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Domestication of *Chrysophyllum albidum* from rainforest and derived savannah ecosystems – phenotype variation and selection of elite trees

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Abstract

Many forest food tree species have immense socio-economic, nutritional and cultural importance. They contribute to food security and increase the diversity of foods necessary to reduce monotony in diets of rural people. Their importance notwithstanding, their regeneration has been neglected. Due to lack of care and old age, fruit yield of existing trees is decreasing, which if not addressed will endanger the rural livelihood. This study investigates phenotypic variation of *Chrysophyllum albidum* in rainforest and derived savanna ecosystems of Nigeria with the aim of selecting elite trees for multiplication as cultivars. From each ecosystem, five villages with high abundance of *C. albidum* trees were selected. One hundred trees (10 from each village) were selected, numbered and tagged. The age and silvicultural history (whether planted or naturally regenerated) of each tree were obtained. Measurements of tree growth parameters and phenotypic variations were made in 2010. Palatability test based on sweetness, fibrousity, juiciness and smoothness was conducted by three test persons. Results indicated greater domestication activity by farmers in derived savanna than rainforest ecosystem. While 6% (3/50) of the trees in rainforest were planted, 36% (18/50) were planted in derived savanna. There was an element of positive selection in domestication by farmers as fruits of domesticated trees were generally bigger, sweeter and non-fibrous. Trees in derived savanna were younger and smaller (age: 30–50 years; dbh: 9.0–117.0cm; height: 6.8–23.3m) than those in rainforest ecosystem (age: 50–55 years; dbh: 19.4–147.2cm; height: 11.0–26.3m) due probably to higher domestication activity, since domesticated trees were generally younger. A high percentage of trees were found within agroforestry plots. Fruit variations were as follows: length: 2.26–4.76cm; width: 2.0–4.10cm; fruit weight: 28.23–86.06g and pulp weight 8.55–46.14g. The criteria for selection of elite trees were big fruits, very sweet, juicy and non-fibrous fruit pulp. Since most trees did not met all the criteria, fruits from the few trees (seven) that met the criteria were collected in 2011 for nursery experiment as an important step towards their domestication. Thus, we have selected elite trees from this first screening and collected fruits for further research and experimentation.

Keywords: *Chrysophyllum albidum*, domestication, phenotype variation, forest food trees, elite trees, Nigeria

Introduction

Though accounting for only 7% of the earth's dry surface area, tropical rainforests account for about 70% of animal and plant species in world ecosystems (Lovejoy, 1997; Onyekwelu *et al.*, 2008). Tropical rainforests are known for their rich biodiversity, being the world's richest biodiverse ecosystem. Between 100 and 300 tree species per hectare have been reported in rainforests (Sollins, 1998; Pitman *et al.*, 2005). A good number of tropical forest tree species have immense socio-economic, nutritional and cultural importance, especially to rural dwellers that depend on them (Okafor, 1991; Ayuk *et al.*, 1999; Onyekwelu and Stimm, 2006). These species could serve as alternative sources of food, especially during the "hungry season" (November to April, when farm crops are planted) and thus contribute to food security. These trees provide a vast array of Non-Timber Forest Products (NTFPs), which provide important and diverse products and services such as food production, health care delivery, economic empowerment, shelter, clothing, cultural and spiritual satisfaction, etc. It has been predicted that the importance of these tree species will increase in coming decades (Ayuk *et al.*, 1999), especially for sustainable development of rural livelihoods that depend on them, which can be attributed to the increasing demand and the emerging domestic and international markets for their products.

Despite their importance, a lot of tropical forest tree species, especially food tree species have been greatly neglected, particularly with respect to their regeneration. The yield of the current crop of trees is decreasing due to their old age and the fact that they have been harvested for decades. Due to lack of care and old age, a lot of the trees species have died or are in the process of doing so. In Nigeria, many forest food tree species are endangered (FORMECU, 1999), with the possibility of going into extinction in the near future except something is done to conserve them or increase their population. Allowing the species to go into extinction will endanger the livelihood of millions of rural dwellers in West Africa and reduce the rich biological diversity of the ecosystem. Artificial regeneration and subsequent improvement of the species (domestication) appears to be a very viable option of saving them from extinction and ensuring that their products are supplied on a sustained basis. This necessitates a study that will investigate the phenotypic characteristics and variation of the tree species, which will aid the selection of elite trees for multiplication as cultivars, which is the first step towards domestication. This study was designed to fill this gap. In this study, the phenotypic variation of *C. albidum* will be investigated in two ecological zones of Ondo State, Nigeria from which elite trees will be selected.

C. albidum, commonly called African star apple or white star apple, is widely distributed from Western Africa through Central to Eastern Africa (Keay, 1989; Onyekwelu and Stimm, 2011). It is among the forest tree species that provides NTFPs of immense domestic importance to rural and urban dwellers in West Africa, with great export potentials (Nwoboshi, 2000). The fruit pulp is widely consumed and thus plays an important role in food security. Apart from serving as a delicacy and an alternative source of food, it also provides alternative source of income and rural employment through the collection and sale of the fruits. *C. albidum* has been noted to be of great nutritional, social and medicinal importance (Okafor, 1979 cited in Onyekwelu and Stimm, 2006). The economic importance of *C. albidum* has increased in recent years due to awareness of its nutritional and medicinal value (Onyekwelu and Stimm, 2011). However, the immense socio-economic importance, the increasing demand and price for the fruit, etc has led to intense exploitation pressure, which has resulted in its stocks diminishing at an alarming rate, such that today, the species has been classified as endangered or threatened (FORMECU, 1999).

Methodology

The study was conducted in two major ecological zones in Ondo State, Nigeria: rainforest and derived savanna. From each ecological zone, a Local Government Area (LGA) with good population of *C. albidum* trees was selected. The selected LGAs were Akure South (rainforest) and Akoko South west (derived savanna). From each LGA, five villages were selected during a reconnaissance survey to farms, home gardens and fallowed fields using selective sampling technique (i.e. based on accessibility of the tree). Thus, a total of ten villages (five from each ecosystem) were involved in the study. The selected villages were: Oba-Akoko, Aiyegunle-Akoko, Eti-Oro, Akowonjo and Aiyelanwa for the derived savanna, while Iju, Ita-Obgolu, Ilara-Mokin, Ero/Isarun and Igbara-Oke were selected from the rainforest ecosystem.

From each village, ten trees were selected, numbered and tagged, which resulted in a total number of 100 trees for the study (i.e. 50 from each ecological zone). The trees were visited with the members of the households that own them and marked for easy identification. The silvicultural history of each tree, such as; whether the tree was planted or not, age of the tree, etc, were obtained from the head of the household. Measurements made on each tree include: total height (m), diameter at breast height (cm), crown diameter (cm), crown height (m), leaf length (cm), leaf width (cm), leaf stalk length (cm) and leaf thickness. For leaf parameter measurements, three leaves were sampled (small, medium and large) from each tree and measured. They were meant to provide an idea of the variation in leaf sizes and used in estimating the mean leaf size for each tree. Three test persons (respondents) were used to conduct the palatability test. All test persons were given fruits from a particular tree and particular village and requested to score based on the following criteria: (i) fruit size, taste, fribousity, juiciness of the pulp and skin roughness. Most data collected were analyzed using descriptive statistics. Student t-test was used to test for significant difference of the measured tree growth parameters in the two ecological zones.

Results and Discussion

Relatively little research and development study has been conducted on the development of indigenous tree crops for wider cultivation. Domestication of indigenous fruit trees emerged as a farmer-driven, marked-led process and has become an important initiative in the tropics (Akinnifesi *et al.,* 2006; Leakey *et al.,* 2005) due probably to their nutritional and socio-economic importance. The results of this study showed evidence of *C. albidum* domestication in rainforest and derived savanna ecological zones. The trees in the study villages were mostly planted within farmland (agroforestry plots), fallow grounds and occasionally in homegardens. However, the level of domestication is higher in derived savanna ecosystem than in the rainforest. In the rainforest, only one out of the five communities assessed is involved in domestication of the species against four communities in derived savanna (Tables 1 and 2). About 6% (3/50) of *C. albidum* trees in the rainforest were planted while 36% (18/50) of the trees in derived savanna were planted (Tables 1 and 2).

Thus, there appears to be a better prospect for the species in derived savanna than rainforest ecosystem, as the young planted trees will replace the old and aging ones. The poor participation of farmers in rainforest ecosystem in the domestication of indigenous forest fruit tree species has been attributed to lack of access to land, lack of seedlings and involvement of farmers in other engagements (Chigbu *et al*., 2011). Boateng and Yeboah (2008) and Franzel *et al.* (2008) reported that local people in Nigeria and Ghana are involved in the conservation of *C. albidum,* which is evidenced by the preference of the farmers for the species as well as the high cultural and social values they have for it. Franzel *et al.* (2008) showed that farmers in lowland humid Africa are involved in *C. albidum* domestication due to its overall value and expected benefits. There was an element of positive selection in the domestication of the species by farmers, which is evidenced by the fact that fruits of domesticated trees were found to be generally bigger, sweeter and non-fibrous. Trees of the species in derived savanna are younger and smaller than those within rainforest, which could be due to the greater domestication activity in derived savanna since a higher percentage of trees in this ecosystem were planted in comparison to the trees in the rainforest. Mean age variation was 30–50 years (range: 10 – 60 years) in the derived savanna and 50 – 55 years (range: 40 – 60 years) in the rainforest. This indicates that trees in derived savanna are younger, which is another evidence of greater domestication activity in the derived savanna.

Table 1: Summary of tree growth parameters of *Chrysophyllum albidum* in the five communities in the rainforest ecosystem

Village	No of trees	Silvicultural history		Total Height (m)			Dbh (cm)			Crown Height (m)			Crown Diameter (m)			Age (yrs)
		Planted	Not Planted	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Mean
Iju	10	0	10	15.4	26.0	20.7	46.3	90.4	68.4	9.5	16.1	12.8	6.2	15.5	10.8	50.0
Ita-Ogbolu	10	0	10	11.0	25.6	18.3	39.9	147.2	93.6	5.5	17.3	11.4	6.6	22.5	14.6	55.0
Ilara-Mokin	10	0	10	14.4	26.2	20.3	19.4	121.3	70.4	6.2	20.4	13.3	7.5	17.5	12.5	55.0
Ero/Isarun	10	3	7	12.0	22.5	17.3	21.0	65.0	43.0	7.8	17.0	12.4	8.3	16.3	12.3	55.0
Igbara-Oke	10	0	10	12.3	23.0	17.6	33.0	110.0	71.5	9.0	19.9	14.4	8.5	15.0	11.8	50.0

	Leaf Length (cm)			Leaf Width (cm)			Stalk Length (cm)			Leaf Thickness (mm)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Iju	15.7	21.7	18.7	5.7	9.2	7.4	2.1	3.4	2.8	1.5	1.5	1.50
Ita-Ogbolu	14.2	19.9	17.1	6.3	7.5	6.9	1.5	2.8	2.1	1.3	1.5	1.40
Ilara-Mokin	15.3	20.5	17.9	5.3	8.6	7.0	1.9	3.6	2.7	1.2	1.8	1.50
Ero/Isarun	15.9	24.3	20.1	5.1	8.6	6.9	1.8	3.2	2.5	1.2	3.5	2.35
Igbara-Oke	13.4	22.6	18.0	5.5	9.8	7.7	1.1	2.6	1.9	1.3	1.7	1.50

Table 2: Summary of tree growth parameters of *Chrysophyllum albidum* in the five communities in the derived savanna ecosystem

Village	No of trees	Silvicultural history		Total Height (m)			Diameter at Breast Height (cm)			Crown Height (m)			Crown Diameter (m)			Age (yrs)
		Planted	Not Planted	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Mean
Oba-Akoko	10	0	10	8.4	24.3	16.4	9.0	69.0	39.0	5.6	18.2	11.9	6.0	14.6	10.3	50.0
Aiyegunle	10	8	2	7.0	17.8	12.4	9.5	63.0	36.3	4.3	15.0	9.7	5.1	15.1	10.1	40.5
Eti-Oro	10	4	6	8.6	21.0	14.8	14.0	48.0	31.0	6.5	17.0	11.8	6.5	16.1	11.3	30.0
Aiyelanwa	10	4	6	10.2	23.1	16.6	18.3	117.0	67.6	7.5	18.8	13.2	7.7	17.2	12.4	40.5
Akowonjo	10	2	8	6.8	14.8	10.8	17.3	34.0	25.7	4.5	11.5	8.0	6.1	11.2	8.6	40.5

	Leaf Length (cm)			Leaf Width (cm)			Stalk Length (cm)			Leaf Thickness (mm)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Oba-Akoko	17.4	25.5	21.5	5.6	28.3	17.0	1.6	3.3	2.5	1.0	1.3	1.15
Aiyegunle	17.8	23.6	20.7	6.5	10.2	8.3	1.2	2.3	1.8	1.0	1.4	1.20
Eti-Oro	21.0	26.6	23.8	7.3	9.5	8.4	2.3	3.6	3.0	1.0	1.3	1.15
Aiyelanwa	18.8	25.7	22.3	6.8	9.4	8.1	1.1	1.8	1.5	1.0	1.3	1.15
Akowonjo	18.8	25.7	22.3	6.3	9.4	7.9	1.9	3.3	2.6	1.2	1.5	1.35

C. albidum trees in the rainforest ecosystem are generally larger and taller than those in derived savanna, which is to be expected since the latter has been shown to be younger than the former. Results indicated that dbh ranged from 19.4 – 147.2 cm (mean: 43.0 – 93.6 cm) and height from 11.0 – 26.2 m (mean: 17.3 – 26.2 m) in the rainforest as against the range of 9.0 – 117.0 cm (mean: 25.7 – 67.6 cm) and 6.8 – 24.3 m (mean: 10.8 – 16.6 m) for dbh and height respectively of trees in the derived savanna (Tables 1 and 2). Crown height and crown diameter were also found to be higher in *C. albidum* trees in rainforest than those in derived savanna. Mean crown height varied from 11.4 – 14.4 m and 8.0 – 13.2 m in rainforest and derived savanna, respectively while mean crown diameter ranged from 10.8 – 14.6 m and 8.6 – 12.4 m in rainforest and derived savanna ecosystems, respectively. However, trees of the species in the derived savanna have longer and wider leaves than those in the rainforest (Table 1 and 2), probably due to the younger age of trees in derived savanna. It was observed that younger *C. albidum* trees appear to have longer and wider leaves than very old trees.

The results of the student t-test (Table 3) shows that the means of the growth parameters (total height, dbh, crown height, crown diameter, etc) of *C. albidum* trees from the two ecological zones are significantly different. The results revealed that mean total height, dbh, crown height, crown diameter, leaf stalk length and leaf blade thickness of *C. albidum* trees in rainforest ecosystem were significantly higher than those of the trees in derived savanna ecosystem (Table 3). However, mean leaf length and mean leaf width of the trees in rainforest was found to be significantly lower than those of trees in derived savanna. This result implies that the phenotypic characteristic of *C. albidum* in one ecological zone differs from that of the species in the other ecological zone.

Table 3: Summary of the results of Student t-test of Tree Growth Parameters Measured from both Zones

Tree growth Parameters	Ecological zones		Student t-test results	Remark
	Rainforest	Savanna		
Total height (m)	18.83	14.19	2.776445	Significant
Diameter at breast height (cm)	69.35	39.91	2.776445	Significant
Crown height (m)	12.86	10.89	2.776445	Significant
Crown diameter (m)	12.38	10.55	2.776445	Significant
Age (yrs)	53.00	41.30	2.776445	Significant
Leaf length (cm)	18.36	22.10	2.776445	Significant
Leaf width (cm)	7.16	9.93	2.776445	Significant
Leaf stalk length (cm)	2.41	2.25	2.776445	Significant
Leaf thickness (mm)	1.65	0.19	2.776445	Significant

Irrespective of the ecological zone, there was a high variation in the phenotypic characteristics of *C. albidum* fruits. Generally, fruit length varied from 2.26 to 4.76 cm while fruit width ranged from 2.0 to 4.10 cm. Total fruit weight varied from 28.23 to 86.06g while pulp weight ranged from 8.55 to 46.14g. Generally, most *C. albidum* fruits from the study villages were ranked as sweet, fibrous, juicy and smooth skin by test persons. However, fruits from some trees, especially at Aiyelanwa were ranked as sour. From derived savanna ecosystem, fruits from trees #2 and #4 at Aiyelanwa and Eti-Oro, respectively were ranked as very sweet but slightly fibrous and juicy by test persons. Also, trees #1, #2 and #5 at Oba-Akoko in derived savanna ecosystem were ranked as very sweet, non-fibrous, juicy and smooth skin. In the rainforest ecosystem, trees #1 and #6 at Ero/Isarun were ranked as very sweet, non-fibrous, juicy and smooth skin. Thus, the results revealed that there are superior *C. albidum* trees that yielded fruits with desirable traits. Selecting these fruits for domestication will ensure that superior fruits are obtained in future. When all the selection criteria (i.e. fruit size, pulp sweetness, fibrousity and fruit pulp juiciness) used in this study were taken into consideration, *C. albidum* trees selected as elite trees for multiplication as cultivars were tree #2 at Aiyelanwa, tree #4 at Eti-Oro, trees #1, #2 and #5 at Oba-Akoko in the derived savanna ecosystem as well as trees #1 and #6 at Ero/Isarun in the rainforest ecosystem. Fruits from these trees were collected in early 2011 for nursery experiment as the first step towards its domestication.

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