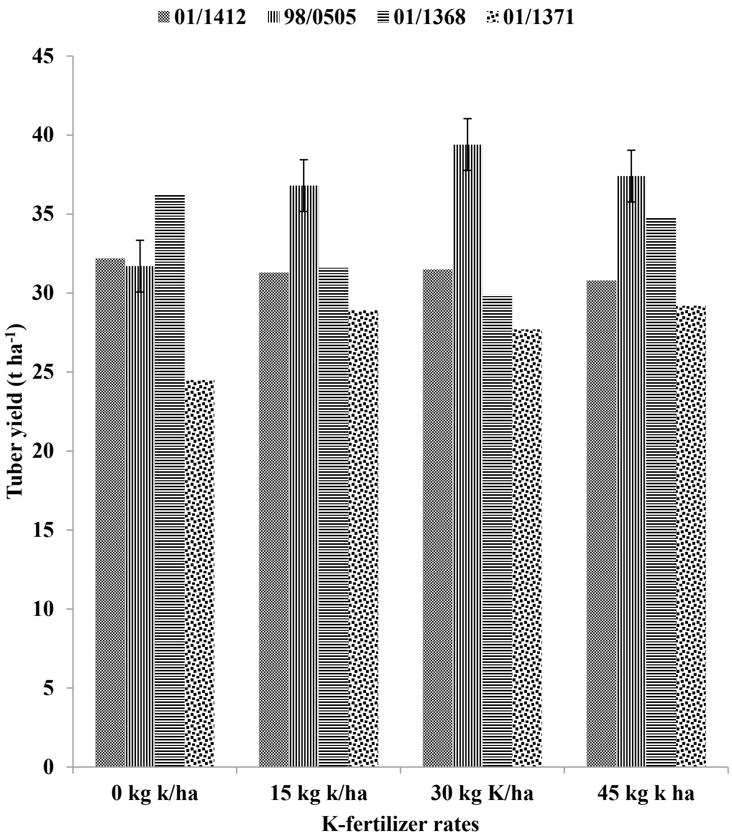
2: *Interaction of time of harvesting × variety on rot incidence in 2013/2014 cropping season*

reduction in the tuber yield of white-fleshed cassava variety relative to the yellow-fleshed counter parts. Agbaje and Akinlosotu (2004) who planted white-fleshed cultivars reported that yield was depressed due to high rot incidence.

The general decrease in tuber yield in 2014/2015 cropping season was due to high rate of rot incidence. This is a clear indication that innate antioxidant in yellow-fleshed cassava varieties suppressed the root rot disease. It is therefore pertinent to note that yellow-fleshed cassava were superior in the endemic face of the root rot diseases. This qualified them as candidate varieties to be recommended to farmers in root rot endemic areas. The actual tuber



3: *Interaction of time of harvesting × variety on tuber yield in 2013/2014 cropping season*



4: *Interaction of variety × potassium on tuber yield in 2013/2014 cropping season* yields obtained from three yellow-fleshed varieties TMS 01/1412 (31.4 t ha^{-1}), TMS 01/1368 (33.1 t ha^{-1}); and TMS 01/1371 (27.6 t ha^{-1}) in 2013/2014 cropping season were substantially lower than the potential yield of 53.1, 46.5, 39.3 t ha^{-1})], respectively as documented by NACGRAB (2014). The yield potential reported was much lower than those documented by De Oliveira *et al.* (2017) who reported 62 t ha^{-1} of fresh tuber in Brazil.

Nitrogen fertilizer significantly influenced cassava yield in 2014/2015 cropping season (Tab. III). Increase in the rate of nitrogen causes corresponding increase in fresh tuber yield up to 60 kg N ha^{-1} and thereafter declined. This agrees with the works of Oyekanmi (2008); Obigbor (2010) and De Oliveira *et al.* (2017). Similarly, Asare *et al.* (2009) reported that the use of 60 kg ha^{-1} N increased root yield to 39.2 t ha^{-1} relative to zero N-fertilizer in the savannah vegetation of Ghana. Fig. 1 attests to the relationship between N and tuber yield. It was a curvilinear relationship and the co-efficient of determination (r^2) was 0.90. This implies that nitrogen fertilizer application accounted for 90% of tuber yield in 2014/2015 cropping season. The application of 60 kg N ha^{-1} had similar effects on root rot diseases of cassava varieties with those of 0 and 120 kg N ha^{-1} levels but significantly produced the highest fresh tuber yield. Higher N–level did not only reduce fresh tuber yield but aggravated root rot disease.

The interactions of time of harvest x variety, time of harvest x variety and variety x potassium on root rot incidence, tuber yield and tuber yield in 2013/2014 cropping seasons, respectively were significant as indicated in Tab. III.

The Interaction of Time of Harvest X Cassava Variety on Root Rot Incidence in 2013/2014 Cropping Season

The observed significant interaction of time of harvest X cassava variety on incidence in 2013/2014 cropping season is an indication that the varieties responded differently to the root rot incidence at the different given time of harvesting (Fig. 2). The white-fleshed cassava (TMS 98/0505) variety consistently had the higher root rot infection than the three yellow-fleshed cassava varieties. Besides, the four varieties had minimal damages at 14 MAP.

The Interaction of Time of Harvest × Variety on Tuber Yield in 2013/2014 Cropping Season

The interaction of time of harvest × variety on tuber yield was significant in 2013/2014 cropping season signifying that there was a differential response of the varieties to time of harvestings. Generally, the harvest made at 14 MAP produced higher cassava fresh tuber yield than the others time of harvesting. But specifically, white-fleshed cassava variety, TMS 01/1412 and TMS 01/1368 harvested at 14 MAP produced the higher fresh tuber than TMS 01/1371 during the low infection observed in 2013/2014 cropping season (Fig. 3).

Interaction of Variety X Potassium on Tuber Yield in 2013/2014 Cropping Season

The rates of potassium was not significant but the interaction of variety X potassium on tuber yield was significant suggesting that cassava varieties responded differently to the levels of potassium. TMS 01/1368 variety gave the highest tuber yield on zero plot while the white-fleshed cultivar produced higher fresh tuber yield on the plots treated with 15 kg K ha^{-1} relative to plot without K fertilizer (Fig. 4). It was reported that adequate supply of nitrogen and phosphorous seems to be more important in producing good tuber yield than a large supply of potassium (IITA, 1990). However, this study has brought to fore the response of cassava to potassium was variety dependent. Therefore blanket recommendation of potassium for optimum tuber yield is uncalled for; rather it should be based on variety to be planted and perhaps the site.

CONCLUSION

The study shows that inherent antioxidant in yellow-fleshed cassava was able to suppress root rot diseases. The application of N-Fertilizer at higher rates of 90 and 120 kg N ha^{-1} aggravated root rot disease. Besides, time of harvesting of TMS 98/0505 varieties cannot be delayed beyond 14 MAP, but the yellow-fleshed cassava varieties can be further delayed to 16 MAP in root rot endemic areas.

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