Unearthing the Hidden Potentials of the Shea Tree (Vitellaria Paradoxa)

By

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Inaugural Lecture Delivered under the Chairmanship of

Professor Gabriel A Teye
Vice-Chancellor, UDS

Venue: Dr. Andani Andan Auditorium
Central Administration, Tamale Campus
University for Development Studies

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PROFESSOR ALBERT KOJO QUAINOO

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Professor of Biotechnology

Profile

PROFESSOR ALBERT KOJO QUAINOO (PhD)

Professor Albert Kojo Quainoo was born on 21st August 1961 to Mr. and Mrs. Quainoo both of blessed memory in Sekondi in the Western Region of Ghana but a native of Gomoa Ojobi in the Central Region.

He had his initial primary school education in Peki and Ho in the Volta Region and continued at the Bagabaga Primary and Middle school in Tamale. He had his entire secondary school education at the Tamale Secondary School from 1976 to 1984. In 1990 he graduated with a BSc. Agriculture and Dip. in Education from the University of Cape Coast, Ghana. He proceeded to Finland and obtained a MSc. Degree in Plant Production at the University of Helsinki in 1994.

He took up a lecturing position at the University for Development Studies, Tamale, Ghana in 1997. Between 1997 and 2002 he took up several responsibilities at the University. He was the first Hall Tutor at the Student Residential Facility and was tasked to develope a tutorial system for the Nyankpala Campus. He served on the Third Trimester Field Practical Programme for the Faculty of Agriculture.

He obtained his PhD in Biological Science (Plant Tissue Culture, Molecular Biology and Germplasm Conservation) at the University of Reading in 2007. In 2008, he obtained the Professional Development Diploma in Management Studies at the Stratford Business School, UK where he took options in Finance and Accounting, Human Resource Management, Strategic Management and Data Processing.

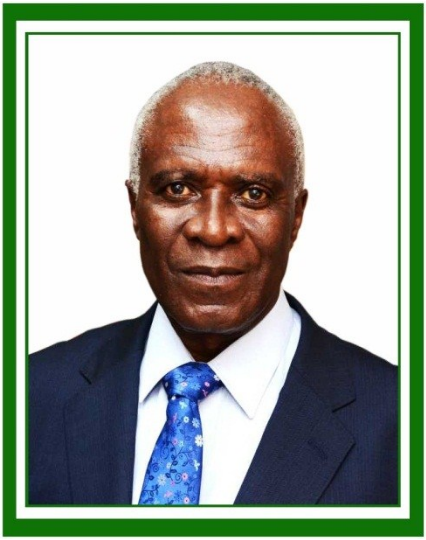
He served as the Head of the Department of Agronomy, Department of Biotechnology where in addition to the Agriculture Biotechnology programme he saw to the establishment and nurturing of two additional new programmes (Biotechnology and Molecular Biology, and Food Science Technology) which are popular programmes in the University. During part of his headship at the Department of Biotechnology he also served as the Vice Dean of the Faculty of Agriculture and is now the Dean.

He has extensive research experience especially in tree crops such as cocoa and the shea tree. He has the passion for the shea tree and wants to help transform the tree by unearthing the potentials of the tree.

Professor Albert Kojo Quainoo is a member of the College of Research Associates (CRA) of the United Nations University Institute for Natural Resources in Africa (UNU-INRA) and a member of the National Biosafety Committee.

He has over 100 scientific publications including 62 referred journal papers, 31 conference proceedings, 26 non-conference papers and a book. He has supervised PhD, MSc and undergraduate students.

Professor Quainoo is involved in several Christian activities especially at the Methodist Church Ghana. He is a class leader, a leader at the Bethel Cathedral Tamale and served for several years as the Society Steward. He is an active member of the Association of Methodist Men's Fellowship where he served as the Vice Chairman and now the Chairman of the fellowship in the Northern Ghana Diocese. He is a conference member of the Methodist Church Ghana and serving on several committees of the church. He is also the Diocesan Treasurer of the Lay Movement of the Northern Ghana Diocese of the Methodist Church Ghana. He is a patron to several organizations in the church.



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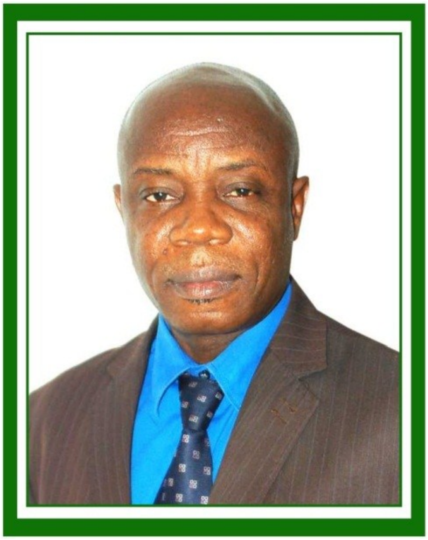

Prof. Gabriel Ayum Teye
VICE-CHANCELLOR

Prof. Seidu Al-hassan
PRO-VICE-CHANCELLOR

Dr. A.B.T. Zakariah
REGISTRAR

Programme

Topic	:	**Unearthing the Hidden Potentials of the Shea Tree (Vitellaria Paradoxa)**
Venue	:	Dr. Andani Andan Auditorium, Central Administration, Tamale Campus
Chairman	:	Vice-Chancellor, **Professor Gabriel A. Teye**
2:00 pm	:	Guests Seated
2:15 pm	:	Vice-Chancellor's Procession (Audience stand)

- Prayers (***Christian*** *and* ***Moslem***)
- Introduction of Chairman by the Registrar, ***Dr. A. B. T. Zakariah***
- Welcome Address/Introduction of Lecturer by the Vice-Chancellor, ***Professor Gabriel A. Teye***
- Lecture on Unearthing the Hidden Potentials of the Shea Tree (Vitellaria Paradoxa) by ***Professor Albert Kojo Quainoo***
- Chairman's Closing Remarks
- Vote of Thanks
- Announcements
- Recession (Audience stand)

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Dedication

This lecture is dedicated to my family and the memory of my parents

UNEARTHING THE HIDDEN POTENTIALS OF THE SHEA TREE
(VITELLARIA PARADOXA)

Introduction

The Vice-Chancellor
Registrar
Pro-Vice-Chancellor
Other Principal Officers
Representatives of other Institutions
Deans and Directors
Heads of Departments
Members of the Academic Board
Members of Convocation
Distinguished Invited Guests
Students and Alumni
Family and Friends
The Press
Ladies and Gentlemen

I am greatly honoured to be given this opportunity by the Vice-Chancellor of the University to welcome you all to my Inaugural Lecture on an important commodity of the North which contributes significantly to the economy of the country. I vividly remember way back in 1974 when my father was transferred from the Volta Region to the Northern Region as a social worker. Our long journey from Ho to Tamale which took four days to complete with the entire family in his small blue Opel Kadett car, the Techiman Tamale portion of the present high ways was not in existence then. It was a jungle with all sorts of colourful wildlife which are no longer around. On entering Kintampo and for the rest of our journey to Tamale my father recognized the persistent presence of this special tree. He took his time to ask for the name of the tree and its use(s). We were more excited when we realized that the tree was the source of the shea butter which we were told will be our source of survival during the harmattan season in Tamale and had over 5 kg of the butter in our luggage. Two weeks on arrival in Tamale (where most of our values, morals and virtues were formed) my father asked us to write an essay on our trip from Ho to Tamale and strangely l was tasked to write an essay on the shea tree.

My dad had the conviction that the shea tree was too big for our understanding and there was the need for an in-depth study of the tree. He was delighted to know that the shea tree was one of the commodities I have been working on and always urged me to look beyond the butter.

However, it was one of my students, Ms. Ruth Ofosu who is currently working with Council for Scientific and Industrial Research (CSIR) who started it all when in 2010 she approached me if l would be interested in supervising her project work on the shea latex. That is how my passion for the shea tree which has festered to involve colleague lecturers and students started.

Ladies and gentlemen, my research background is broad, from plant production, seed science, horticulture, tissue culture, germplasm conservation, biotechnology, wet and dry chemistry biochar research and management. I have worked on several commodities involving cereals, legumes, root and tubers, vegetables and the tree crops. Very often I ask myself where do l belong. I think l have a soft spot for the tree crops which most scientists especially those in academia will avoid simply because it takes a long time to gather meaningful data on them for scientific publications. For me all my interesting publications are on the tree crops (Cocoa and the shea trees) of which l have a special passion for the shea.

Ladies and gentlemen, when we talk about the shea tree all that come to mind is the shea butter, hardly do we mention any other product of the tree. There is therefore the need for us especially those in the research community to know and understand the tree. I have therefore chosen to present the shea tree in a different way and today l am here to deliver my Inaugural Lecture on the science of the shea tree.

Ladies and gentlemen, the shea tree has such great untapped potentials such that if properly researched into can be exploited for the generation of employment opportunities for millions of Ghanaians. This Inaugural Lecture on the topic “Unearthing the hidden potentials of the shea tree” seeks to create the needed awareness for scientists and researchers to implement effective policies for the management of the shea tree particularly for less known products to generate more income for the rural farmers in Northern Ghana. We need to be brave to take bold and strong decisions on the science of the shea tree to maximize its potentials.
With these short opening remarks, l would like to crave your indulgence to journey with me through this Inaugural Lecture.

1.0 Introduction

The shea tree (Vitellaria paradoxa), is utilized extensively in the semi-arid savannah parklands from Senegal in West Africa, where the sub species paradoxa is mainly found, to Sudan/Uganda in the East of Africa where the sub species nilotica is found. Shea covers the entire northern Ghana, more than 78,000 km^2 (Maranz *et al.*, 2004) with a potential annual yield of about 130,000 metric tons of shea products ((Dogbevi, 2009). Hence, shea is an important multipurpose tree and serves as the principal source of income for the local population in the Sahel region. Shea products are good for rural poverty reduction in Northern Ghana since they are sources of livelihood for women in the rural areas.

Literature on shea nut chemical compositions across the Sahel region has shown great diversity for fat and fatty acid composition (Maranz *et al.*, 2004; Di Vincenzo *et al.*, 2005; Davrieux *et al.*, 2010). The West African shea butter is solid while the East African butter is fluid with each attracting different market premium. Shea butter fat is the current primary and most important product from the shea tree but utilization of additional hidden potentials of the shea tree is yet to be tapped (Di Vincenzo *et al.*, 2005; Davrieux *et al.*, 2010; Quainoo *at al.*, 2012; Quainoo, 2016).

First, studies of the shea latex have revealed that this material has comparatively low protein content, which makes it more suitable for production of items like balloons, gloves and condoms since the chances of latex allergy is likely to be low (Chawla *et al.*, 2011; Ofosu and Quainoo, 2013). Additionally, shea latex can form an important component for fabrication of composite bioplastics (Riyajan, 2015) using designer starch (Sagnelli *et al.*, 2017) and highly innovative starch/non-cellulose/rubber blends (Drakopoulos *et al.*, 2017) helping to solve one of the most urgent global problems related to plastics pollution (Cole *et al.*, 2011). Importantly, agro-ecology of the shea tree does not seem to significantly affect the proximate composition of the latex (Quainoo *et al.*, 2015). Second, the shea nut industry generates tremendous volumes of waste products, with only minor economic use. However, shea nut shell waste has been found effective for phytoremediation of heavy metals in contaminated soils (Quainoo *et al.*, 2015; Alkorta *at al.*, 2004). Third, the biochar of the shea nut shell has been successfully used to manage nematodes and to improve soil fertility (Fataw *et al.*, 2018; Lehmann *et al.*, 2006) and also shea nut cake has been demonstrated as biochar raw material for soil amendment. Hence, research on the shea tree adaptability, latex and waste valorisation technology to harness shea-derived products is expected to support a sustainable empowerment of a shea parkland economy.

This Inaugural Lecture is meant to present the other side of the shea tree which has not attracted serious research interest and attention.

2.0 Description and distribution of the shea tree

2.1 Description of the shea tree

The shea tree (*Vitellaria paradoxa* L.) is a large, long-lived tree that is native to the Sahel region of West Africa and is a key species in traditional agroforestry systems and an important source of edible oil shea butter, which is derived from the seed (Wiersema and Leon, 1999).

The shea tree or karate in French is in the Sapotaceae family under the accepted name *Vitellaria paradoxa*, formerly called *Butyrospermum paradoxum* (Henry *et al*, 1983). The shea tree is widely encountered in non- coastal areas of the dry Savannas, forests, and parklands of the Sudan zone of Africa (Boffa *et al.*, 1996). The oldest specimen of the shea tree, as reported in existing literature was first collected by Mungo Park on 26th May, 1797 (Fobil, 2007; Dogbevi, 2009).

Shea is a neglected woody plant in terms of mainstream domestication, despite a long tradition of utilization by rural people. The shea butter is the source of vegetable fat which in West Africa is second in importance only to palm oil. A wide variety of useful products are made from this tree but by far the most important is the shea butter oil derived from the kernels. The tree remains essentially a wild resource across its range stretching from Senegal in the west to Uganda in the east.

The sub species *nilotica* found in East Africa and its catchment area is distinguished from the sub species *paradoxa* found mainly in West Africa by dense *ferruginous indumentum* on the pedicels and outer sepals. The flowers tend to be larger with style lengths 12-15 cm in *paradoxa* (Hemsley1968)

Shea leaves

Flowering shea tree

Shea tree bearing fruits

Shea tree with a closed canopy

Picture 1: Different growth stages of the shea tree

2.2. Distribution of the shea trees in Africa

In Africa the shea tree is found stretching from Sudan to Guinea, across nearly twenty different countries including Benin, Ghana, Chad, Burkina Faso, Cameroon, Central African Republic, Ethiopia, Guinea Bissau, Guinea, Ivory Coast, Mali, Niger, Nigeria, Senegal, Sierra Leone, Southern Sudan, Togo, Uganda, Democratic Republic of Congo and Kenya (FAO, 1988; DFSC, 2000 and Manasieva, 2011). The species range forms an almost unbroken belt approximately 5000 km long by 500 km wide from Senegal to Uganda (Bonkoungou, 1987).

In Ghana, the shea tree mainly grows in the three Northern Regions where the climate is dryer as compared to the south. The northern sector of Ghana covers approximately two-thirds of the country's land space located in the dry Sudan and Sahelian savannah area where rainfall is low, erratic and unpredictable. Environmental degradation and vegetation removal as a result of annual bush fires are common. Typically, the shea occurrence zone lies in the zone of 600 and 1400 mm of annual rainfall (DFSC, 2000).

Shea trees grow in abundance in the wild in almost half of the country occurring mostly in the entire area of Northern Ghana, with land coverage of over 77670 km^2 in Western Dagomba, Southern Mamprusi, Western Gonja, Lawra, Tumu, Wa and Nanumba with Eastern Gonja having the densest stands. It is also reported that in Ghana, it grows extensively in the Guinea Savannah and less abundantly in the Sudan Savannah (FAO, 1988 and Fobil, 2007).

The tree is a major component of the woody flora of the Sudan and Guinea savannah vegetational zones of sub-Saharan Africa (Lovett and Haq, 2000). Sparse Shea tree covers are found in the Brong-Ahafo, Ashanti, Eastern and Volta regions in the south of the country (Fobil, 2007).

Figure 2.1: Map of Ghana Showing Shea Growing Areas in Green

Source: *Quainoo et al., (2012). International Journal of Biology, Pharmacy and Allied Sciences, 1 (2): p. 84-98.*

2.3. Economic Importance of the Shea tree

The nut from the shea tree serves as the main source of livelihood for the rural women and children who are engaged in its gathering and processing. Shea oil is the main edible oil for the people of Northern Ghana and is the most important source of fatty acids and glycerol in their diet. It has anti-microbial properties, which gives it a place in herbal medicine. It plays a significant role in the pharmaceutical and cosmetic industries. Almost every part of the tree has some uses. For example, the leaves are used as fodder and also as an ingredient for making alkaline and paint (Lovett and Haq, 2000). The roots and bark also have numerous medicinal uses (Millee, 1984; Soladoye, Orhiere and Ibimode, 1989; Fobil, 2007). The fruit, when ripe, is either eaten as a snack or also as a famine food (MaAllan, Acbischer and Tomlinson, 1996). The leaves constitute good forage for animal feed and also used to improve soil fertility. The wood is hard and reportedly termite-resistant, and is desirable as lumber (Wiersema and Leon, 1999).

2.4. Relevant Publication Information

Quainoo A.K., Nyarko G., Davrieux F., Piombo G., Bouvet J.M., Yidana J.A., Abubakari A.H., Mahunu G.K., Abagale F.K., Chimsah F.A., (2012). Determination of biochemical composition of shea *Vitellaria paradoxa* nut using near infrared spectroscopy (NIRS) and gas chromatography. *International Journal of Biology, Pharmacy and Allied Sciences*, 1 (2): p. 84-98.

Abstract

The shea tree *Vitellaria* paradoxa L. is the most prevalent tree crop in northern Ghana with the shea butter fat as the most important product from the tree. Difference in the shea butter fat quality is mainly attributed to bioclimatic variations in temperature and rainfall. The purpose of this study was to apply near infrared, wet chemistry and gas chromatography to characterize the fat and free fatty acid profiles of shea butter fat from three locations (Paga, Nyankpala and Kawampe) in Ghana. The shea nuts from the three locations in Ghana conformed to the West Africa shea nuts on the global data base on shea nuts compiled at CIRAD. Samples from Paga recorded the highest moisture content ranging between 5.63 % and 12.04 % (dry matter) with a mean content of 6.83 % and a standard deviation of 1.30 % whilst samples from Kawampe recorded the lowest moisture content with a mean of 5.23 %. Samples from Kawampe recorded the highest fat content ranging from 47.07 % to 57.39 % (dry matter) with a mean content of 52.69 % and a standard deviation of 2.55 % with samples from Paga recording the lowest fat content with a mean of 48.84 %. Stearic acid content of the samples

was higher than oleic acid content from the three locations with virtually the same ratio of saturated and unsaturated fatty acids. Correlation between wet chemistry values and near infrared spectroscopy (NIRS) predicted values for moisture content (calibration set) with regression of 0.974 indicating the ability of NIRS to differentiate between nuts from different regions. The nature of the dried shea nuts before processing affected the quality of the shea butter fat as moulded samples recorded higher free fatty acids reducing the quality of the shea butter fat. Fatty acid methyl esters (FAME) analyses indicated that the samples from the three locations in Ghana were mostly saturated with stearic and oleic acids and less of palmitic, vaccenic, linoleic and arachidic acids in the fatty acid profiles of shea butter fats.

Keywords: Shea nut butter fat, Fat content, Moisture Content, NIRS, Free Fatty Acid, Gas Chromatography.

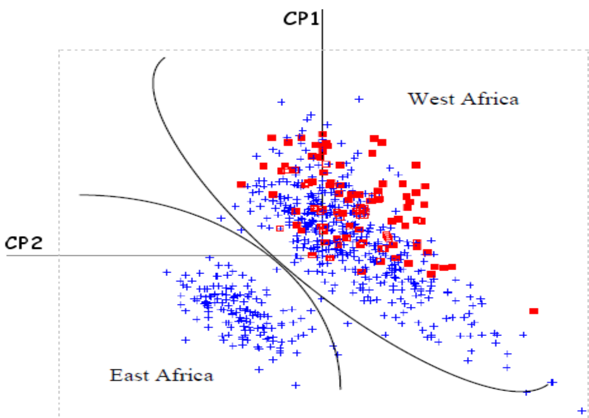

Figure 2.2: Scatter Plots of the 105 Shea**. 2:** From Ghana in Red Samples

Source: *Quainoo et al., (2012) International Journal of Biology, Pharmacy and Allied Sciences, March, 1(2): 84-98.*

Table 2.1: Descriptive Statistics of Wet Chemistry Values of Shea

	LOCATION	SAMPLE NO	MINIMUM	MAXIMUM	MEAN	SD
MOISTURE	Nyankpala	35	4.61	7.10	5.55	0.57
	Paga	35	5.63	12.04	6.83	1.30
	Kawampe	35	4.58	6.00	5.23	0.37
FAT	Nyankpala	35	42.05	59.45	52.19	3.76
	Paga	35	35.79	54.49	48.84	3.13
	Kawampe	35	47.07	57.39	52.69	2.55
STEARIC ACID	Nyankpala	35	38.57	52.16	45.71	3.06
	Paga	35	38.55	49.00	43.90	2.67
	Kawampe	35	39.08	49.46	44.06	2.34
OLEIC ACID	Nyankpala	35	35.19	46.24	40.88	2.64
	Paga	35	37.84	46.98	42.63	2.30
	Kawampe	35	36.95	47.90	42.87	2.46
RATIO (SATURATED /UNSATURATED FATTY ACID)	Nyankpala	35	0.79	1.50	1.11	0.16
	Paga	35	0.79	1.20	0.99	0.10
	Kawampe	35	0.80	1.22	1.00	0.10

Source: *Quainoo et al., (2012) International Journal of Biology, Pharmacy and Allied Sciences, March, 1(2): 84-98.*

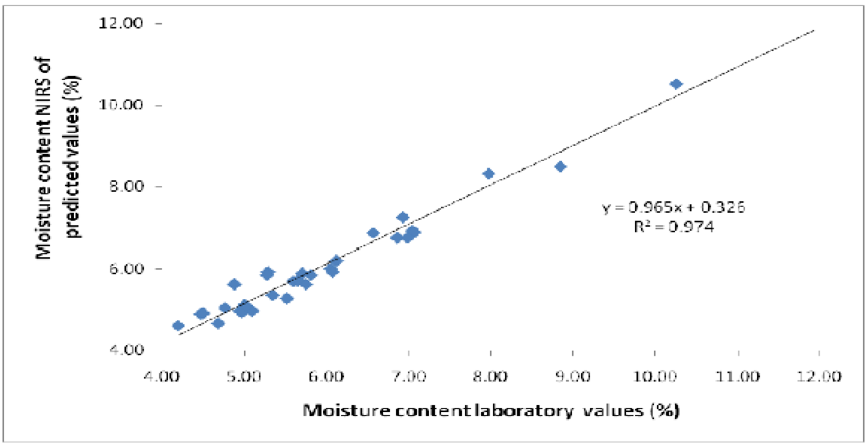

Figure 2.3: Scatter Plots of Moisture Content of Laboratory Values Versus NIRS-

Source: *Quainoo et al., (2012) International Journal of Biology, Pharmacy and Allied Sciences, March, 1(2): 84-98.*

Table 2.2: Free Fatty Acid of Shea Butter Fat Expressed as Percentage by Mass

SAMPLE	LOCATION	WEIGHT OF SAMPLE (G)	TITRATION VOLUME (ML)	ACIDITY (%)
1117022	Nyankpala	0.4433	0.7	3.75
1117003	Paga	0.3539	1.06	7.11
1117009	Paga	0.3401	1.44	10.05
1117012	Nyankpala	0.3421	2.53	11.55
1117015	Nyankpala	0.3534	2.58	17.32
1117017	Nyankpala	0.3805	9.28	57.89
1117018	Nyankpala	0.3431	6.12	40.76
1117023	Nyankpala	0.3961	3.42	20.49
1117033	Nyankpala	0.3081	4.5	3.47
1117037	Nyankpala	0.381	5.52	33.38
1117057	Kawampe	0.3548	0.72	4.82
1117073	Nyankpala	0.3539	1.32	8.85
1117076	Nyankpala	0.3334	2.4	17.09
1117005	Paga	0.3902	2.46	14.96
1117013	Kawampe	0.3273	0.5	3.63
1117058	Kawampe	0.3544	0.46	3.08
1117059	Kawampe	0.3538	0.66	4.43
1117072	Kawampe	0.435	0.52	2.75
1117074	Paga	0.3448	0.94	6.47
1117077	Kawampe	0.4492	0.94	4.96

Source: *Quainoo et al., (2012) International Journal of Biology, Pharmacy and Allied Sciences, March, 1(2): 84-98.*

3.0 Shea latex

The shea tree has a great untapped capacity for producing large amounts of latex that can constitute an important source of raw material for the gum and rubber industry which can create employment opportunities for millions of Ghanaians (Dogbevi, 2009). Research on potential uses of the latex from the shea tree is practically non-existent.

Gradually, evidence is emerging that the shea latex could be put to economic use. A published paper by Quainoo and his associates in 2015 suggested that no matter the agro-ecological zone of the shea tree, the tapped shea latex proximate composition in terms of moisture content, crude protein, crude fat and carbohydrate are not affected. Research on the shea latex raises several research questions which needs to be addressed.

3.1 Description of latex

The bark of most trees is a complex network of laticifers, or latex vessels. Each vessel is merely one-third of the thickness of a human hair and exudes latex when the bark is cut (Omo-Ikerodah *et al.*, 2009). In the chemical industry's nomenclature, the term latex is applicable to any emulsion of polymers, including synthetic rubbers and plastics (Cyr, 1982).

According to Cotter, Hill and Ross (2009) the natural latex is a complex milky sap comprising rubber (cis -1, 4-poly -isoprene), protein substances, minerals and polyphenols which are synthesized in specialized cells called laticifers in over 2000 plants species grouped under 300 genera as secondary metabolite.

The natural rubber latex is obtainable from different species of plant trees (Yip and Cacioti, 2002). Aside the natural latex being a carrier medium of various nutrients, the latex also acts as a protective fluid against insect predators for the trees (Dean, 1987). The best period for commencing the tapping of the rubber latex is March to April and September.

This may present the opportunity for the shea tree to receive the needed research attention for the total exploitation of the tree and open investment opportunities in the catchment area of the shea tree leading to poverty alleviation and improvement of the economies of the shea tree producing areas.

Picture 2: Tapping of shea latex

Picture 3: (A) Unrefined shea latex (B) Refined shea latex

Source: *Quainoo A.K. (2016) Unearthing the Hidden Potentials of the Shea Tree (Vitellaria paradoxa). ISBN: 9789988-2-3468-3.*

3.2 Research direction

Gradually, research information is being made available on the shea latex, however a lot still needs to be done to understand the chemical and physical composition of the latex, and the biology of the shea tree. This Inaugural Lecture will emphasises works already carried out to provide useful information on the potential use of the shea latex. The outcome will further broaden the knowledge base of the shea tree and its products for future research work.

3.3 Relevant Publication Information

3.3.1 *Fosu R. and Quainoo A. K. (2013). Comparism of the Proximate Composition of Shea (Vitellaria paradoxa) and Rubber Latex (Hevea Brasilienesis).* International Journal of Research Studies in Biosciences (IJRSB) Volume 1, Issue 2, November 2013, pp 14-16 www.arcjournals.org

Abstract

The shea latex sample was tapped from different shea trees and the rubber latex sample was obtained from Kade in Ghana. The latex samples were spread on tarpaulin and subjected to air drying for three days. The samples were then poured into a transparent container and sent to the laboratory for the proximate analysis. Results from the study indicated that latex proximate composition varied considerably and is dependent on a number of factors including climatic conditions, season of the year and time of tapping. The study also revealed higher percentages of moisture, crude protein and carbohydrate in rubber latex than in shea latex. There was higher percentage of ash and crude fat in shea latex than in rubber latex. The shea latex yield was higher when tapping was done at 45°C however, continuous tapping of the same tree eventually reduced yield. The study revealed that shea latex can be exploited and used to manufacture products such as balloons, gloves and condoms because of its low protein content compared to rubber latex.

Key words: Shea tree, (*Vitellaria paradoxa*) rubber tree, (*Hevea brasilienesis*), latex.

Table 3.1: Proximate composition of Shea and rubber latex

	Shea latex (SHL)	Rubber Latex (RL)		
Parameter (%)	Mean±S.D	Mean±S.D	P. Value	LSD
Crude Protein	1.961±0.124	2.075±0.013	0.326	0.381
Ash	5.835±0.783	3.721±0.873	0.126	3.569
Moisture Content	0.965±0.162	4.395±0.148	0.002	0.670
Crude Fibre	57.208±10.252	1.154±0.264	0.016	31.200
Carbohydrate	33.494±10.068	90.610±2.130	0.016	31.310

Source: *Fosu R. and Quainoo Albert K. (2013). International Journal of Research Studies in Biosciences. Vol. 1, Issue 2, November*

3.3.2 *Quainoo A. K., Abdul-Aziz B., F. K. Abagale F.K. and Abubakari A. H. (2015). Effect of Agro-ecological Zones on the Proximate Composition of Shea Latex (Vitellaria paradoxa L.).* Research in Plant Biology, 5(1): 09-16.

Abstract

Shea latex was tapped from different trees from cultivated and fallow fields at Yagaba, Nyankpala in the Northern Guinea Savannah Agro-ecological zone and Kawampe in the Transitional Agro-ecological zone of Ghana. Generally, agro-ecological zones and land use did not influence the quality of the proximate composition of the Shea latex. Proximate composition of the Shea latex did not differ with land use and agro-ecological zone. Crude fat, moisture content and ash content although were slightly higher in cultivated fields were not affected by land use and location. However, crude protein level in latex was significantly higher at Yagaba and significantly lower in cultivated fields.

Source: ***Quainoo et al***. *(2015). Research in Plant Biology, 5(1): 16-19, 2015*

Table 3.2: Proximate Composition of Shea Latex Across Agro-ecological Zones

Location	Crude Fat (%)	Crude Protein (%)	Moisture (%)	Ash (%)
Kawampe	52.030±5.500	0.976±0.131	2.039±0.680	5.040±0.491
Nyankpala	53.920±7.556	0.992±0.203	1.912±0.711	4.951±0.633
Yagaba	53.850±6.082	1.134±0.242	1.861±0.583	4.944±0.531
FPr	0.607	0.017	0.663	0.850
LSD	4.296	0.118	0.407	0.377

Source: ***Quainoo et al. (2013). Research in Plant Biology, 5(1):16-19, 2015***

4.0 Potential utilization of shea nut shells in phytoremediation of heavy metals

4.1 Phytoremediation

Soil and water pollution through human activities such as mining and agriculture resulting in the degradation of the environment has attracted public attention over the years. The implications derived from eating foods containing these heavy metals are very horrific and deadly and therefore necessitates characterization and remediation of the soil bionetworks.

A solution to these problems has either been expensive or non-existent. The shea nut industry generates tremendous volumes of waste products, with only minor economic use. However, shea nut shell waste which until recently had no economic use has been found effective for phytoremediation of heavy metals in contaminated soils (Quainoo *et al*., 2015; Alkorta *et al*., 2004).

4.2 Relevant Publication Information

Quainoo, A. K., Konadu, A. and Kumi, M. (2015). The Potential of Shea Nut Shells in Phytoremediation of Heavy Metals in Contaminated Soil Using Lettuce (Lactuca sativa) as a Test Crop. *Journal of Bioremediation and biodegradation. Vol.6. Issue 1. http://dx.doi.org/10.4172/2155-6199.1000268*.

Abstract

Contamination of soil and water by heavy metals cause serious risks to living organisms especially humans and the ecosystem in general through direct contact, inhalation and dermal contact. In this study, shea nut shells were used as adsorbent for heavy metals from contaminated soil. Shea tree (Vitellaria paradoxa) is one of the economic tree crops prevalent in Northern Ghana. Leafy vegetables depend on water for their growth and survival and have massive potential of accumulating heavy metals in their edible parts. Accumulation of heavy metals in leafy vegetables makes them dangerous to human health when consumed. It is within this perspective, which made it imperative for the application of shea nut shells to remove heavy metals such as manganese, iron, zinc and copper from contaminated soil with lettuce (Lactuca sativa) as a test crop. Plastic pots filled with soil from Nyankpala with drainage holes at the bottom and contaminated water from Zoomlion landfill site at Gbelahi in Northern Region of Ghana was used. Atomic Absorption Spectrophotometer was used to determine manganese, iron, zinc and copper in the test crop (lettuce). The mean concentration of heavy metals after 21 and 42 days of transplanting were; Fe (271.135 mg/kg and 457.791 mg/kg), Mn (45.245 mg/kg and 77.211 mg/kg) and Zn (20.049 mg/kg and 50.108 mg/ kg). The concentration of copper was below the level of 0.001 mg/kg. According to the results obtained from this research, shea nut shells have the potentials of adsorption of heavy metals from contaminated soil and water hence it is recommended as a suitable means of phytoremediation.

Keywords: Soil; Heavy metals; Waste water; Vegetables; Shea nut shells

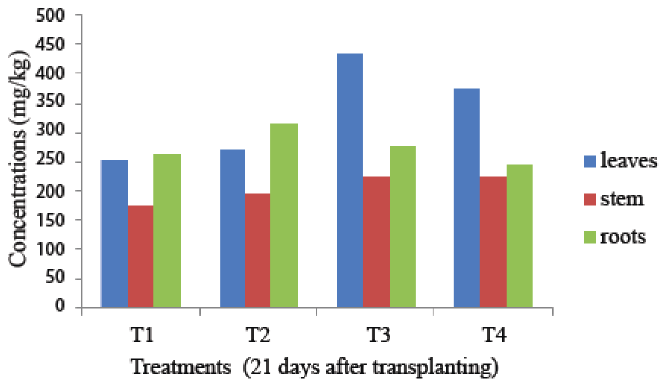

Figure 4.1a: Accumulation of iron by lettuce at 21 days after transplanting.

Source: *Quainoo A.k., Konadu A. and Kumi M. (2015). J. Bioremed Biodeg 5: 268. doi:10.4172/2155-6199.1000268*

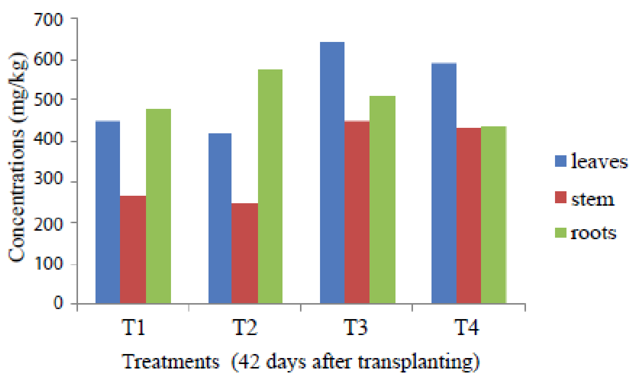

Figure 4.1b: Accumulation of iron by lettuce at 42 days after transplanting.

Source: *Quainoo A.k., Konadu A. and Kumi M. (2015). J. Bioremed Biodeg 5: 268. doi:10.4172/2155-6199.1000268*

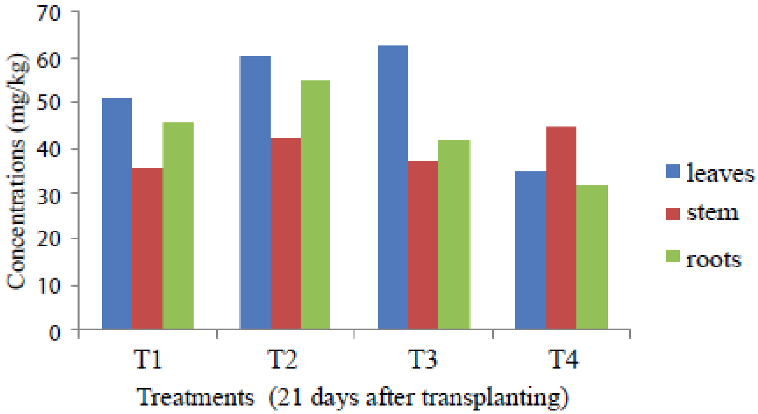

Figure 4.2a: Accumulation of manganese by lettuce at 21 days after transplanting.

Source: *Quainoo A.k., Konadu A. and Kumi M. (2015). J. Bioremed Biodeg 5: 268. doi:10.4172/2155-6199.1000268*

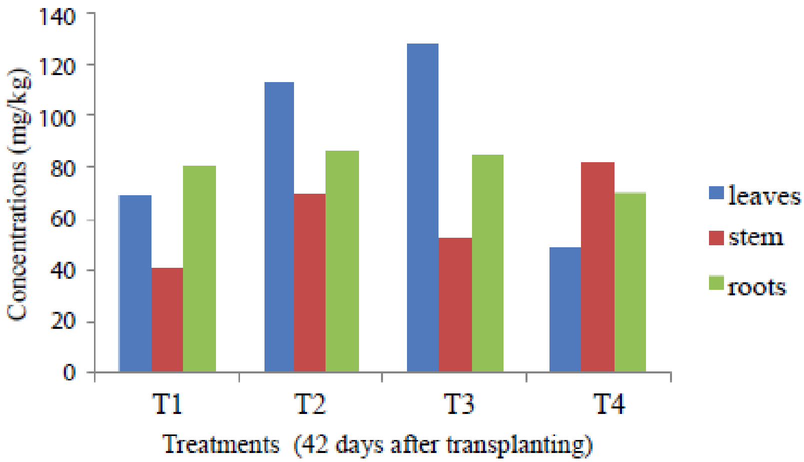

Figure 4.2b: Accumulation of manganese by lettuce at 42 days after transplanting.

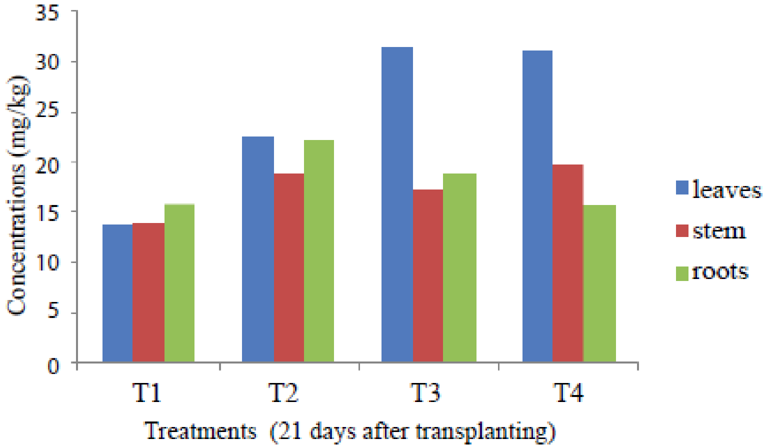

Figure 4.3a: Accumulation of zinc by lettuce at 21 days after transplanting.

Source: *Quainoo A.k., Konadu A. and Kumi M. (2015). J. Bioremed Biodeg 5: 268. doi:10.4172/2155-6199.1000268*

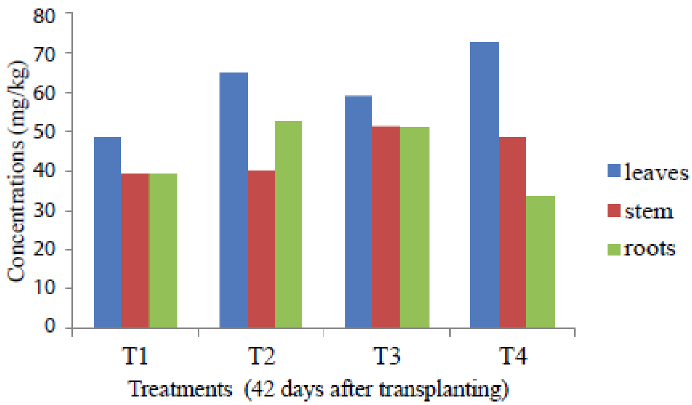

Figure 4.3b: Accumulation of zinc by lettuce at 42 days after transplanting.

Source: *Quainoo A.k., Konadu A. and Kumi M. (2015). J. Bioremed Biodeg 5: 268. doi:10.4172/2155-6199.1000268*

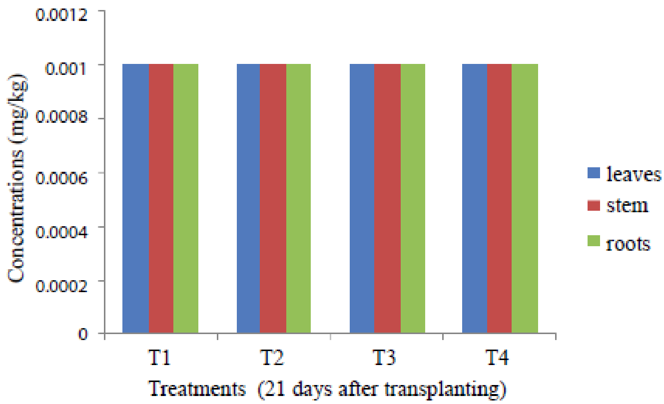

Figure 4.4a: Accumulation of copper by lettuce at 21 days after transplanting.

Source: *Quainoo A.k., Konadu A. and Kumi M. (2015). J. Bioremed Biodeg 5: 268. doi:10.4172/2155-6199.1000268*

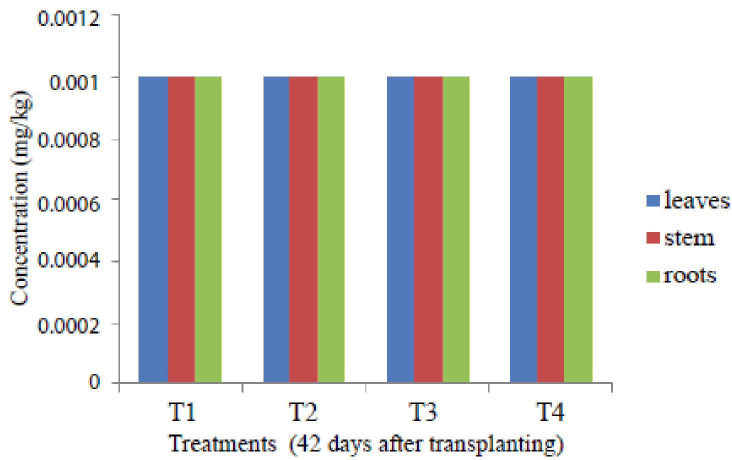

Figure 4.4b: Accumulation of Copper by Lettuce at 42 days after transplanting.

Source: *Quainoo A.k., Konadu A. and Kumi M. (2015). J. Bioremed Biodeg 5: 268. doi:10.4172/2155-6199.1000268*

Picture 4: (A) Shea nut shell (B) Grinded shea nut shells

Source: *Quainoo A.k., Konadu A. and Kumi M. (2015). J. Bioremed Biodeg 5: 268. doi:10.4172/2155-6199.1000268*

4.3 Abudu Ballu Duwiejuah, Samuel Jerry Cobbina, Albert Kojo Quainoo, Abdul Halim Abubakari, Noel Bakobie (2018). Adsorption of Potentially Toxic Metals from Mono and Multi-Metal Systems Using Groundnut and Shea Nut Shell Biochar. *Journal of Health and Pollution, 8(18): 6-19, April-June.*

Summary

Background. Adsorption is a unique and promising method for the removal of trace metals from an aqueous environment using cost-effective and readily available biochars.

Objective. The present study examined mono and simultaneous adsorption of cadmium (Cd), mercury (Hg) and lead (Pb) onto biochars produced at pyrolysis temperatures of 350 ± 5°C and 700 ± 5°C.

Methods. Fifty mg/l of trace metal ions with 2 g/50 ml of adsorbent dosage were leached at constant room temperature of 24 ± 0.5°C in the laboratory with a constant contact time of 72 minutes. A total of

126 elutes were obtained from the batch experiments and conveyed to the Ecological Laboratory at University of Ghana for the analysis. Results. In the mono-component system of Cd, Hg and Pb, removal efficiency was almost 100% using groundnut, shea nut shell, and a combination of groundnut and shea nut shell biochars. The experiment showed that shea nut shell biochars have the strongest affinity for trace metal ions in the mono aqueous phase. In the binary system, the removal efficiency was over 99.60% for cadmium and 100% for mercury. The ternary experiment showed an order of adsorption of $Pb^{2+} > Hg^{2+} > Cd^{2+}$ for Cd, Hg and Pb ions onto groundnut and shea nut shells biochars. Fast pyrolysis temperatures and some types of biochar showed a slight increase in the adsorption efficiency of metal ions, but the increase was not statistically significant ($p > 0.05$).

Conclusions. The study revealed that the Langmuir adsorption isotherm was the best fit model for trace metal ion adsorption onto biochars in the batch experiment. The interactive effects of binary and ternary metal systems onto biochars are antagonistic and synergistic in nature. Based on these results, it is recommended that further competitive adsorption studies of these biochars should be undertaken for accurate estimation of adsorption in natural environments.

Source: Abudu Ballu Duwiejuah et at. (2018). Journal Health Pollution 18: 16-29 (2018).

5.0 Shea biochar: Its applications/prospects in agriculture in Ghana

5.1 What is biochar

It is a solid by-product rich in carbon obtained from carbonization of biomass heated to temperatures between 300 ^{0}C and 1000 ^{0}C in low or if possible zero concentration of oxygen (Komang and Orr, 2016). It is produced from diverse raw materials such as agriculture crop residue, wood waste and animal manures (Roupcova *et al*., 2017). The term biochar was initially introduced in 1999 to distinguish it from activated carbon from fossil fuels (Burns, 2017) and was introduced in 2006 as a soil amendment product (Lehmann, Gaunt and Rondon, 2006). Organic portion of biochar has much less total carbon (40-75%) as compared to charcoal (75% or more) but high in mineral content such as calcium, phosphorous, nitrogen, potassium and carbonate ions (Jenkin and Jenkinson, 2009).

The type of reaction that takes place between biochar and the soil is mostly dependent on factors such as feedstock composition, pyrolysis process conditions, biochar particle size and mode of delivery, and soil properties (Kuzyakov *et al*., 2009).

The synergistic relationship between biochar and the environmental management gives rise to four major categories which are energy production, soil improvement, climate change mitigation and waste management, which when utilized individually or coupled together has social or financial benefits (Lehmann and Joseph, 2009).

5.2 Biochar production

Temperature is the most important parameter to consider in biochar formation as biochar derived at low temperatures (below or about 500 ^{0}C) are of different properties as compared to those formed at high temperatures (Brandstaka *et al.,* 2010; Elad *et al.,* 2011).

Generally, biochars generated at high temperatures are superior to those formed at low temperatures due to high value in pore space. However, some times biochar produced at low temperatures tend to be of very good quality since they have low pH values, high cation exchange capacities (CEC) and lower ash contents which makes it suitable as a soil amendment (Elad *et al.,* 2011).

Generally, woody and herbaceous biomass consist of cellulose, hemicellulose and lignin. The heat value of lignin is twice that of cellulose which makes feedstock biomass high in lignin content the most suitable for production of high quality biomas (Zeelie, 2012).

5.3 Importance of biochar

Research has shown benefits of biochar application to soil characteristics and environment. Biochar's porous nature allows for absorbtion and adsorbtion of water, nutrients, ensure favourable conditions for microbes to inhabit the soil leading to improvement of the soil (Reddy, 2014).

Biochar's long residence time in the soil and energy production offers a way to sequester carbon from the atmosphere by reducing greenhouse gas emissions and as well as reduce losses of nutrients through leaching (Lehmann, Gaunt and Rondon, 2006). The high cation exchange capacity of biochar, improves nutrient use efficiency. Biochar help raise pH, improving availability of nutrients to crops. Biochar enhances soil microbiota (Reddy, 2014). Biochar serves as a silage agent, feed additive, slurry treatment, manure composting, water treatment in fish farming, substitute for peat in potting soil (Schmidt and Wilson, 2014).

5.4 These are my thoughts on potential use of shea biochar

My observations on biochar research (locally) seem to be biased toward its application for soil amendment. There is a hypothesis that biochar application may have an impact on the complex system of rhizosphere-root-soil-pathogens due to chemical and physical properties such as soil moisture holding capacity, nutrient content, pH, adsorption and absorption properties and many more (Graber *et al.,* 2014).

Ample evidence suggests that biochar foliar application has been successfully used to manage pathogens in several crops such as tomato, pepper, cucumber. Traditionally we use kitchen ash on okro and garden egg plants to manage pests.

This is a fertile ground for research as I am yet to read about using biochar to manage storage pests. We have used shea nut shell biochar to manage nematodes in tomato (Fataw, Quainoo and Kankam, 2019).

5.4 Relevant Publication Information

Fataw Ibrahim, Albert Kojo Quainoo and Frederick Kankam (2019). Effect of Shea Nut Shell Biochar on Root Knot Nematodes (Meloidogyne spp.) of Tomato (Solanum lycopersicum L.). *Annual Research & Review in Biology 30(2): 1-7, 2018; Article no. ARRB.45187 ISSN: 2347-565X, NLM ID: 101632869*

Abstract

Effect of shea nut shell biochar on root knot nematodes and performance of tomato was investigated under nematode inoculated soils. Steam sterilized soil was admixed with biochar, which was later inoculated with 1000 second stage juveniles (J2) two weeks after transplanting. Tomato variety (Petomech-GH) was planted in potting medium of soil to biochar ratio of one part of biochar (250 g) is to one part of soil (1B1S), one part of biochar is to two parts of soil (1B2S), two parts of biochar is to one part of soil (2B1S), and no biochar application (control). Steam sterilized soil amended with biochar inoculated with 1000 second stage juveniles (J2). The result indicated that, biochar increased the pH of the soil, lessened the adverse effects of Meloidogyne spp., resulting in decline in galling and improvement in growth and yield of tomato. Increased biochar concentration resulted in decreased nematode gall formation on the roots of the tomato plant. Biochar amended soils resulted in lower egg masses.

Increased biochar concentration resulted in decreased performance of tomato plant. Tomato plants treated with low biochar concentrations (1B2S and 1B1S) produced higher fruit numbers and weights, and plant biomass.

Source: Fataw Ibrahim, Albert Kojo Quainoo and Frederick Kankam (2019). Annual Research and Review in Biology 30(2): 1-7, 2019; Article no. ARRB.45187 ISSN: 2347-565X, NLM ID: 101632869

6.0 Germplasm conservation

6.1. Establishment of shea botanical garden

Preservation and germplasm conservation of shea genetic materials is crucial in the face of urbanization, demand for land for estate development and expansion in agriculture land. Germplasm collection from various areas of Northern Ghana based on cultivar lines using indigenous knowledge and molecular markers to create a digital library (herbarium) will go a long way to preserve and document the shea tree. Recording the geographic coordinates for the accessions using a GPS positioning system will further enrich the data for future research.

Determination of genetic variation among shea trees to establish cultivar lines using morphological, biochemical and molecular markers will help establish a matrix of geographic distance bases on longitude and latitude GPS positions from sampling sites to study correlation between the matrix and the genetic distance matrix. This should be followed with the establishment of s hea tree botanical garden to conserve shea based on cultivar lines to serve as reference materials. The facility should be protected from bush fires and roaming animals.

6.2 Propagation of Shea tree

Traditionally, *Vitellaria paradoxa* is propagated by seed and in some areas obtaining seed for planting is difficult as all the fruits are nearly collected for butter production. This is worsened by the short viability of seeds in storage as a result of the high oil content of the seeds. To overcome the problem of poor seed germinations, attempts have been made using grafting and budding techniques to generate new planting materials with the aim of increasing the growth rate and reducing the time to fruiting (Grollean, 1989). Although, some successes have been made the outcome has been slow. Furthermore, the current approach of grafting and budding of shea trees are not performed on cultivar lines which may be a disadvantage to the establishment of a shea plantation. Layering has also been successful, yet it is still difficult to practise. These techniques need to be improved through further research to permit the multiplication of superior trees.

In the face of shortening bush fallow cycles and increasing pressure on fuelwood resources which threatens *Vitellaria paradoxa* population in Northern Ghana, there is an increasing need to generate and conserve genetic resource base of the shea tree. Furthermore, recent calls in Ghana to move from the present state of shea tree cultivation (all shea cultivars mixed together) to the establishment of shea tree plantations requires planting shea trees of the same cultivar on the same plantation.

6.3 Macro-propagation of shea tree

Shea tree development has been noted to be one of the most effective strategies to reduce poverty and adapt to climate change. However, increased shea tree production must be carefully adjusted to expected climate alterations. The quality of the shea tree must be secured for the long term resilience of the trees utilization by reviving plantations through quality selection of robust genotypes among shea germplasm. DNA-based molecular markers would assist easy and reliable identification of shea varieties. The method to be used should be rapid, simple, and efficient, and requires no sequence information of the plant genome of interest and will provide new simple way to develop molecular markers for assessing genetic diversity of shea germplasm (Xiong *et al.*, 2011).

Tissue culture technique such as somatic embryogenesis has been routinely used both as a means of propagation, as well as a valuable model for investigating the structural, physiological and molecular events occurring during embryo development (Stasolla and Yeung, 2003). The technique has been applied on tree crops such as cocoa to generate uniform planting materials (Maximova *et al.*, 2002). The technique has also been successfully applied on cocoa and cassava generating disease free planting materials from cocoa swollen shoot virus infected trees and cassava mosaic infected trees respectively (Quainoo, Wetten and Allainguillaume 2008; Damba, Quainoo and Sowley, 2013).

This technique makes it ideal for the selection of disease-free planting materials for breeding programmes, multiplication and micro-propagation of agricultural materials and the development of genetic transformation. The technique also has an important role to play in germplasm conservation and distribution. This technique should be applied on shea tree in an attempt to generate clonal propagules (somatic embryos) for mass propagation in Northern Ghana. The outcome will result in the development of the shea tree on cultivar lines as a resource material for sustainable income generation. It will also make materials available for shea plantation and contribute to the prevention of environmental degradation and poverty alleviation.

6.4 Research directions

Tissue culture techniques through somatic embryogenesis should be applied to establish a protocol for the generation of somatic embryos for the shea tree. Once a robust protocol for shea tree embryogenesis is established, clonal propagules for mass propagation of the shea tree will become possible to pave the way for the establishment of commercial shea plantation.

7.0 Biochemical composition of shea butter and shea latex

7.1 Shea butter based on cultivar lines

Presently, shea butter is the most important product from the shea tree and is mostly extracted by women. Literature on chemical composition of shea nut across the Sahel region has shown great diversity for fat and fatty acid composition (Di Vincenzo *et al.*, 2005). Differences between East Africa shea butter where the sub species nilotica is found and West African shea butter where the sub species paradoxa is dominantly found is mainly based on the stearic and oleic acid composition of the butter (Davrieux *et al.*, 2010). The West African shea butter is solid while the East African butter is fluid. These variations were mainly attributed to bioclimatic variations in temperature and rainfall. Since the shea nuts picked for butter extraction come from different shea cultivars growing together, it stands to reason that if shea nuts are picked and extracted for butter based on cultivar lines, the outcome will be shea butter with different fat and fatty acid composition, quality and market premium.

The free fatty acid of shea butter determines its quality and marketability. However, free fatty acid determination is carried out by a chemical method that involves titration which is time consuming, labor intensive and requires large amounts of reagents. Near–infrared reflectance spectroscopy (NIRS) offers an attractive alternative because it is fast, non-destructive, involves no sample preparation and provides a safe working environment (Rao *et al.*, 1993). Correlation between wet chemistry values and NIRS predicts values for moisture content (calibration set) with a regression of 0.974

indicating the ability of NIRS to differentiate between nuts from different cultivar lines (Quainoo *et al.*, 2012).

There is the need to apply advance technologies such as NIRS, wet chemistry and chromatography to characterize the fat and free fatty acid profiles of shea butter fat based on shea cultivar lines across different agro-ecological zones to establish the effect of bioclimatic factors on shea butter quality. This will aid in the selection of cultivar lines for the establishment of shea tree plantation which is the preferred way to proceed.

Picture 5: Different types of shea butter

8.0 Conclusion

The shea tree (*Vitellaria paradoxa*), is utilized extensively in the semi-arid savanna parklands from Senegal in West Africa, where the sub species paradoxa is mainly found, to Sudan/Uganda in the East of Africa where the sub species nilotica is found. Shea is an important multipurpose tree and serves as the principal source of income for the local population in the Sahel region. However, present shea tree production is only partly resilient due to for example extensive cutting of trees for fuel wood and charcoal. Climate change is already affecting the productivity and effects are expected to be increasingly more severe. Information on shea tree sustainable production is lacking but it is expected that the tree stock germplasm in the shea parkland areas is not fully adjusted for optimized adaptation to changed growth conditions due to climate change. Shea butter fat is the current primary and most important product from the shea tree but utilization of additional hidden potentials of the shea tree is yet to be tapped. First, studies of the shea latex have revealed that this material has comparatively low protein content, which makes it more suitable for production of items like balloons, gloves and condoms since the chances of latex allergy is likely to be low. Additionally, shea latex can form an important component for fabrication of composite bioplastics with the potential to solve one of the most urgent global problems related to plastics pollution. Second, the shea nut industry generates tremendous volumes of waste products, with hitherto only minor economic use. However, shea nut shell waste has been found effective for phytoremediation of heavy metals in contaminated soil. Third the biochar of the shea nut shell has been successfully used to manage nematodes. Hence, research on the shea tree adaptability, latex and waste management technology to harness shea-derived products is expected to support a sustainable empowerment of shea parkland economy.

8.1 Recommendation

The essence of this Inaugural Lecture is to draw the attention of the research community and policy makers to have a second look at the shea tree to capitalise on it hidden potentials to stimulate economic growth and development of the country. The tree has not attracted the needed research funds and interest. The development of the perennial crop sub-sector especially the shea nut crop has been noted to be one of the most effective strategies that can reduce poverty and support local communities to adapt to climate change. Women are mostly involved in the collection, processing and marketing of shea nut and butter. The outputs of this Inaugural Lecture will inform both local and national policies on the shea tree that can lift millions of rural women out of poverty. This Inaugural Lecture is expected to remind or build the capacity of African University staff for the sustainable management of the shea tree by touching on aspects of the shea tree that has not attracted research interest in the past. Governments and relevant stakeholders could make these possible if apart from the main product (shea butter) research funds and energy are harnessed to study the biology of the tree, domesticate and conserve the tree through advance propagation techniques. The science of the shea tree and its products needs special attention if we are to uncover the potentials of the tree to maximize its usefulness.

8.2 Acknowledgement

I acknowledge the special contribution of my parents who drew my attention to the shea tree and Ms. Ruth Fosu my undergraduate student who initiated me into shea tree research. Her hard work led to the extending the frontiers of shea latex research. I am grateful to my colleagues especially Professor Felix K. Abagale, Dr Samuel Cobbina and Dr Abdul-Halim Abubakari who have collaborated with me in shea/biochar research. I am indebted to students whose works have broadened my research base in shea. Dr Isaac K. Addai who looked at the technical content of my published book and this brochure. I will be ungrateful if I fail to acknowledge the massive contribution of Mr Edwin Thompson, the University Librarian who edited and improved upon the quality of the document. Suggestions from other staffs of the University Library (Dr Florence Plockey, Charlotte Yenbil and Setor Lotsu) and others helped improved this brochure. I am indebted to my family for their love, support and prayers.

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