A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 1-5

Survey of the current distribution and status of bacterial blight and fungal diseases of cassava in Guinea

B.A. Bamkefa[1], E.S. Bah[2] and A.G.O. Dixon[3]

[1]International Institute of Tropical Agriculture, PMB 5320, Ibadan, Nigeria.
[2]Institut de Recherche Agronomique de Guinée, Guinea.
[3]Sierra Leone Agricultural Research Institute, Freetown

Corresponding Author: B.A. Bamkefa
Email: b.bamkefa@gmail.com

Manuscript received: 02/08/2010; accepted:15/11/2010

Abstract

A survey was carried out of 86 cassava fields in the lowland savanna; humid forest, mid-altitude savanna, and lowland humid savanna agroecological zones of Guinea. Each field was assessed for the incidence and severity of cassava bacterial blight (CBB), cassava anthracnose disease (CAD), *Cercospora* leaf blight (CLB), and brown leaf spot (BLS). Samples of diseased leaves were collected and used to identify associated pathogens. CBB was present in all the four major ecozones. The disease was observed in 88.88% of the fields visited in the humid forest. For other ecozones, results were 70.5% (mid-altitude savanna zone), 73.07% (lowland humid savanna), and 77.7% (low-land savanna). Anthracnose disease was observed in the humid forest and lowland humid savanna zones, but not in either of the others. CAD was observed in 11.11% of the fields visited in the humid forest, and in 19.23% in the lowland humid savanna. The disease was not observed in either of the others. CLB and BLS were observed in all the zones; however, the severity of both diseases was generally low and they did not seem to pose a serious threat to cassava tuberous root yield.

Key words: cassava, bacterial blight, *anthracnose, cercospora*

Introduction

Cassava production is estimated by the Food and Agriculture Organization (FAO) at an annual global production of 202, 648, 218 t, Africa produces 108,109, 713 t. Out of these, Guinea produces 1, 350, 000 t (FAO Update to FAO, 2009). It is an essential part of the diet of more than half a billion people around the globe (FAO Update to FAO, 2009). The activities of various disease agents are some of the major constraints to achieving the full potential of cassava production in Africa. In cassava, losses in tuber yield from diseases can be as high as 90% (Wydra and Msikita, 1998). The need to protect cassava against diseases is, therefore, a crucial aspect in enhancing the production of the crop.

Materials and Methods

Farmers' fields were surveyed across the four agroecological zones of Guinea between 8 and 30 of August 2005. The survey followed the method described by Ogbe et al (2003). The number of cassava farms examined in each ecozone varied, depending on availability. A total of 86 farmers' fields were surveyed: lowland humid savanna (maritime Guinea) (26); humid forest (27); mid-altitude savanna (mid-Guinea) (17); lowland savanna (high Guinea) (18). In each farm, the assessment of disease severity was made on 30 randomly selected plants. Each plant was rated on a scale of 1–5 for cassava bacterial blight (CBB), cassava anthracnose disease (CAD), and *Cercospora* leaf blight (CLB); and on a scale of 1–4 for brown leaf spot (BLS) following the scoring system described by Wydra and Msikita (1998).

Leaf samples with CBB, BLS, CLB and CAD symptoms were collected for the isolation of pathogens. Isolation and identification was made at the Crop Protection laboratory of Foulaya – Kindia. The geographic position of the each farm was recorded using the Global positioning system (GPS).

Results

Geographical distribution of cassava bacterial and fungal diseases

CBB: CBB was present in all the four major ecozones. The disease was observed in 88.88% of the

fields visited in the humid forest. For other ecozones, results were 70.5% (mid altitude savanna zone), 73.07% (low-land humid savanna), and 77.7% (low-land savanna). When the results are considered across different ecological zones, higher severity scores of 3.05 were obtained for cassava farms in the low-land humid savanna; while farms in the other ecozones generally had severity scores from 2.76 to 2.94 (Fig. 6).

Locations in the mid-altitude and humid forest generally had low disease severity scores, while those in the humid lowland and lowland savanna had high scores. The highest mean severity score was recorded in Faranah (Marella) (3.76). Other areas with high severity scores were Kindia (Yombokoure) (3.07), Mamou (Sara) (3.58), Boffa (kafilya) (3.46), Forecariah town (3.46) and Gueckedou (Sabala) (3.46).

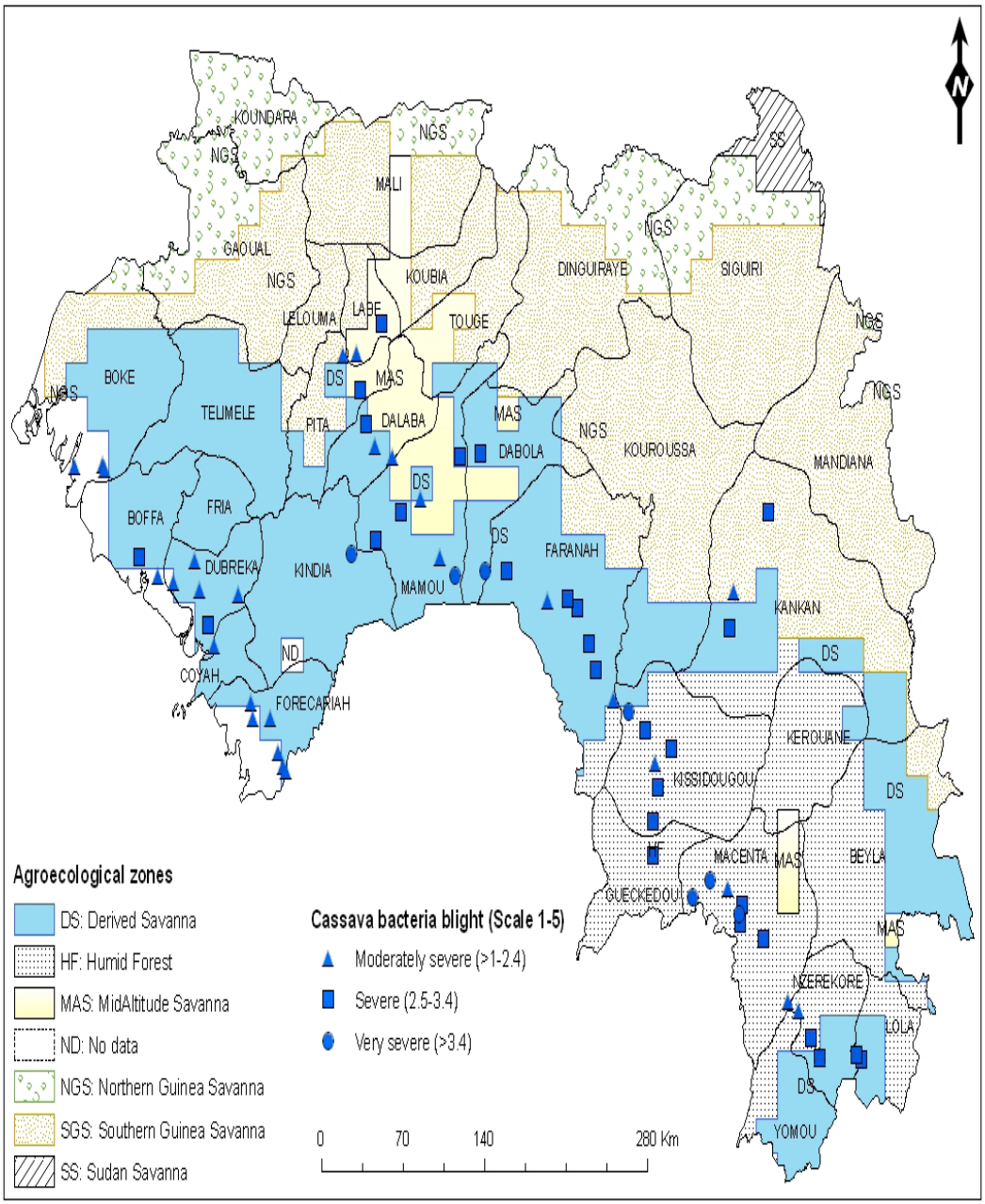

Figure 1: Map of Guinea showing the distribution of CBB across the various agro ecological zones.

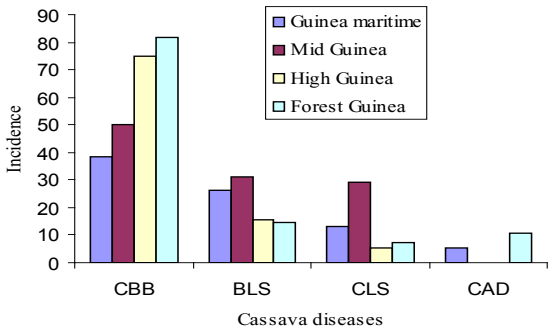

Fig 2. Incidence of cassava bacterial blight (CBB), cassava brown leaf spot (BLS), cerosporal leaf spot (CLS) and cassava anthracnose disease (CAD) in four agroecologies in Guinea.

CAD: Anthracnose disease was observed in the humid forest and derived savanna zones fig 3 , but not in any of the other ecozones (Fig. 3). CAD was observed in 11.11% of the fields visited in the humid forest, and in 19.23% in the lowland humid savanna. The disease was not observed in any of the other areas (Fig. 6). Higher mean severity scores were obtained in Lola (Lola camp) (3.0), Macenta (zebela) (3.0), (seredou) (2.6), and Dubreka (tanene) (2.66).

BLS and CLB: These two fungal foliar diseases were observed in all the ecozones. Their distribution trend varied across the ecozones (Fig. 5). CLB was observed in 7.4% of the fields visited in the humid forest, and in 29.4% in the mid-altitude savanna, in 42.3% in the low-land humid savanna, in the low-land savanna, only one field showed the disease.

Disease symptoms of BLS were recorded in 14.81% of the fields visited in the humid forest, 16.66% in the low-land savanna, 41.17% in the mid-altitude savanna zone, 65.38% in the low-land humid savanna. (Fig 6).

Mean severity scores of both diseases across the regions ranged from 1.0 – 3.8 for BLS and from 1.0 to 2.7 for CLS in the lowland humid savanna, and from 1.0 to 4 for both diseases in the mid-savanna regions, scores from 1.0 to 3.5 for BLS and from 1.0 to 2.1 for CLS were obtained for the regions in low-land savanna, in the humid forest areas, BLS varied from 1.0 to 4, while CLS scores varied from 1.0 to 3. The highest severity scores (4) for BLS was obtained in Mamou (Hafia) and Kissidougou (Boribana). The highest severity score of 4 for CLS were obtained at Mamou (foye) and Dalaba (sebhory) areas. (Fig 4)

Discussion

CBB: There is a high regional variation in CBB incidence between the savanna agroecological zones and the humid forest zone. We found the highest incidence of 88.8% in the forest regions and the lowest in the mid-altitude savanna. These results did not agree with the report of Wydra and Msikita (1998) who observed a higher incidence, up to 60%, in the savanna zone and a lower incidence of 24% for the rain forest. The very high rainfall during the survey

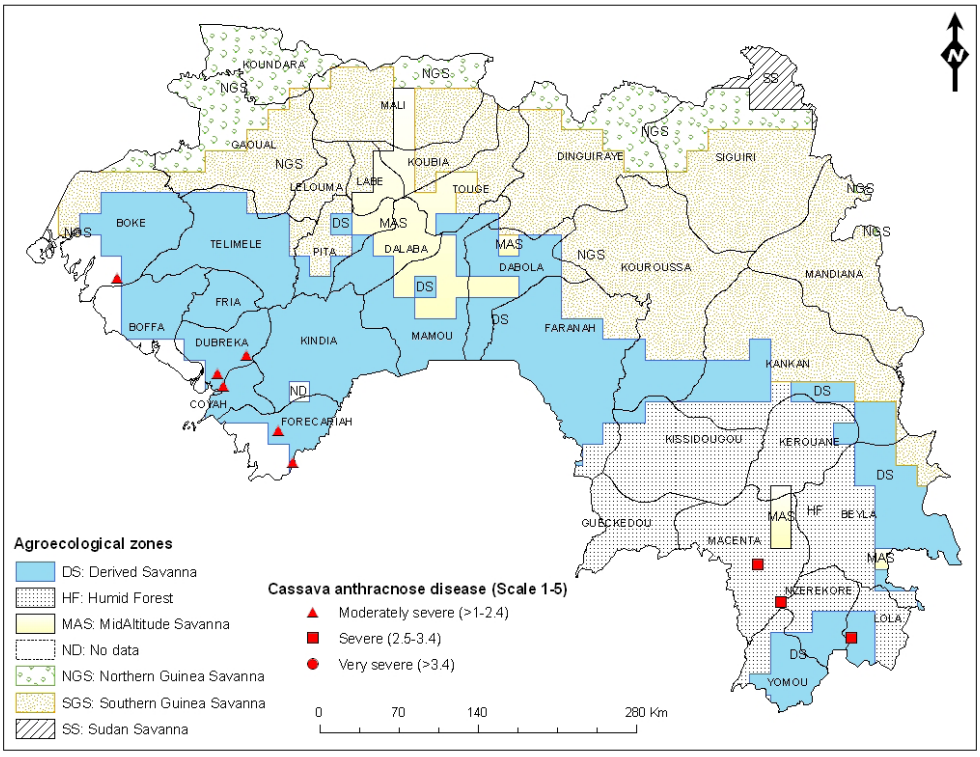

Figure 3: Guinea, showing the distribution of CAD across the various agroecological zones.

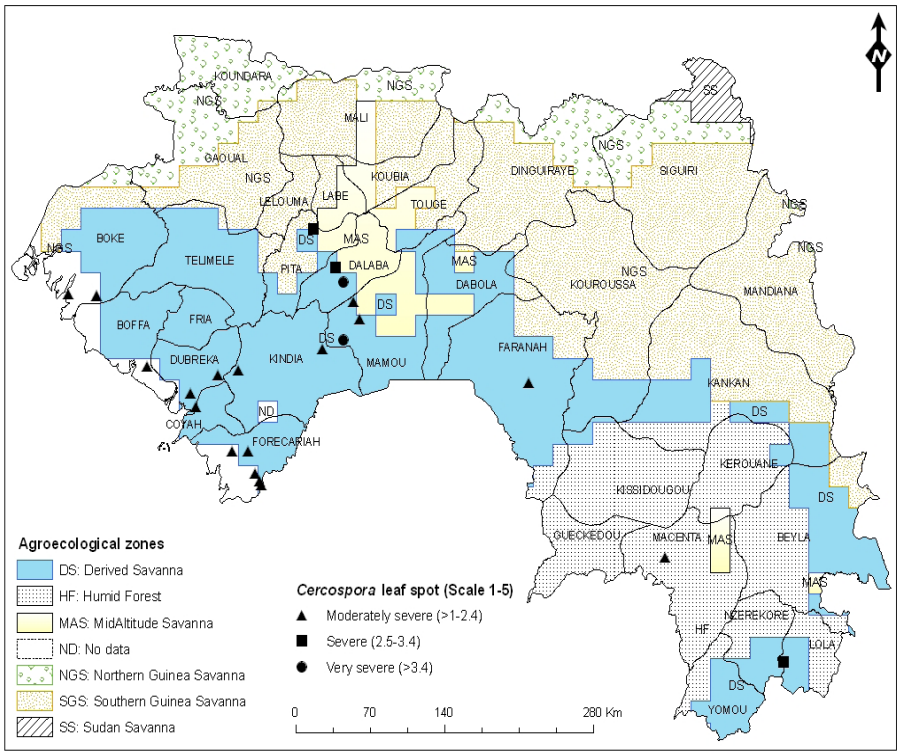

Figure 4: Map of Guinea, showing the distribution of CLS across the various agro ecological zones.

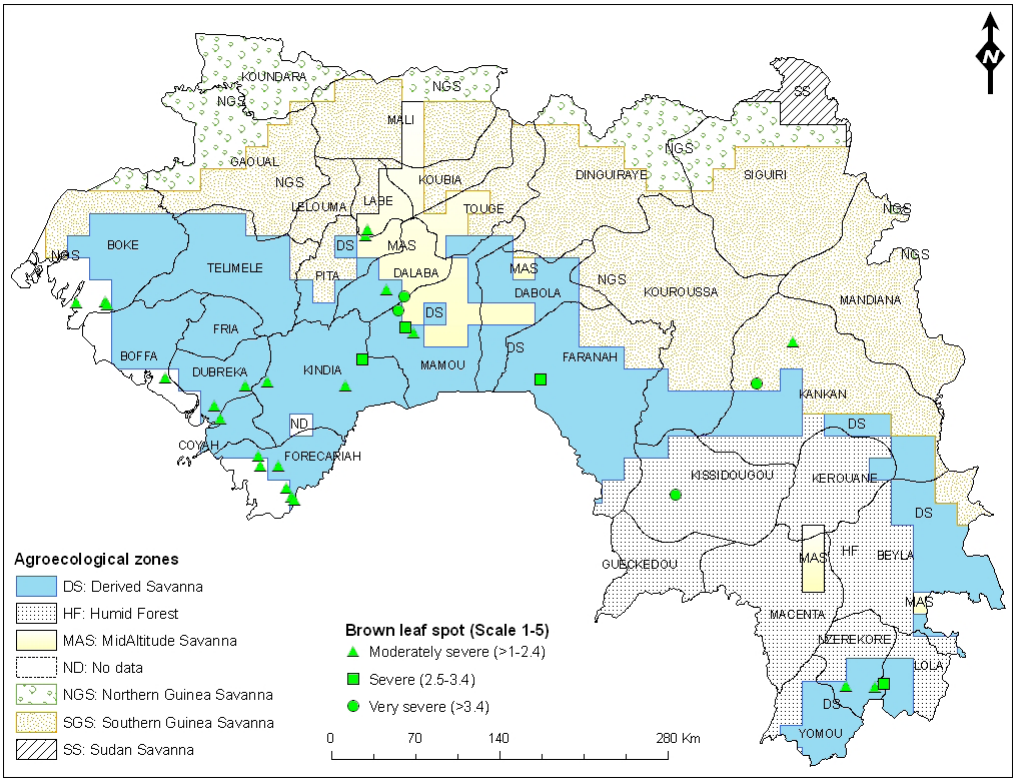

Figure 5: Map of Guinea, showing the distribution of BLS across the various agro ecological zones.

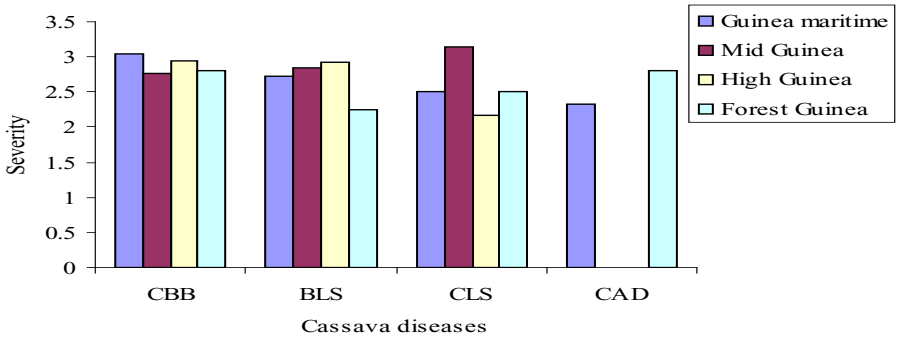

Fig 6. Severity of CBB, CAD, BLS and CLS in four agroecolgies in Guinea.

may be the explanation, as reported by (Hahn et al 1989) who reported that the severity and incidence are highly correlated to the amount of rainfall.

Anthracnose: The prevalence of CAD recorded in the humid forest and lowland humid savanna regions in any of the fields in the mid-altitude and lowland savanna zones was in line with the observations and findings in surveys conducted across West Africa showing that site and plant incidence of CAD were high across countries in the rain forest and considerable in the transition forest zones, less in the savanna zones, and unimportant in the mountain zone (Wydra and Msikita 1998).

CLB and BLS: These diseases were present in all the ecozones; however, their severity decreased rapidly towards the savanna zones. This result is in line with the observation of where high incidence of BLS was found on cassava plants infested with mealybugs, corresponding in Guinea to the case of mid-altitude savanna and lowland humid savanna.

Conclusion

This survey established the regional importance of CBB in the various ecozones of Guinea. CAD, BLS, and CLB seem to be less important compared with the severe infection of cassava mosaic begomovirus observed in cassava fields in all agroecologies. While the lowland humid savanna has the lowest CBB pressure, it is ideal for the establishment of a multiplication program ensuring CBB-free planting material.

The breeding program for cassava must, therefore, continue to emphasize multiple disease resistance in selection. A multiplication program is also needed for the supply of clean, improved planting materials to the farmers, as this remains the only viable option for the management of the diseases.

References

FAO Update to 2009. Championing the cause of cassava. Food and Agriculture Organization (FAO) News and Highlights, April 2000. www.fao.org/news/2000

FAO, 2004. FAOSTAT. www.fao.org

Hahn S.K., Isoba J.C.G. and Ikotun T. 1989. Resistance breeding in root and tuber crops at the International Institute of Tropical Agriculture, Ibadan, Nigeria. Crop Protection 8: 147−168.

Ogbe F.O., Thottappilly G., Dixon A.G.O., Atiri G.I. and Mignouna H.D. 2003. Variants of East African cassava mosaic virus and its distribution in double infections with African cassava mosaic virus in Nigeria. Plant Disease 83(3):229–232.

Wydra K. and Msikita W. 1998. An overview of the present situation of cassava diseases in West Africa. *In*: Root crops and poverty alleviation. Proceedings of the sixth Triennial Symposium of the International Society for Tropical Root Crops–Africa Branch, Lilongwe, Malawi, 22-28 October 1995, edited by M.O. Akoroda and I.J. Ekanayake. Polygraphics Venture Limited, Ibadan, Nigeria.

A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 6-10

Functional and pasting properties of cassava – sweetpotato starch blends

A.A. Adebowale, L.O. Sanni and E.L. Fadahunsi

Department of Food Science and Technology, University of Agriculture, PMB 2240, Abeokuta, Nigeria

Corresponding Author: A.A. Adebowale
Email: deboraz2002@yahoo.com

Manuscript received:19/10/2010; accepted: 31/01/2011

Abstract

Starch is an important constituent in many foods and plays an obvious role in achieving the desired viscosity in products such as sauces, pie fillings, salad dressings, puddings, etc. Blending different starches has been reported to result in desirable functional properties which help to overcome some end-use limitations of native starches. Therefore, the purpose of this study was to determine the functional and pasting properties of cassava–sweetpotato starch blends with the aim of improving the utilization of these starches in food and non-food applications. Starches were isolated from cassava roots and sweetpotato tubers using standard procedures. The starches were dried, milled, and blended in different proportions. The functional and pasting characteristics of the starch blends were determined using standard analytical procedures and instruments. The functional properties of the starch blends were significantly different (P<0.05) from 100% cassava and sweetpotato starches except in bulk density and pH. Bulk density ranged from 0.64 to 0.67 g/ml, Water absorption index ranged from 69.07 to 87.00% and dispersibility from 64.80 to 87.60%. The least gelation concentration ranged between 2.00 and 3.73%. The pH of the starch blends was between 6.70 and 6.80. The swelling power of the starch blends increased with increasing temperature and was considerably higher than that of 100% sweetpotato starch but lower than that of 100% cassava starch. Total titratable acidity of the starch blends was lower than that of 100% cassava and sweetpotato starches. The pasting profile of the starch blends was significantly different from that of the 100% cassava and sweetpotato starches. Peak viscosity (310.05−379.29 RVU), trough (162.67−203.42 RVU), breakdown viscosity (169.13−177.46, RVU), and final viscosity (200.50−274.50 RVU) were lower than those of 100% cassava and sweetpotato starches. Set back viscosity ranged between 66.30 and 82.00 RVU. Time to attain peak viscosity ranged from 4.47 to 4.97 min, while the starches, pasting temperature ranged from 73.65 to 91.60 °C. Blending sweetpotato starch with cassava starch significantly improves some functional properties of sweetpotato starch. The blend containing 75% cassava starch and 25% sweetpotato starch showed higher pasting stability than 100% cassava and sweetpotato starches, due to its low setback viscosity.

Key words*:* cassava, sweetpotato, starch, pasting, functional

Introduction

Starch is not only one of the most abundant biopolymeric assemblies in nature but also a major food component on a world-wide scale and one of the main food ingredients, both in native or modified forms. The range of food products containing starch in one form or another is almost limitless. But the utility of starches is based almost entirely upon their natural or synthesized functional characteristics. The particular physical and chemical characteristics of individual starches are the keys to their commercial success. Starch plays an obvious role in achieving the desired viscosity in products such as sauces, pie fillings, corn starch pudding, etc. In food systems, starch is used to influence or control characteristics such as aesthetics, moisture, consistency, and shelf stability. It can be used to bind, expand density, clarify or opacify, attract or inhibit moisture as well as to stabilize emulsions and act as texturizing agent.

Starches are extracted from several different starchy raw materials, such as barley, maize, rice, sweetpotato, and cassava. Sweetpotato and cassava are two major starchy root and tuber crops used in many tropical countries (Osundahunsi et al 2003). Sweetpotato starch has been used as an ingredient in bread, biscuits, cakes, juice, ice cream, and noodles

or converted to glucose and isomerized glucose syrup (Zhang et al 1999). Cassava starch is used to produce variety of value-added products such as sweeteners, alcohol, acids, and other chemicals (Klanarongs et al 2001). Cassava starch is used in industries due to its high yield, very low cost, and unique characteristics such as a clear viscous paste (Klanarongs et al 2001).

Starches from different plant sources exhibit different varieties of characteristic functional properties such as specific viscosity, flow properties, swelling and resistance to swelling, and gel texture, etc. The functional properties of starch are dependent on the variety, environment, and the extraction process and can also be altered by subsequent enzymatic or chemical modification (Stephen 2008). Cassava starch has a low gelatinization temperature (65-70 °C), a rapid increase in viscosity after gelatinization, and forms a clear, soft gel with better cold stability, but a very cohesive texture. It is ranked very high among starchy staples because it gives a carbohydrate production which is about 40% higher than rice and 25% more than maize (Nyerhorvwo 2004). Sweetpotato starch has been found to be easier to cook, to have a lower potential for retrogradation, but to be less stable during heating than starches from cassava.

One way to overcome some functional limitations of native starches is by blending different starches. Obanni and Bemiller (1997) reported that a blend of native starches may be formulated to achieve some of the desired characteristics of modified starches. The amount of scientific information available on the functional and pasting properties of cassava and sweetpotato starches cannot be compared with that from the major cereal starches such as wheat and corn starches. A significant amount of research needs to be conducted on the functional characteristics of native as well as modified starches from tropical roots and tubers for them to become competitive with corn and wheat starches, locally and internationally. Therefore, this study was conducted to determining the functional and pasting properties of cassava–sweetpotato starch blends with a view to providing information that will improve the utilization of these starches in food and non-food applications.

Materials and Methods

Cassava and sweetpotato starches were extracted according to the methods described by Oyewole and Obieze (1995) and Lilia and Collando (1999). Five different starch blends were obtained as shown below:

Cassava starch	75%	25%	50%	-	100%
Sweetpotato starch	25%	75%	50%	100%	-

Determination of functional properties. Bulk density was determined by the method of Wang and Kinsella (1976), least gelation concentration by method of Coffman and Garcia (1977), and dispersibility by the method of Kulkarni et al (1991). Swelling power at different temperatures was determined as described by Takashi and Sieb (1988), and water absorption index as described by the modified method of Anderson (1982). Total titratable acidity was determined by Pearson's (1985) method while pH was measured using a digital pH meter (AOAC, 1990).

Determination of pasting properties. Pasting properties were determined using a Rapid Visco Analyser (RVA) (model RVA 3D+; Network Scientific, Australia). The sample was turned into slurry by mixing 3 g of starch powder with 25 ml of water inside the RVA can. This was inserted into the tower, which was then lowered into the system. The slurry was heated from 50 to 95 °C and cools back to 50 °C within 12 min, The contents were rotated at a speed of 160 rpm with continuous stirring with a plastic paddle. Parameters estimated were peak viscosity, trough, setback viscosity, final viscosity, pasting temperature, and time to reach peak viscosity.

Statistical analysis. All data obtained were subjected to One-Way Statistical Analysis of Variance (ANOVA) using SPSS (version 17, 2010). Means were separated using Duncan's Multiple Range Test (DMRT).

Results and discussion

Functional properties of cassava–sweetpotato starch blends. The results from the functional properties of the starch blends are presented (Table 1). The functional properties of the starch blends were significantly different (P<0.05) from 100% cassava and sweetpotato starches except in bulk density and pH. Bulk density ranged from 0.64 to 0.67 g/ml. The bulk density is an important parameter that determines the ease of packaging and transportation of powdery or particulate foods. Bulk density is an important functional property in many food applications. For instance, it has been found to affect the sensory acceptability of starch noodles, handling and packaging requirements, as well as transport costs (Nwabueze et al 2009). Water absorption index ranged from 69.07 to 87.00% and dispersibility from

64.80 to 87.60%. The least gelation concentration (LGC) ranged between 2.00 and 3.87%. Dispersibility is a measure of the degree of reconstitution of flour or flour blends in water, the higher the dispersibility the better the flour reconstitutes in water (Adebowale et al 2005). The higher dispersibility value exhibited by all the starches is indicative of their ability to produce smooth or consistent paste. LGC is a measure of the minimum amount of starch or blends of starch powder that is needed to form a gel. The LGC of the starch blends was higher than that of 100% cassava and sweetpotato starches a smaller hence, less amount of the starch blend would be required to form paste during processing (Adebowale et al 2005) compared were 100% cassava and sweetpotato starches. The pH of the starch blends was between 6.70 and 6.80. Total titratable acidity (TTA) of the starch blends was lower than that of 100% cassava and sweetpotato starches; while the pH of the starch blends was similar to that of 100% cassava and sweetpotato starches. The TTA when related with the pH values shows that the starch has the low acid content characteristic of root and tuber starches (Onitilo et al 2007).

The swelling power of the starch samples at different temperature is presented (Fig 1). The swelling power of the starch blends increased with increasing temperature and was considerably higher than that of 100% sweetpotato starch but lower than that of 100% cassava starch. All the starches showed a gradual increase in swelling power with the increase in temperature and this suggested that these starches had weaker internal associative forces maintaining the granule structure.

Pasting properties of cassava–sweetpotato starches. The pasting properties of cassava– sweetpotato starch blends are presented (Table 2). The pasting profile of the starch blends was significantly different from that of the 100% cassava and sweetpotato starches. Peak viscosity (310.05–379.29 RVU), trough (162.67–203.42 RVU), breakdown viscosity (169.13–177.46, RVU) and final viscosity (200.50–274.50 RVU) were lower than those 100% cassava and sweetpotato starches. Peak viscosity is the maximum viscosity attained during or soon after the heating portion of the amylograph pasting test. Peak viscosity indicates the water binding capacity of the starch or mixture. It is often correlated with final product quality (Maziya-Dixon et al 2007). The peak viscosity occurs at the equilibrium point between swelling that causes an increase in viscosity and rupture and alignment that cause its decrease. Setback viscosity ranged between 66.30 and 82.00 RVU. Setback has been correlated with the texture of various products and high setback is also associated with syneresis or weeping during freeze/thaw cycles (Maziya-Dixon et al 2007). The higher the setback value, the lower the retrogradation during cooling and the lower the staling rate of the products made from the starch (Adeyemi and Idowu 1990). The setback viscosity of the blend of 75% cassava with 25% sweetpotato starch was considerably lower than 100% starches, indicative of the potential of the blend to form a much more stable starch paste than 100% cassava and sweetpotato starches. The time to attain peak viscosity ranged from 4.47 to 4.97 min; the starches, pasting temperatures ranged from 73.65 to 91.60 ^{o}C. The ability of starch to imbibe water and swell is primarily dependent on the pasting temperature. The higher the pasting temperature, the faster the tendency for a paste to be formed (Dreher and Berry 1983). The starch blends exhibited a higher pasting temperature than to 100% cassava and sweetpotato starches.

Table 1: Functional properties of cassava–sweetpotato starch blends

Sample	Bulk density (g/ml)ns	Water absorption index (%)	Dispersibility (%)	pHns	Least gelation concentration (%)	Total titratable acidity
100% cassava	0.65	86.80^{d}	85.40^{b}	6.80	2.00^{a}	2.07^{b}
75% cassava : 25% sweetpotato	0.67	69.07^{a}	84.80^{b}	6.78	2.00^{a}	2.07^{b}
25% cassava : 75% sweetpotato	0.65	77. 60^{c}	64.80^{a}	6.70	3.38^{b}	1.38^{a}
50% cassava : 50% sweetpotato	0.67	70.40^{b}	87.60^{b}	6.70	3.73^{b}	1.73^{ab}
100% sweetpotato	0.64	87.00^{d}	71.80^{a}	6.75	2.07^{a}	2.07^{b}

Values are means of three replicates.
Mean values having different superscript within column are significantly different (P<0.05)
ns not significantly different (P>0.05)

Table 2: Pasting properties of cassava – sweetpotato starch blends.

Sample	Peak (RVU)	Trough (RVU)	Break Down (RVU)^{ns}	Final Viscosity (RVU)	SetBack (RVU)	PeakTime (min)^{ns}	Pasting temperature (°C)
100% cassava	379.29^{d}	201.83^{d}	177.46	274.50^{c}	72.67^{ab}	4.47	81.68^{b}
75% cassava : 25% sweetpotato	310.05^{a}	134.21^{a}	175.84	200.50^{a}	66.30^{a}	4.77	73.65^{a}
25% cassava : 75% sweetpotato	360.21^{c}	187.84^{c}	172.38	269.84^{c}	82.00^{b}	4.90	88.88^{c}
50% cassava : 50% sweetpotato	331.79^{ab}	162.67^{b}	169.13	239.50^{b}	76.83^{ab}	4.97	91.60^{d}
100% sweetpotato	376.29^{d}	203.42^{d}	172.75	273.50^{c}	70.09^{ab}	4.57	82.55^{b}

Values are means of three replicates.
Mean values having different superscript within column are significantly different (P<0.05)
ns not significantly different (P>0.05)

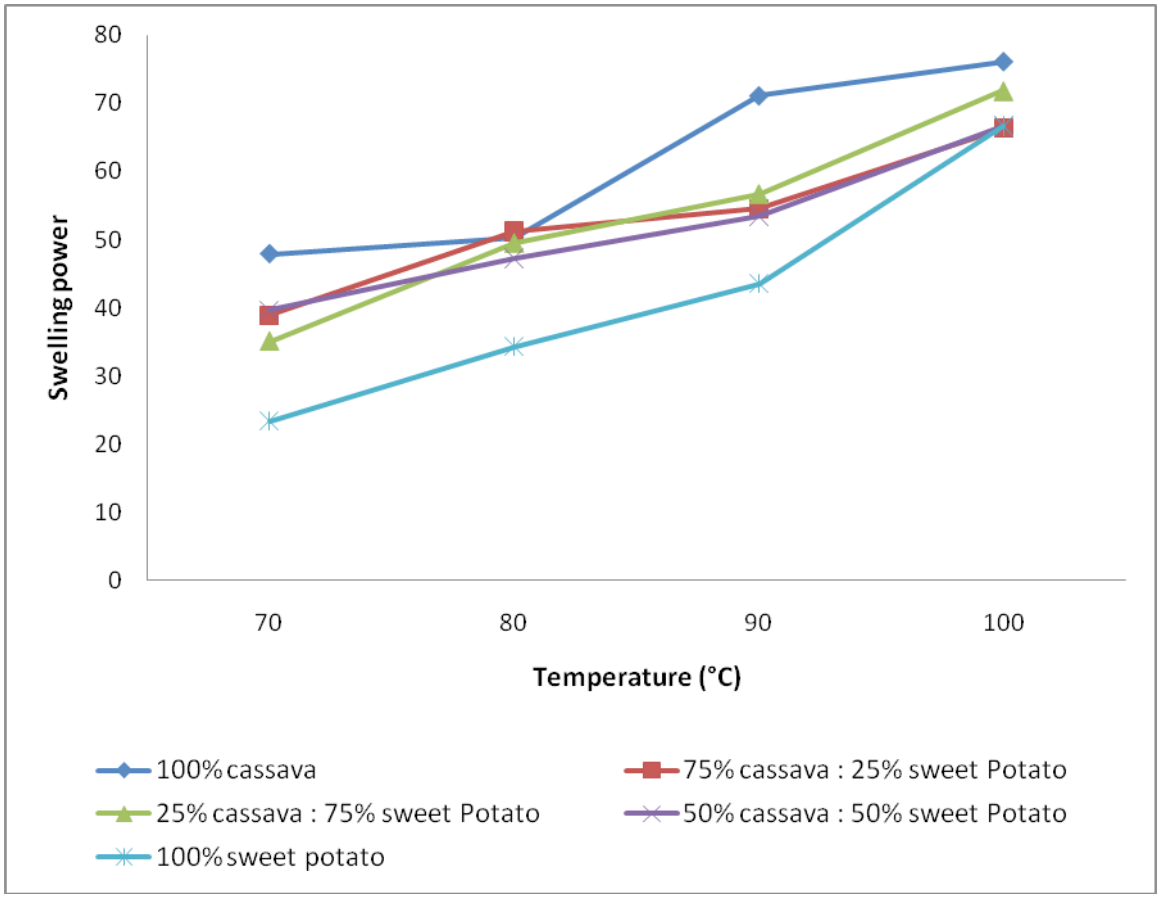

Figure 1: Swelling power of cassava-sweetpotato starch blends at different temperatures.

Conclusion

In conclusion, blending sweetpotato starch with cassava starch significantly improves some functional properties of sweetpotato starch. The blend containing 75% cassava starch and 25% sweetpotato starch showed a higher pasting stability than 100% cassava and sweetpotato starches.

References

Adebowale A.A., Sanni L.O. and Awonorin S.O. 2005. Effect of Texture Modifiers on the Physicochemical and Sensory Properties of Dried Fufu. Food Science and Technology International, 11(5):373–382.

Adeyemi I.A. and Idowu M.A. (1990). Sensory evaluation and nutrient composition of weaning food from pregelatinized maize-sweetpotato mixtures. Plant Foods for Human Nutrition, 44:149–155.

Anderson R.A. 1982. Water absorption and solubility and amylograph characteristics of roll – cooked small grain products. Cereal Chemistry 59: 265–270.

Coffman C.W. and Garcia V.V. 1977. Functional properties and amino acid content of a protein isolated from mung bean flour. Food Technology, 12: 473–484.

Dreher M.L. and Berry J.W. 1983. Buffalo gourd root starch. Part I. Properties and structure. Starch/ Starke 35:76–81

Kulkarni K.D., Kulkarni D.N. and Ingle U.M. 1991. Sorghum malt-based weaning formulations: preparation, functional properties, and nutritive value. Food and Nutrition Bulletin 13(4): 322–327.

Lilia S. and Collando R.C.J. (1999). Genetic variation in the physical properties of sweetpotato starch. Journal of Agriculture and Food Chemistry, 47: 4195–4201.

Maziya-Dixon B., Dixon A.G.O. and Adebowale A.A. 2007. Targeting different end uses of cassava: genotypic variations for cyanogenic potentials and pasting properties. International Journal of Food Science and Technology 42(8): 969–976.

Nyerhovwo J.T. 2004. Cassava and the future of starch. Electronic Journal of Biotechnology ISSN: 0717–3458

Nwabueze T.U., Glory A. and Anoruoh G.A. 2009. Evaluation of flour and extruded noodles from eight cassava mosaic disease (CMD)- resistant varieties. Food Bioprocess Technology, DOI 10.1007/s11947-009-02000-4.

Obanni M. and Bemiller J.N. 1997. Properties of some starch blends. Cereal chemistry 74: 431–436.

Onitilo M.O., Sanni L.O., Daniel I., Maziya-Dixon B. and Dixon A. 2007. Physicochemical and functional properties of native starches from cassava varieties in Southwest Nigeria. Journal of Food, Agriculture & Environment, 5 (3&4):108–114.

Oyewole O.B. and Obieze N. 1995. Processing and characteristics of "Tapioca" meal from cassava. Tropical Science 35: 19–22.

Takashi S. and Seib P.A. 1988. Paste and gel properties of prime corn and wheat starches with and without native lipids. Cereal chemistry 65: 474–480.

Wang J.C. and Kinsella J.E. 1976. Functional properties of novel proteins; alfalfa leaf protein. Journal of Food Science, 41:286–289.

A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 11-16

Chemical and functional qualities of high quality cassava flour from different SMEs in Nigeria

A.A. Adebowale[1], S.A. Sanni[2] and Y.S. Koleoso[1]

[1]Department of Food Science and Technology
[2]Department of Nutrition and Dietetics, University of Agriculture, PMB 2240, Abeokuta, Nigeria

Corresponding author: A.A. Adebowale
Email: deboraz2002@yahoo.com

Manuscript received:19/10/2010; accepted: 31/01/2011

Abstract

In 2002, the Federal Government of Nigeria came up with the Presidential Initiative on Cassava, aimed at making cassava a cash crop, and thereafter legislated a policy the inclusion of 10% high quality cassava flour (HQCF) in wheat flour for use in Nigeria. This stimulated increased production of HQCF by small−medium enterprises ISMES across Nigeria. The flour milling industries stopped the purchase of HQCF from processors from April 2007 alleging that of HQCF of the right quality specifications was not available, among other economic reasons. This study was therefore conducted to determine the chemical composition, functional and pasting properties of HQCF obtained from different SMEs in Nigeria. Five samples of HQCF were obtained and there chemical composition, pasting and functional properties were determined using standard analytical procedures. The contents of Starch (75.5–76.6%), sugar (8.28−8.57%), and ash (0.7–0.8%) were within the Standard Organization of Nigeria (SON) standards; pH (6.5−6.9) was within the neutral range characteristic of HQCF. HCN contents (3.17−6.53 mg HCN_{eqv} / 100 g) were within the values recommended by SON (<10 mg HCN_{eqv} / 100 g). The moisture content of the HQCF samples was slightly higher than the 10% maximum recommended by SON. The chemical compositions of the HQCF samples were not significantly different, except for the protein and HCN contents. Significant variation (P<0.05) was found in the functional properties of the HQCF samples. Winnosa sample had the highest bulk density (0.66 g/cm^3), Agrivest and Jaffe had the lowest (0.58 g/cm^3). The oil absorption index ranged from 61.50% (Jaffe) to 72.50% (Fulcrum). Emulsion capacity ranged between 24.23 (Peak) and 42.74% (Jaffe). Peak flour had the highest foaming capacity (3.73%); while Jaffe had the lowest (1.48%). Dispersibility ranged from 71.50 to 80.50% and water absorption capacity ranged from 73.00 to 78.50%.The flours showed the high peak viscosities and low setback viscosities characteristic of cassava flour. The peak viscosity ranged from 132.84 to 333.46 RVU, with Agrivest flour having the lowest value and fulcrum floor the highest. Breakdown viscosity ranged from 73.84 to 173.04 RVU, Final viscosity from 88.88 to 215.75 RVU, and setback viscosities from 32.46 to 57.38 RVU. Fulcrum flour had the highest breakdown and final viscosities. Agrivest flour had the lowest breakdown viscosity; Winnosa flour had the lowest final and setback viscosities. Time to attain peak viscosity was lowest for Winnosa flour (4.30 min) and highest for Peak flour (4.60 min). The highest (79.20 °C) pasting temperature was recorded by Winnosa and the lowest (76.00 °C) by Agrivest flour. The pasting profile of the HQCF flours was significantly different (P<0.05) except for the pasting temperature. The study concluded that the quality of the HQCF samples was within the limits set by SON.

Key words*:* high quality cassava flour, chemical composition, functional properties, pasting profile, quality and standards*.*

Introduction

Cassava (*Manihot esculenta* Crantz) is a root crop cultivated and consumed as a staple in many regions of the developing world. Cassava, once termed the neglected crop of the down-trodden, is fast becoming an elite food crop in sub-Saharan Africa (Phillips et al 2006). Cassava has played and will continue to play a major role in efforts to alleviate the African food crisis because of its efficient production of food energy, year-round availability, tolerance to extreme stress conditions, and suitability for peasant farming and the food system in Africa (Hahn and Keyser 1985; Hahn et al 1987, Maziya-Dixon et al 2007).

The potential of the crop is large because it offers the cheapest source of food calories and the highest yield / unit area. Nigeria is the highest cassava producer in the world, producing one-third more than Brazil and almost twice the production capacity of Thailand and Indonesia (Phillips et al 2006; FAOSTAT, 2008). The country currently produces over 44 million t / year (FAOSTAT 2008); a figure expected to double by 2020. Although the world leader in cassava production, Nigeria is not an active participant in the cassava trade in the international markets because most of her cassava is targeted at the domestic food market.

In 2002, the Federal Government of Nigeria came up with the Presidential Initiative on Cassava aimed at making cassava a cash crop, This led to the legislation of a policy of 10% inclusion of high quality cassava flour (HQCF) in wheat flour for utilization by the bakery, confectionery, noodle-making and other allied companies. This stimulated increased production of HQCF by small and medium-scale enterprises (SMEs) across Nigeria. The direct consequence of the policy was that Nigerian flour-milling industries required an annual 300,000 t of HQCF. To meet this demand, various stakeholders across the federation created awareness and encouraged the establishment of cassava SMEs, which embarked on the large-scale production of HQCF in their factories.

Specifications were established by the regulatory bodies and other stakeholders. Trainings and workshops were organized by governmental and non-governmental research institutions to train potential and existing owners SMEs and workers on the techniques for producing HQCF with the right quality standards and specifications for inclusion in wheat flour for bread and confectionary. The flour-milling industries stopped the purchase of HQCF from processors from April 2007, alleging that HQCF of the right quality specifications was not available among other economic reason. This study was therefore conducted to determine the chemical composition, and functional and pasting properties of HQCF from different SMEs in Nigeria.

Materials and methods

In the study, the HQCF analyzed was obtained from different locations in Nigeria.

1) Peak Product Enterprises, km 16–17 Abeokuta − Lagos expressway, Laala village, Abeokuta, Ogun State.
2) Winnosa Global Resources Ltd, 14 Market Road, Igbogila Abavo, Delta State.
3) Fulcrum Nigeria Ltd, km 12, Iju Ebiye road, Akinleye village, Ogun state.
4) Jaffe Nigeria Ltd, km 12 Abeokuta − Lagos express way, Abule bus/stop, Obada-Oko, Ogun State.
5) Agrivest Concept International Ltd, Agbadu cassava farm, Kabba – Lokoja Expressway, Kogi State.

Determination of chemical composition. The moisture, protein, ash, crude fiber and fat contents of the samples were determined using the AOAC (1990) method. The starch and total sugar contents were determined using a colorimetric method as described by Dubois et al (1956). The amylase content was determined using the method of Williams et al (1958); cyanogenic potential was determined using the method described by Bradbury et al (1999). Phytic acid and phytate contents were determined using the method of Harland and Oberleas (1986) and the pH was determined by mixing 5 g flour in a beaker containing 25 ml of distilled water. This was allowed to stand for 30 mins with constant stirring. The pH was measured with the aid of pH meter (AOAC 1990).

Determination of functional Properties. The bulk density was determined by the method of Wang and Kinsella (1996), water absorption capacity as described by Ruales et al (1993), dispersibility by Kulkarni et al (1991), emulsion stability by Hayta et al (2002), foaming capacity and oil absorption capacity according to Sathe and Salunkhe (1981).

Determination of pasting properties. Pasting properties were determined using a Rapid Visco Analyser (RVA) (model RVA 3D+; Network Scientific, 5Australia). The sample was turned into slurry by mixing 3 g with 25 ml of water inside the RVA can. The can was inserted into the tower, which was then lowered into the system. The slurry was heated from 50 to 95 °C and cooled back to 50 °C within 12 min, The can was rotated at a speed of 160 rpm. The contents were continuously stirred with a plastic paddle. Parameters estimated were peak viscosity, trough, setback viscosity, final viscosity, pasting temperature, and time to reach peak viscosity.

Statistical Analysis. All data obtained were subjected to Statistical Analysis of Variance (ANOVA) using SPSS (version 17, 2010). Means were separated using Duncan's Multiple Range Test (DMRT).

Results and Discussion

Chemical composition of HQCF in the Nigerian market. Table 1 shows the chemical composition of HQCF from different SMEs in Nigeria. The chemical compositions of the HQCF samples were not significantly different except for protein and HCN contents. The moisture content was slightly higher than 10% maximum recommended by Standard Organization of Nigeria (SON) (Sanni et al 2005). The lower the initial moisture content of a product to be stored, the better the storage stability of the product and the higher the efficiency of the drying method, because this shows that a considerable amount of moisture contained in the fresh sample or product has been removed. The high moisture content recorded in this study might be due to moisture absorption during storage in the factories' warehouse. The moisture content of HQCF fresh from the flash dryer (used by all the SMEs where the HQCF was sourced) usually ranged from 5 to 10% (unpublished flash dryer production efficiency audit report by Cassava: Adding Value for Africa (C:AVA Nigeria). Hence, there is the need for the SMEs producing HQCF in Nigeria to use packaging materials with very high moisture barrier properties. Also, the ambient air within their warehouses needs to be improved. This can be achieved by installing industrial air extractors to maintain the ambient relative humidity and temperature so as to minimize moisture absorption by the HQCF during storage. However, all the flour samples could still be stored for up to 7 months because their moisture contents were below the levels reported by Ukpabi and Ndimele (1990) who found that *gari* samples with a moisture content of < 16% but > 13% could be stored for 2−7 months without mold infestation. The contents of starch (75.5–76.6%), sugar (8.28−8.57%), ash (0.7–0.8%) were within the SON standards; while pH (6.5−6.9) were within the neutral range characteristic of HQCF. HQCF is simply unfermented cassava flour; hence, the almost neutral pH recorded by the samples analyzed is indicative of good GMP in the SMEs from where the flours were sourced because fermentation of cassava produces acids which tend to shift the pH of fresh cassava mash to an acidic medium. The phytic acid contents ranged from 7.45 to 8.15 mg/100 g and the phytate contents was 2.65−3.00 mg/100 g. The HCN contents of the flours (3.17−6.53 mg HCN_{eqv} / 100 g) were within the values recommended by SON (<10 mg HCN_{eqv} / 100 g) (Sanni et al 2005). The values were considerably lower than those found in *gari*, *eba*, and cooked cassava roots by Marfo et al (1990).

There is no consensus on the safe levels of cyanide for both human and animal consumption (Maziya-Dixon et al 2007) by scientists and international regulatory agencies. Mahungu et al (1987) noted that a great danger of chronic poisoning might occur if roots with more than 150 mg HCN/kg are consumed. According to Koch et al, (1992), when the peeled portion contains <50 mg HCN/kg of freshly grated cassava, the cassava can be taken as harmless to the consumer. A concentration of between 50 mg HCN/kg and 80 mg HCN/kg may be slightly poisonous; 80–100 mg HCN/kg is toxic, while concentrations above 100 mg HCN/kg of grated cassava are fatal (Koch et al 1992; Maziya-Dixon et al 2007). Presently in Nigeria, grating/crushing is being promoted in production of high quality cassava flour (HQCF) because it leads to the production of flour with negligible amounts of residual cyanide contents after drying. The joint FAO/WHO Food Standards Program Codex Committee on Contaminants in Foods (JECFA) 3rd Session held in the Netherlands in 2009 concluded that a level of up to 10 mg HCN/kg in the Standard for Edible Cassava Flour (CODEX STAN 176-1989) was not associated with acute toxicity (WHO 1993). A review of the available data by European Food Safety Authority (EFSA Journal) in 2004 arrived at a similar conclusion (JECFA 2009).

Functional properties of HQCF in Nigerian markets. The results of rests of the functional properties of HQCF from different SMEs in Nigeria are presented in (Table 2). Significant variation (P<0.05) was found in the functional properties of the Table 2 samples. Winnosa sample had the highest bulk density (0.66 g/cm^3); Agrivest and Jaffe had the lowest (0.58 g/cm^3). The bulk density is an important parameter that determines the ease of packaging and transportation of particulate foods. The bulk density of the flours is comparable to values reported by Shittu et al (2007) for HQCF from 43 cassava varieties resistant to mosaic disease (CMD). The oil absorption index ranged from 61.50% (Jaffe) to 72.50% (Fulcrum). Oil absorption is an indication of the amount of oil that can be absorbed by the physical matrix of a food. It indicates the degree of hydrophobicity (Voutsinus and Nakai. 1983) of flour. Emulsion capacity ranged between 24.23 (Peak) and 42.74% (Jaffe). Peak flour

had the highest foaming capacity (3.73%) while Jaffe had the lowest (1.48%). Dispersibility ranged from 71.50 to 80.50% and water absorption capacity from 73.00 to 78.50%. Dispersibility is a measure of the degree to which of flour or flour blends reconstitute in water; the higher the dispersibility, the better the flour reconstitutes in water (Adebowale et al 2005). The higher dispersibility values exhibited by all the Samples of HQCF analyzed are indicative of their ability to produce a smooth dough in composite with wheat flour.

Pasting properties of HQCF in Nigerian markets. The pasting profile of high quality cassava flour samples from different SMEs in Nigeria is shown in Table 3. The peak viscosity ranged from 132.84 to 333.46 RVU with Agrivest flour having the lowest and Fulcrum hlour the highest. Breakdown viscosity 73.84 to 173.04 RVU, Final viscosity from 88.88 to 215.75 RVU, and setback viscosities ranged, and from 32.46 to 57.38 RVU. The time to attain peak viscosity was lowest for Winnosa flour (4.30 min) and highest for Peak flour (4.60 min). The highest (79.20 °C) pasting temperature was recorded by Winnosa flour and the lowest (76.00 °C) was recorded Agrivest flour. The pasting profiles of the HQCF flours were significantly different (P<0.05) except for the pasting temperature. One of most common methods for determining the pasting profile of starch-based food products is through an amylograph pasting profile. Information on the pasting profile of flours has been used to correlate the functionality of starchy food ingredients in processes such as baking (Idowu et al 1996; Rojas et al 1999) and extrusion cooking (*Ruales* et al 1993). The peak viscosity is the maximum viscosity attainable during the heating cycle; the trough is an index of the starch granules' stability in heating; setback viscosity is an index of the retrogradation of linear starch molecules during cooling. It has been very difficult from past work to predict the bread-making potentials of cassava flour without wheat floor from its amylograph pasting properties. However, in agreement with previous work, it was concluded that attaining gelatinization at a lower temperature led to improved bread-baking quality (Defloor et al 1994). High peak viscosity and stability (or low breakdown viscosity) were also associated with cassava starch which produces acceptable bread (Adeyemi et al 1978). The flours showed the high peak viscosities and low set back viscosities characteristic of cassava

Table 1: Chemical composition of HQCF in Nigerian markets.

Composition (%)	Peak	Winnosa	Agrivest	Jaffe	Fulcrum
Moisture^{ns} (%)	14.47	14.56	14.56	14.36	14.41
Protein (%)	0.96 a	1.49 c	1.31 bc	1.14 ab	0.96 a
Fat^{ns} (%)	0.50	0.40	0.50	0.50	0.50
Amylose^{ns} (%)	13.40	13.30	13.20	13.50	13.00
Sugar^{ns} (%)	8.35	8.52	8.57	8.44	8.28
Starch^{ns} (%)	75.6	76.6	75.5	75.9	75.7
Ashns (%)	0.80	0.80	0.70	0.80	0.70
Crude Fiber^{ns}	1.50	1.54	1.60	1.54	1.48
Phytic acid^{ns} (mg/100g)	8.00	8.35	7.45	7.45	8.15
Phytate^{ns} (mg/100g)	2.85	3.00	2.65	2.65	2.90
HCN (mg HCN_{eqv}/100g)	5.15c	6.53cd	3.17a	4.36b	5.94c
pH^{ns}	6.70	6.70	6.90	6.50	6.50

- Values are means of 2 replicates
- Mean values having different superscript within row are significantly different (P <0.05).
- ns not significantly different

Table 2: Functional properties of HQCF in Nigerian markets.

Properties	Peak	Winnosa	Agrivest	Jaffe	Fulcrum
Bulk Density (g/cm3)	0.60ab	0.66c	0.58a	0.58a	0.63bc
Oil Absorption Capacity (%)	70.50c	66.25b	66.00b	61.50a	72.50c
Dispersibility (%)	78.00b	80.50c	79.00bc	71.50 a	79.00bc
Foaming capacity (%)	3.73c	2.66abc	2.06ab	1.48a	2.77bc
Emulsion Capacity (%)	42.74d	34.59c	27.27ab	24.23a	32.69bc
Water Absorption Capacity (%)	74.00b	78.50d	74.50bc	76.00c	73.00a

- Values are means of 2 replicates
- Mean values having different superscript within the same row are significantly different (P<0.05).
- ns not significantly different

Table 3: Pasting properties of HQCF in Nigerian markets.

Variables	Peak	Winnosa	Agrivest	Jaffe	Fulcrum
Peak (RVU)	279.30^{b}	132.84^{a}	158.46^{a}	277.58^{b}	333.46^{c}
Trough (RVU)	134.27^{cd}	56.42^{a}	84.63^{b}	123.75^{c}	160.42^{d}
Break down viscosity (RVU)	145.09^{b}	76.42^{a}	73.84^{a}	154.34^{b}	173.04^{c}
Final viscosity (RVU)	185.54^{b}	88.88^{a}	122.75^{a}	181.13^{b}	215.75^{b}
Setback (RVU)	51.34^{a}	32.46^{b}	38.13^{b}	57.38^{a}	55.34^{a}
Pasting time (min)	4.60^{bc}	4.30^{a}	4.40^{ab}	4.50^{bc}	4.37^{ab}
Pasting temperature (°C)^{ns}	78.9	79.2	76.0	78.8	78.4

- Values are means of 2 replicates
- Mean values having different superscript within row are significantly different ($P < 0.05$).
- ns not significantly different ($P>0.05$).

flour. Further works is needed to really determine quantitatively how the pasting properties of cassava flour relate to its functionality or end use, especially in baking, bread pastry, and confectionary.

Conclusion

The quality characteristics of the five samples of HQCF investigated for their quality characteristics showed significant variations ($P<0.05$) in some of quality parameters evaluated. The functional properties of the flour samples were significantly different ($P<0.05$). Significant differences ($P<0.05$) were recorded in the pasting profile of the flour samples, except for the pasting temperature. The qualities of the HQCF samples were within the limits set by the SON and the Codex.

Acknowledgement

Engr Ayo Olubori, the CEO Peak Products Enterprises Nigeria Limited, Abeokuta, Nigeria, and the President of Nigerian Cassava Processors and Marketers Association are highly appreciated for assisting us in sourcing the HQCF samples used for the study.

References

Adebowale A.A., Sanni L.O. and Awonorin S.O. 2005. Effect of Texture Modifiers on the Physicochemical and Sensory Properties of Dried Fufu. Food Science and Technology International, 11(5):373–382.

Adeyemi I.A. and Omolayo O. 1984. Utilization of cocoyam flour and starch for biscuit and cake making. Nigerian Journal of Science. 18:34–37.

AOAC. 1990. Official Methods of Analysis of the Association of Analytical Chemists. 15th ed. Arlington, USA.

Bradbury M.G., Egan S.V. and Bradbury J.H. 1999. Determination of all forms of cyanogens in cassava roots and cassava products using picrate paper kits. Journal of the Science of Food and Agriculture 79:593–601.

Defloor I., De Geest C., Schellekens M., Martens A. and Delcour J.A. 1994. Impact of genotype and crop age on the breadmaking and physicochemical properties of flour produced from cassava (*Manihot esculenta* Crantz) planted in the dry season. Journal of the Science of Food and Agriculture 66:193–202.

FAOSTAT (2008).Top twenty highest cassava producing countries. http://faostat.fao.org/site/333/default.aspx , Accessed September, 2010.

Idowu M.A., Oni A. and Amusa B.M. 1996. Bread and biscuit making potential of some Nigerian cocoyam cultivars. Nigerian Food Journal, 4:1–12.

Harland B.F. and Oberleas D. Anion Exchange Method for Determination of Phytate in Foods: Collaborative Study. Journal of Association of Official Analytical Chemistry 69:667−670.

Hahn S.K. and Keyser J. 1985. Cassava: a basic food of Africa. Outlook on Agriculture 4:95–100.

Hahn S.K., Mahunyu N.M., Ofoo J.A., Msabaha M.A.M., Lutaladio N.B. and Dahniya M.T. 1987. Root crops and the African food crisis. Pages 24−29, Proceedings of the Third Technical Symposium of the International Society for Tropical Root Crops −African Branch, Owerri, Nigeria, edited by E.R. Terry, M.O. Akoroda, and O.B. Arene.. IDRC-28C, Ottawa, ON, Canada.

Hayta M., Alpsalm M. and Baysar A. 2002. Effects of drying methods on functional properties of Tarhana: A wheat flouryoghunt mixture. Journal of Food Science 67:740–744

JECFA (Joint FAO/WHO Food Standards Programme Codex Committee on Contaminants in Foods) 2009. Discussion Paper on Cyanogenic Glycosides; Prepared by the Electronic Working Group members (Australia, New Zealand, Netherlands, Brazil, European Community, Indonesia, Denmark, Ghana, Thailand, Tonga, Vanuatu, FAO, WHO and Nigeria. Third Session, Rotterdam, the Netherlands, 23–27 March 2009).

Koch B., Nielsen V.S., Halker B.A. , Olsen C.E. and Moller B.L. 1992. The biosynthesis of cyanogenic glucosides in seedlings of cassava (*Manihot esculenta* Crantz). Archives of Biochemistry and Biophysics, 291:141–150.

Kulkarni K.D., Kulkarni D.N. and Ingle 1991. Sorghum malt-based weaning formulations: preparation, functional properties, and nutritive value. Food and Nutrition Bulletin 13(4):322–327.

Mahungu N.M., Yanaguchi Y., Almazan A.M. and Hahn S.K. 1987. Reduction of cyanide during processing of cassava into some traditional African foods. Journal of Food and Agriculture. 1:11–15.

Marfo E.K., Simpson B.K., Idowu J.S. and Oke O.L. 1990. Effect of Local Food Processing on Phytate Levels in Cassava, Cocoyam, Yam, Maize, Sorghum, Rice, Cowpea, and Soybean. Journal of Agricultural and Food Chemistry, 38:1580−1585.

Maziya-Dixon B., Dixon A.G.O. and Adebowale A.A. 2007. Targeting different end uses of cassava: genotypic variations for cyanogenic potentials and pasting properties. International Journal of Food Science and Technology 42(8): 969–976.

Phillips T.P., Taylor D.S., Sanni L. and Akoroda M. 2006. A cassava industrial revolution in Nigeria: the potential for a new crop, IITA, Ibadan, Nigeria, and FAO, Rome, Italy.

Rojas J.A., Rosell C.M. and Benedito de Barber C. 1999. Pasting properties of wheat flour-hydrocolloid systems. Food Hydrocolloids, 13:27–33.

Ruales J., Valencia S. and Nair B. 1993. Effect of processing on the physico-chemical characteristics of quinoa flour. Starch / Starke 45:13–19.

Sanni L., Maziya-Dixon B., Akanya J., . Okoro C.I., Alaya Y., Egwuonwu C.V., Okechukwu R., Ezedinma C., Akoroda M., Lemchi J., Okoro E. and Dixon A. 2005. Standards for Cassava Products and Guidelines for Export. IITA, Ibadan, Nigeria. 93 pp.

Sathe S.K. and Salunkhe D.K. 1981. Functional properties of the Great Northern Bean (*Phaseolus vulgaris*) flour. Journal of Food Science 46:1–74

Shittu T.A., Sanni L.O., Awonorin S.O., Maziya-Dixon B. and Dixon A. 2007. Use of multivariate techniques in studying the flour making properties of some CMD resistant cassava clones. *Food Chemistry* 101:1606–1615

Ukpabi U.J. and Ndimele C. 1990. Evaluation of the quality of *gari* produced in Imo State, Nigeria, Nigerian Food Journal 8:105−110.

Wang J.C. and Kinsella J.E. 1976. Functional properties of novel proteins; alfalfa leaf protein. Journal of Food Science 41:286–289.

WHO (World Health Organization)(1993). Cyanogenic glycosides. *In*: Toxicological evaluation of certain food additives and naturally occurring toxicants. Geneva, World Health Organization, 39th Meeting of the Joint FAO/WHO Expert Committee on Food Additives (WHO Food Additives Series 30). Available at http://www.inchem.org/documents/jecfa/jecmono/v30je18.htm

A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 17-23

Distribution and current status of cassava mosaic disease and begomoviruses in Guinea

E.S. Bah[1], B.A. Bamkefa[2], S. Winter[3], and A.G.O. Dixon[4]

[1]Institut de Recherche Agronomique de Guinée, Conakry, Guinea
[2]International Institute of Tropical Agriculture, Ibadan, Nigeria
[3]DSMZ -Plant Virus Division, Messeweg 11/12, Braunschweig, Germany
[4]Sierra Leone Agricultural Research Institute, Freetown

Corresponding Author: B.A. Bamkefa
Email: b.bamkefa@gmail.com

Manuscript received: 02/0/2010; accepted: 30/12/2010

Abstract

Several begomovirus species and strains causing cassava mosaic disease (CMD) have been reported from cassava in Africa. A diagnostic survey was made in the four agroecological zones of Guinea to determine the status of CMD and cassava begomoviruses and to ascertain if the virulent Ugandan variant of the *East African cassava mosaic virus* (EACMV-Ug2) was present. In the southern Guinea savanna; humid forest, midaltitud savanna, and derived savanna, 88 farmers' fields were visited. Each field was assessed for the incidence and severity of the disease. The CMD status was rated as mild, moderately severe, or severe. Cassava leaf samples were collected from plants showing the disease symptoms from farmers' fields on which CMD severity was also rated on a 5-point scale. Whitefly populations were estimated in each field as low, moderate, or high. Samples of diseased leaves were sent to Germany, DSMZ Plant Virus Division, for the identification of associated pathogens. The CMD status in most farmers' fields was moderately severe or severe. The lowland humid savanna had the highest severity (2.67) and ranged from 1.9 to 4.07. Only one field with an improved variety in the humid forest did not have any CMD symptoms. Across the country, the CMD symptoms were found in 73.61% of the farms. The highest incidence of the disease was in the derived savanna ecozone (81.9%). The mid altitude savanna had the lowest incidence (64.9%). Whitefly was found in all the fields surveyed. The highest populations were found in the midaltitude and derived savanna, while the lowest were obtained in the humid forest and southern Guinea savanna agroecologies. Differential PCR for ACMV, EACMV, EACMCV, and all other African and non-African begomoviruses in cassava conducted at DSMZ with leaf samples provided on FTA cards showed that only 22 PCR positive samples were obtained: five were infected with ACMV only; seven were infected with EACMCV only; and 10 were infected with mixtures of EACMCV and ACMV. There was no indication of other virus strains present in the country. This is the first report of EACMCV and mixtures with EACMCV and ACMV in Guinea.

Key word: cassava, mosaic virus, Guinea, whyte fly

Introduction

Cassava (Euphorbiaceae: *Manihot esculenta* Crantz) is Africa's second most important food crop; accounting for approximately one-third of the total staple food production. It was introduced into West and East Africa from Brazil at two independent events by Portuguese slave ships: western coast in the seventeenth century and eastern coast in the eighteenth century (Jones 1959). Both socioeconomic and biological constraints limit the average yield to about 10 t/ha, a value that is far below the potential yield of between 30.8 and 51 t/ha as estimated at research stations (Hahn et al 1989).

The most important disease and principal constraint affecting cassava production in sub-Saharan Africa is the cassava mosaic virus disease (CMD) (Hahn et al 1980; Legg and Fauquet 2004). The disease has been reported in all cassava-growing countries in Africa and

in the Indian subcontinent. Yield losses are enormous, especially if susceptible cultivars are cultivated (Fargette et al 1988; Otim-Nape et al 1994). On such cultivars, 90 to 100% yield losses were recorded in Uganda during a recent CMD pandemic (Otim-Nape et al 2000). These yield losses are due mainly to a reduction in photosynthetic leaf area (Theberge 1985; Allem and Hahn 1991).

The disease is associated with several whiteflies (*Bemisia tabaci*)−transmitted geminiviruses belonging to the genus Begomovirus, family Geminiviridae, which are characterized by having ssDNA genomes a twin-isometric particle morphology (Harrison 1985; Brown et al 1995). Several viral species of the begomoviruses occur in cassava (most common natural host) in sub-Saharan Africa. These include *African cassava mosaic virus* (ACMV) (Bock and Woods 1983; Guthrie 1987), *East African cassava mosaic virus* (EACMV), which has been reported from five East African countries, including Madagascar (Hong et al 1993; Swanson and Harrison 1993; Harrison et al 1997), as well as NIGERIA (Ogbe et al 1999) and Ghana (Offei et al 1999), *East African cassava mosaic Cameroon virus* (EACMCV) identified in Cameroon and first described by Fondong et al (1998); and Fondong te al (2000) has also been found in Nigeria (Ariyo et al 2003) and Côte d' Ivoire (Pita et al 2001). *East African cassava mosaic Malawi virus* (EACMMV), *East African cassava mosaic Zanzibar virus* (EACMZV) (Maruthi et al 2002), *South African cassava mosaic virus* (SACMV) is confined to the South African Republic (Berrie et al 1997, 1998, 2001; Rey and Thompson 1998) and Madagascar (Ranomenjanahary et al 2002) while a further distinct begomovirus species from cassava in Zanzibar described by Maruthi et al (2002) as the East African cassava mosaic Zanzibar virus (EACMZV) is confined to coastal regions of East Africa (Were et al 2004).

With the re-emergence of a severe epidemic form of CMD in Uganda in the 1980s, a new begomovirus type was described, referred to as either the Uganda variant virus (Zhou et al 1997) or a distinctive strain of EACMV (EACMVUG) (Deng et al 1997). This virus evolved as a recombination event between genomic segments of DNA-A of EACMV and a coat protein fragment of ACMV. Infections with this distinct strain of EACMV (EACMV-UG) (Deng et al 1997) resulted in severe disease symptoms, especially in mixed infections with ACMV (Harrison et al 1997). This virus is highly aggressive and was reported to be moving at a rate of 20 km/year (Gibson 1996; Otim-Nape et al 1997), devastating cassava fields. The rapid spread of this virus from Uganda to neighbouring countries (Legg and Ogwal 1998) and especially recent reports confirming the presence of EACMV-UG2 in the Democratic Republic of Congo (DRC) and Congo Republic (Neuenschwander et al 2002), as well as in Gabon (Legg, personal communication), indicated its movement towards the West African countries where ACMV predominates. This apparent westwards expansion poses a serious threat to cassava production in West Africa. In addition, mixed infection of ACMV and EACMV, which gave rise to the "Uganda variant" have already been reported from major cassava growing countries of West Africa. Nigeria, Ghana, Togo, Côte d'Ivoire, and Guinea (Fondong et al 1998; 2000; Offei et al 1999; Ogbe 2001; Ogbe et al 1999; 2003). Mixed infections are more severe than a single infection on cassava plants, and may provide further opportunities for the recombination into more virulent strains. In view of the current importance of cassava in the subregion, threats to production must be considered very seriously and preventive strategies should be vigorously pursued with urgent priority. This study was therefore undertaken to determine the status of CMD and cassava begomoviruses, and to ascertain if the virulent Ugandan variant of the *East African cassava mosaic virus* (EACMV-Ug2) was present in Guinea.

Materials and methods

Farmers' fields were surveyed across the four agroecological zones of Guinea between 8 and 30 August 2005. The survey followed the method described by Ogbe et al (2003). The number of cassava farms examined in each ecozone varied, depending on availability. A total of 88 farmers' fields were surveyed: derived savanna (26); humid forest (27); midaltitude savanna (17); southern Guinea savanna (18). The geographic position of the each field was recorded using the Global Positioning System (GPS). Cassava fields were selected at regular intervals of at least 20 km, and the assessment of disease severity was made on 30 randomly selected plants along two diagonals in each field. Each plant was rated on a scale of 1–5 in which 1 represented no symptoms and 5, the most severe symptoms including severe chlorosis, leaf distortion, and plant stunting (Hahn et al 1980). The whitefly population was estimated by recording the number of adult whiteflies on the five topmost apical leaves on a scale of 1 – 3 where 1=

low (1 – 50 whiteflies/plant), 2 = moderate (50 to 100 whiteflies/plant), and 3 = high (> 100 whiteflies/plant). On average, two leaf samples were collected in each field, depending on the degree of CMD severity, using the FTA cards. Samples of leaves were sent to DSMZ Plant Virus Division in Germany for identification.

Detection and differentiation of bogomoviruses in cassava. To provide a high resolution of the virus (es) present in a respective sample, a polymerase chain reaction (PCR) assay was followed using differential primers amplifying specific virus species or, a subset of strains. Sixteen primers with unique sequences to each begomovirus were used to discriminate among virus species and strains. Two primers, Begomo 146 and 672, from sequences that are common to all cassava begomoviruses were included for virus detection purposes (Ariyo et al 2005).

For PCR analysis, leaf samples were subjected to DNA isolation, essentially following a plant DNA minipreparation method (Dellaporta et al 1983). From each DNA preparation, 1 µl was subjected to PCR in a total volume of 50 µl. The reaction consisted of 2.5 µl $MgCl_2$ (50 mm), 1 µl of each primer (100 qmol), 5 µl of 10X Taq polymerase buffer, 1 µl dNTPs (10 mm) and 0.5 µl (2.5 units) of Taq DNA polymerase (Gibco BRL, Karlsruhe, Germany). After an initial denaturation step of 3 min at 95 ^{o}C, 35 PCR amplification cycles were conducted, consisting of 1 min denaturation at 95 ^{o}C, 1.5 min primer annealing (at temperatures specified for the respective primer combinations) and 1 min strand extension at 72 ^{o}C, PCR amplification was terminated by a final extension period of 10 min at 72 ^{o}C. After PCR, 10 µl of each reaction was subjected to gel electrophoresis in 1% agarose gels to evaluate PCR-amplified virus genome fragments.

Results

Geographical distribution of cassava mosaic diseases. In all the four major ecozones, CMD was present and was observed in 96% of the fields visited in the humid forest (Fig. 1). The midaltitude and southern Guinea savanna generally had low disease severity scores, while the humid forest and derived Guinea savanna had higher scores. The highest mean severity score was recorded in Kindia (Mambia) (4.07); other regions with high severity scores were Kindia (Bokaria) (3.77), Mamou (Ourekaba) (3.73), Mamou (Kenzy) (3.70) Pita (Bendougou) (3.73), N'zérékoré (Borta) (3.70) (Fig. 1).

Discussion

This study on the distribution of geminiviruses in cassava was intended to present an update on the status of CMD and the occurrence of cassava mosaic begomovirus species and strains in Guinea. The highest incidence of CMD was obtained in the derived savanna, and the Kindia region. This is in agreement with the results obtained by Okao-Okuja et al (2004) during their survey from November to December 2002 in Guinea and Senegal. Wydra and Msikita (1998) noted that low average CMD incidence was regionally observed on different ecozones (Cameroon, wet savanna (29%), Cameroon, mountain forest (38%), Bénin, transition forest (45%), whereas in most other ecozones, plant incidence was between 64 and 97%. The higher severity (2.93), found in the derived savanna, is in agreement with the observations of Wydra and Msikita (1998) who reported that the average severity of infected plants varied between score 2.2 (Bénin, transition forest) and 3.4 (Cameroon, wet savanna) on the scale of 1 to 5.

The highest populations of whiteflies were found in the midaltitude and derived savanna. This showed an apparent relationship between CMD incidence, severity, and whitefly populations and was in accordance with the findings of Muimba-Kankolongo et al (1998). They found higher incidence and severity of CMD in southern Africa during warm periods when whitefly populations, and activity were highest. However, in Nigeria, vector population, CMD incidence, and severity were highest on plants established in the forest-savanna transition, followed by those in the humid rain forest and were lowest in the northern Guinea savanna (Akano et al 1998). This suggested that the vector has great influence on CMD occurrence. There is a need for more detailed studies over the course of the season in the derived savanna of Guinea and for breeders to disseminate resistant varieties quickly to farmers. The virus distribution map of West Africa can now be extended to Guinea
The need to protect cassava against this virus is, therefore, a crucial aspect in enhancing the production of the crop. Of the various measures that have been employed to control CMD, the two main approaches are the use of virus-resistant varieties and phytosanitation (Thresh and Cooter 2005). The use of resistant varieties has remained the most economical and ecologically sustainable control measure (Jennings 1994). Breeding for resistance to CMD and the search for virus-resistant genotypes started in

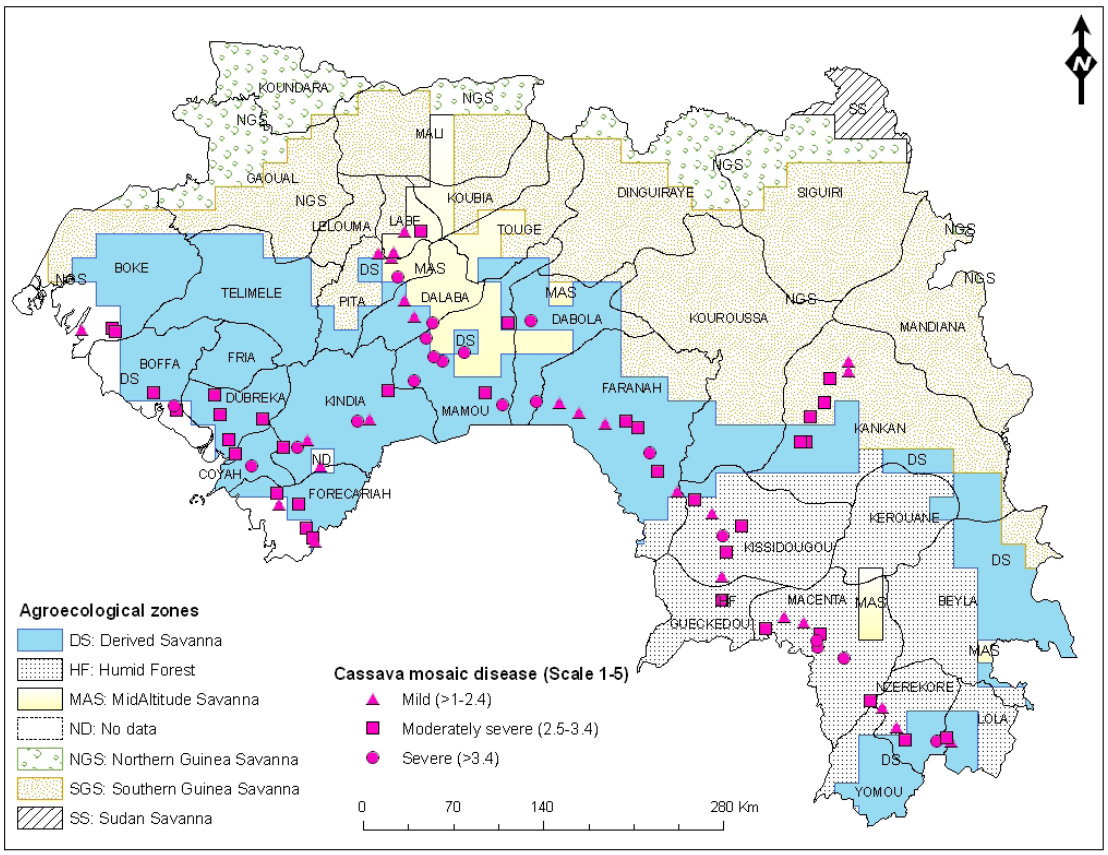

Fig 1. Guinea, showing the distribution of farms with different levels of CMD severity across the various agroecological zones.

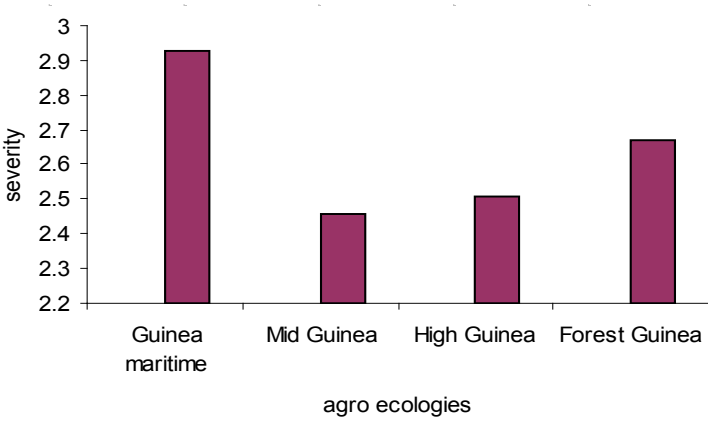

Fig 2. Severity of CMD in four ecologies in Guinea.

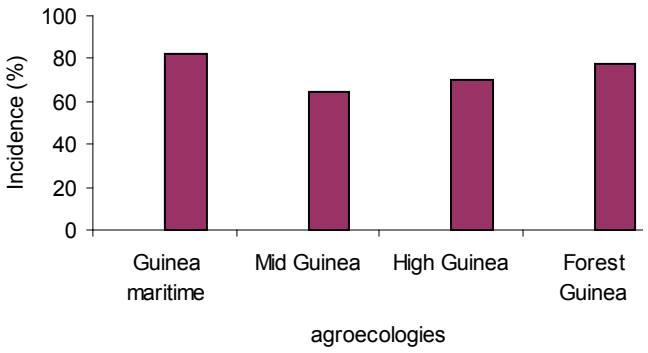

Fig 3. Incidence of CMD in four agrowcologies in Guinea

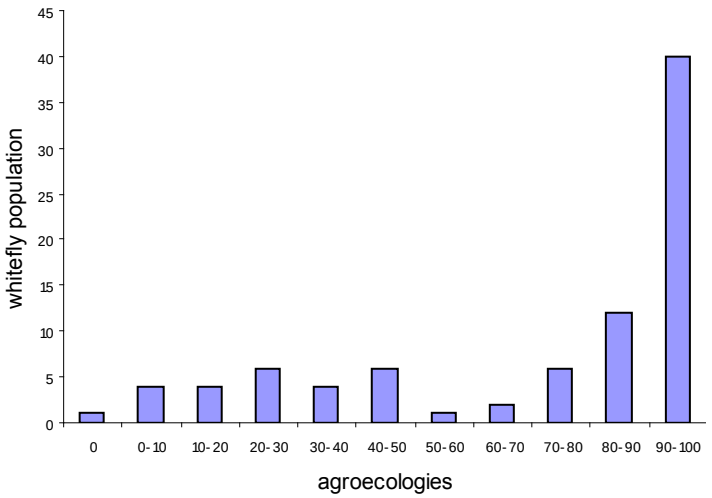

Fig 4. Distribution of whitefly populations in cassava fields surveyed in Guinea.

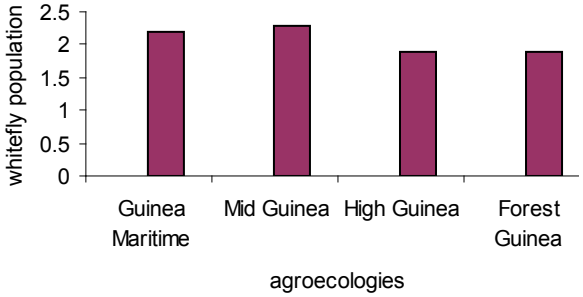

Fig 5. Whitefly populations on cassava fields in four agroecologies in Giunea.

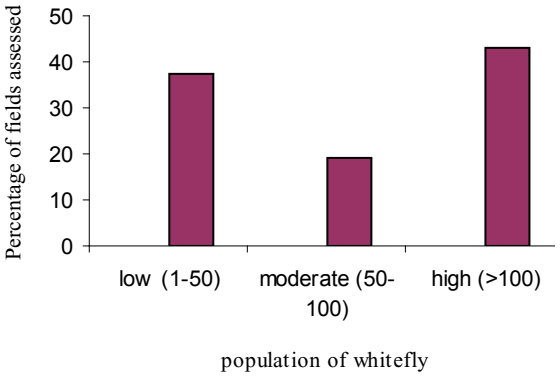

Fig 6. Distribution of white fly populations in cassava fields surveyed in Guinea.

the late 1920s (Otim-Nape et al 1998). Since then, there have been trials of cultivars and selections in several countries including Kenya, Tanzania, Uganda, Madagascar, Zaire (now Democratic Republic of Congo) and Nigeria (Jennings 1994). TME 4 and 96/1089A, selected recently at IITA (Ibadan, Nigeria), remain solid and resistant to EACMCV or ACMV or both infections, even with high virus pressure.

Higher severity scores of 2.93 were obtained for cassava farms in the derived savanna; farms in the other ecozones generally had severity scores ranging from 2.46 to 2.67 (Fig. 2).

The incidence of CMD was higher in the derived savanna (81.9%) but lower in the midaltitude savanna (64.9%) (Fig 3).

More fields were recorded in the category of 90-100% incidence than in any other and more than 60% had an incidence score > 80% (Fig 4).

Whitefly populations varied across fields in all the agroecological zones. The highest number of whiteflies / plant was found in the midaltitude savanna; the humid forest and southern Guinea savanna had the lowest populations (Fig 5).

Low (37.5%), moderate (19.3%) and high (43.18%) populations of whitefly were recorded in all fields visited (Fig. 6).

From the 22 samples that tested positive:
5 were infected with ACMV only
7 were infected with EACMCV only
10 were infected with EACMCV and ACMV.
This means that EACMCV is the most prevalent virus in all fields visited and we have a 50/50 situation of EACMCV and ACMV.

References

Akano A., Ng S.Y.C., Asiedu R. and Atiri G. 1998. Performance in three agroecologies of virus-tested cassava genotypes derived from meristem culture. Pages 194–198 *In*: M.O. Akoroda and I.J. Ekanayake (eds.) Root Crops and Poverty Alleviation. Proceedings of the sixth Symposium of ISTRC-AB, Lilongwe, Malawi, 22–28 Oct. 1995. IITA Ibadan, Nigeria.

Allem A.C. and Hahn S.K. 1991. Cassava germplasm strategies for Africa. Pages 65–73. *In*: Ng N.Q., Perrino P., Attere F., and H. Zedah (eds.) Crop Genetic Resources of Africa. Proceedings of Institute of Crop Gremplasm Resources of Africa, Ibadan, Nigeria, 17–20 Oct. 1988.

Ariyo A., Koerbler M., Dixon A.G.O., Atiri G.I. and Winter S. 2005. Molecular variability and distribution of cassava mosaic begomoviruses in Nigeria. Journal of Phytopathology 153: 226–231.

Belloti A.C., Braun A.R., Arias B., Castillo J.A., and Guerrero J.M. 1994. Origin and management of neotropical cassava arthropod pests. African Crop Science Journal 2:407–417.

Berrie L.C., Plamer K.E., Rybicki E.P., Hyadat S.H., Maxwell D.P. and Rey M.E.C. 1997. A new isolate of African cassava mosaic virus in South Africa. African Journal of Root and Tuber Crops 2:49–52

Berrie L.C., Rybicki E.P. and Rey M.E.C. 1998. Molecular characterisation of a distinct South African cassava infecting geminivirus. Archives of Virology 143: 2253–60.

Berrie L.C., Rybicki E.P. and Rey M.E.C. 2001. Complete nucleotide sequence and host range of South African cassava mosaic virus: further evidence of recombination amongst begomoviruses. Journal of General Virology 82: 53–58.

Bock J.K. and Woods R.D. 1983. Etiology of African cassava mosaic disease. Plant Disease 67:994–995.

Brown J.K., Frohlich D.R. and Rosell R.C. 1995. The sweetpotato or silverleaf whiteflies: biotypes of *Bemissia tabaci* or a species complex? Annual Review of Entomology 40: 511–534.

Dellaporta S.L., Wood J. and Hicks J.R. 1983. A plant DNA mini-preparation: version II. Plant Molecular Biology Report 1:19–21.

Deng D., Otim-Nape G.W., Sangare A., Ogwal S., Beachy R.N. and Fauquet C.M. 1997. Presence of a new virus associated with cassava mosaic outbreak in Uganda. African Journal of Root and Tuber Crops 2:23–28.

Fargette D., Fauquet C. and Thouvenel J.C. 1988. Yield losses induced by African cassava mosaic virus in relation to the mode and the date of infection. Tropical Pest Management 34: 89–91.

Fondong V.N., Pita J.S., Rey C., Beachy R.N. and Fauquet C.M. 1998. First report of the presence of East African cassava mosaic virus in Cameroon. Plant Disease 82:1172.

Fondong V.N., Pita J.S., Rey M.E.C., de Kochko A., Beachy R.N. and Fauquet C.M. 2000a. Evidence of synergism between African cassava mosaic virus and a new double-recombinant geminivirus infecting cassava in Cameroon. Journal of General Virology 81: 287–297.

Gibson R.W. 1996. The report of a survey monitoring the spread of the epidemic of the African cassava mosaic virus from Uganda into Western Kenya. Internal report. Natural Resources Institute, Chatham, UK.

Guthrie E. J. 1987. African cassava mosaic virus disease and its control. Pages 1–9 *In*: Proceedings of the International seminar on African Cassava Mosaic Virus Diseases and its control. Yamoussoukro, Côte D'Ivoire 4–8 May 1987 CTA, Wageningen, The Netherlands.

Hahn S.K., Terry E.R. and Leuschner K. 1980. Breeding cassava for resistance to cassava mosaic disease. Euphytica 29:673–683.

Hahn S.K., Isoba G.G.J. and Ikotun T. 1989. Resistance to cassava mosaic breeding in root and tuber crops at the International Institute of Tropical Agriculture, Ibadan, Nigeria. Crop Protection 8:147–148.

Harrison B.D. 1985. Advances in geminivirus research. Annual Review of Phytopathology 23: 55–82.

Harrison B.D., Zhou X., Otim-Nape G.W., Liu Y. and Robinson D.J. 1997. Role of a novel type of double infection in the geminivirus-induced epidemic of severe cassava mosaic in Uganda. Annals of Applied Biology 131:437–448.

Hong Y.G., Robinson D.J. and Harrison B.D. 1993. Nucleotide sequence evidence for the occurrence of three distinct whitefly-transmitted geminiviruses in cassava. Journal of General Virology 74:2437–2443.

Jennings D.L. 1994. Breeding for resistance to African cassava mosaic geminivirus in East Africa. Tropical Science 34: 110–122.

Jones W.O. 1959. Manioc in Africa. Standard University Press, Stanford, Ca. USA. 315 pp.

Legg J.P. 1999. Emergence, spread and strategies for controlling the pandemic of cassava mosaic virus disease in east and central Africa. Crop Protection. 18:627–637.

Legg J.P. and Fauquet C.M. 2004. Cassava mosaic geminiviruses in Africa. Plant Molecular Biology 56, 585–599.

Legg J., James B., Cudjoe A., Saizonou S., Gbaguidi B., Ogbe F., Ntonifor N., Ogwal S., Thresh J., and Hughes J. 1997. A regional collaborative approach to the study of ACMVD epidemiology in sub-Saharan Africa. Pages.1021–1033. *In*: Adipala E., J. S. Tenywa and M. W. Ogenga-Latigo (eds). African Crop Science Conference Proceedings, Vol. 3, Pretoria, South Africa, 13-17 Jan. 1997. Makerere University, Kampala, Uganda.

Legg J.P. and Ogwal S. 1998. Changes in the incidence of African cassava mosaic virus disease and the abundance of its whitefly vector along south-north transects in Uganda. Journal of Applied Entomology 122:169–78.

Maruthi M.N., Colvin J., Seal S. and Thresh J.M. 2002. First report of a new begomovirus species infecting cassava from Zanzibar. Plant Disease 86:187.

Muimba-Kankolongo A., Teri J.M., Mahungu N.M., Porto M.C.M., Jerico C., Mukumbira J., Zacaria A. and Kanju E. 1998. Rate of re-infection and prospects for control of African cassava mosaic disease in southern Africa. Pages. 157–162 *In*: Akoroda M.O. and I. J. Ekanayake (eds). Root Crops and Poverty Alleviation. Proceedings of sixth Symposium of ISTRC–AB, Lilongwe, Malawi, 22-28 Oct. 1995.

Neuenschwander P., Hughes J.d'A., Ogbe F., Ngatse J.M. and Legg J.P. 2002. Occurrence of the Uganda variant of East African cassava mosaic virus (EACMV-Ug) in western Democratic Republic of Congo and the Congo Republic defines the westernmost extent of the CMD pandemic in East/ Central Africa. Plant Pathology 51:385.

Offei S.K., Owuna-Kwakye M. and Thottappilly G. 1999. First report of East African cassava mosaic begomovirus in Ghana. Plant Disease 83: 877.

Ogbe F.O., Atiri G.I., Robinson D., Winter S., Dixon A.G.O., Quinn F.M. and Thottappilly G. 1999. First report of East African cassava mosaic begomovirus in Nigeria. Plant Disease 83: 398.

Ogbe F.O 2001. Survey of cassava begomovirus in Nigeria and the response of resistant cassava genotypes to the African cassava mosaic begomovirus infection. PhD thesis, University of Ibadan, Nigeria. 197 pp.

Ogbe F.O., Thottappilly G., Dixon A.G.O., Atiri G.I. and Mignouna H.D. 2003. Variants of East African cassava mosaic virus and its distribution in double infections with African cassava mosaic virus in Nigeria. Plant Disease 83(3) 229–232.

Okao-Okuja G., Legg J.P., Traore L. and Alexandra Jorge M. 2004. Virus associated with Cassava Mosaic Disease in Senegal and Guinea Conakry. Journal of Phytopatology 152:69–76

Okogbenin E., Porto M.C.M. and Dixon A.G.O. 1998. Influence of planting season on incidence and severity of African cassava mosaic disease in the subhumid zone of Nigeria. Pages 388-393 *In*: Akoroda M.O. and I.J. Ekanayake eds. Root Crops and Poverty Alleviation. Proceedings of Sixth Symposium of ISTRC–AB, Lilongwe, Malawi, 22–28 Oct. 1995. IITA, Ibadan, Nigeria.

Otim-Nape G.W., Shaw M.W. and Thresh J.M. 1994. The effects of African cassava mosaic geminivirus on the growth and yield of cassava in Uganda. Tropical Science 34: 43–54.

Otim-Nape G.W., Bua A., Thresh J.M., Baguma Y. and Ogwal S. 1997. Cassava mosaic virus disease in Uganda: the current pandemic and approaches to control. Natural Research Institute, Chatham, UK.

Otim-Nape G.W., Thresh J.M., Bua A., Baguma Y. and Shaw M.W. 1998. Temporal spread of cassava mosaic virus disease in a range of cassava cultivars in different agro-ecological regions of Uganda. Annals of Applied Biology 133: 415–430.

Otim-Nape G.W., Bua A., Thresh J.M., Baguma Y., Ogwal S., Ssemakula G.N., Acola G., Byabakama B., Colvin J., Cooter R.J. and Martin A. 2000. The current Pandemic of Cassava Mosaic Virus Disease in East Africa and its control. National Agricultural Research Organization (NARO), Uganda; National Resource Institute. (NRI), University of Greenwich, UK; and Depertment of International Developement. (DFID), UK; Hobbs the Printers Ltd., Totton, Hampshire, UK.

Pita J.S., Fondong V.N., Sangare A., Kokora R.N.N. and Fauquet C.M. 2001. Genomic and biological diversity of the African Cassava geminiviruses. Euphytica 120: 115–125.

Ranomenjanahary S., Rabindran R. and Robinson D.J. 2002. Occurrence of three distinct begomoviruses in cassava in Madagascar. Annals of Applied Biology. 140:315–318.

Rey M.E.C. and Thompson G. 1998. Cassava mosaic virus disease in South Africa. Roots 5:3–5.

Swanson M.M. and Harrison B.D. 1993. Serological relationships and epitope profile of isolates of *okra leaf curl geminivirus* from Africa and the middle East. Biochemistry 75: 707–711.

Theberge R.L. 1985. Common African Pests and Diseases of cassava, yam, sweetpotato and cocoyam. IITA, Ibadan, Nigeria. 108 pp.

Thresh J.M. and Cooter R.J. 2005. Strategies for controlling cassava mosaic virus disease in Africa. Plant Pathology 54: 587–614.

Were H.K., Winter S. and Maiss E. 2004. Viruses infecting cassava in Kenya. Plant Disease 88:17–22.

Wydra H.K. and Msikita W. 1998. An overview of the present situation of cassava diseases in West Africa. Pages198–206 *In*: Akoroda M.O. and I.J. Ekanayake (eds). Root Crops and Poverty Alleviation. Proceedings of Sixth Symposium of ISTRC – AB, Lilongwe, Malawi, 22-28 Oct. 1995. IITA, Ibadan, Nigeria.

Zhou X., Liu Y., Calvert L., Munoz C., Otim-Nape G.W., Robinson D.J. and Harrison B.D. 1997. Evidence that DNA-A of a geminivirus associated with severe cassava mosaic disease in Uganda has arisen by interspecific recombination. Journal of General Virology 78:2101–2111.

A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 24-29

Studies on population build-up of *Scutellonema bradys* in *Dioscorea* species

J.I. Oluwatayo[1], R. Asiedu[2] and S.O. Adesiyan[3]

[1]Department of Crop & Environmental Protection, University of Agriculture, Makurdi, Nigeria;
[2]International Institute of Tropical Agriculture, Ibadan, Nigeria;
[3]Department of Crop Protection & Environmental Biology, University of Ibadan, Ibadan, Nigeria

Corresponding Author: J.I. Oluwatayo
Email: iyeh2010@yahoo.com

Manuscript received: 06/12/2010; accepted: 15/02/2011

Abstract

Field and storage evaluation of four yam cultivars TDr 131 (*Dioscorea rotundata*), TDa 85/00257 (*D. alata*), Igangan (*Dioscorea cayenensis*), TDe 3041 (*D. esculenta*) in intercrop with three other crops, cocoyam (*Xanthosoma sagittifolium*), ginger (*Zingiber officinale*) and maize (*Zea mays*) to the occurrence and abundance of the yam nematode, *Scutellonema bradys* showed significant variation in dry rot incidence which increased throughout the period of storage. There was a significant positive correlation (r = 0.77; $P \leq 0.05$) between soil nematode population and number of nematodes extracted from the peels of the tubers. Intercropping susceptible yam cultivars with maize, ginger, and cocoyam significantly ($P \leq 0.05$) reduced soil nematode population by 38%, 42%, and 54%. Data analysis showed that fewer nematodes were able to survive on tubers in the intercropped plots as compared to the sole plots. Nematode populations increased 14-foldin the untreated plots and 2-fold in the intercropped plots.

Key words*: Scutellonema bradys*, nematode population, dry rot

Introduction

Steiner and LeHew (1933) first discovered the species *Scutellonema bradys* to be the cause of a disease of yam. Symptoms of attack include necrotic lesions produced just beneath the yam skin, extending slightly to the starchy tissue and these are generally associated with the dry rot of yam tubers that occurs in the outer 1 to 2 mm of tuber directly associated with *S. bradys*. The initial stage of dry rot consists of cream and light yellow lesions below the outer skin of the tuber. There are no external symptoms at this stage. *S. bradys* reproduces and builds up large populations in stored yam tubers and causes severe damage during storage. The life cycle of *S. bradys* is simple. Eggs are laid in soil or plant tissues (roots and tubers) where they hatch and the juveniles develop into adults by subsequent moulting. All stages are infective. *S. bradys* invaded the young, developing tubers through the tissues of the tuber growing point, alongside emerging roots and shoots, and also through cracks or damaged areas in the suberized epidermis (Bridge 1972). *S. bradys* continues to feed and reproduce in stored yam. They feed intracellularly in tuber tissues, resulting in rupture of cell walls, loss of cell contents, and the formation of cavities.

Material and methods

Four yam cultivars (TDr 131, TDa 85/00257, Igangan, and TDe 3041) and three of the resistant crops (*Xanthosoma sagittifolium*, *Zingiber officinale* and *Zea mays*) were selected out of the crops screened for resistance to *S. bradys* in which these three crops proved to be non-host. Mounds were made and all treatment combinations were planted. Plants were artificially infested with approximately 500 *S. bradys* per mound (Pi) by introducing known weights of infested yam peels close to the bases of the plants. There were four replications.

Nematode numbers (plants and soil) were assessed at harvest. Tubers were further stored and assessed for population build-up of the nematode. Soil nematode population densities were assessed at 8, 16, and 32 weeks after artificial infestation. Soil samples were processed by modified Baermann funnel extraction method to extract motile stages of *S. bradys*. Initial and final population density values included all motile stages. Nematode counts were recorded as number /100- cm^3 soil and /100 g tuber peel. Mature tubers were rated visually on a 0–10 scale: 0 = clean tubers; 2 = small yellowish

lesions; 4 = dark brown lesions; 6 = continuous dark dry rot layer; 8 = deep cracks in the tuber skin; 10 = malformation of tuber and flaking off of parts of the epidermal layers.

Harvested tubers (all cultivars used) were stored in the barn (Fig. 1) to investigate population build-up of *S. bradys*.

Tubers were sampled at harvest and stored, thereafter, tubers were sampled at 8 weeks after harvest and 16 weeks after harvest to examine population build-up of the nematodes. The difference in sampling period was to allow ample time for the nematodes to complete their life cycle and to multiply. The sampled tubers were peeled and nematodes were extracted from the peels and counted. Initial (Pi) and final (Pf) nematode population density ratios were calculated.

One tuber from each variety was sampled at every sampling time. Tuber weight was taken from specific tubers from the various cultivars kept aside for that purpose.

Record was also taken of tuber weight in storage at every sampling period. Dry matter accumulation of tubers was taken by oven-drying (60^{o} C) 140 g weight of the various species to constant weight. The final weight was recorded and the loss in weight through drying was used to calculate the dry matter percentage.

Analysis of variance (ANOVA) was used to test the hypothesis that there was no difference in yield,

Figure 1 Stored tubers used for population build-up study.

visible symptoms of infection, and level of infestation by the nematode on tubers. Mean separation was by Least Square Means (LS Means) with option Pdiff (probability associated with the difference) of SAS statistical package version 6.12 as a test for significance.

Results and Discussion

The variation of soil nematode population with increase in the age of yam *(S. bradys* counts at different sampling times) is shown (Fig. 2). Different trends in the population density of nematode were observed in both sole and intercropping, and between the cultivars in the same plot. A low population density of *S. bradys* was found in the soils of intercropped plots. The difference between the nematode population of the cocoyam, ginger, and maize intercrop for each yam species was not significant, but that of sole yam and intercrop for each yam species was highly significant with the nematode population of the sole yam plot continuously on the increase until tuber maturity, for all the yam species. At crop maturity, nematode population was sparse in most of the plots, except for the sole yam crops. Nematodes increased mostly from inoculation to 8 weeks after inoculation in the intercrop plots, and thereafter, the population density decreased significantly with the establishment of the resistant plant materials on the field.

However, in the sole crop plots, the nematode population density increased throughout the growth period, leading to a soil population increase of about 14-fold at harvest compared to 2-fold increase in the intercropped plots. The number of nematodes in the soil increased from an initial 500 to 8501 for untreated sole plots and 1756 for the intercrop (Fig. 1 above). Intercropping yam cultivars with cocoyam significantly ($P \leq 0.05$} reduced soil nematode population by 54%, with ginger by 42% and with maize by 38%.

Fresh tuber weights and numbers were affected (P=0.05) by *S. bradys* (Table 1). Fresh tuber weights decreased (P=0.05), whereas tuber disease severity increased with increasing final population (Pf) per tuber as a function of increasing *S. bradys* initial population (Pi). Final population densities of *S. bradys* in stored tubers increased (P=0.05) as a function of increasing Pi (Table 2). The observed Pf were highest at Pi 10,000. Final population densities in tubers were 10.0 to 10.4 times higher than in soil at Pi = 10,000 and 4.6 times higher at Pi =500. There was a gradual increase in the nematode population in the tubers during storage. Damage in storage was more pronounced in tubers from sole plots. This showed that *S. bradys* infestation had significant effects on the storability of tubers. Reproductive rates (Pf/Pi) of *S. bradys* in tubers were inversely related (P=0.05) to Pi. There were no differences among treatment initial population densities. At harvest there were significantly greater numbers of nematodes in tubers and the surrounding soil of the sole yam (host to *S. bradys*) than in the intercrops. Sole *D. cayenensis* yielded significantly higher soil population densities than the remaining treatments. Also, there were significantly fewer nematodes in the peels of tubers from the intercropped plots than from the sole.

Population densities of *S. bradys* increased and caused severe damage on tubers and crops under greenhouse conditions. These results are consistent with field observations and those of storage where large numbers of *S. bradys* were associated with high yield losses. Inoculation of yam tissues with 500 *S. bradys* juveniles and adults isolated from infested tubers resulted in a 12-fold increase in nematode numbers within 10 weeks (Adesiyan 1976). In our study, the rate of nematode increase at Pi 10000 and Pi 500 in soil and tubers combined was 34-fold. The true rate of nematode increase was probably much higher, since peels and soil for 24 hours in water yield only about 50% of the total population (Bolton et al 1990). There was a significant variation in the reaction of the cultivars at the indicated weeks of storage. Cultivars intercropped with cocoyam, ginger, or maize showed favorable responses, with the lowest nematode population of 770 recorded in *D. esculenta*/cocoyam intercrop at 16 weeks of storage. A marked increase in nematode population within 8 weeks was recorded in *D. rotundata, D. alata, D. esculenta* and *D. cayenensis* planted sole. From the results of this study, nematode population in the infested tubers increased throughout the period of storage and it is evident that *S. bradys* has the ability to reproduce fast in yam during storage.

This agrees with the findings of Adesiyan (1976), and Cadet and Daly (1996), who reported evidence of the effect of feeding and reproduction of S. bradys on stored tubers resulting in weight loss and dry rot symptoms. Weight reduction can occur with late harvested tubers in dry soil and during storage as a result of moisture loss through cracked epidermal layers. Smith (personal communication) in Cote d'Ivoire estimated that weight differences between healthy and diseased tubers harvested from the field were about 20 to 30%. These

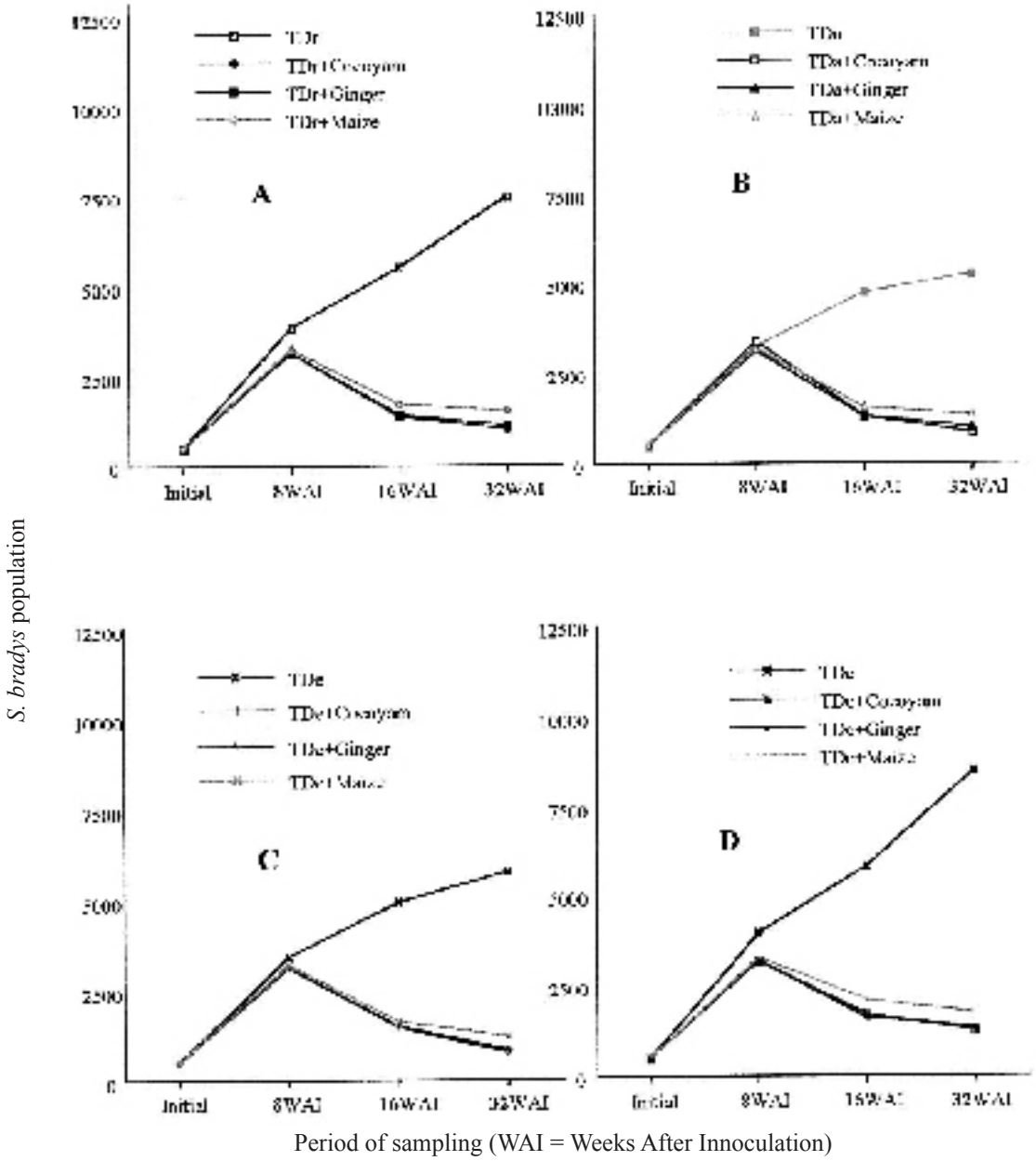

Figure 2. Scutellonema bradys counts at diffferrent sampling periods

A = *Dioscorea routundata*, B = *Dioscorea alata*, C = *Dioscorea esculenta* and D = *Dioscorea cayenesis*

differences would become more marked by the losses in tubers during storage. Adesiyan et al 1975) showed that, during storage, *S. bradys* infection resulted in a significant increase in water loss from *D. rotundata* and *D. cayenensis* tubers and a reduction in the edible portions of tubers of these species and also in the *D. alata* in yam barn. According to Adesiyan (1976), the variation in the weight loss amongst different species and between the healthy and infected tubers, is due to an increase in respiratory activity in the nematode-infected yam tubers and hence a higher rate of weight loss than in the healthy yam. This indicates that high weight losses during storage are mostly caused by pathogens, and that healthy yam tubers can be stored for a few months without appreciable losses in the weight of the edible portion. Kwoseh et al (1998) observed increases in the S.bradys population by 10 to 170 times over a 5-month period and 340 to 820 times over 12-months. In another study, Augustus and Jeffrey

Conclusions

Crop yield depends upon the initial nematode density and the rate of reproduction. The level of susceptibility is expressed as the ability of the nematode to survive and cause damage on the plants. A considerable quantity of yam is lost during storage. On a global

Table 1. Tuber weights (gm) at harvest and in storage (mean ± s.e.)

Cropping System	At Harvest		6 Weeks after Harvest		12 Weeks after Harvest		Disease severity
	Treated	Untreated	Treated	Untreated	Treated	Untreated	
TDr sole	*2100 ±86	900 ±86	* 1965 ±86	718 ±86	*1893 ±86	606 ±86	7.56
TDr +	* 1900 ±78	1300 ±79	* 1765±78	1120 ±79	* 1693 ±78	1007 ±79	1.55
Cocoyam TDr + Ginger	* 1900 ±74	1300 ±71	* 1697 ±121	1118 ±71	*1681 ±85	1006±71	2.98
TDr + Maize	*1700 ±70	1200 ±64	*1600 ±70	1018 ±64	*1493 ±70	908 ±64	3.37
TDa sole	*2800 ±59	800 ±58	*2663 ±59	658 ±58	*2580 ±59	586 ±58	6.75
TDa + Cocoyam	* 1900 ±50	1500 f50	*1763 ±50	1358 ±50	* 1682 ±50	1286 ±50	1.74
TDa + Ginger	*2600 ±43	1700 ±43	*2463 ±43	1557 ±43	*2381 ±43	1486 ±43	3.13
TDa + Maize	*2600 ±37	1300 ±38	*2461 ±37	1153 ±38	*2381±37	1082 ±38	2.84
TDc sole	* 1500 ±29	500 ±29	*1385 ±29	352 ±29	*1333 ±29	270 ±29	7.94
TDc + Cocoyam	* 1300 ±22	1000±21	* 1185 ±22	850 ±31	* 1134 ±22	772 ±21	1.52
TDc + Ginger	* 1400 ±14	1000 ±16	* 1285 ±14	850 t16	* 1232 ±14	770 ±16	3.33
TDc + Maize	* 1200 ±8	1000±7	* 1085 t8	827 ±51	* 1040 ±8	670 ±7	3.39
TDe sole	*200 ±14	96 ±6	* 178 ±19	57 ±6	* 163 ±13	32 ±5	6.80
TDe + Cocoyam	100 ±8	100 ±14	80 ±8	66 ±17	67 ±5	38 ±4	1.55
TDe + Ginger	100 ±16	100 ±8	84 ±6	61 ±9	66 ±7	35 ±8	3.34
TDe + Maize	100 ±14	100 ±0	80 ±14	61 ±1	63 ±13	31 ±2	3.15

Values are means of four replicates. Within experiments means of the same figure in vertical columns are not significantly different.
TDr = Tropical *Dioscorea rotundata* TDe = Tropical *Dioscorea esculenta*
TDa = Tropical *Dioscorea alata* TDc = Tropical *Dioscorea cayenensis*
* refer to treated tuber significantly ($P \leq 0.05$) different from the untreated

Table 2: Nematode numbers from yam tubers (100 g peel) at harvest and in storage from untreated plots (mean+s.e.).

Cropping System	At harvest	8 weeks after harvest	16 weeks after harvest	Rate of nematode increase (RF) Pf/Pi
TDr sole	4575 ± 45	13825 ±46	27455 ± 41	6.0
TDr + Cocoyam	175 ± 6	525 ±11	1053 ±12	6.0
TDr + Ginger	225 ±7	676 ±24	1284 ±14	5.7
TDr + Maize	375 ±9	1120 ±22	2180 ±29	5.8
TDa sole	5225 ±20	7652 ±41	15174 ±15	6.0
TDa + Cocoyam	181 ±8	466 ±5	937 ±3	3.2
TDa Ginger	219 ±14	609 ±8	1324 ±14	4.0
TDa + Maize	499 ±14	1050 ±4	2006 ±6	5.2
TDe sole	2852 ±38	8549 ±2	16994 ±4	6.1
TDe + Cocoyam	127 ±6	384 ±3	770 t36	6.0
TDe + Ginger	211 ±9	643 ±2	1266 ±44	6.0
TDe + Maize	302 ±4	906 ±5	1803 ±15	6.0
TDc sole	2534 ±25	15605 ±86	31347 ±34	12.4
TDc + Cocoyam	156 ±0	555 ±13	1084 ± 6	6.0
TDc + Ginger	223 ±15	667 ±0	1307 ±5	7.0
TDc + Maize	350 ±14	1491 ±30	2904 ±10	8.3

Values are means of four replicates. Within experiments means of the same figure in vertical columns are not significantly different. RF = Reproductive Factor, Pf = nematode population density at sampling date,
Pi = initial nematode population density #/100g peel
TDr = Tropical *Dioscorea rotundata* TDe = Tropical *Dioscorea esculenta*
TDa = Tropical *Dioscorea alata* TDc = Tropical *Dioscorea cayenensis*

basis, postharvest losses account for about 26% of world yam production (Anon 1974). Most of the yam decay in storage in Nigeria is a disease complex initiated by nematodes and aggravated by fungi and bacteria (Odihirin 1977) which are, in effect, secondary invaders. He pointed out that in the absence of nematode infection or harvest wounds on yam tubers, fungi are incapable of causing infection. Nematodes, therefore, in addition to their own direct effects, predispose the tubers to secondary invaders, which contribute immensely to the heavy storage losses. The possibility exists to exploit allelochemicals for yam nematode control, either by rotation or intercropping.

References

Adesiyan S.O. 1976. Host range studies of the yam nematode, *Scutellonema bradys*. *Nematropica*, 6(2): 60–63.

Adesiyan S.O., Odhirin R.A. and Adeniji M.O. 1975. Economic losses caused by yam nematode, *S. bradys* in Nigeria. *Plant Dis. Reptr*. 59(6): 477–480.

Anonymous 1974. Production Yearbook, FAO, Rome, Italy. Vol. 28 (1): 70pp

Augustus M. and Jeffrey C.P. 1998. Plant parasitic nematodes associated with soils, intercrops and tubers of yam in Ghana. Pages 639−644 *In*: Seventh International Symposium, ISTRC-AB, Cotonou, Bénin, 11–17th October, 1998. Edited Akoroda, MO and Ngeve, JM. Polygraphics Venture, Ibadan.

Bolton C., De Waele D. and Basson S. 1990. Comparisons of two methods for extracting *Ditylenchus destructor* from hulls and seeds of groundnut. *Revue de Nematologie* 13: 233–235.

Bridge J. 1972. Nematode problems with yams *Disocorea* spp. in Nigeria. PANS 18 (1): 89–91.

Cadet P. and Daly P 1996. Use of nematicides to produce yam planting material free of *Scutellonema bradys* in Martinique. Crop Protection.15(2): 187–195.

Kwoseh C., Plowright R.A., Stanfield J. and Asiedu R. 1998. Culturing *Scutellonema bradys* on yam tuber slices. Pages 575−576. *In*: Seventh International Symposium, ISTRC-AB, Cotonou, Bénin, 11–17th October, 1998. Edited Akoroda, MO and Ngeve, JM. Polygraphics Venture, Ibadan.

Odhirin R.A. 1977. The role of plant-parasitic nematodes in storage, and mobilization of some tubers and grains in drought situations. Paper presented at the Conference on the Aftermath of Drought in Nigeria. Baguada Lake Hotel, Kano. 18–20th April, 1977.

Steiner G. and LeHew R.R. 1933. *Hoplolaimus bradys* sp. (Tylenchidae: Nematodes) the cause of a disease of yam (*Dioscorea* sp.). Zoological Anza. 101 (9–10): 260–264.

A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 30-37

Allelopathic potential of plant extracts against *Scutellonema bradys*

J.I. Oluwatayo[1], R. Asiedu[2] and S.O. Adesiyan[3]

[1]Department of Crop and Environmental Protection, University of Agriculture, Makurdi, Nigeria;
[2]International Institute of Tropical Agriculture, Ibadan, Nigeria;
[3]Department of Crop Protection & Environmental Biology, University of Ibadan, Ibadan, Nigeria

Corresponding Author: J.I. Oluwatayo
Email: iyeh2010@Yahoo.com

Manuscript received: 06/12/2010; accepted:15/02/2011

Abstract

Experiments were carried out in the laboratory of the International Institute of Tropical Agriculture (IITA) and the Department of Agriculture, University of Reading, UK, to investigate the toxicity of some plant materials against *S.bradys*. Laboratory investigations confirmed extracts of neem, cocoyam, ginger and maize to be effective against the yam nematode and as contact nematicides since their extracts killed the nematodes within two weeks. However, the percentage mortality was directly correlated with concentrations of the extracts and exposure time. Phytochemical screening of dried neem fruit, maize root, ginger root, and cocoyam corm powder for their chemical composition revealed the presence of oils, alkaloids, saponins, and flavonoids which may be responsible for the non-host status.

Keywords: Toxicity, extracts, mortality

Introduction

The yam nematode*, Scutellonema bradys* (Fig. 1) is a migratory endoparasite present in soils, roots, and tubers. It is the cause of a decay of tubers known as "dry rot disease" (Fig. 2) and constitutes one of the most difficult pest problems encountered in the economic production of the yam crop (Obigbesan and Adesiyan 1981). Sizeable populations of the nematode can be found in soil at the beginning of the yam growing season (Adesiyan and Badra 1982).

Yams are propagated from whole tubers or pieces of tubers which are the principal means of dissemination of *S. bradys*. Comparatively low populations of the nematode (less than 20 tubers) do not produce external symptoms of damage (Bridge 1973) and thus the risk of dissemination through tubers is greater.

The objectives of the research were: to evaluate the toxicity of crude plant extracts on the yam nematode, and determine the chemical constituents of the plant(s) that significantly suppress nematode multiplication.

Materials and methods

Neem fruits lying on the ground around the trees were collected and left to dry in the sun. The dried fruits were stored in jute sacks and later pounded carefully in a mortar into a coarse powder. Granule size of the milling was 2.36 sieve aperture. Roots of maize (TZSR-W-1) and ginger (UG1) and corms of cocoyam (Tania) were rinsed in water to remove soil. They were chopped into pieces, completely air-dried and then pounded into fine powder using a hand mill. The mesh size of sieve was 500µm (Tyler equivalent 32 mesh). A different size was used from that used for the neem fruit powder because of the difference in particle size.

To detect the best medium of extraction, ethanol and distilled water were used as follows: Ten grams of neem, ginger, cocoyam, and maize root powders were weighed into heating bottles and 100 m1 of distilled water was added to each. The bottles were then heated over a water bath for an hour, allowed to cool, and the extract was sieved through Whatman No. 1 filter paper in a funnel. The same procedure was repeated using 95% ethanol. The filtrate obtained (Plate l A) was taken to be the stock solution (100,000 ppm). Serial dilutions were prepared to obtain graded extracts of 75,000 ppm, 50,000 ppm and 25,000 ppm from the 100,000 - ppm (stock) solution. Distilled water (0 ppm) was used as the control. The effects of the extracts from neem, ginger, cocoyam and maize

roots on S. *bradys* were tested in the Germplasm Health laboratory of the International Institute of Tropical Agriculture (IITA), Ibadan. Aliquots of 1ml of nematode suspension containing 20 male and female adults of *S. bradys* were dispensed into each of the 136 transparent Syracuse dishes set up for the study. A magnetic stirrer was used to ensure that every 1 ml of the aliquot contained approximately the same number of S. *bradys*. Aliquots of 1 ml, each of ethanol and water extracts (100,000 ppm, 75,000 ppm, 50,000 ppm and 25,000 ppm) and distilled water (control) were dispensed unto the 1 ml nematode suspensions in the Syracuse dishes.

The addition of 1 ml nematode suspension and 1 ml extract (treatment) in the Syracuse dishes brought the effective concentration of ethanol and water extracts to 50,000 ppm, 37,500 ppm, 25,000 ppm and 12,500 ppm. The treatments including control were left in the laboratory at room temperature (Plate l B). The Syracuse dishes were covered with glass lids to prevent evaporation. The nematodes that formed a C-shape and did not move when touched with a needle were considered dead. These were counted and picked out of the extract every 24 hr for 14 days. There were 40 treatments in all (five concentrations by four extracts by two solvents). The experiment was replicated four times, providing 160 observations. As the experiment progressed, the Syracuse dishes containing the ethanolic extracts became so turbid and greasy that it become impossible to see through the dishes and count. As a result, the experiment involving the ethanolic extracts was terminated at this point and proceeded with only aqueous extracts.

The plant materials were sun-dried and made into powder as earlier described. They were screened for their chemical composition in the laboratory at the Department of Agriculture, University of Reading, UK, using the method of Harbone, 1973. The methodology varied slightly depending on the phytochemical that was been screened.

A test for oil was achieved using the grease spot test. A dilute ether solution for each crop was made by mixing 0.5 g of each of the powders with 10-m1 ether. One drop of the solution was placed on a clean sheet of paper and allowed to dry. Observations were made for translucent spots that confirm the presence of oil.

To test for alkaloids, approximately 0.5 g of each of the powdered materials was warmed (60 °C) with 10 ml of 20% $HZSO_4$ on a Bunsen burner for 2 min and filtered. One ml portion of each was treated with a few drops of Dragendroff's reagent. Orange-red precipitate indicated the presence of alkaloids. As a confirmatory test, Thin Layer Chromatography (TLC) plates were spotted with the various plant extracts and sprayed with Dragendorff's reagent. Orange-red colour on the spots indicated the presence of alkaloids

In the test for saponins, approximately 0.5 g of each of the powdered materials was shaken with 5 ml of distilled water and heated to boiling point. Frothing indicated the presence of saponins. As a confirmatory test, the filtrates were added to 3 ml of arachis oil and thoroughly shaken to form a stable emulsion. This was left to stand for about 5 min. The presence of a stable emulsion indicated the presence of saponins.

In the test for tannins, approximately 0.5 g of each of the powdered materials was mixed with water and heated on a water bath. The mixture was filtered and ferric chloride reagent was added to the filtrate. A dark blue or dark green solution indicated the presence of tannins.

To test for flavonoids, one milliliter of each of the aqueous extracts was dissolved in dilute sodium hydroxide solution. A yellow solution that became colorless on the addition of hydrochloric acid confirmed the presence of flavonoids. Only these few phytochemicals were tested because equipments and reagents were not available.

A toxicity evaluation study of the plant materials on *S. bradys* was carried out by introducing plant crude extracts into aliquots of nematode suspension and observing the possible influence of allelochemicals, as already described.

Data obtained were analyzed using Generalized Linear Model, Mixed Model Procedures and Repeated Measures Analysis.

Plate 1A and 1B: Aqueous and Ethanolic plant extracts (A) and Arranged Synercus dishes containing extracts and nematode aliquots (B).

Results and Discussion

The mortality rate of *S. bradys* in crude plant extracts varied at the different levels of concentration in all the test plants (Figs. 3-6). The mortality of *S: bradys* in extract from neem was greater (P=0.05) than from cocoyam, ginger, maize, or the water control (Figs. 3-6). Extracts from cocoyam and ginger induced

more mortality than maize, but the difference was not significant. At 50,000 ppm concentration of the extracts in less than 7 days, there was total mortality of the nematodes by all the plant extracts, indicating maximum inhibitory properties.

The result of the effects of neem fruit extract on *S. bradys* is shown in Fig. 3. Neem extract at all concentrations used was lethal to the nematodes. There was a general increase in percentage nematode mortality with the increase in extract concentration. There was a maximum percentage mortality of 100% by 3 days after inoculation. However, the number of nematodes killed at specified time was directly correlated with the concentration of the extract. The control (zero concentration extract of distilled water) had the significantly lowest percentage of dead nematodes (< 10% after 7 days) throughout the experiment. Mortality rate was recorded throughout the period.

The result of the effects of cocoyam extract on *S. bradys is* shown in Fig. 4. In a pattern similar to the effect of neem extract, there was a general increase in percentage nematode mortality at all the concentrations of extracts tested on *S. bradys,* with an increase in days after inoculation. At 10 days after the introduction of the extract, 100% mortality was observed in all the concentrations. However, at a zero extract concentration (distilled water) the nematode mortality recorded was about 12%. The nematode mortality rate was directly correlated with the concentration of the extract. The cocoyam extracts had complete suppression on nematode survival as 100% mortality was recorded at the end of the experiment.
The result of the effects of ginger extract on *S. bradys* is shown in Fig. 5. There was a general increase in percentage nematode mortality with the increase in extract concentration with a maximum percentage mortality of 100% at 4 days and 10 days after inoculation for the maximum and minimum extract concentrations of 50,000 and 12,500 respectively. The least mortality was recorded with extract concentration of zero (distilled water).

The result of the effects of maize root extract on the yam nematode is shown in fig. 6. The results follow the same trend as for neem, cocoyam, and ginger. Maize root extract suppressed the nematode completely as 100% mortality was recorded by day 14. Maize root extract at the lowest concentration of 12,500 ppm significantly increased the mortality of *S. bradys* compared with the control. However, mortality of between 20 and 25% was recorded with the zero concentration (distilled water).

The results obtained from screening plant materials for chemical composition are shown in Table 1. The results revealed that all the plant materials tested contained some alkaloids, as they reacted positively to Dragendorff's reagent. The specific alkaloids and their levels were not determined. Results also showed the presence of oil in all plant parts examined except maize roots. Again, the type and quality of the oil was not determined due to limitations in experimental equipment. Results showed high saponin contents in all the samples, except maize root extract. Of all materials tested, only maize root extract tested positive for flavonoids. The results of studies on the toxicity of extracts showed that there was a general increase in the percentage number of nematodes killed with increases in extract concentration. There was 100% mortality of *S. bradys* in aqueous extracts of powdered dry neem fruit at 7 days exposure time, at 10days for cocoyam corms and ginger roots, and at 13days for maize roots. Percentage mortality was directly correlated with concentrations of the extracts. At zero concentration level, there was no significant mortality rate. In this study the increased concentration of extracts had a significant faster nematode mortality rate with increased exposure time, in all the extracts. There was nematode sensitivity to extracts and neem fruit powder was the most toxic, recording the highest nematode mortality in a few days. The results showed that all the plant materials eyaluated were effective against *S. bradys*. These results corroborate earlier studies using neem and plant extracts against other nematodes. Neem fruit extract was effective against *M. javanica* under laboratory conditions (Paruthi et al 1997*)*. Preliminary *in vitro* screening of *Jawan,* a water-based formulation of neem seed extract, against populations of *Pratylenchus loosi, Radopholus similis* and *Rotylenchus reniformis* maintained in petri plates was found to be very promising, as one drop of the compound diluted 10- and 20- fold brought about 100% mortality in *2*-3 days (Gnanaprasam et al 1993).

In a laboratory screening of some oil cake extracts, it was observed that neem oil cakes at 100 ppm or 1000 ppm stock solutions made by soaking 10 g in 100 m1 water for 48hr, were effective against *Pratylenchus thornei* and gave 70-100% nematode mortality (Sebastian and Gupta 1997). Oils with nematicidal activity also immobilized more than 80% of juveniles of the root-knot nematode *Meloidogyne javanica* and

inhibited hatching at a concentration of 1,000 µ/liter (Oka et al 2000). Leaf extracts of neem, datura (*Datura var. alba* [D. mete I]) and calotropis (*Calotropis procera*) were found to be toxic to *Helicotylenchus dihystera*. The toxicity of extracts increased with an increase in their concentration as well as in the exposure time. An increase in the growth of tomato plants was found to be associated with the increasing concentration of extracts and subsequent decrease in the nematode population (Firoza and Maqbool 1996). There has not been any work in nematode control using any cocoyam, ginger, and maize extracts. However, ginger extract has been used widely in the control of plant and animal diseases, especially bacterial diseases of plants (Mar-Mar-Nyein et al 1996). Cocoyam has already been identified to contain phenolic compounds (Uhazurike and Arinze 1996) and maize to contain soluble auxin oxidases (Beffa et al 1990) and phenyl acetic acid (Anaya et al 1995). Basic phytochemical screening consists of performing simple chemical tests to detect the presence of alkaloids, tannins, saponins, anthraquinones, cardenolides, etc., in plant extracts. Confirmatory tests were, always carried out to eliminate errors from false positive reactions (Harborne 1973). *In vitro* investigation of resistant factors in neem fruit, cocoyam corm, ginger root and maize root showed that these plant materials contain alkaloids, saponins, oils, and flavonoids which may be responsible for their resistant status. The presence of alkaloids and essential oils in the extracts could therefore be said to have inhibited activities in the biosynthesis of proteins in the yam nematode. Higher concentrations of organic oils of neem and castor (*Ricinus communis*) proved effective in preventing larval penetration and gall production in the roots of tomato infected by *M. incognita* (Poornima and Vadivelu 1997). This present study showed that the extracts possibly contain some allelochemicals that may be responsible for the observed lethal effects on *S. bradys*. Nematode populations around the roots of resistant plants, sometimes decline at a more rapid rate than can be explained by starvation, and it is presumed that toxins of plant origin are responsible (Rice 1984). For example α-Terthienyl compounds isolated from some species of marigold and a glycoside from asparagus were identified as the toxic factors. The direct toxicity of neem fruit has been attributed to some of the chemicals extracted from it, such as nimbin, salannin, thronemone, aza, and nimbidine (Devakumar et al 1986) which are nematicidal. An inhibitory allelopathic potential is exerted by corn and other cereals (Shukla et al 1997). They screened oil seeds, especially maize, for natural antioxidants and observed flavonoids, tannis, alkaloids, and oil among others present. Uhazurike and Arinze (1996) identified phenolic compounds in cocoyam and phenolic compounds are supposed to be alkaloids or secondary metabolites. They observed high inhibitory activity and phenol peroxidase activities in cocoyam. The results of our study showed that cocoyam, ginger, and maize contain inhibitory properties that can reduce S. *bradys* population in the soil.

Conclusion

The tests carried out here were general (preliminary) and hence, further tests are required for specifics (types) of the various phytochemicals. In the laboratory, extracts from neem fruit, cocoyam, ginger and maize at 50,000, 37,500, 25,000 and 12,500 ppm caused 100% mortality of *S. bradys*. The level of performance of the extract was proportional to the concentration. Water was a better medium than alcohol for the extraction, because of reaction between alcohol and the oil contained in the plants which made it impossible to view the contents of the Synercuse dishes. Preliminary phytochemical screening of neem fruit powder, cocoyam corm, ginger root and maize root indicated the presence of alkaloids, oils, saponins, and flavonoids, and these are supposed allelochemicals. Based on results, we hypothesize that incorporating allelopathy into agricultural management will reduce the use of pesticides.

Table 1: Inference from preliminary phytochemical screening of extracts from plant materials

	Neem fruit	Ginger roots	Cocoyam corms	Maize roots
Alkaloids	+	+	+	+
Oil	+	+	+	_
Saponins	+	+	+	_
Tannins	_	_	_	_
Flavonoids	_	_	_	+

+ Present − absent

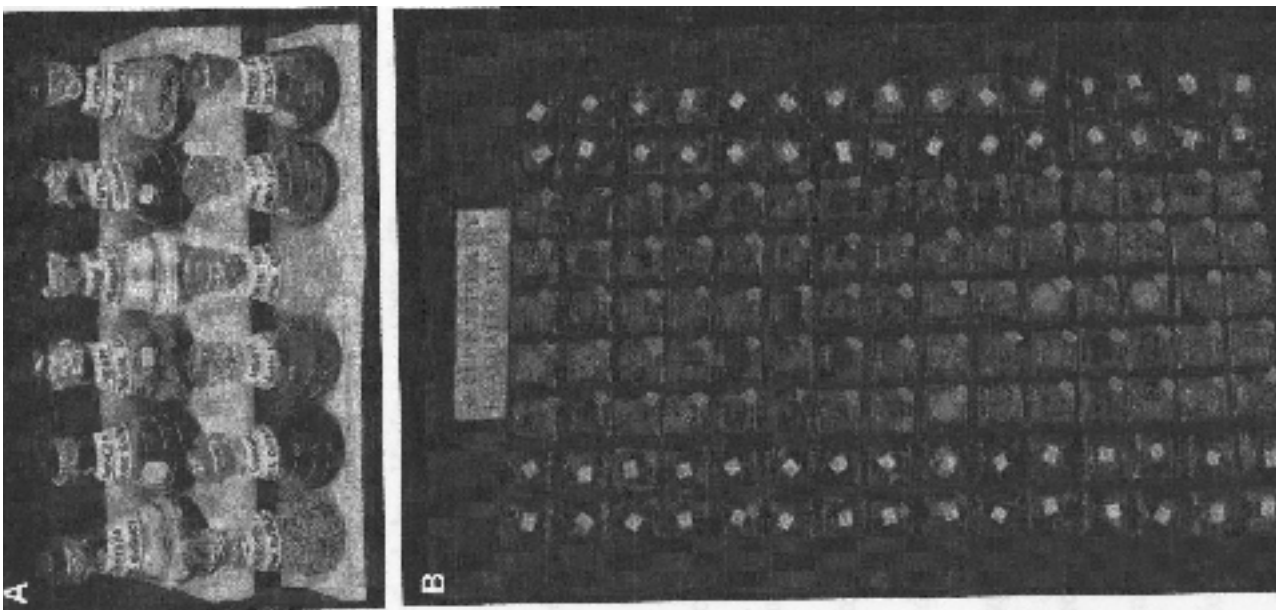

Plate 1A and 1B: Aqueous and Ethanolic (A) and Arranged Synercus dishes containing extracts and nematode aliquots (B)

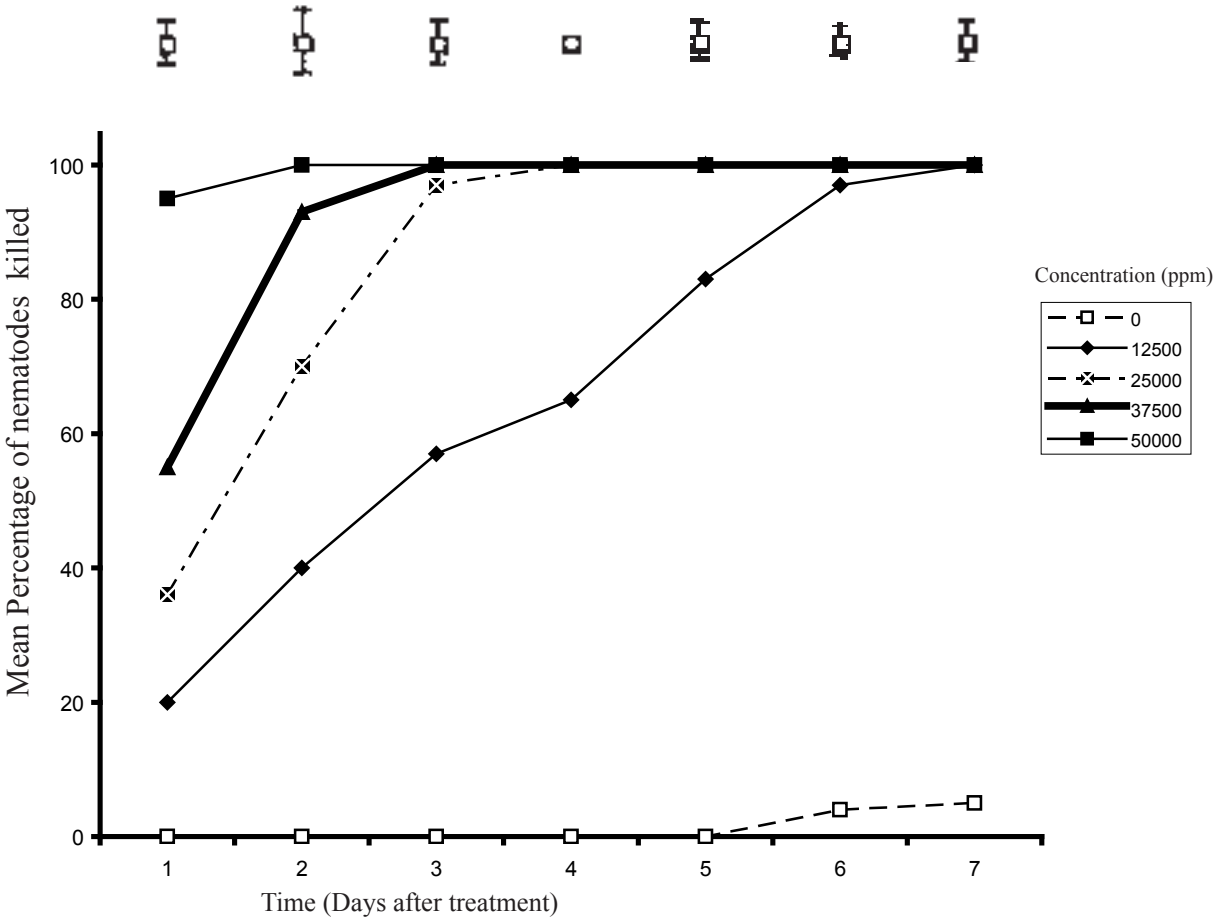

Fig 3. Percentage of *Scutellonem bradys* adults killed by specified number of days at different concentrations of aqueaous neem extract

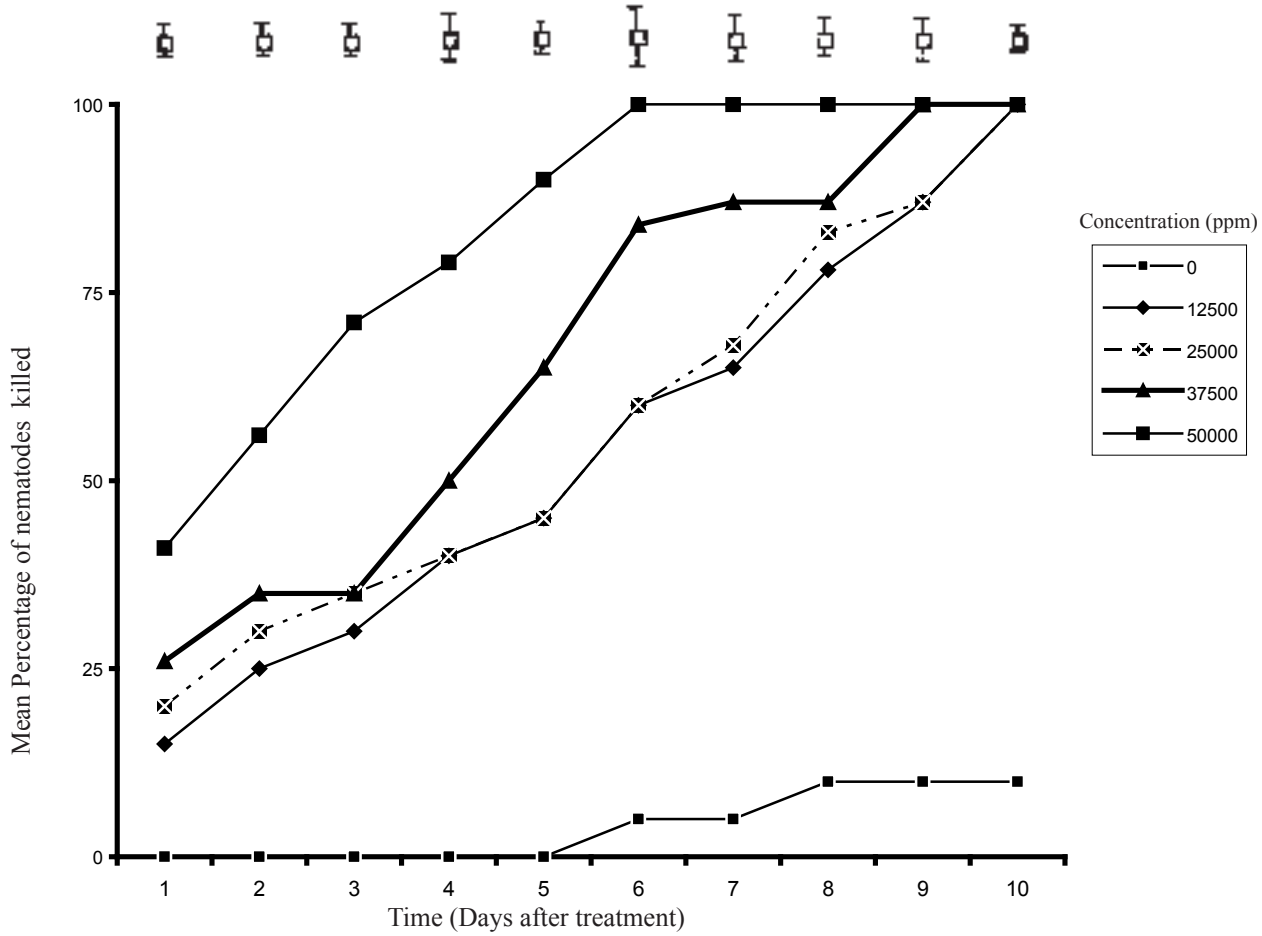

Fig 4. Percentage of Scutellonem bradys adults killed by specified number of days at different concentrations of aqueaous cocoyam extract

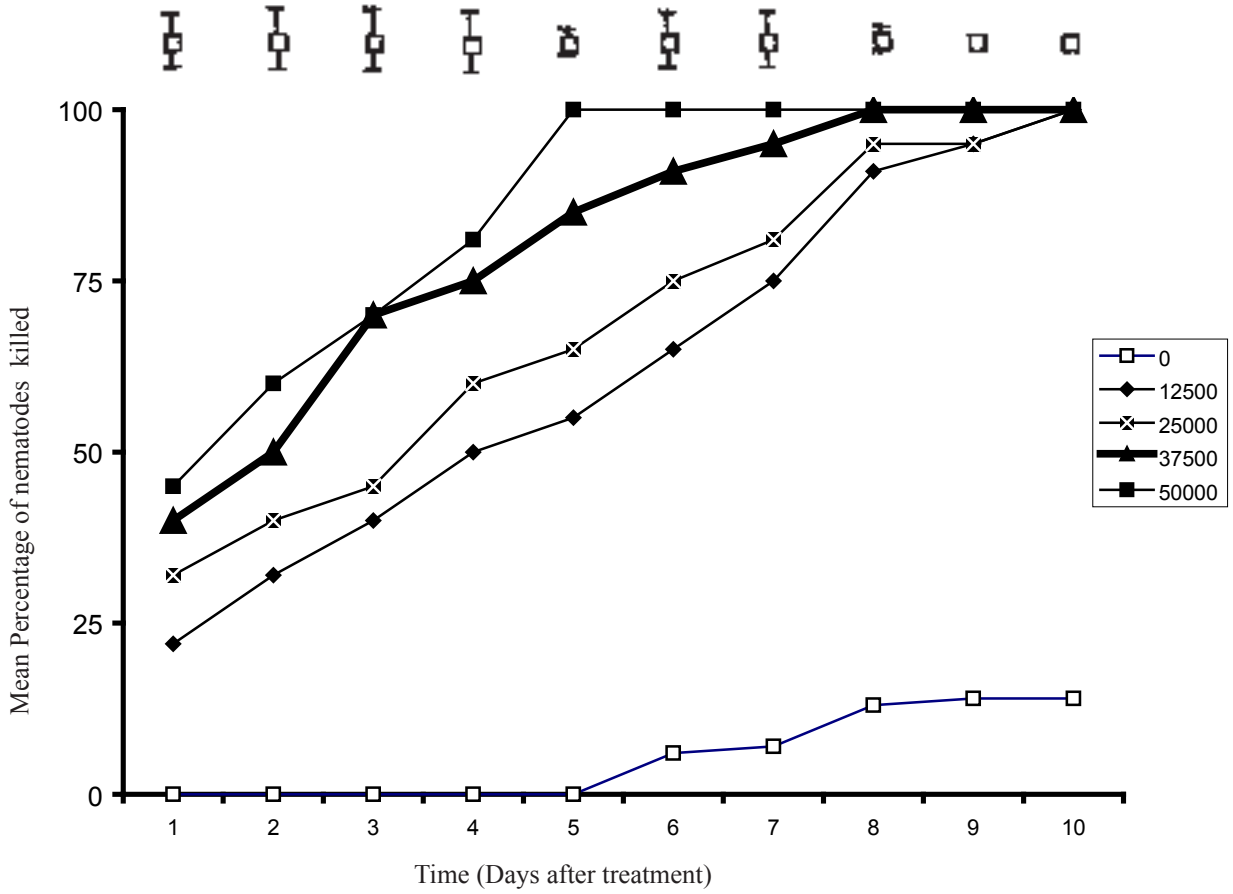

Fig 5. Percentage of Scutellonem bradys adults killed by specified number of days at different concentrations of aqueaous ginger extract

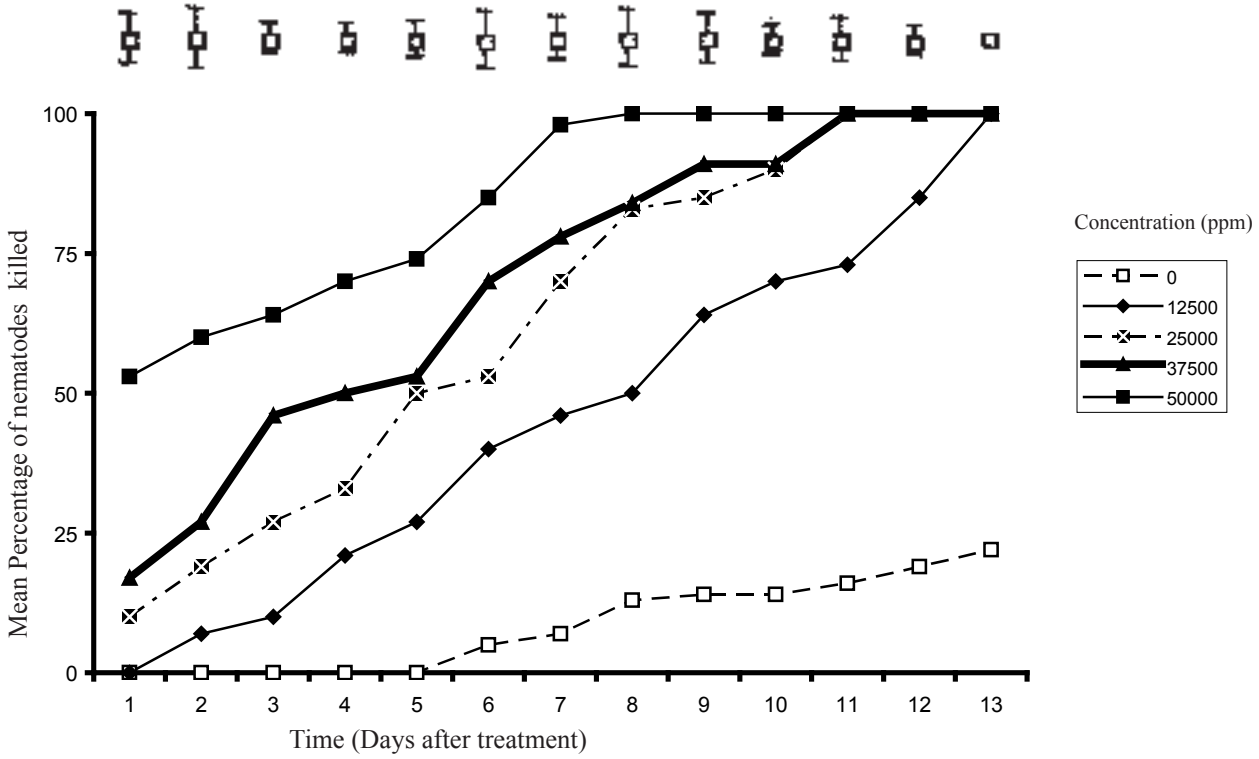

Figure 6. Percentage of Scutellonem bradys adults killed by specified number of days at different concentrations of aqueaous maize root extract

References

Adesiyan S.O. and Badra T. 1982. Granular nematicides for control of yam nematodes, S*cutelloneam bradys* and relevant residues in raw tubers. *Journal of Nematology*, 14: 213–216 pp.

Anaya A.L., Hernandez-Bautista B.E., Paleyo-Benavides H.R., Calera M., Fernandez-Luisell E., Inderjit (ed.); Dashin, K.M.M. (ed); and Einhellig, F.A. 1995. *Allelopathy* in Mexican plants more recent studies. Pp 224−241 *In*: Allelopathy: Organisms, processes and Applications. ACs symposium series 582.

Beffa R., Martin H.V. and Pilet P.E. 1990. *In vitro* oxidation of indoleacetic acid by soluble auxin-oxidases and peroxidases from maize roots. Plant Physiology. 94:2 485−491.

Bridge J. 1973. Nematodes as pests of yams in Nigeria. Mededelingen Facultiet Landbouwwetens Chappen Gent., 38: 841−852.

Devakumar C., Mukherji S.K. and Goswami B.K. 1986. Chemistry and nematicidal activity of neem (*Azadiracta indica*) constituent. National Symposium on Insecticidal plant and control of Environmental Pollution, (Bharatidasan University, Tiruchirapali, India), Abstr. P. 18.

Firoza K. and Maqbool M.A. 1996. Effect of plant extracts in the control of *Helicotylenchus dihystera* (Cobb, 1983) Sher, 1961. *Pakistan Journal of Nematology* 14:(1) 61−66.

Gnanaprasam N.C., Mohotti M., Sureshkumar B. and Udamulla G.P. 1993. Effect of *Jawan* a neem-based natural pesticide in controlling nematode pests of tea. Sri-Lanka Journal of Tea Science 62:(2) 47−52.

Harbone J.B. 1973. Phytochemical Methods: A guide to Modern Techniques of Plant Analysis. Chapman & Hall, London, 279pp.

Mar-Mar-Nyein, Win-Myint, Mu-Mu-Sein-Myint, Mya-Bwin and Tin-aye. 1996. Antibacterial properties of essential oils from six medicinal plants. MyanmarHealth-Sciences-Research Journal. 8:2 62−65.

Obigbesan G.O. and Adesiyan S.O. 1981. The influence of fertilizer nutrients on population levels

of *Scutellonema bradys* in three yam species. *Nematologia Mediterranea* 9: 21−28.

Oka Y., Nacar S., Putievsky E., Ravid, U; Yaniv Z. and Spiegel Y. 2000. Nematicidal activity of essential oils and their components against the root-knot nematode. Phytopathology 90: 710−715.

Paruthi I.J., Puna A. and Banerjee M.K. 1997. *In-vitro* evaluation of some neem pesticides against root-knot nematode, *Meloidogyne javanica*. Annals of Agricultural Biology Research. 2(21):137–139; ref.

Poornima K. and Vadirelu S. 1997. Effect of some organic oils and their cakes on the infectivity of root-knot nematode. *Meloidogyne incognita* affecting tomato. *Indian Journal of Nematology* 27(1) 70−73.
Rice, E.L. 1984. Allelopathy. 2nd Edition. Academic Press, New York, 422 pp.

Sebastian S and Gupta P. 1997. Laboratory screening of some nematicidal and oil-cake extracts against *Pratylenchus thornei*. Indian Journal of Nematology. 27(1)133−134.
Shukla V.K.S., Wanasundara P.K. J.P.D. and Shahidi F. 1997. Natural antioxidants from soil seeds. Natural-antioxidants; Pages 97 – 132 *In*: Chemistry-health-effects-and-applications. AOCS Press, Champaign, USA.

Tran D.X., Tsuzuki E., Terao H. Matsuo M., Trans D.K. and Ill-Min C. 2004. Evaluation on phytotoxicity of neem (*Azadirachta indica*. A. Juss) to crops and weeds. Crop Protection 23: 335–345pp.

Uhazurike N.C. and Arinze A.E. 1996. Changes in phenol oxidase and peroxidase levels in cocoyam tubers of different postharvest ages infected by *Sclerotium rolfsii* sacc. *Nahrung* 40(1): 25–27.

A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 38-49

Expanding the application of cassava value chain technologies through UPoCA project

B. D. James[1], P. Bramel[2], E. Witte[3], R. Asiedu[2], D. Watson[2], and R. Okechukwu[2]

[1]International Institute of Tropical Agriculture, Freetown, Sierra Leone
[2]International Institute of Tropical Agriculture, Ibadan, Nigeria
[3]United States Agency for International Development, Washington, USA

Corresponding Author: B.D. James
Email: b.james@cgiar.org

Manuscript received: 06/12/2010; accepted: 15/02/2011

Abstract

Cassava has long been expected to play a key role in rural economic growth in Africa, but are we there yet? Although research partnerships have produced elite cassava varieties with 50% more yielding potential and demonstrated technologies to boost processing and marketing of cassava, the sub-sector is constrained by low productivity and marketing difficulties. In DR Congo, Ghana, Malawi and Sierra Leone, for example, cassava value chain actors are yet to respond to 2007 estimated $59 million trade opportunities through substitution of imported wheat flour with locally produced high quality cassava flour. Industrial pull for cassava would also aggravate hunger and poverty if yields do not increase from current national averages of 5 to 19t/ha to more than 25t/ha expected of released varieties under low input agriculture. In 2008, USAID and IITA initiated the project "Unleashing the Power of Cassava in Response to Food Price Crisis (UPOCA) as a multi-country and inter-institutional partnership enabling cassava sub-sectors to realize their full potential in rural economies. UPoCA project covers DR Congo, Ghana, Malawi, Mozambique, Nigeria, Sierra Leone, and Tanzania. UPoCA project draws on prior research results to increase on-farm cassava productivity and value adding processing for markets. By end 2009, small holder beneficiaries associated with 55 partner organizations and 11 agricultural related firms established 306 community cassava stem multiplication sites and root production farms totalling 10,097ha with 58 improved varieties. Through experiential learning at 24 hands-on short-term courses, 345 men and 142 women learnt improved techniques in cassava production, processing, product development, and packaging/labelling and 8 technologies were introduced to rural communities. Seven other papers in this symposium, based on these evolving UPoCA achievements, show that a longer-term cassava research for development partnership platform of this nature will enable cassava sub-sectors to contribute significantly to rural economic growth in Africa.

Key words: Cassava, UPoCA, productivity, value addition, income

Introduction

Cassava has long been recognized as a staple food crop with potentials as a raw material base for a wide range of processed products. Over the past three decades, cassava development research by IITA and its partners in Sub-Sahara Africa (SSA) has significantly enhanced these features in the crop. In the mid-1990s, IITA and partners focused on cassava crop improvement research for development activities within her component research programs and two sub-regional networks: EARRNET in East Africa and SARRNET in Southern Africa. Through a combination of conventional and new approaches, the partnership has developed improved cassava varieties which combine multiple pest/disease resistance with superior postharvest qualities, and improve the yield potential in many locations (Okechukwu and Dixon 2008). At least 165 improved varieties have been released in 26 countries (Dixon et al 2010). The availability of these elite cassava varieties with 50% more yielding potential reflects the vision of an expanded future role of cassava in food, feed, and industrial applications. However, the cassava sector in SSA has been and continues to be constrained by low on-farm productivity and marketing difficulties.

A vital step to increase on-farm yields/productivity, promote value addition targeting diverse markets in schemes to commercialize the crop enabling it to

contribute significantly to poverty reduction strategies Available research results suggest that generally a 1% increase in crop yield will reduce the number of people living under $1 by 2 million in SSA (Thirtle et al 2003). In the cassava sub-sector, persisting challenges to the realization of the food and market potential of the crop relate largely to lack of sustainable mechanisms for area-wide scaling-out of proven research results. Problems with distributing planting material of elite varieties mean that farmers continue to grow local, low yielding varieties. Smallholder farmers in Africa also lack access to knowledge and equipment which could add value to their harvests, and skills to use it. Small holder also lack access to diversified markets. To help address these productivity problems, IITA R4D partnerships have helped to enhanced cassava yield stability and productivity through an Africa-wide biological control program which halted and reversed devastating losses caused by alien invasive pest species (Neuenschwander, 2001;Yaninek et al 1993; Neuenschwander et al 2003).

In recent years, the challenges have addressed by multi-country projects which facilitate shifts from traditional processing techniques associated with low value and poor quality products towards beneficiary linkages for value added processing (Mahungu et al 2010; Sanni et al 2010). A number of such initiatives are triggered mainly by recent global food price crisis, and focus on using previously developed best-bet production, processing and marketing approaches and innovations to ensure sustainable cassava value chains and markets. For example, in 2008, USAID famine trust project "Unleashing the Power of Cassava in Response to Food Price Crisis (UPoCA) was initiated as a 2-year transitional multi-country set of activities for cassava sub-sectors to realize its potential in rural economies. USAID and IITA selected cassava as a commodity that can contribute decisively to on-going efforts to promote rural economic growth with spill over benefits to urban populations. The UPoCA project, implemented by IITA through a inter-institutional partnerships in DR Congo, Ghana, Malawi, Mozambique, Nigeria, Sierra Leone, and Tanzania and draws on prior research results to increase on-farm cassava productivity and value adding processing for markets.

The purpose of the 2-year (2009 and 2010) UPoCA project is to provide adequate supply of cassava products at economically affordable prices through availability of improved varieties, production and processing. To work towards achieving this purpose, UPoCA proposed to rapidly mass propagate improved and high yielding cassava varieties; promote farm gate and value adding processing of cassava for food and markets; train farmers in improved cassava production techniques. The expected impact from achievement of these objectives will be cassava yield increased by at least 30% more than baseline figures, reduced fluctuations in food availability and price through increased cassava productivity triggered by value adding and utilization at levels. This would lead to

a) enhanced household and national food security,

b) increased income,

c) improved wellbeing and nutrition for beneficiary populations.

This paper presents an overview of progress of the UPoCA project towards its purpose and is based on implementation experiences in the 7 project countries. Six other papers in this symposium, based on these evolving UPoCA achievements, elaborate on this overview to show that a longer-term cassava research for development partnership platform of this nature will enable cassava sub-sectors to contribute significantly to rural economic growth in Africa. The paper concludes by indicating emerging R4D areas needing attention to more effectively move success towards full achievement of the project's purpose.

Materials and methods

UPoCA project implementation strategy draws on prior cassava research results and experiences to promote end users' access to technical innovations developed elsewhere and increase the range and applicability of cassava technologies and practices. Based on these experiences, project implementation uses a programmatic approach in which activities are anchored firmly at community levels with direct action by key cassava value chain actors to impact on the communities.

At project inception, IITA initiated consultative discussions with key partners in each of the seven countries with the view to organize and hold national and regional project implementation planning workshops. At national consultative workshops IITA link scientists introduced the project to a wider range of stakeholder groups, participants discussed elements of the project and harmonized views on needs and drafted national work plans and budgets. By end of the series of national workshops, IITA identified

potential National Coordinators for recruitment, noted project implementation partners in the country and established the project management team.

The set of national consultative workshops culminated in a regional project planning workshop 19–21 January 2009, at IITA-Ibadan, Nigeria for joint implementation planning by 26 participants from IITA and various partner institutions in the 7 project countries. The specific workshop objectives were to enhance communication, understanding and commitment among project leaders in the search for common ground and harmonized views on problem and opportunity analysis; define more precisely project targets and performance indicators and related targets by which to measure project achievement; streamline national project work plans to reflect a common understanding of regional focus in project implementation. Workshop presentations and general deliberations took place in plenary sessions whilst details were fleshed out in smaller break out working groups. The views of beneficiary groups as captured at national consultative activities were provided in country reports presented at the regional workshop. Through a process of brainstorming, ranking of constraints and discussions the workshop specified priority issues and secured consensus on the three Immediate Results areas in the USAID/IEHA Results framework for the project.

In order to assure effective scaling out for greater impact within available resources, the project reviewed proposed plans on operational sites and use of households as the unit to track technology spread. In view of the discussions, the project reduced the number of administrative regions for field activities according to felt needs, e.g., from 10 to 6 States in Nigeria, 12 to 6 Districts in Sierra Leone, 8 to 4 districts in Malawi, 13 districts in 2 regions in Ghana. Also, in recognition that households differ in composition and size even within same localities; participants agreed that it will be most practical to track technology spread by individual farmers and processors. On vulnerability indices, participants agreed that the target beneficiaries to be listed would generally be poor small-holders and at least 35% of them would by default fall in one or more vulnerability classes.

Workshop participants identified the following scaling out approaches to tstrengthen community capacity and trigger positive changes in agricultural performance:

- Selecting operation sites based on a combination of criteria including a) prior cassava R4D; b) participation in the projects baseline surveys; c) partnership opportunities with other on-going funded activities by agricultural development agencies; d) probability of synergies in efforts with other agencies; e) beneficiary interest in cassava production and processing; f) existing cassava processing activities.

- Building end-user ownership of processes through beneficiary listing of direct beneficiary groups and individuals associated with partner stakeholders group with on-going investment in community outreach activities.

- Building cadres of national ToT expertise comprising change agents with primary responsibility to facilitate experiential/hands-on learning of technologies by beneficiaries mostly associated with project's partner organizations

- Area-wide dissemination of technologies with allied information resources for increased cassava productivity and value-added cassava processing

- Facilitating experiential/hands-on learning to increase informed decision making in cassava production and value added processing by direct beneficiaries

- Promoting interconnectivity between value chain actors, especially between producers and processors, in attempts to encourage the development of cassava enterprises

- Mass media communications to increase national and global visibility of cassava utilization pathways, the nature of constraints and "best-bet" available interventions.

Results

Project inception. Consultative planning workshops identified 9 major areas of constraints undermining cassava profitability in the countries. Participants proposed and agreed on interventions deserving project investment to address these problems (Table 1) and develop a detailed plan of operations to guide operations. The plan specified activities; performance indicators and related targets, resource allocation, timelines in implementations, and responsibilities of experts/agencies to be involved in the project implementation. Key actors on location-specific implementation activities included producer

groups with emphasis on women, the youth and other vulnerable groups), agro-processors/private sector, government and NGO agencies. Project management teams introduced the project to USAID missions and formally launched in the countries. In Ghana and Sierra Leone the launching ceremonies were hosted and chaired by representatives of the United States Embassies in the countries. Table 2 summarizes the achievements based on agreed target by indicators. By end of September 2010, the project scored well on 16 (72.7%) out of 22 indicator targets agreed upon during regional implementation workshop. The following results expand on achievements made in key activities.

Expanded on-farm productivity. To boost on-farm productivity, 58 elite varieties were planted by small holder farmers associated with 55 partner organizations and 11 agricultural related firms. The partners established 380 community cassava stem multiplication fields on 643ha and planted 11,540ha cassava farms. GIS projections, based on passive spread at 5km per year from each of the introductions sites, indicate that these varieties will spread to populations within buffer zones of 79,500 km^2 and 107,500 km^2 in 2010 and 2011 respectively. Following training on competitive cassava production techniques in Sierra Leone, the resource persons and participants used the training experience to develop a user-friendly yield assessment methodology for use by project partners to measure yield in their farms. In addition to measuring root yields, the methodology allows for estimation of plant population (for use in advising farmers on appropriate plant spacing required for higher yields) and root rot incidence (to advice on researchable areas to promote sustainability of yields. The UPoCA yield data collection protocol is being used to estimate root yields by the project trained field agents and farmers. By end 2010:

- UPoCA-DRC collected yield parameters on 150 farms in seven territories and five provinces: Maluku (Kinshasa province), Bulungu and Idiofa (Bandundu), and Mbanza Ngungu and Seke Banza (Bas Congo province), Kisangani hinterland (Orientale province), and Ngandajika (Kasai Oriental province). One hundred thirty fields were investigated. The average age of the cassava farms were 12.1 months and 13.1 months for farms planted with improved varieties, and landraces respectively. The average number of tuberous root per plant in field totally planted with improved varieties was 4.4 roots/plant compared to 2.7 roots/plant in field planted totally with landraces (2.70 roots/plant). Average root yields were estimated at 18.9 t/ha planted with improved varieties only and 9.4 t/ha planted with landraces only. Root yields tended to be higher in the rain forest of Orientale,and Bas-Congo provinces.

- In Ghana, average yields for 5 varieties were 24.06 t/ha; 4.44 to 35.88 t/ha; 9.37 to 31.68t/ha; 3.07 to 57.5t/ha; and 6.5 to 33.25t/ha for varieties *Abasafitaa*, *Afisiafi*, *Bankyehemaa*, *Esambankye* and *Tekbankye* respectively.

- In Sierra Leone, yield data was collected from 240 farmers' fields in 12 districts. Farm age at harvest averaged 12months (range: 9 to 24 months); farm size averaged 1.2ha (range 0.1ha to 18.2ha); plant population averaged 13,157 stands per ha (range: 2,800 to 35, 60 plants). Root yield averaged 13.5 kg/ha and varied widely between 1kg to 36.6 kg/ha. Root rot incidence also varied widely from none to 25.4% roots lost to the disease. Highest root yields (>15 tons/ha) were forested districts.

Capacity devolution. UPoCA project introduced smallholder beneficiaries to the economic potential of the crop and to cassava crop management practices through training. The training curriculum was covered five integrated short-term courses. The course were a) principles and applications of Global Positioning Systems; b) techniques for profitable cassava production; c) processing cassava into food and industrial products; d) packaging and labeling cassava products for markets; e) planning and managing a small cassava processing enterprise. Forty (40) hands-on courses were delivered in the seven project countries. Through these courses, 915 men and 782 women learnt improved techniques and skills cassava production, pest management, processing, products development, quality compliance, packaging and labelling of products and business planning. Box 1 profiles an example of one of the courses delivered. Through these courses, the project introduced to rural communalities one biopesticide for control of the variegated grasshopper *Zonocerus grasshoppers*, 5 different low-cost cassava processing equipment (motorized graters, hydraulic press, hammer mill, mechanical sieves, gari roasting bays), one improved sun-drying shed and one steam dryer for drying cassava flours. This activity involved equipment upgrades, especially with stainless steel to replace mild steel in the cutting and grinding edges of graters and hammer mills.

Across the seven countries, beneficiaries groups leant how to produce a wide range of primary cassava products and their derivatives the majority of which were hitherto either known but crudely prepared or unknown in the target communities. These products included odorless fufu flour, high quality cassava flour (HQCF), gari, soya fortified gari, starch, tapioca granules, 10% to 20% HQCF composite bread, diverse cassava snacks (e.g.., chin-chin, cassava meat ball, cassava root fritters, cassava croquettes, cassava cocktail tidbits, doughnuts, cassava egg rolls, cassava cookies, cassava queen cakes, cassava strips and cassava meat pie.

To strengthen capacity of trained participants the project sourced and disseminated at least five (5) technical and training support materials. Additionally, the project collaborated with other cassava initiatives at IITA (e.g., CFC cassava project in Tanzania, USAID cassava projects in Nigeria) to co-produce and/or draft the following new learning materials to help improve skills of end-users:

- A cassava variety handbook' Improved cassava variety handbook' describing 59 improved cassava varieties being grown by farmers in Nigeria and some UPoCA countries.
- A cassava processor's guide book on quality management in the production of High Quality Cassava Flour
- Swahili translation of the IITA cassava recipe book. This will increase sub-regional visibility and effectiveness and impact of IITA.
- A manual for agribusiness training in Ghana,
- A manual on managing a small business by cassava processors in Nigeria

Box 1: Profile of ToT course delivery

Country: Sierra Leone
Course title: Cassava Processing and product development and utilization
Duration: The training was conducted from June 9 to 12, 2009.

Pre-course evaluation: About 15% of the participants had background in food related processing activities or certification. Most of them were unaware of new cassava products and approaches to add value to the existing traditional products, quality requirements from cassava products and processing machines, cassava products fortification for nutritive quality, and essential factors to be considered in product development.

Participants' expectations. Most participants expected to have skill gap analysis of what are the problems encountering in producing quality cassava products, what methods should they introduce to their beneficiaries to add value to cassava, what are new in equipment sourcing, operation and maintenance, how best can they embark on product development, can they actually produce high quality cassava products and infant foods.

Objectives. The course was conducted to enable UPoCA partner organizations (GOs and NGOs) in Sierra Leone to train, coach, and guide on post-harvest, processing, product development and machine specifications.

Synopsis. Resource persons were drawn from IITA-Nigeria, the University of Agriculture, Abeokuta, Nigeria and Njala University, Sierra Leone. The course covered cassava post-harvest (general remarks, storage Losses, key constraints, storage methods and management issues); cassava processing (uses of cassava, processing purpose, equipment, adding value and processing methods); cassava value chains (characteristics, benefits, marketing challenges); new products (market research, new food products, food preservation, grades and standards); cassava for nutrition (fortified products, quality assurance, food legislation); hands on practical (group level); interactions (group discussions, plenary discussions, experience sharing and course evaluation)

Learning methods. Resource persons employed participatory approaches for information sharing, video show, power point display, group interactions, practical demonstrations and observations during the workshop.

Achievements. Twenty (29) participants trained in trouble shooting & using 5 processing equipment to produce cassava products - Motorized cassava grater, screw press, motorized hammer mill, sieves, product drying platforms; processing of High Quality Cassava Flour (HQCF), Starch, Soya fortified gari and fermented fufu flour to ensure income generation, industrial applications and process improvement. During the 4-day training, participants were able to produce four primary products from cassava storage roots: High Quality Cassava Flour (HQCF); Soya-fortified gari; Fermented cassava flour (for instant fufu); High Quality Cassava Starch (participants made

Tapioca, a roasted wet cassava starch, from the high quality starch). Additionally, participants used IITA cassava recipes booklet to produce seven secondary products by fortifying HQCF with a range of locally available animal and plant protein sources. The food products developed from HQCF were Croquette (christened "CAFICO" by the participants); cocktail tidbits (christened "teeth-bites"); doughnuts; chin-Chin; complementary food (baby food); cassava fritters; cassava egg roll. No imported wheat flour was used in any of the products. The cassava food products stand to impact positively on household and national food security.

Post course evaluation. Participants were able to produce HQCF, Fufu, Starch and their derivatives. They also produced nutrient based cassava –soy products deriving joy in adding value to by products from cassava and soybean. In all, the groups performed excellently well in practical and have sense of fulfilling. From their post-workshop evaluation reports,

Support to enterprises. To support the institutional base of emerging cassava enterprises requesting advice for value added cassava processing, the project provided technical assistance and support to a number enterprises, projects and agencies in the countries, e.g.:

Linking farmers to processors. Famers were linked to markets to assure sustainable raw material supplies for processing in a number of cases. In Nigeria, for example, cassava growers in Niger State were linked by the project to a buyer Ekha Agro company. The agreement was brokered with the aim to ease the negative effect of cyclical glut and price fluctuations in cassava production chain. The MoU provides that the Niger State Cassava Growers Association will cultivate 5,000 hectares of cassava in 2009/2010 season using improved cassava planting varieties under technical supervision of UPoCA project in Nigeria. Ekha Agro guaranteed through a purchase order for 200 tons of fresh cassava roots per day for one year at the agreed farm gate price. In SierraLene, the Pujehun Growth Centre (Pujehun district) and Kpandebu Growth Centre (Kenema district) were linked to an initial set fi GIS verified 72.3ha and 94.6ha farms (including UPoCA farmers) respectively within 20km radius of the factories to assure sustainable raw material supply. The Pujehun growth centre was also linked to Union Trust Bank which provided a one year loan equivalent to $10,000 for the purchase of raw materials and packaging materials, and to "Home Food and Drinks Ltd" company as a primary market outlet for the cassava products or sale in the capital city Freetown. Also in Sierra Leone, UPoCA project linked Quifel Natural Resources (international agri-business firms initiating agri-business in the country) was assisted to analyze soil samples collected at sites the firm has leased to grow cassava on a commercial scale. The soils were very acidic with pH of 3.8 to 4.3 and natural fertility status at the site was very low with organic carbon content under 104%. Mineral fertilizer application at N: 125kg; P_20_5: 30 kg; K_2O: 150 kg per ha was recommended for the cassava farms. It was also recommended to use a Calcium Phosphate fertilizer to reduce soil acidity.

Linking fabricators to processors. A total of 12 equipment fabricators were linked to cassava processors in the seven countries. In DR Congo, the project linked selected processors to ACOMMERCONGO, AGRIMAC and BENIBOOD/FABRICATION, the 3 most important processing equipment fabricators in the country. In Nigeria, Memis construction Ltd, and Fataroy steel industry limited, were linked to processors in Oyo state, producer of gari. In Tanzania, Entremech engineering linked with the project to manufacture quality cassava processing machines, with technical backup form IITA Tanzania. Similarly in Sierra Leone, Ken Metal Works was trained jointly by the UPoCA and CFC projects in the country and linked to development agencies and processors for manufacture if quality graters, hydraulic presses and hammer mills.

Technical advice on management and technical issues. Technical advice was provided on management and technical issues in cassava processing. In Malawi, the assistance involved equipment upgrades and flour/starch drying facilities is assisting four (4) processing centres: Masimbe Investments (produces cassava starch), Mbwandimbwandi gardens (produces high quality cassava flour), Kasiya Maliro investments (high quality cassava flour) and Chisi Investments (high quality cassava flour). In Sierra Leone, for example, the project advised a World Bank supported Rural and Private Sector Development Project of Ministry and Agriculture, Forestry and Food Security/ Ministry of Trade and Industry on management and technical issues in cassava processing by FBOs at 32 processing sites that were being established. The technical advice covered a) type and capacity of equipment for the intended processing systems (e.g., root peelers, chippers, graters, presses, sieves, gari roasters, packaging materials and transport issues); b) standardized equipment list for processing cassava

into various products such as gari, starch and flour (this focused on functional linkages in equipment assembly for cassava products production; and c) appropriate designs for civil works structures housing facilities for cassava processing (this involved re-tooling existing buildings, appropriate factory design to house a multi-purpose cassava factories, factory hygiene and crop-livestock integration.

Quality management and compliance status. Quality management and compliance status was undertaken in Ghana, Mozambique and Tanzania to assess the quality and safety problems encountered in the countries. In Ghana, the project worked with Caltech Ventures Ltd. to improve quality management and compliance in cassava processing. In Tanzania and Mozambique, six and five rural-based small-scale processing enterprises were assessed respectively. The quality and safety challenges encountered at these sites were largely indicative of the general quality-related problems of cassava processing in Ghana. The principal problems related more to the adherence of good manufacturing and hygienic practices than to process control. The lapses in adherence to good manufacturing practices/GMP included the lack of adequate drainage systems and other facilities for handling waste; free flow of liquid waste into the bush; non-availability of hand washing facilities specifically designated for the purpose; absence of changing rooms for the production staff; staff not being compliant with the non-wearing of jewelries during processing operations; staff not wearing recommended protective clothing during processing; absence of hygiene rules for visitors; absence of adequate tools for cleaning and sanitation of the facilities; absence of written standard operating systems; absence of a specific responsible officer to be in charge of sanitation and hygiene or quality issues; and inadequate cleanliness of net screens, ceilings, and overhead fixtures in the processing halls. A major constraint to processing identified in Mozambique was lack of the processing machines in the local market for making high grade products. As a result, the processors used manual processing methods which result in low production capacity and low quality of products, especially gari and flour. Related to quality management was assistance to national standards bureaus, e.g., the project worked with Sierra Leone Standards Bureau (SLSB) to draft standards for the four products (*Tui* and fufu flour), gari, HQCF, and cassava chips) for consideration by the appropriate technical committee of SLSB.

Sale of cassava products. Market studies were limited to perception surveys on opportunities and constraints faced by cassava value chains actors namely, traders, consumers and agro processors for producing and marketing cassava in Mozambique and Sierra Leone. The preliminary data showed that concerted efforts to commercialize the products are rare in the countries. Market data collection guidelines developed by the project were yet to be effectively implemented in a way that would verifiable data in any of the seven countries.

Project visibility. Global visibility of the project was promoted through at least 39 web news (Box 2) backed by print articles, radio, TV broadcast, field days and dignitary activity site visits covering project activities across the countries. Initially, a 6-page illustrated flyer was developed to introduce the project to diverse audiences. The flyer titled "Combating the food crisis through science" traced the causes of food price crisis; introduced the response of USAID/ IITA partnership on cassava; explained the UPoCA implementation strategy; outlined the special benefits to be derived from the project; featured a cassava entrepreneur who typifies a range of capacity building challenges facing the development of cassava value chains at rural levels.

In Ghana, information on the rapid multiplication of cassava and product development and standard compliance were broadcasted on six radio stations and information centers in the project's implementing districts/municipalities. The radio stations and information centers were Nkwa FM, Assin North Municipality, Aboaso Information Center, Bekwai Municipality; Edwenase Information Center, Bekwai Municipality; Onyame Akwan Dooso Information Center, Adansi North District; Asomdwoe Information Center, Adansi North District; and Oheneba Information Center, Obuasi Municipality. In Sierra Leone, project beneficiaries and a few partners engaged in community radio broadcast on cassava through (daily) 15-30 minutes "Farmers' Talk" program of Cotton Tree News (CTN); http://www.cottontreenews.org/ CTN is funded by the European Union, Ireland and Germany and produced and broadcast by Fondation Hirondelle, Media for Peace and Dignity, in partnership with Fourah Bay College at the University of Sierra Leone and the United Nations Integrated Peacebuilding Office in Sierra Leone (UNIPSIL). CTN links with Star Radio in neighboring Liberia

In the last 2 quarters of the project UPoCA partners collaborated with IITA Regional Communications

Office to initiate a series of "UPoCA People" stories in flyer forms highlighting success, opportunities and challenges faced by project beneficiaries in the countries

Project visibility was further increased through at least 11 field days and dignitary site visits e.g. Regional Farmers' Day exhibition and in Ghana, WFP/FAO World Food Day Commemoration in Sierra Leone; cassava open days organized by the project beneficiary groups in DR Congo (e.g., GROPAM, FDM, CARITAS-Matadi, CRAFOD and PRODI), Nigeria (Ido LGA council of Oyo State), in Malawi (Press Agriculture's Estate 87; activity site visit to UPoCA Nigeria by Congresswoman Sheila Jackson Lee, member of the United States House of Representative, 18th District, Texas with officials from USAID Nigeria and of other USAID sponsored Project in the country; and by a joint team of JICA/Japan and Cameroon scientists planning for cassava commercialization and food security in Cameroon.

Discussion and conclusion

The historical view of cassava as "a poor man's crop" in SSA limits efforts to fully exploit the crop's commercial potential as a raw material in food, feed and industrial products. This view exists because poorer households are marginalized and often live in marginalized areas, the same areas where cassava can perform well within farmers' food security coping strategies. This affiliation suggests that development of market opportunities for cassava can improve food security and contribute substantially to poverty alleviation especially among resource constrained households. Ensuring food security and sustained productivity requires adequate technical and manpower resources on the ground to effectively trigger positive changes in the performance of agricultural sub-sectors. International networking and collaboration helps to enable national programs have ready access to such resources.

UPoCA project achievements provide evidence that the project is stimulating the emergence of many rural enterprises for value-added processing of cassava and cassava products development fir wealth creation. This paper summarizes project achievements for the period January 2009 to September 2010. During that period, project activities did not deviate from addressing the key constraints identified at implementation planning workshops. Whilst the project scored excellently on 72.7% of the planned 22 indicator targets, it should be noted that the % delivery data on yield indicator is from sites from DRC, Ghana and Sierra Leone only.

Reliability in supply of raw material at competitive cost will largely determines the viability of processing operations. The numerous seed and root production farms will continue to serve as sources of rapid horizontal spread of new/improved varieties. This will enable individual and producer groups to assure self supply of healthy planting materials of the varieties. The reduction in dependency on external suppliers of planting material would reduce unit costs and timeliness of delivery. This could be an essential trigger to boost rural entrepreneurship in cassava. Another essential trigger is higher yields for raw material supplies, and the data from DR Congo, Ghana and Sierra Leone indicate average root yield from farms with improved varieties were above the 2007 national average yields of 5 – 8t/ha in the respective countries. While in some cases productivity has been increased through the use of improved varieties, intensive agronomic mentoring will improve the observed plant population and reduce yield variations enabling farmers to further increase on-farm productivity of the varieties.

To strengthen their viability as partners to agribusinesses, the farmers/farmers groups would need to acquire the organizational and managerial skills required to manage large input supply and crop marketing activities. Efforts to organize cassava supply lines for processing need would need to consider the effects of a number factors on steady and predictable flow of the materials, e.g., ease of access to fresh marketing channels; ease of access to other processing outlets; influence of variations in farmer and consumer preferences on uptake of new varieties, supply variations including transportation and harvesting difficulties, seasonal effects on drying operations and the overall seasonality of agricultural production processes..

Through experiential learning, a core team of resource persons from IITA and national organizations has not only increased scientific literacy of a large number of men and women change agents but provided a foundation to reduce disconnects between availability/discovery and end-user access and application of cassava research results. This enables participants to later on empower colleague producer groups, agroprocessors and entrepreneurs with technical knowledge and skills required to embark on profitable cassava business. Concerted efforts to commercialize cassava are however rare in the countries, except in Nigeria. To tap into the high food and income generating potential of the crop, project beneficiaries

need to be aware of identifiable sectors with potential to pull industrialization of cassava. These include feed industries, wheat substitution in bread, pastries and snacks and starch (and its derivatives) industry in the domestic and regional market. Industrial pull for cassava is however still limited in the countries. Mechanisms to ensure guaranteed regular supply of good quality cassava will involve organized and facilitated linkages enabling cassava value chain actors to ensure the safety and quality of cassava products.

New challenges will be presented in consolidating a shift towards market-oriented production systems. This is particularly so in an atmosphere of urgent demand by a wide range of UPoCA stakeholder groups to enable cassava producers and related food industry to diversify their income sources. The kinds of new challenges emerging from the implementation experience of the UPoCA project include:

- Generation and promotion of economically productive varieties with profitable functional, nutritional and quality characteristics for different end-uses and markets. Cassava is practically all carbohydrate. In recent years, however, IITA breeding programs have developed "yellow-fleshed" cassava varieties containing pro-Vitamin A. This nutritional quality is lacking in many existing improved cassava varieties. The varieties need to be adapted to, multiplied and disseminated in localities of FBO beneficiaries and other government-supported interventions.

- Employing improved techniques to produce cassava for viable markets: This process will involve greater reliance on input and output delivery systems and integration with other sectors of the domestic, regional and international economies in order to maximize returns on investments. Along with this will be experiential learning by the FBOs to boost national average yields toward the proven on-farm potentials of at least 25t/ha. At such yield levels, FBOs will be in a good position to easily justify requests for automated cassava processing equipments.

- Overcoming the interlocking problems of poverty, low productivity and resource degradation: Addressing these features of the cassava sub-sector will help reduce unit production cost and lower the real cost of food for consumers whilst still preserving the natural resource base.

- Institutionalising standards: Standards for cassava processing and cassava products quality management will pave the way for food safety compliance in health and trade.

- Cassava crop-livestock integration to further expand utilization of the crop.

Addressing these kinds of challenges requires a longer-term research for development engagement with stakeholders and beneficiary groups. This will enable the partnerships to fully embed cassava sub-sectors within the framework of national expectations of an expanded future role for cassava in food, feed and industrial applications in the countries

Project UPoCA, a transition activity by its nature, has laid a solid foundation that needs to be built upon in order to meet these expectations. The evolving achievements of UPoCA indicate that a longer-term R4D partnership of that nature will enable cassava

Table 1: Priority constraints and proposed interventions

Key constraints	Proposed interventions	
	Action	Implementing partners
Production issues		
1. Poor & declining soil fertility leading to low productivity	Training on nature of the problem, corrective measures, sources of information, technical and material inputs; weed management	- National research institutes - Agrochemical dealers - Ministries and development agencies/ MDAs; agricultural development projects
2. Inadequate supply of clean planting materials of improved varieties	Establish private and community seed farms; training in rapid multiplication and quality control of stems	- Nat research institutes - MDAs and agricultural development projects - Private sector (firms and individuals) - Farmers groups
3. Biotic threats	Training in pest management, stem and plant health; biological control applications; Mass Information Education and Communication (IEC)	- Crop protection services - MDAs and agricultural development projects - Community radio networks - Farmers groups
Post-harvest issues		
4. Poor quality metals in processing machines	Upgrade existing machines; replace mild steel with stainless steel in cutting edges; training in equipment fabrication, repair and maintenance	- National research institutes - Private sector/national machine fabricators - Agro-dealers - Food processors
5. Poor storage quality of fresh roots and processed products	Training in value-added processing techniques; introduce improved packaging facilities	- National research institutes - MDAs and agricultural development projects - Private sector in packaging - Food processors
6. Poor drying of cassava products	Introduce processors to improved dryers; fabricate new rural friendly dryers	- National research institutes - Private sector/national machine fabricators - Agro-dealers - Food processors
Market issues		
7. Lack of cassava market information	Assess market potential of cassava products; establish strategy to link producers to markets' IEC	- National research institutes - MDAs and agricultural development projects - Community radio networks
8. Lack/ low of awareness of grades and standards for cassava products	Agro-enterprise training; IEC value-added processing and quality needs; field day demonstrations of cassava products and recipes	- National research institutes - National standards bureaus - Equipment fabricators - Agro-dealers - Farmer groups and food processors - Community radio networks

Table 2: Summary of UPoCA achievement by end September 2010

Common indicators	Overall target	Overall achieved by end Sept 2010	% delivery on overall project target
SO 1.1: Number of rural households benefiting directly from interventions			
IR 1: Access to improved production technologies and practices increased			
IR 1.1: No. of rural farmers & processors benefiting directly from interventions	395000	350,018	88.6
IR 1.2: No. of vulnerable households benefiting directly from interventions	184925	28,263	15.3
IR 1.3.1a: Male attendance at short term training	620	979	>100
IR 1.3.1b: Female attendance at short term training	305	833	>100
IR 1.3.2: Type of Training	5	24	>100
IR 1.3.3: No. of Trainings	42	44	>100
IR 1.3.4: Other trainings	900	428	47.6
IR 1.4: No. of Seed Farms Established	26	390	>100
IR 1.5: Area of Seed Farms Established (ha)	176	710.2	>365.6
SO 1.2: Gross margin per hectare for targeted (cassava) commodities			
IR 2: Increased agricultural productivity			
IR 2.1: Gross margin per hectare for targeted commodities ($)	200	0.0	0.0
IR 2.2: No. of technologies made available for transfer	6	16.0	>100
IR 2.3: Crop productivity (t/ha)	20	24.2	>100
IR 2.4: Area (ha) under improved cassava varieties	27000	12,566.2	46.5
IR 3: Improved agric marketing & commercial viability of micro/SME			
IR 3.1: No. agriculture-related firms benefiting directly from interventions	35	58	>100
IR 3.2: No. of partner organizations & active institutional members of those partner org.	36	71.0	>100
IR 3.3: No. of producers' organizations, trade & business associations, & CBOs assisted	13	239	>100
IR 3.4: Number of public-private partnerships formed	19	2.0	10.5
IR 3.5: No. of jobs	27000	26,956	99.8
IR 3.6: Sales ($) of agricultural commodities/products/services	17320000	70,579.2	0.4
IR 3.7: No. of fabricators linked	12	21.0	>100
IR 3.8: No. of products introduced and improved	5	24.0	>100
IR 3.9: No. of Information resources developed	5	13.0	>100

value chain actors to contribute significantly to national economic growth in Africa.

References

Dixon A.G.O., Okechukwu R.U., Akoroda M.O., Ilona P., Ogbe F., Egesi C.N., Kulakow P., Ssemakula G., Maziya-Dixon B., Iluebbey P., Yomeni M.O., Geteloma C., Jamews B., Eke-Okoro O.N., Sanni L., Ntawuruhunga P., Tarawali G., Mahungu N., Lemchi J., Ezedinma C.I., Okoro E., Kanju E., Adenji A.A., and Nwosu K. 2010. Improved cassava variety handbook. IITA Integrated Cassava Project, Ibadan, Nigeria.

Mahungu N. M., Jumbo S., Sandifolo V., Howard D., Mhone A., Nthonyiwa A., and Rusike J. 2010. Linking farmers to markets: Opportunities and challenges for cassava farmers. *In*: Mahungu, N. M (Ed.) 2010. Root and Tuber crops for Poverty Alleviation through Science and Technology for Sustainable Development. Proceedings of 10th ISTRC-AB Symposium, Maputo, Mozambique, 8−12 October, 2007. Pp46−56

Neuenschwander P. 2001. Biological control of the cassava mealybug in Africa: a review. *Biological Control* 21, 214−229

Neuenschwander P; Langewald J., Borgemeister C. and James B. 2003. Biological control for increased agricultural productivity, poverty reduction and environmental protection in Africa. *In*: P. Neuenschwander, C. Borgemeister, J. and Langewald (eds) *Biological Control in Integrated*

Pest Management Systems in Africa, Pp 377−405. CABI International, Wallingford.

Okechukwu R. and Dixon A.G.O. 2008. Genetic gains from thirty years of cassava breeding in Nigeria for storage root yield and disease resistance in elite cassava genotypes. *Journal of Crop Improvement* 22(2): 181−208

Sanni L., Abass A., Dixon A., Tarawali G. and Westby A. 2010. Sustainable approach to cassava processing in Africa. *In* Mahungu, N.M. (Ed.) 2010. Root and Tuber crops for Poverty Alleviation through Science and Technology for Sustainable Development. Proceedings of 10th ISTRC-AB Symposium, Maputo, Mozambique, 8-12 October, 2007. Pp 410−425

Thirtle C., Lin L. and Piesse J. 2003. The Impact of Research Led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia and Latin America. Proceedings of the 25th International Conference of Agricultural Economists (IAAE), 16-22 August 2003, Durban, South Africa. Pp 1300−1308

Yaninek J. S., Onzo A. and Ojo B. 1993. Continent-wide experiences releasing neotropical phytoseiids against the exotic cassava green mite in Africa. *Experimental and Applied Acarology* 16,

A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 50-57

Assessment of farmers' field for root rot disease on improved cassava varieties released in Nigeria

C.G. Afolabi[1], O.C. Okechukwu[3], I.A. Kehinde[1], and R.U. Okechukwu[2]

[1]University of Agriculture, Abeokuta, Nigeria
[2]International Institute of Tropical Agriculture, Ibadan, Nigeria;
[3]University of Ibadan, Ibadan, Nigeria

Corresponding Author: C.G. Afolabi
Email:

Manuscript received: 10/07/2011; accepted: 15/12/2011

Abstract

More cassava is grown in Nigeria than anywhere else, but production is still limited by several factors including root rot disease which is common in cassava growing areas. A survey was carried out to assess farmers' fields for yield and root rot disease on cassava varieties in seven States of Nigeria. Field assessment was based on 5 m by 5 m quadrats in two locations within a plot by counting the number of plant stands, total number of fresh roots, number of rotted roots, and weight of fresh roots within the quadrat. Across States and within varieties there were significant differences ($P \leq 0.05$) in number of plants, total root number, fresh root yield (t/ha) and rot (%). This could be attributed to differential management practices, soil type and fertility, age of crop, and environmental conditions. The highest fresh root yield was observed on Abutu (52.2 t/ha); the lowest yield was on Bendel (5.4 t/ha). Both are local varieties. Improved varieties had a comparative yield advantage of 20 t/ha local varieties despite the fact that more rots (11.1%) were observed on improved varieties than on local varieties (2%). The damage experienced on improved varieties was largely due to the age of the crop and susceptibility to waterlogged fields. These underscore the need for farmers growing improved varieties not to leave their cassava on the field for more than 15 months, especially if such fields are prone to waterlogging. Botryodiplodia theobromae, A. niger, A. flavus, F.usarium solani, F. oxysporum, and Armileria melea were associated fungi recovered from the rotted samples across locations.

Keywords: Cassava, yield, root rot, fungal pathogens, farmers' field assessment.

Introduction

Cassava (*Manihot esculenta* Crantz) is a major food crop for an estimated 260 million people in Africa (El-Sharkawy, 1993). Nigerian cassava production is by far the largest in the world; one-third more than the production in Brazil and almost double the production of Indonesia and Thailand. Cassava production in other African countries, such as the Democratic Republic of the Congo, Ghana, Madagascar, Mozambique, Tanzania, and Uganda, appears small in comparison with Nigeria's substantial output (Philips et al. 2004). Much of the cassava is produced in the forest, derived, and southern Guinea savanna agroecozones of Nigeria that largely fall within the areas with good soil and adequate rainfall. Although cassava can produce a crop with minimal inputs, optimal yields are recorded from fields with average soil fertility levels for food crop production and regular availability of moisture.

Cassava ranks highly as a major staple food crop, particularly for the low income earners and resource-poor farmers in the developing economies of sub-Saharan Africa (Hahn *et al*. 1989). However, in recent times, the crop is progressively gaining a strategic position in global trade as a result of the efforts by various research and development stakeholders in developing value-added cassava-based products for human consumption and industrial uses (Onyeka et al. 2005). Various food applications take advantage,of properties of cassava starch, the odorless, clear paste and high freeze-thaw stability, (Plucknett et al. 2003). The starchy roots can be processed into *gari*, *fufu, lafu, Kpokpogari*, or *bobozi*; they also used for making tapioca. Industries take advantage of the clear appearance of cassava starch and the sticky texture of its cooked paste in the manufacture of adhesives and glue (CSTRU, 2007). Processed cassava starch can compete with other starches for sizing paper and

textiles, producing pharmaceutical dustings and disintegrating pills, biodegradable products, ethanol and acetone, explosives, and corrugated boxes (Plucknett et al. 2003).

Ezedinma et al. (2007) in a study to assess the trends in cassava production since the 1990s indicated that the increase in production in Nigeria is principally as a result of area expansion rather than increased yield /ha. The causes for low yields/ha are diverse but diseases and numerous pests are known to partially contribute. Diseases affect plant establishment and vigor, inhibit photosynthetic efficacy, and in some cases cause pre-harvest or post-harvest deterioration (Lozano et al. 1981; IITA 1990). Diseases can lead to total crop failure with losses in tuber yield as high as 90% under favorable conditions (Wydra and Msikita, 1998). Among the diseases that attack cassava, the incidence of root rots has been reported to be higher in the forest areas than in other ecologies (Chalwe et al. 1999; Onyeka 2002). The stagnation in yield may be connected with the activities of the soil's hidden root rot fungi; especially when the improved varieties cultivated were not deliberately developed for root rot resistance. Root-rotting pathogens affect mostly the underground portion of the plant (and are hence out of sight). Because the plant has an extensive root system (and thus can remain standing despite a significant portion of its roots being rotted), the nature and extent of the root rot problems are poorly understood and quantified in Africa. Compared with other major diseases of cassava, root rots caused by several fungi are the most poorly understood and among the least studied (Bandyopadhyay et al. 2006). Root rot, apart from reducing yield, can also reduce the quality of roots harvested. Thus this current study tends to assess cassava yield and the incidence of root rots on improved and local cassava varieties on farmers' fields in seven States of Nigeria.

Materials and Methods

Survey sites and sampling. The study was carried out in Oyo, Osun, Ondo, Ekiti, Kogi, Benue, and Nasarawa States (Table 1). Oyo State is located within the derived savanna zone of the country. With a bimodal rainfall distribution averaging between 1300 and 1500 mm annually, and maximum temperatures varying from 25 to 35°C. Osun, Ondo, and Ekiti States are within the humid forest, characterized by two growing seasons, starting from April to November with an annual rainfall of 1500 to 2000 mm, average annual temperature of 24.5 to 27.5°C. Kogi, Benue, and Nasarawa States lie within the southern Guinea savanna zone with an annual bimodal rainfall averaging between from 1000 mm to 1300 mm , and temperatures ranging from 26 to 38°C.

The study was initiated in November 2010 and continued for 2 months. Sixty-two farmers selected from 80 villages were involved. The villages were selected based on propagative materials distributed to the farmers in the previous year by IITA, Ibadan through the project of USAID-*Unleashing the Power of Cassava in Africa* . Fields that were planted during a similar period were selected to minimize variation caused by different planting dates. Generally, planting took place between July and August 2009. In each farmer's field, a quadrat measuring 5 m × 5 m area was demarcated in two spots where observations were recorded. Observations were made on number of plant stands in a quadrat, total number of roots, number of rotted roots, and weight of fresh roots. Rotted samples were randomly selected for the isolation of the associated fungi.

Data collected were subjected to analysis of variance using general linear model procedure. Means were separated by Duncan Multiple Range Tests (DMRT).

Isolation and identification of associated fungi in the laboratory. Roots showing rot symptoms were collected from each site where the diseases were observed during the survey for the detection of the associated pathogen in the laboratory. Isolation of rot pathogens was carried out on acidified potato dextrose agar (PDA). Small tissue pieces of diseased samples were surface sterilized for 3 min in 10% sodium hypochlorite solution, rinsed in 5 changes of sterile distilled water and dried on sterilized paper towels before inoculation on acidified PDA. The inoculated plates were incubated at 27 °C for 5–7 days during which pure cultures of microbial growth were established for identification. Confirmation of associated causal pathogens of rot was carried out, based on the morphological and cultural characteristics on PDA, and microscopic observation following the fungi identification key of Barnett and Hunter (1998).

Results and Discussion

A total of 29 cassava varieties were examined during the survey, 13 improved and 16 local varieties. The number of plants and total number of roots differed significantly ($P \leq 0.05$) between States and varieties (Table 2), which indicates that farmers did not use the

Table 1. Farmers' location and coordinates of each location collected during the survey.

State	LGA	Village	Longitude	Latitude
Oyo	Akinyele	IITA Idi-Ose	7 49.895	3 90.706
Oyo	Ido	Aafa Dauda	7 29.615	003 44.129
Oyo	Ido	Idi Amu	7 31.343	003 42.204
Oyo	Ido	Ilaju	7 32.917	003 35.975
Oyo	Ido	Elere Akilo	7 31.271	003 37.709
Oyo	Ido	Elere Akilo	7 31.478	003 38.350
Oyo	Ibarapa East	Idi Ata	7 31.563	003 32.954
Oyo	Ibarapa East	Idi Ata	7 31.896	003 33. 078
Oyo	Ibarapa East	Idi Ata	7 32.233	003 32.761
Oyo	Ibarapa East	Olokete	7 32.103	003 28.107
Oyo	Ibarapa East	Olokete	7 32.086	003 28.030
Oyo	Saki East	Igbo Osanyin, Ago Amodu	8 36.095	003 36.600
Oyo	Saki East	Igbo Osanyin, Ago Amodu	8 35.756	003 36.397
Oyo	Saki West	Aba Ogbomosho	8 44.940	003 28.523
Oyo	Saki West	Aba Ogbomosho	8 44.616	003 28.997
Oyo	Saki West	Aba Ogbomosho	8 43.540	003 27.088
Oyo	Kajola	Elewure	8 02.447	003 25.475
Oyo	Kajola	Elewure	8 02.320	003 25.520
Oyo	Kajola	Elewure	8 02.136	003 26.854
Oyo	Kajola	Elewure	8 02.416	003 25.505
Oyo	Oyo West	Fasola	7 54.625	003 45.744
Oyo	Oyo West	Fasola	7 54. 665	003 45.817
Oyo	Atiba	Busari	7 57.776	004 02.650
Oyo	Atiba	Sakuta	08 02.926	003 99.426
Oyo	Atiba	Sakuta	08 03. 038	003 59.314
Osun	Aiyedire	Ile Ogbo	07 35.972	004 17.143
Osun	Aiyedire	Ile Ogbo	07 35.357	004 16.704
Osun	Aiyedire	Ile Ogbo	07 35.679	004 16.844
Osun	Aiyedire	Ile Ogbo	07 35.655	004 16.825
Osun	Aiyedire	Ile Ogbo	07 35.791	004 17.130
Osun	Odo-Otin	Oponda	08 03.035	004 40.753
Osun	Odo-Otin	Oke-Otin	07 59.480	004 41.480
Osun	Odo-Otin	Oke-Otin	07 59.035	004 41.315
Osun	Obokun	Esun	07 42.419	004 45.366
Osun	Ilesa-East	College farm	07 35.735	004 43.228
Osun	Ede South	Olorogbo	07 40.608	004 25.457
Osun	Ede South	Awere-Alamo	07 41.819	004 25.245
Osun	Ede South	Awere-Alamo	07 41.819	004 25.249
Osun	Ede South	Ologobi Oja	07 40.243	004 26.089
Osun	Ede South	Olorubu	07 40.802	004 25.640
Osun	Atakumosa-West	Oloja Ibala	07 43.728	004 35.068
Osun	Atakumosa-West	Oloja Ibala	07 43.107	004 35.453
Osun	Osogbo	Oke-osun Farm Settlement	07 44.604	004 31.752
Osun	Egbedore	Ido-Osun	07 47.959	004 29.657
Osun	Egbedore	Ido-Osun	07 49.603	004 31.865
Ekiti	Ikole	Ipao	07 59.230	005 36.031
Ondo	Ile-oluji/Oke-Igbo	Agiodo	07 10.680	004 51.521
Ondo	Ile-oluji/Oke-Igbo	Gloryfield Rd	07 12.134	004 51.197
Ondo	Ile-oluji/Oke-Igbo	Farm Settlement	07 14.121	004 51.651
Ondo	Akure North	Km 5, Owo Rd.	07 16.107	005 15.915
Ondo	Owo	Otu land	07 16.562	005 30.799
Ondo	Owo	Iyana Otaago	07 16.800	005 31.084

Contd.

Kogi	Ankpa	Acharana	07 18.517	007 28.099
Kogi	Bassa	Gboloko	07 45.511	006 52.847
Kogi	Bassa	Gboloko	07 45.459	006 52.838
Kogi	Dekina	Egume	07 33.411	007 16.529
Kogi	Dekina	Anyigba	07 32.817	007 13.699
Kogi	Dekina	Anyigba	07 32.798	007 13.640
Kogi	Dekina	Agada,Abocho	07 35.843	006 51.773
Kogi	Ofu	Ofagada	07 03.471	007 06.478
Kogi	Okene	Ere	07 32.141	006 08.877
Kogi	Okene	Ageva	07 31.728	006 10.026
Kogi	Okene	Oguda	07 21.584	006 22.334
Kogi	Okene	Oguda	07 22.053	006 22.776
Kogi	Adavi	Osara	07 37.972	006 24.100
Kogi	Okene	Osara	07 37.799	006 23.915
Kogi	Mopamuro	Amuro	08 09.443	005 55.405
Kogi	Yagba West	Ejiba	08 16.564	005 39.676
Kogi	Yagba West	Ejiba	08 17.468	005 39.221
Benue	Otupko	Upu	07 13.880	008 10.708
Benue	Otupko	Otobi	07 05.326	008 07.421
Benue	Otupko	Otobi	07 05.457	008 07.362
Benue	Otupko	Otobi	07 06.909	008 06.188
Benue	Otupko	Otukpicho	07 16.774	008 11.648
Benue	Konshisha	Mpav	07 20.034	008 38.866
Nasarawa	Kokona	Maisauri	08 50.139	007 57.634
Nasarawa	Karu	New Karshi	08 51.691	007 35.289
Nassarawa	Nassarawa Eggon	Ubbe	08 52.581	008 25.530
Nassarawa	Wamba	Wayo	08 51.158	008 37.113

Table 2. Analysis of variance for number of plant, total fresh root, fresh root yield (t/ha) and rotted roots (%) for 29 varieties of cassava in farmer's fields in 7 States

		Number of plants		Total fresh roots		Fresh root yield (t/ha)		Rotted root (%)	
Source	DF	Mean Square	Pr>F	Mean Square	Pr>F	Mean Square	Pr>F	Mean Square	Pr>F
State	6	349	0.004	14874	0.005	446	0.011	248	0.001
Rep(State)	7	36	0.410	1601	0.401	63	0.358	14	0.998
Variety	28	123	<.0001	5147	<.0001	208	<.0001	633	<.0001
State*Variety	21	108	<.0001	1861	0.244	127	0.003	343	0.000
Error	154	35		1529		57		131	
Total	216								
R-Square		0.643		0.516		0.559		0.597	

recommended spacing during planting but responded differently, based on need and land availability. The number of plants within the examined quadrat ranged from 8 in Powerline to 41 in Akpofafa, while the total root number ranged from 60 in Pakidudu to 218 in Akpofafa; all are local varieties (Table 3). The varied plant population and root number within the quadrat suggest that farmers' economic interest accounts for the variability. We observed that some farmers partially mechanized their farming operations by plowing their fields before planting; others used local heaps. Also, while some farmers planted cassava as a sole crop, others intercropped and this largely affected the plant population and invariably the root number. Furthermore, the age of the crop, the variety, the soil structure, the soil fertility, and environmental conditions during growth will greatly determine the number of roots harvested. The state × variety interaction was highly significant (Table 2) for the number of plants, indicating that farmers did not plant the same way in each State. There was no significant interaction for total root number, suggesting that the

majority of the varieties reacted similarly in terms of the total root number in those States.

Table 3 shows fresh root yield (t/ha) and rot (%) for each of the varieties. The fresh root yield (t/ha) differed ($P \leq 0.05$) significantly among the States and within the varieties. This shows that the varieties responded differently to local environmental conditions, soil fertility, and management practices by farmers in each State. Fresh root yield ranged between 5 t/ha in Bendel and 52 (t/ha) in Abutu, and the grand mean was 18.3 t/ha. Both are local varieties. We observed that the exceptional yield of Abutu could be due to specific location adaption and the length of time it has stayed on the field. On average, we observed that improved varieties still performed better in term of fresh root yield (18 t/ha) than the local varieties (16.2 t/ha) (Table 3). Though this performance of improved varieties over local varieties looks marginal, when we consider that improved varieties mature faster than the local varieties, it would be evident that the turnover could be larger than as shown here. Furthermore, there was a significant difference ($P \leq 0.05$) in State × variety interaction for fresh root yield. This is a response to differential management practices, soil fertility, environmental conditions, and type of varieties that are available within a State as these conditions are not homogenous. The highest fresh root yield was recorded in Oyo State (20 t/ha), followed by Kogi and Benue States with 19 t/ha. The lowest yield was recorded in Ondo State with 9 t/ha (Fig. 1). This confirms previous common knowledge that the three States have a favorable environment for root and tuber crops. A lot of farmers grow cassava in these

Table 3. Varietal mean performance for number of plants, total fresh roots, fresh root yield (t/ha) and rotted roots (%).

Variety	No of plant	Total fresh roots	Fresh root yield (t/ha)	Rotted root (%)
91/02324	20.4	119.4	20.7	13.0
92/0057	25.0	132.5	24.9	14.0
92/0326	20.3	108.7	10.4	37.1
95/0289	21.8	96.0	20.0	19.2
96/1632	25.4	114.8	17.7	26.5
97/2205	35.0	161.0	35.1	0.0
98/0505	22.8	99.3	18.2	26.6
98/0510	15.2	77.5	17.3	29.2
98/0581	25.5	111.8	16.5	23.5
Aba-Iyawo	21.0	70.5	15.6	0.5
Abutu	22.0	190.0	52.2	0.0
Ademola	19.0	88.0	17.3	1.0
Akata	23.0	77.5	12.2	3.5
Akpofafa	41.0	218.5	31.3	0.5
Arubielu	9.5	84.0	14.0	0.0
Atududu	20.0	95.3	7.7	0.0
Bendel	18.5	71.0	5.4	2.8
Ege-dudu	14.5	111.5	17.6	0.7
Ichenke	34.0	97.5	19.8	0.0
M98/0068	25.0	143.0	14.2	35.1
Mokosooku	18.5	150.5	17.4	1.0
NADP	30.0	160.8	20.9	0.4
Odongbo	15.3	66.6	14.7	1.9
Oko-iyawo	19.1	116.3	16.1	3.1
Pakidudu	16.0	60.0	10.8	0.0
Powerline	7.5	72.0	13.4	1.5
TME419	21.0	117.0	19.9	10.8
TMS30572	16.7	103.8	16.6	1.0
Local	28.0	133.7	14.1	1.8
Mean	21.8	112.0	18.3	8.8
SE	1.3	7.0	1.7	2.2
Improved varieties	20.1	110.8	18.0	11.1
Local varieties	19.8	106.8	16.2	2.0

States because the environmental conditions, and soil structure favour production. More of the farmers grow lots of improved cassava and this accounted for the high yields recorded in their farms, especially by those farmers who received both improved varieties and agronomic training from IITA.

There were also significant differences ($P \leq 0.05$) in rotted roots (%) between the States and within the varieties and also State x variety interaction. Rotted roots ranged from 0 % in six varieties (97/2205, Abutu, Arubielu, Atududu, Ichenke, and Pakidudu) to 37 % in 92/0326 (Table 3). We observed that the high level of rot observed on improved varieties was largely due to the length of time they had stayed on the field (age of the crop) and the excessive rainfall experienced during the 2010 cropping season which made some fields waterlogged. Previous reports also associated rots with water logged fields (CTA 2008). This underscores the need for farmers to plant on soil that is well drained that would not retain water. Soils prone to waterlogging require the use of high ridges or mounds.

Although waterlogged fields could also limit the production of local varieties these seem to be more tolerant than the improved varieties. However, the ability of the local varieties to stay for 2-3 years longer on the field than the improved varieties suggest that they possess heritable characteristics that can be incorporated into the high yielding improved varieties. Therefore, there is need for cassava breeders to look at these quality traits in local varieties and incorporate some in the improved varieties for better performance. We also observed that more rots were recorded in Kogi (10%) and Oyo States (8%), with Nasarawa State having the least rot (0.2 %) (Fig. 1). The high level of rots recorded in Kogi State was largely due to heavy rain recorded in 2010 which made most field waterlogged, especially at Ejiba, Yagba West LGA. Likewise in Moniya, Akinyele LGA in Oyo State most of the samples of improved varieties were rotted due to their long duration on the field.

Although the frequency of occurrence of associated fungi was not directly measured, we were able to isolate fungi on some of the randomly selected rotted

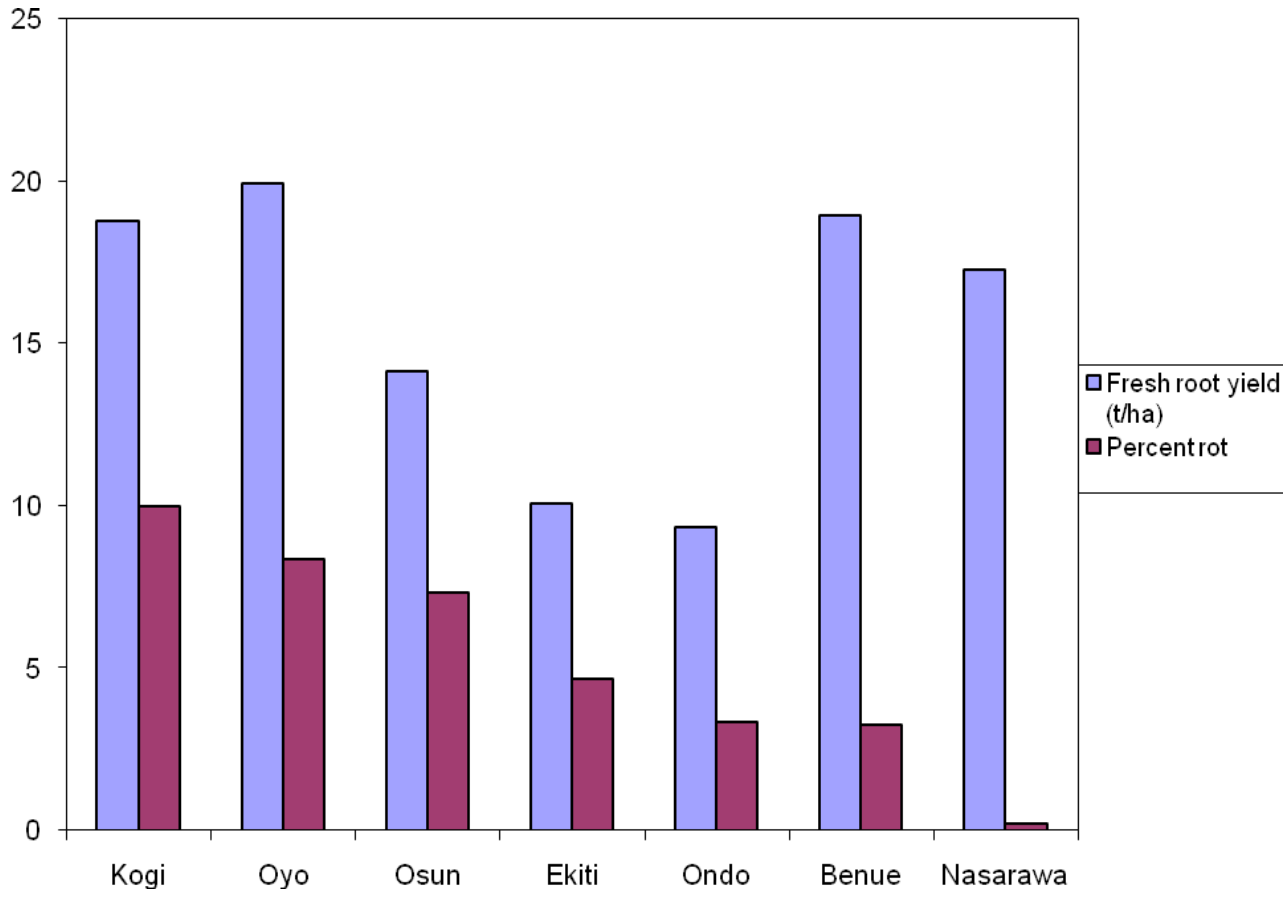

Fig. 1. Fresh root yield (t/ha) and rotted root (%) in seven States of Nigeria.

roots. This was due to the condition of most of the samples and the duration of the survey, coupled with the fact that it was not part of the focus of this study and has been dealt with by several investigator. However, the commonly isolated fungi were *Botryodiplodia theobromae, Fusarium oxysporum, F. solani, Aspergillus niger, A. flavus, Sclerotium rolfsil, Armilleria melea,* and *Trichoderma* species. The most prevalent pathogen on the samples across the seven States remained *B. theobromae*. Previous reports have associated these pathogens were cassava root rot disease in Nigeria (Onyeka 2002; Onyeka et al. 2004; Bandyopadhyay et al. 2006). Pathogens gain entrance to the roots through wounds created by man and other root knot microbes especially nematodes.

In conclusion, improved varieties of cassava have a promising potential in achieving food sufficiency if losses from root rot could be adequately reduced. Emphasis should be made by the breeders on improving the tolerance level of the improved varieties to root rot, waterlogging, and resistance to pathogen stress. Farmers should also be encouraged to cultivate more of the improved varieties and harvest them early to enjoy the added yield.

Acknowledgement

We appreciate the contributions of IITA, Ibadan and the project *Unleashing the Power of Cassava in Africa* toward making this study a success.

References

Bandyopadhyay, R.; Mwangi, M.; Aigbe, S. O., and Leslie, J. F. 2006. *Fusarium* species from the cassava root rot complex in West Africa. *Phytopathology 96*:673-676.

Barnett, H. L., and Hunter B. B. 1998. Illustrated General of Imperfect Fungi. 4th Edition. American Phytopathological Society, Mineapolis Burgress Publishing Co. pp. 218.

Chalwe A., Malambo, C., Zimba, K., Nawa, I and Muimba-Kankolongo, A. (1999). Cassava root rots and associated micro-organisms in Zambia. *In* Food security and crop diversification in SADC countries: the role of cassava and sweet potato, Akoroda, M.O. and Teri, J.M. (eds). Pages 317 – 324. Proceedings of the scientific workshop of SARRNET, 17-19 August 1998, Zambia.

CTA. 2008. Overcoming root rot diseases of cassava. NARO QAS for Agriculture. http://www. runetwork. de/html/fr/articles/article.html? article_id=5123. Accessed January 2011.

CSTRU. (2007). Thai Cassava Starch: A new choice for industrial use. Kasetsart Agricultural and Agro-Industrial Product Improvement Institute, Kasetsart University, Bangkok 10900, Thailand, In: http:// www.cassava.org/doc/Thai% *20Cassava%20Starch. pdf*

El-Sharkawy, M. A. 1993. Drought-tolerant cassava for Africa, Asia, and Latin America. BioScience 43(7):441-451.

Ezedinma, C. I.; Lemchi, J.; Okechukwu, R. Sanni, L.; Ogbe, F.; Akoroda, M. O. and Dixon, A. (2007). Status of cassava production in Nigeria pages 183-189 *in* Mahungu, N.M. and Manyong, V.M., (eds.) Advances in Root and Tuber Crops Technologies for Sustainable Food Security, Improved Nutrition, Wealth Creation and Environmental Conservation in Africa. Proceedings of 9th ISTRC-AB Symposium, Mombasa, Kenya, 1–5 November 2004.

Hahn, S.K.; Isoba J.C.G. and Ikotun T. 1989. Resistance Breeding in Root and Tuber Crops at International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. *Crop Protection.* 8: 147-168.

IITA. 1990. Cassava in Tropical Africa: a reference manual. IITA, Ibadan, Nigeria.

Lozano, J.C, Bellotti, A., Rayers, J.A., Howeler, R, Leihner, D.and , Doll, J. 1981. Field problems of cassava. Centro Internacional de Agricultura Tropical (CIAT) Cali, Colombia.

Onyeka, T.J. 2002. Cassava root rot fungi in Nigeria; variability in *Botryodiplodia theobromae* isolates and evaluation of cassava germplasm for root rot resistance. PhD thesis, University of Ibadan

Onyeka T.J., Ekpo, E.J.A.,and Dixon A.G.O 2004. Cassava root rot disease in West Africa: Review of recent literature and the field situation in Nigeria. *In*: Akoroda, M.O, Ngeve, J.V (eds.) Root crops in the 21st century. Proceedings of the 7th Triennial Symposium of the International Society of the Tropical Root Crops Africa Branch (ISTRC-AB). ISTRC-AB/IITA, Ibadan, Nigeria. Pages. 584-588.

Onyeka, T. J., Dixon A.G.O.; Bandyopadyay R., Okechukwu R.U. and Bamkefa B. 2005. Distribution

and Current Status of Bacterial Blight and Fungal Diseases of Cassava in Nigeria. *ICP Technical Report* 01. IITA, Ibadan, Nigeria.

Phillips, T. P., Taylor, D. S., Sanni, L. and Akoroda, M. 2004**.** A cassava industrial revolution in Nigeria: The potential for a new industrial crop. FAO Rome,Italy.Pages 60.

Plucknett, D.L., Philips, T.P. and Kagbo, R.B. 2003. The global cassava strategy for cassava: Transforming a traditional tropical root crop. The Global Cassava Development Strategy and Implementation Plan Volume 1, Report of the FAO/ WHO Expert Consultation, Rome,Italy Pages 17-21.

Wydra, K. and Msikita, W. 1998. An Overview of the present situation of cassava diseases in West Africa. In: Akoroda M.O., Ngeve J.V. (eds.) Root crops in the 21st century. Proceedings of the 7th Triennial Symposium of the International Society of the Tropical Root Crops Africa Branch (ISTRC-AB). ISTRC-AB/IITA, Ibadan, Nigeria. pp.198–206.

A Research Article in AJRTC (2011) Vol. 9 No. 1: Pages 58-63

Distribution of improved varieties of cassava and potential impact on root yield and disease reduction in Nigeria

R.U. Okechukwu[1], I.A. Kehinde[2], C.G. Afolabi[1], B. James[1] , and C. Egesi[3]

[1]International Institute of Tropical Agriculture, Ibadan, Nigeria
[2]University of Agriculture, Abeokuta, Nigeria
[3]National Root Crops Research Institute, Umudike, Nigeria

Corresponding Author: R.U. Okechukwu
Email: r.okechukwu@cgiar.org

Manuscript received: 08/07/2011; accepted: 05/12/2011

Abstract

Eleven improved varieties project were multiplied in 2009 by primary producers associated with the USAID/ IITA project *Unleashing the Power of Cassava in Africa in response to the Food Price Crisis* (UPoCA) in seven States of Nigeria. In 2010, stems from these multiplication farms were distributed to farmers in these States. Prior to the distribution exercise a baseline survey was conducted on 630 farm families to ascertain among other issues their perception of cassava mosaic disease and other cassava pests. At the end of the harvest 2010 planting season, a survey of a subset of the recipients (80 villages) showed that the farmers are better informed and are replacing local varieties with improved varieties but would still need more extension service support on the best time to harvest these varieties to minimize losses due to rot.

Key words: Cassava, UPoCA, seed system, cassava mosaic disease, root rot, variety spread

Introduction

The Project *Unleashing the Power of Cassava in Response to Food Price Crisis* (UPoCA), funded by United States Agency for International Development (USAID) and implemented by IITA was a 2-year multi-country Special Project. It was implemented in Ghana, Malawi, Mozambique, Nigeria, Sierra Leone, Democratic Republic of Congo, and Tanzania. One major objective is the rapid mass propagation of improved and multiple pest/disease resistant varieties. The introduction and dissemination of these high yielding varieties and their subsequent adoption is expected to increase cassava yield by 30% above baseline figures.

Cassava (*Manihot esculenta* Crantz) is an important root crop in Nigeria. It serves as a staple for many households and recently is being promoted as an industrial crop. Nigeria still remains the largest producer of cassava in the world but the cultivation of low yielding varieties and ineffective extension systems has led to a wide gap between farmers potential and actual yields.

In 2002, IITA raised the alarm about the threat of the new Ugandan virus strain (EACMV-Ug2) of cassava mosaic disease (CMD) entering Nigeria (Ogbe et al. 2002). The Government of Nigeria, and Shell Petroleum Development Company of Nigeria (SPDC) consequently responded by funding the setting up of the Integrated Cassava Project (ICP). This project successfully deployed CMD resistant and high yielding cultivars and this led to increase cassava productivity. Since then subsequent cassava initiatives have made it a priority to promote CMD resistant varieties in areas that were not covered by ICP (Dixon et al. 2008). This paper presents the extent and approach of the distribution, improved varieties by UPoCA in States not covered by ICP and the farmers perception on disease mitigation and crop yields before and after their reception of the improved varieties.

Multiplication and dissemination strategy

The Project partnered with the National Root Crops Research Institute, Umudike, and farmers' associations to mobilize farmers, acquire the improved varieties listed in Table 1, multiply them, and distribute them to farmers. The primary multiplication sites were selected based on geographical spread in the

country. It was essential to minimize costs from to transportation by bringing the multiplication sites close to target zones. In 2009, the primary multipliers received the improved varieties and contract fees to produce stems. They were supervised by UPoCA personnel to ensure good plant population, and the maintenance of phytosanitary standards. Seed farms were tasked to produce about 10,000-15,000 plants/ha. The Project owned 60-90% of the stems while the farmer got all the roots and the remaining stems. In the next season, stems from these farms were harvested for widespread distribution to other farmers.

The seed farms also served as demonstration sites for the host community. All primary seed farms were georeferenced and the flow of varieties was documented. Timing of the process was season-driven and the first year of multiplication was made to tail into the planting season of the second year.

Baseline

Prior to the setting up the primary farms, a baseline survey was conducted. In Nigeria, 630 locations were surveyed during the baseline field activity. Twenty-eight enumerators and 7 supervisors were employed in this task which included the administration of questionnaire and the geo-referencing of surveyed villages and farms. Training of enumerators, field work, and data entry were concluded on 23 September 2009. Figure 1 below shows villages surveyed in each of the Project states and location of primary multiplication sites.

Ten households each from 9 villages were surveyed from three senatorial districts of each of the 7 States. Most household heads and respondents were males but 19% were female. Farming is the major profession and the age of most of the respondents (70%) was within 35-60 years. Questions pertaining to their perception of CMD and other cassava pests were administered in this survey.

Post-distribution survey

The study was carried out in seven UPoCA States of Oyo, Osun, Ondo, Ekiti, Kogi, Benue, and Nasarawa. The study was initiated in November 2010 and continued for 2 months. Sixty-two farmers selected from 80 villages were involved. Fields that were planted during a similar period were selected to minimize variation caused by different planting dates. Generally, planting took place between July and August 2009. In each farmer's field, a quadrat measuring 5m x 5m area was demarcated in two spots where observations were recorded on number of plant stands in a quadrat, total number of roots, number of rotted roots and weight of fresh roots. A short questionnaire was then administered to the farmer on issues concerning diseases and yield.

Data collected were subjected to analysis of variance using the general linear model procedure. Variety by yield related traits assessed were analyzed using a GGE biplot (Yan, 2001) Data from the questionnaire were analyzed using the frequency statistic of SPSS 17.0 (SPSS, 2010).

Results and Discussion

Baseline cassava yields from farmer's fields ranged from 1 to 15.3 t/ha in the two years before the commencement of UPoCA. The highest yield came from Benue State (Table 2). These values were estimated by the farmers. The 2010 evaluation were actual measurements (Table 3) and the farmers all agreed that the yield was much more than their previous yield.

Most respondents agreed that acreage to cassava production has increased in the past 5 years (60%), 14% felt there has not been any change. While 82% of the farmers agreed to gradually replace their local varieties with these improved varieties, 18% were undecided.

Table 1. Released cassava varieties promoted by UPoCA in Nigeria

Year of release	Country	Variety name
Pre-2005	Nigeria	TMS 30572
2005	Nigeria	TMS 97/2205, TMS 98/0505, TMS 98/0510, TMS 98/0581 and TME 419
2006	Nigeria	TMS 92/0326, TMS 92/0057, TMS 96/1632, TMS 98/0002, and NR 87184
2008	Nigeria	TMS 96/1089A, NR 930199

Table 2. Farmer perceived cassava yields at baseline survey (t/ha).

State	Improved varieties only		Local varieties only		Mixed varieties		All varieties	
	Yr 2008/09	Yr 2007/08	Yr 2008/09	Yr 2007/08	Yr 2008/09	Yr 2007/08	Yr 2008/09	Yr 2007/08
Benue	15.30	11.81	14.32	11.82	13.20	11.66	14.27	11.76
Ekiti	0.04	0.03	9.97	9.97	0.00	0.00	3.34	3.33
Kogi	0.37	0.21	1.24	0.50	4.29	2.58	1.97	1.09
Nasarawa	9.10	9.23	4.27	4.16	7.89	16.78	7.09	10.06
Ondo	6.94	7.57	0.63	0.55	9.16	9.30	5.58	5.81
Osun	8.69	8.76	6.47	5.97	9.89	10.45	8.35	8.39
Oyo	1.21	1.81	2.78	3.74	1.02	1.37	1.67	2.31

Table 3. Root yield (t/ha) and rotted roots (%) from improved cassava varieties grown by farmers in the seven states in 2010.

State	Fresh root yield (t/ha)	Rotted roots (%)
Benue	16.3	4.5
Ekiti	9.9	4.4
Kogi	18.1	14.1
Nasarawa	20.8	0.3
Ondo	10.6	3.5
Osun	14.7	10.1
Oyo	24.0	15.5
Mean	16.3	7.5
SE	1.9	2.2

Eighty-seven percent of the farmers responded that they are aware of CMD as a problem at baseline and all the farmers evaluated in 2010 did not observe CMD. They however reported incidence of cassava bacterial blight and root rot. They also reported losses from grasscutters or cane rats (*Thryonomys swinderianus*) to TME 419.

During the baseline survey, farmers were asked to indicate if the characteristics listed in Table 5 were important for their consideration of a variety for adoption. The results from all the States showed that all characteristics were important. In terms of ranking, fresh root yield was most important and dry matter the least. This is probably because the price they receive from sale of roots is measured by weight which includes the water content of the cassava. Consequently, the bigger the root, the more money they make. Dry matter content would be probably most appreciated by the cassava processors.

While market price, market demand, and maturity period rank as highly important to the farmers, the cyanide content of the varieties and the period of underground storage after maturity were not so important. The low ranking of period of underground storage could indicate why the farmers lost about 4.5 to 15.5%of their root yield to rot. Okechukwu et al. (2008), and Okechukwu and Dixon (2009) have reported that there is no variety absolutely resistant to root rot among these released varieties and that early harvest (9–11 months after planting) is still the best way to reduce losses. Root rot also

Table 4. Cassava pests experienced by farmers in their farms.

Response	State							
	Benue	Ekiti	Kogi	Nasarawa	Ondo	Osun	Oyo	Total
CMD	100.0	100.0	100.0	100.0	100.0	75.0	29.4	87.4
Grasscutter	0.0	0.0	0.0	0.0	0.0	2.8	11.8	1.8
Grasshopper	0.0	0.0	0.0	0.0	0.0	0.0	35.3	3.6
Termite	0.0	0.0	0.0	0.0	0.0	22.2	11.8	6.0
Tuber rotting	0.0	0.0	0.0	0.0	0.0	0.0	11.8	1.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5. Important characteristics farmers consider when choosing cassava varieties to grow.

	State								Ranked
	Benue	Ekiti	Kogi	Nasarawa	Ondo	Osun	Oyo	Total	1st
Dry matter content									
No	71.1	76.7	7.9	12.2	69.5	17.8	41.3	42.1	
Yes	28.9	23.3	92.1	87.8	30.5	82.2	58.8	57.9	17.3
Root yield									
No	15.6	18.0	20.7	31.1	37.8	67.1	53.1	34.4	
Yes	84.4	82.0	79.3	68.9	62.2	32.9	46.9	65.6	96.7
Maturity period									
No	27.3	27.0	13.4	31.1	51.1	54.8	61.2	38.0	
Yes	72.7	73.0	86.6	68.9	48.9	45.2	38.8	62.0	95.9
Disease resistance									
No	67.9	29.5	41.0	41.1	50.6	19.7	83.0	45.7	
Yes	32.1	70.5	59.0	58.9	49.4	80.3	17.0	54.3	72.9
Perceived cyanide									
No	81.8	70.5	49.2	47.2	49.4	79.5	72.4	63.0	
Yes	18.2	29.5	50.8	52.8	50.6	20.5	27.6	37.0	45.6
Market price									
No	37.1	39.8	14.8	42.2	39.3	65.0	62.8	43.0	
Yes	62.9	60.2	85.2	57.8	60.7	35.0	37.2	57.0	94.1
Market demand									
No	57.5	43.8	19.8	43.3	41.1	63.1	64.1	47.4	
Yes	42.5	56.2	80.2	56.7	58.9	36.9	35.9	52.6	90.6
Period of underground storage after maturity									
No	76.2	62.5	42.5	44.4	55.6	61.9	71.8	58.9	
Yes	23.8	37.5	57.5	55.6	44.4	38.1	28.2	41.1	84.1

Table 6. Varietal mean performance for number of plants, total fresh roots, fresh root yield (t/ha), and rotted roots (%) for 13 improved cassava varieties grown in farmers' fields in 2010.

Variety	No. of plants	Total fresh roots	Fresh root yield (t/ha)	Rotted roots (%)
92/0326	20.3	108.7	10.4	37.1
M98/0068	25.0	143.0	14.2	35.1
98/0581	25.5	111.8	16.5	23.5
TMS30572	16.7	103.8	16.6	1.0
98/0510	15.2	77.5	17.3	29.2
96/1632	25.4	114.8	17.7	26.5
98/0505	22.8	99.3	18.2	26.6
TME419	21.0	117.0	19.9	10.8
95/0289	21.8	96.0	20.0	19.2
91/02324	20.4	119.4	20.7	13.0
NADP	30.0	160.8	20.9	0.4
92/0057	25.0	132.5	24.9	14.0
97/2205	35.0	161.0	35.1	0.0

significantly ($P \leq 0.05$) influenced by genotype and environment interaction. Most root rot is recorded in the humid forest and the least is in the Sudan savanna agroecological zone. This is true in this case also, as more rots were recorded in Oyo, Osun, and Kogi States (which are closer to the humid forest of Nigeria) unlike in Nasarawa State (savanna zone).

Across all the states, 97/2205 had the highest yield (35.6 t/ha) while 92/0326 had the least yield. Figure 2 shows that 92/0326 was mostly susceptible to root rot. TMS30572 and NADP had also low levels of root rot recorded. These are old improved varieties that have been in circulation for over 35 years in Nigeria.

Conclusion

To date, UPoCA has achieved over 145ha of seed farms and has provided over 15,000 farmers with improved varieties. By 2011, it is hoped that the propagation of improved varieties, backed by farmer training in integrated cassava crop management, will lead to on-farm yields at least 30% greater than those with existing traditional varieties. Much work is still required to tackle postharvest problems such as the early deterioration of cassava after harvest and rot due to underground storage for over 15 months. In the interim, extension service support to farmers should teach that to reap the real yield from improved varieties currently being spread in Nigeria early harvest, not up to 15 months, should be practiced.

Acknowledgment

Many thanks to USAID and IITA for funding the UPoCA project and to all partners in Nigeria.

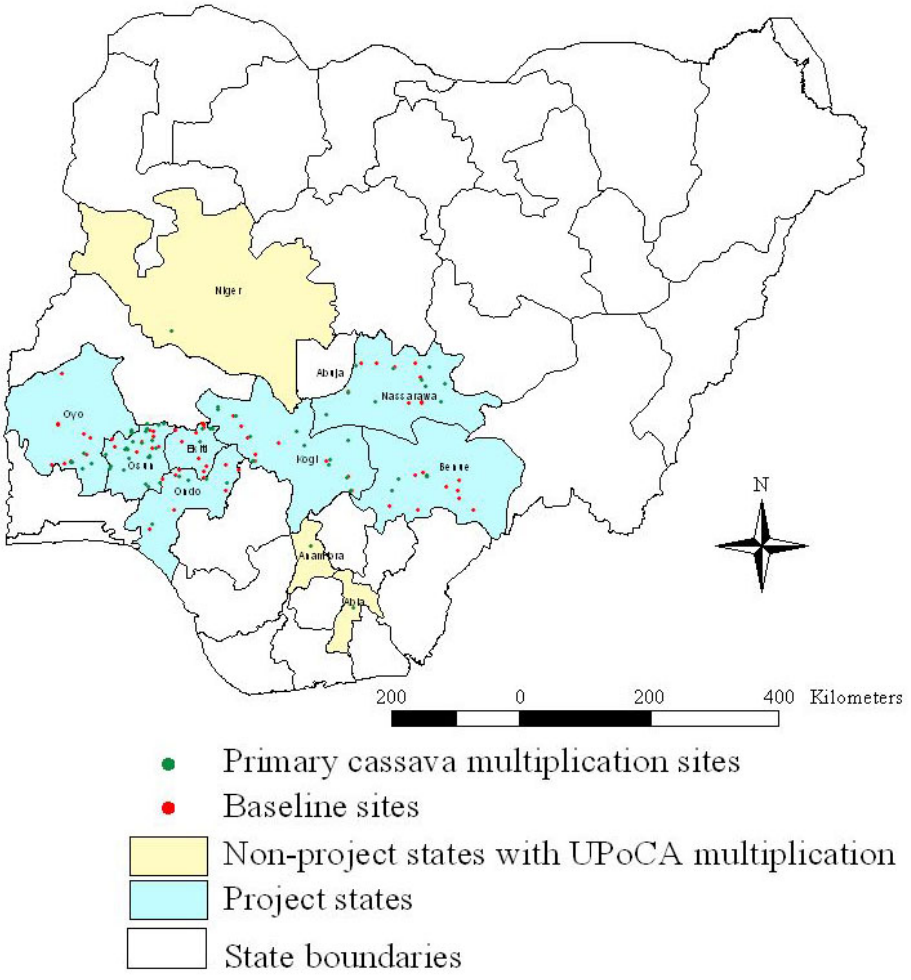

Figure 1. Villages surveyed for baseline information and cassava multiplication sites.

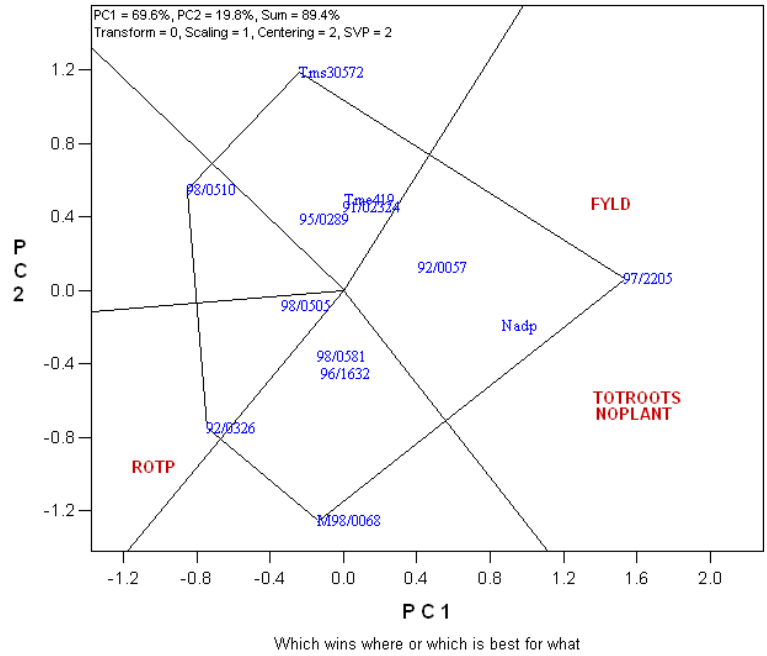

Figure 2. GGE Biplot analysis of 13 improved varieties and their association with yield related traits assessed in 2010 from farmers' fields.

References

Dixon A.G.O., Akoroda M.O., Okechukwu R.U., Ogbe F., Ilona P., Sanni L.O., Lemchi J., Ssemakula G., Yomeni M.O., OkoroE., and Tarawali G. 2008. Fast track selection approach to release of elite genotypes of cassava for various uses in Nigeria's cassava economy. Euphytica. 160: 1-13.

Okechukwu R.U., Dixon A.G.O., Akoroda M., Mwangi M., and Bandyopadhyay R. 2008. Root rot resistance in new cassava varieties introduced to farmers in Nigeria. Experimental Agriculture 44: 1-10.

Okechukwu R.U. and Dixon A.G.O. 2009. Performance of Improved Cassava Genotypes for Early Bulking, Disease Resistance, and Culinary Qualities in an Inland Valley Ecosystem. Agronomy Journal 101(5):1258-1265.

SPSS. 2010. SPSS statistics base 17.0, users guide. SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL. 616 pp.

Yan W. 2001. GGEBiplot-a Windows application for graphical analysis of multi-environment trial data and other types of two-way data. Agronomy Journal 93:1111–1118.