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Global Research on Genus *Adansonia*

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ABSTRACT

A Scientometric study was carried out to measure the global research out put on genus *Adansonia*. This study is based on publications output on *Adansonia* during 1945-2013 as indexed by SCI-Expanded databases. It reflected that as many as 257 documents have been published with an average output of 3.77 publications per year that collected 2794 total citations, with an average of 10.87 citations per document, and h-index at 29. A total of 500 authors have contributed to this, and collaborative work of four authors accounted for about 56% of the publications. 'Document' category had maximum share (85.6%); the most popular subject category was "plant sciences" (76 articles), and the most common source (journal) was *Agroforestry Systems* (17 articles). The Universitéd'-Abomey-Calavi, Benin was the lead institute and USA, the leading country in number of publications with 22 and 42 publications, respectively. Madagascar, the home of six endemic species of *Adansonia*, published only 11 articles. Most of the publications were from non-native, developed countries which can be attributed to the availability of resources and access. Major international collaborations were between the technologically advanced countries and native countries of the species, revealing a symbiotic relationship. Though *Adansonia* is an economically and ecologically important genus, it has not attracted researchers' attention so far. Out of nine species, *Adansonia digitata* has been the most studied species.

Introduction

Adansonia, commonly called Baobab, is an economically and ecologically important genus, represented by at least 09 species, mostly native to Madagascar. The species are: *A. digitata* L., *A. fony* Baill., *A. rubrostipa* Jum. and H. Perrier, *A. grandidieri* Baill., *A. gregorii* F.Muell., *A. madagascariensis* Baill., *A. perrieri* Capuron, *A. suarezensis* H. Perrier and *A. za* Baill (www.theplantlist.org). *A. gregorii* is endemic to Australia, while *A. kilima* Pettigrew *et al.* to Africa and *A. digitata* native to Africa and Arabian peninsula.

The *Adansonia* spp. are employed for the treatment of fever, dysentery, measels, sores and as tonic to malarial patients (FAO, 1988). Its fruits are rich in vitamin C and the fruit pulp is used in the preparation of soft drinks (Sidibe *et al.* 1998). Leaves are rich in protein and used as staple food in rural areas of Africa (Yazzie *et al.* 1994). Dried leaves find use in soup preparation; flowers are eaten raw or used in the preparation of drink (Delisle *et al.* 1997); seeds which are rich in protein are used as staple food apart from oil yield and roasted seeds play a substitute of coffee (Dirar 1993); bark produce strong fiber and employed in making ropes, mats and hat (Igboedli *et al.* 1997); wood, as fuel (Venter and Venter 1996); and pods and leaves as animal feed, *etc*. In addition, genus *Adansonia* is ecologically an important component in dry deciduous forest of Madagascar and bushy lands of Africa.

Scientific research, especially nature related, natural products in particular, is vast and complex that personal knowledge and experience are no longer sufficient to understand the research output and trend (Pendlebury 2010). The scientometric study (i.e. counting, measuring, comparing quantities and analyzing measurements) is now viewed at global level as the best tool to measure research performance (Garfield 1979, Geuna and Martin 2003). The present study attempts to scientometrically analyze the research output/trend on the ecologically and economically important genus *Adansonia* in terms of number of publications, most productive authors, countries, institutes and map collaboration and authorship patterns.

Methodology

The Web of Science (*WoS*) published by Thompson Reuters, USA, as online version of Science Citation Index (SCI)-Expanded of Institute for Scientific Information, Philadelphia, USA was used to retrieve data published on *Adansonia* during the period 1945-2013 (68 years). The *WoS* is a multi-disciplinary database which includes 8471 journals under 172 categories as on the year 2013. It also covers open access journals and over 148,000 proceedings from the most significant conferences, symposia, seminars, colloquia, workshops and conventions worldwide. The *WoS* was chosen as it provides addresses of author, co-authors and includes core journals.

The key word "Adansonia" was used to search worldwide *Adansonia* literature. Article details *viz*., abstracts, keywords and author's affiliations were downloaded and thoroughly checked to remove irrelevant publications. The impact factor (IF) of the journals was collected from the *Journal Citation Reports* 2012. Domestic and International Collaborations were determined by professional addresses of each author. Manuscripts coauthored by researchers from more than one country were noted as "international collaboration" works. Important indicators like year-wise publication trends, document type, authorship, language of publication, distribution of subject category, keywords, dominating journals, highly cited articles, highly productive authors, countries of publication, institutes and journals were studied (Martin 1996).

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Table 1. Ranking of journals with the most articles on Adansonia by ≥ 3 number of articles

	Source Titles	Record Count	IF (2012)	Country
1.	Agroforestry Systems	17	1.373	Netherlands
2.	Acta Horticulturae	8	--	Belgium
3.	Ecology of Food and Nutrition	8	0.800	England
4.	African Journal of Biotechnology	7	--	Kenya
5.	African Journal of Ecology	6	0.631	England
6.	Plant Foods for Human Nutrition	6	2.358	Netherlands
7.	Bois et Forets des Tropiques	5	0.370	France
8.	Economic Botany	5	1.925	United States
9.	Forest Ecology and Management	5	2.766	Netherlands
10.	Journal of Ethnopharmacology	5	2.755	Ireland
11.	South African Journal of Botany	5	1.409	South Africa
12.	Fruits	4	0.797	France
13.	Genetic Resources and Crop Evolution	4	1.593	Netherlands
14.	International Journal of Food Sciences And Nutrition	4	1.257	England
15.	Journal of the Science of Food and Agriculture	4	1.759	England
16.	New Forests	4	1.636	Netherlands
17.	Pharmaceutical Biology	4	1.206	Netherlands
18.	Planta Medica	4	2.348	Germany
19.	Human Ecology	3	--	United States
20.	International Symposium on Underutilized Plants for Food Security, Nutrition, Income and Sustainable Development	3	--	Tanzania
21.	Plant Systematics and Evolution	3	1.312	Austria
22.	Taxon	3	2.782	Slovakia
23.	Tree Physiology	3	2.853	Canada

Table 2. Web of Science 'Subject Area'

Research areas	No.	Research areas	No.
Plant Sciences	76	Veterinary Sciences	3
Forestry	39	Zoology	3
Food Science Technology	31	Agricultural Engineering	2
Agronomy	28	Biology	2
Nutrition Dietetics	28	Chemistry Organic	2
Ecology	22	Genetics Heredity	2
Horticulture	18	Geography Physical	2
Pharmacology Pharmacy	16	Geosciences Multidisciplinary	2
Chemistry Applied	15	Instruments Instrumentation	2
Chemistry Medicinal	11	Nuclear Science Technology	2
Evolutionary Biology	11	Parasitology	2
Agriculture Multidisciplinary	10	Physics Atomic Molecular Chemical	2
Biotechnology Applied Microbiology	10	Physics Nuclear	2
Environmental Sciences	10	Area Studies	1
Integrative Complementary Medicine	8	Chemistry Multidisciplinary	1
Multidisciplinary Sciences	7	Chemistry Physical	1
Biochemistry Molecular Biology	6	Dermatology	1
Biodiversity Conservation	5	Education Educational Research	1
Mycology	5	Endocrinology Metabolism	1
Agriculture Dairy Animal Science	4	Engineering Chemical	1
Medical Laboratory Technology	4	Family Studies	1
Anthropology	3	Infectious Diseases	1
Energy Fuels	3	Materials Science Multidisciplinary	1
Entomology	3	Ophthalmology	1
Environmental Studies	3	Ornithology	1
Geochemistry Geophysics	3	Public Environmental Occupational Health	1
Medicine General Internal	3	Social Sciences Interdisciplinary	1
Sociology	3	Soil Science	1
Tropical Medicine	3		

Table 3. Ranking of countries and institutes by their output of research papers on *Adansonia*, during1945-2013

Publications	Countries	Rank	Institutions	Publications
42	USA	1	Université d'Abomey-Calavi, Benin	22
30	Nigeria	2	Ghent University, Belgium	14
27	South Africa	3	University of Antwerp, Belgium	11
24	Belgium	4	CIRAD, France	10
22	Benin	5	University of Antananarivo, Madagascar	9
22	France	6	University of Copenhagen, Denmark	9
17	Germany	7	University of the Witwatersrand, South Africa	9
16	England	8	University of Southampton, UK	7
15	Burkina Faso	9	Goethe University, Frankfurt	6
15	Mali	10	Harvard University, USA	6
12	Australia	11	French National Institute for Agricultural Research	6
11	Kenya	12	Babeș-Bolyai University, Romania	6
11	Madagascar	13	University of Ibadan, Nigeria	6
10	Denmark	14	University of Pretoria, South Africa	6
9	India	15	University of Wisconsin–Madison, USA	6
9	Senegal	16	Woods Hole Oceanographic Institution, USA	6
7	Netherlands	17	Baobab Trust, Kenya	5
6	Italy	18	University of Ouagadougou, Burkina Faso	5
6	Romania	19	Aix-Marseille University, France	5
6	Zimbabwe	20	University of California System, USA	5

Table 4. Top authors with ≥ 6 articles on Adansonia

	Authors	No.	Affiliations
1.	Assogbadjo, AE	16	National University of Benin, Benin
2.	Sinsin, B	14	National University of Benin, Benin
3.	Van Damme, P	11	Ghent University, Belgium
4.	Kakai, RG	10	National University of Benin, Benin
5.	Samson, R	10	University of Antwerp, Belgium
6.	Danthu, P	9	[1] University of Antananarivo, Madagascar [2] CIRAD, France
7.	Sanchez, AC	9	University of York, England
8.	Kyndt, T	8	Ghent University, Belgium
9.	Baum, DA	7	University of Wisconsin-Madison, USA
10.	Chadare, FJ	7	National University of Benin, Benin
11.	De Smedt, S	7	University of Antwerp, Belgium
12.	Bayala, J	6	ICRA WCA Sahel, Bamako, Mali
13.	Jensen, JS	6	Plantning og Landskab, Denmark
14.	Lowy, DA	6	Flex El LLC, USA
15.	Patrut, A	6	Babeș-Bolyai University, Romania
16.	Von Reden, KF	6	Woods Hole Oceanographic Institution, USA

Table 5. Authorship pattern

Authorship	Publication count	% share
Single author	23	8.95
2 authors	46	17.90
3 authors	47	18.29
4 authors	52	20.23
5 authors	30	11.67
6 authors	24	9.34
7 authors	14	5.45
8 authors	8	3.11
9 authors	7	2.72
10 authors	2	0.78
11 authors	2	0.78
22 authors	1	0.39
57 authors	1	0.39
Total	257	100

Table 6. Publications received ≥ 29 citations

Cites	Average citations per Year	Publication details
199	11.71	Baum DA, Small RL and Wendel JF (1998) Biogeography and floral evolution of baobabs (Adansonia, bombacaceae) as inferred from multiple data sets. *Systematic Biology* 47(2):181-207.
174	7.91	Belsky AJ, Mwonga SM, Amundson RG, Duxbury JM and Ali A (1993) Comparative effects of isolated trees on their under canopy environments in high-rainfall and low-rainfall savannas. *Journal of Applied Ecology* 30(1):143-155.
65	4.33	Lockett CT, Calvert CC and Grivettili LE (2000) Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought. Study of rural Fulani, Northeastern Nigeria. *International Journal of Food Sciences and Nutrition* 51(3): 195-208.
63	3.32	Nordeide MB, Hatloy A, Folling M, Lied E and Oshaug A (1996) Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district, Koutiala, in Southern Mali. *International Journal of Food Sciences and Nutrition* 47 (6):455-468.
61	3.59	Sena L P , Vanderjagt DJ, Rivera C, Tsin ATC, Muhamadu I, Mahamadou O, Millson M, Pastuszyn A and Glew RH (1998) Analysis of nutritional components of eight famine foods of the Republic of Niger. *Plant Foods for Human Nutrition* 52(1): 17-30.
61	3.05	Locher CP, Burch MT, Mower HF, Berestecky J, Davis H, VanPoel B, Lasure A, VandenBerghe DA and Vlietinck AJ (1995) Anti-microbial activity and anti-complement activity of extracts obtained from selected Hawaiian medicinal plants. *Journal of Ethnopharmacology* 49(1): 23-32.
55	9.17	Maes WH, Achten WMJ, Reubens B, Raes D, Samson R and Muys B (2009) Plant-water relationships and growth strategies of Jatropha curcas L. seedlings under different levels of drought stress. *Journal of Arid Environments* 73(10): 877-884.
51	2.32	Prentice A, Laskey MA, Shaw J, Hudson GJ, Day KC, Jarjou LMA, Dibba B and Paul AA (1993) The Calcium and Phosphorus Intake of Rural Gambian Women during Pregnancy and Lactation. *British Journal of Nutrition* 69 (3): 885-896.
46	2.42	Smith GC, Clegg MS, Keen CL and Grivetti LE (1996) Mineral values of selected plant foods common to southern Burkina Faso and to Niamey, Niger, West Africa. *International Journal of Food Sciences and Nutrition* 47(1): 41-53.
43	2.15	Baum DA (1995) The Comparative Pollination and Baobabs (Adansonia-Bombacaceae). *Annals of the Missouri Botanical Garden* 82(2): 322-348.
43	2.15	BAUM DA (1995) A Systematic Revision of Adansonia (Bombacaceae). *Annals of the Missouri Botanical Garden* 82(3): 440-470.
41	5.86	Assogbadjo AE, Kakai R, Glele, Chadare FJ, Thomson L, Kyndt T, Sinsin B and Van Damme P (2008) Folk classification, perception, and preferences of baobab products in West Africa: Consequences for species conservation and improvement. *Economic Botany* 62(1): 74-84.
41	4.56	Assogbadjo AE, Kyndt T, Sinsin B, Gheysen G and Van Damme P (2006) Patterns of genetic and morphometric diversity in baobab (Adansonia digitata) populations across different climatic zones of Benin (West Africa). *Annals of Botany* 97 (5): 819-830.
39	1.70	Belsky AJ (1992) Effects of Trees on Nutritional Quality of understory Gramineous Forage in Tropical Savannas. *Tropical Grasslands* 26(1): 12-20.
37	5.29	Pavlic D, Wingfield MJ, Barber P, Slippers B, Hardy GE, St J and Burgess TI (2008) Seven new species of the Botryosphaeriaceae from baobab and other native trees in Western Australia. *Mycologia* 100(6): 851-866.
36	3.60	Assogbadjo AE, Sinsin B, Codjia JTC and Van Damme P (2005) Ecological diversity and pulp, seed and kernel production of the Baobab (Adansonia digitata) in Benin. *Belgian Journal of Botany* 138(1): 47-56.
36	1.64	Belsky AJ, Mwonga SM and Duxbury JM (1993) Effects of Widely spaced Trees and Livestock grazing on understory Environments in Tropical Savannas. *Agroforestry Systems* 24(1): 1-20.
35	5.00	Lamien-Meda A, Lamien CE, Compaore MMY, Meda RNT, Kiendrebeogo M, Zeba B, Millogo JF and Nacoulma OG (2008) Polyphenol content and antioxidant activity of fourteen wild edible fruits from Burkina Faso. *Molecules* 13(3): 581-594.
35	3.18	Dhillion SS and Gustad G (2004) Local management practices influence the viability of the baobab (Adansonia digitata Linn.) in different land use types, Cinzana, Mali. *Agriculture Ecosystems and Environment* 1001 (1): 85-103.
35	1.67	Saka JDK and Msonthi JD (1994) Nutritional-value of edible Fruits of Indigenous Wild Trees in Malawi. *Forest Ecology and Management* 64 (2-3): 245-248.
33	1.94	Barminas JT, Charles M and Emmanuel D (1998) Mineral composition of non-conventional leafy vegetables. *Plant Foods for Human Nutrition* 53(1):29-36.
32	2.46	Gebauer J, El-Siddig K and Ebert G (2002) Baobab (*Adansonia digitata* L.): a review on a multipurpose tree with promising future in the Sudan. *Gartenbauwissenschaft* 67(4:): 155-160.
31	1.82	Proll J, Petzke KJ, Ezeagu IE, Metges CC (1998) Low nutritional quality of unconventional tropical crop seeds in rats. *Journal of Nutrition* 128 (11): 2014-2022.
31	0.82	Woolfe ML, Chaplin MF and Otchere G (1977) Studies on mucilages extracted from okra fruits (*Hibiscus esculentus*) and baobab leaves (*Adansonia digitata*). *Journal of the Science of Food and Agriculture* 28(6):519-529.
30	3.33	Chapotin SM, Razanameharizakab JH and Holbrook NM (2006) Baobab trees (*Adansonia*) in Madagascar use stored water to flush new leaves but not to support stomatal opening before the rainy season. *New Phytologist* 169(3):549-559.
30	2.31	Atawodi SE, Ameh DA, Ibrahim S, Andrew JN, Nzelibe HC, Onyike EO, Anigo KM, Abu EA, James DB, Njoku GC and Sallau AB (2002) Indigenous knowledge system for treatment of trypanosomiasis in Kaduna state of Nigeria. *Journal of Ethnopharmacology* 79 (2):279-282.
30	2.00	Anani K, Hudson JB, De Souza C, Akpagana K, Tower GHN, Arnason JT and Gbeassor M (2000) Investigation of medicinal plants of Togo for antiviral and antimicrobial activities. *Pharmaceutical Biology* 38(1):40-45.
29	2.42	Kristensen M and Lykke AM (2000) Informant-based valuation of use and conservation preferences of savanna trees in Burkina Faso. *Economic Botany* 57(2): 203-217.
29	2.07	Murray SS, Schoeninger MJ, Bunn HT, Pickering TR, Marlett JA (2001) Nutritional composition of some wild plant foods and honey used by Hadza foragers of Tanzania. *Journal of Food Composition and Analysis* 14(1): 3-13.

Table 7: Keywords pattern [Number of documents with each of the keyword occurring in at least 3 documents]

Keywords	Frequency	Percentage	Keywords	Frequency	Percentage
Adansonia digitata	49	4.52	Sap flow	4	0.37
Baobab	29	2.68	Senegal	4	0.37
Adansonia	13	1.20	Vitamin C	4	0.37
Photosynthesis	11	1.02	Age determination	3	0.28
Madagascar	10	0.92	Antibacterial	3	0.28
Non-timber forest product	10	0.92	Antioxidant activity	3	0.28
Africa	8	0.74	Antioxidant capacity	3	0.28
Agroforestery	8	0.74	Bombacoideae	3	0.28
Domestication	8	0.74	Conservation	3	0.28
Benin	7	0.65	Diet	3	0.28
Bombacaceae	7	0.65	Dispersal	3	0.28
Medical plant	7	0.65	Diversity	3	0.28
Stomatal conductance	7	0.65	Drought avoidance	3	0.28
Climatic zones	5	0.46	Ethnic groups	3	0.28
Malvaceae	5	0.46	Genetic variation	3	0.28
Regeneration	5	0.46	Indigenous fruit tree	3	0.28
Savanna	5	0.46	MaxEnt	3	0.28
Antiviral	4	0.37	Mortality	3	0.28
Ascorbic acid	4	0.37	NTFP	3	0.28
Baobab seed	4	0.37	Nutrition	3	0.28
Baobabs	4	0.37	Phytochemistry	3	0.28
Biodiversity	4	0.37	Pollination	3	0.28
Biogeography	4	0.37	Quantitative ethnobotany	3	0.28
Burkina Faso	4	0.37	Stem succulent	3	0.28
Ethnobotany	4	0.37	Togo	3	0.28
Fermentation	4	0.37	vegetable	3	0.28
Parkia biglobosa	4	0.37	water storage	3	0.28
Population structure	4	0.37			

Table 8. Major international collaborations with ≥ 5 publications

Collaborator countries	Publications
Belgium and Benin	10
Burkina Faso and Mali	8
France and Madagascar	6
USA and Romania	6
USA and South Africa	6
Denmark and Burkina Faso	5
Denmark and Mali	5
Romania and South Africa	5

Results and Discussion

A total of 257 documents have been published on the Genus Adansonia between 1945-2013 as per the WoS database. They received 2794 total citations with an average of 10.87 citations and scored 29 in h-index. The first publication on Adansonia was QUELQUES DONNEES NOUVELLES SUR LA PHARMACOLOGIE DES FEUILLES DE BAOBAB (ADANSONIA DIGITATA) by VINCENT, D; BRYGOO, P AND SERO, I published in journal PRESSE MEDICALE in the year 1946. Next one appeared after a gap of 25 years. Until the year 2000, genus *Adansonia* failed to attract researchers' focus. However, from 2000 onwards, it saw continuous publications achieving > 10 publications per year from 2006 onwards (Fig. 1). The total number of documents could be classified into 9 types with 'articles' having maximum share (85.6%), followed by proceedings (8.5%), reviews (3.8%), meeting abstracts (3.11%), notes (1.5%), letters (0.7%), and book chapters, corrections and editorial material (0.3% each). All the publications were in English but 12 in French.

One hundred fifty one journals have published documents on *Adansonia* with varied frequencies. Agroforestry Systems ranked first with 17 articles, followed by Acta Horticulturae and Ecology of Food and Nutrition with 8 articles each and African Journal of Biotechnology ranked third with 7 articles. (Table 1).

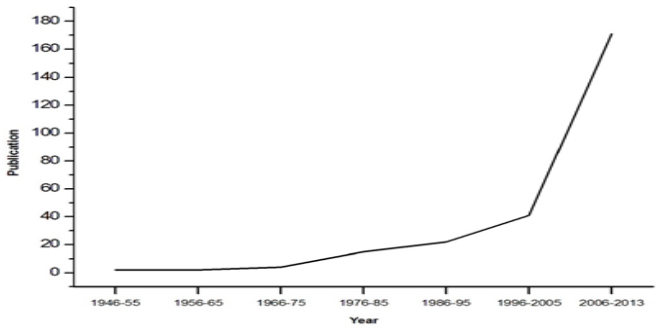

Fig 1. Global SCI publication trend on *Adansonia*

In journal "Adansonia", only two papers are on Adansonia! The five most popular subject categories under WoS for Adansonia research were as follows: Plant Sciences (76), Forestry (39), Food Science Technology (31), Agronomy and Nutrition Dietetics (28 each); all the 44 subject categories are enumerated in Table 2. Of the 58 countries that have published literature on Adansonia, USA ranks topmost with 42 publications. However, among the institutes, it is The Université d'Abomey-Calavi, from the west African country Benin ranks first with 22 publications.

It is interesting to note that most of the publications on *Adansonia* are from non-native countries. Among the top 20 countries and institutes, 10 countries and 12 institutes are from

non-native countries. Madagascar, the home of seven species published only 11 articles and most of them indicate collaborative work (i.e. six with France, three with USA, etc.). In top 20 countries, *Adansonia* is found only in 10 countries. These 10 nations have published 146 documents and 98 such works are the result of collaboration with non-native countries (Table 3). One hundred forty one funding agencies have supported research and development projects on *Adansonia*. The South African National Research Foundation funded most works numbering five publications. One hundred seventeen funding agencies supported only one publication each.

A total of 500 authors have contributed to *Adansonia* literature. Leading authors are: Assogbadjo (16), Sinsin (14), Van Damme (11), Kakai (10) and Samson (10), publications respectively. Top five authors together share 23.73 % of the total publications (Table 4). The authorship pattern is in favour of four authors (52) and 2, 3 and 4 authorship together makes 56.4% of the total publications (Table 5).

Tracking citations and understanding their trends in the context is a key to evaluate the impact and influence of research (Pendlebury 2010, Wohlin 2005). Significance of a work or a researcher is established by citations, not merely by number of publications. Some scholars may produce many papers of little significance and some publish only a few papers but of great significance (Cole and Cole 1967). Therefore, highly cited articles were identified, maximum citations have collected by Baum et al. (199 citations; 11.71 average citations per year), it is followed by Belsky et al. (174 citations; 7.91 average citations per year), Lockett et al. (65 citations; 4.33 average citations per year). Twenty nine articles are cited by at least 29 times, 20 articles have received 35 or more citations, 86 articles have 10 or more citations, 115 articles have less than 09 citations and 56 articles are not cited (Table 6).

Analysis of keywords reflects research trends and emphasis on a given subject (Law et al. 1988, Ding et al. 2001, Przyjazny and Kokosa 2002, Lee 2008). In *Adansonia* literature, as many as 747 keywords were used with 1059 occurrence. *Adansonia digitata* (49) had highest frequency, followed by Baobab (29). Baobab is indeed common English name of *Adansonia digitata*. High frequency of these keywords (i.e. hot topic of research) indicates that Adansonia is an economically significant plant which plays an important role in the ecosystem (Table 7). International collaborative works as shown in table 8 reveals a kind of symbiotic relationship between technologically advanced country and native country of the species as observed earlier by Frame and Carpenter (1979).

Conclusion

Genus *Adansonia* is economically and ecologically important but studied less. Only 257 publications appear in SCI databases (1946-2013) and Scopus databases (1951-2013) accounts for 328. Madagascar has six endemic species but published 11 articles only. Counties to which *Adansonia* is native are in either developing or under developed category. Limited exposure and access to information resources could be attributed to such a low representation of publications from these countries. USA has published maximum number of papers, followed by Nigeria, South Africa, Belgium, Benin, France, Germany, England, etc. *Adansonia digitata* is the most studied species may be due to economic value, worldwide cultivation and ecological role.

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