Journal of Biodiversity, Bioprospecting and Development

Woldetensay, et al., J Biodivers Biopros Dev 2014, 1:3
DOI: 10.4172/2376-0214.1000133

Research Article Open Access

Opportunities for Bioprospecting Genetic Resources in Ethiopia

Zeleke Woldetensay, Mekonnen Amberber, Anteneh Tamirat and Abiyselassie Mulatu*

Access and Benefit Sharing Directorate, Ethiopian Biodiversity Institute, P.O. Box 30726, Addis Ababa, Ethiopia

***Corresponding author:** Abiyselassie Mulatu, Access and Benefit Sharing Directorate, Ethiopian Biodiversity Institute, P.O. Box 30726, Addis Ababa, Ethiopia, Tel: +251-911-185650; Fax: 251-11-6613722; E-mail: abiyselassiemulatu@gmail.com

Received date: Sep 01, 2014, **Accepted date:** Oct 27, 2014, **Publication date:** Oct 31, 2014

Abstract

Bioprospecting involves the search of biodiversity for valuable genetic or biochemical resources/information or both for purely scientific or commercial purposes.

Objective: The aim of the study was to identify potential genetic resources for bioprospecting and assess opportunities for future bioprospecting in Ethiopia.

Methods: Ethno-biological data and sector-based data were collected from the local and scientific community respectively by using preference ranking, direct matrix ranking, paired comparison, semi-structured interviews and field observations.

Results: Local people obtained medicinal plant species more from wild vegetation (52.5%) than homegardens (40%) and market (7.5%). *Stephania abyssinica*, *Ensete ventricosum* and *Urtica simensis* were ranked as priority species among the potential genetic resources which were identified by the key informants. *Arundinaria alpine* (94), *Hypericumre volutum* (85) and *Ensete ventricosum* (102) were ranked first as multi-purpose genetic resources from each study area. *Yushania alpine*, *Urtica simensis*, *Thymus schimperi* and some mushrooms were identified with bioprospecting potential for commercialization by the key informants.

Conclusion: The results in the present study indicate that the studied woredas (districts) in Ethiopia possess rich medicinal plant species, and the local people have rich ethno-biological knowledge. The results can be used as opportunities for bioprospecting.

Keywords: Bioprospecting; Commercialization; Ethno-biological data; Key informants; Medicinal plant; Potential genetic resource; Sector-based data

Introduction

The world leaders met in Rio de Janeiro, Brazil in 1992 discussed various factors that threaten biodiversity. The Rio summit adopted a convention on Biodiversity. The three objectives of the convention were conservation of Biological diversity, sustainable use of its components and the fair and equitable sharing of benefits arising from the utilisation of the genetic resources. The third objective of CBD is of particular importance to developing countries as they hold most of the world's biodiversity and it is considered to create incentive for the other two objectives. However, access to genetic resources and fair and equitable sharing of benefit from the use of these resources was a contentious issue and negotiation on the issue took more than six years. Thereafter, the 10th Conference of Parties (COP10) adopted a protocol called Nagoya Protocol in Nagoya, Japan, on 29 October 2010. The objective of the protocol among others is to ensure the sharing of benefits from the use of genetic resources and associated traditional knowledge, that is, in order for users to gain access to genetic resources and associated traditional knowledge they must agree to provide fair and equitable benefits to the provider country and in order for them to receive those benefits a provider country must facilitate access to the resources.

Bioprospecting is the exploration of biological resources and the associated traditional knowledge for commercially valuable genetic resources. Bioprospecting activities have provided many valuable products and commercial applications such as the discovery of natural products that can be used as medicines for humanity or crucial starting points for making related products that have improved medicinal properties. Although bioprospecting activities accrue benefit to the owner of biological resources or stewards of these resources, exploitation of these resources without recognition of the stewards or the national governments from the source country has become a problem today. Thus, despite its many positive aspects, current bioprospecting practices often degraded into biopiracy, or misappropriation of biological resources and/or the patenting on processes based on traditional knowledge from indigenous communities.

The patent on teff (*Eragrostis teff*) products is a typical example of misappropriation of genetic resources from the source country. Access and benefit sharing agreement was made on teff genetic resources between the Ethiopian negotiators (the Ethiopian Institute of Biodiversity Conservation, IBC and the Ethiopian Institute of Agricultural Research, EIAR) and a Dutch company, called Health and Performance Food International (HPFI) in 2005. Whereas Ethiopia complied with the agreement and provided access to the teff genetic resources in question, the Dutch commercial counterpart, HPFI, failed in large part to comply with its obligations under the agreement. Though the company was declared bankrupt in 2009, it established other companies and transferred values to these companies. These companies, in turn, continued to produce and sell teff flour and teff products, and expand their activities to other countries and continents. The Dutch company breached the well-established agreement between the parties and produced patent from European intellectual property office on the indigenous Ethiopian crop and the associated traditional knowledge and then sought to entice Ethiopia to negotiate away ownership of teff varieties. [1-3]. Although, Andersen and Winge [3] indicated that there are still possibilities for Ethiopia to get the patent revoked and bring the case to court, the violation and non-compliance creates loss of good trust and becomes a hurdle to bioprospecting activities. Thus internationally binding laws such as the Nagoya Protocol is believed to support compliance, provide legal certainty and transparency for both providers and users of genetic resources.

In recent years bioprospecting has acquired increased attention as countries inquire about to conserve their biodiversity and share the benefits from bioprospecting [4]. Agreements are taken as a means of improving national capacities to add value to natural resources and share benefits with developed countries at the same time ensuring that these resources are protected and used sustainably [5].

Ethiopia is endowed with diverse biological resources. The country is a major centre of origin and diversity of important crops and has been identified as one of the eight Vavilov Centers of the World [6]. However, these diverse and huge biological resources have not been used in a way that changes the socio-economic conditions of the country. Despite the challenges encountered in previous access and benefit sharing agreements, Ethiopia is still among the countries that are willing to benefit from their rich biodiversity. After ratification of the Convention on Biological Diversity (CBD), the country issued a national policy on biodiversity conservation and research; issued access and benefit sharing legislations; and recently ratified the Nagoya Protocol that will help to obtain benefits from bioprospecting activities. However, transparent legal frameworks have to be developed to ensure benefit from bioprospecting deals. Moreover, there is still lack of adequate scientific knowledge and documentation of the potential of its genetic resources that can provide baseline data for bioprospecting. The current paper reports the result of a study of the potential genetic resources for bioprospecting, opportunities and challenges in Ethiopia.

The general objective of the study was to assess the overall potential, opportunities and challenges of genetic resources with a special emphasis on medicinal plants for bioprospecting in some areas of the country.

The specific objectives were to:

- Identify the potential genetic resources for bioprospecting particularly medicinal plants.
- Survey and identify bioprospecting opportunities and challenges in Ethiopia.
- Produce a document with relevant information for bioprospectors to access genetic resources.

Materials and Methods

Description of the study area

The study areas were purposely selected from three national regional states namely, Oromiya, Amhara, Southern Nations Nationalities and Peoples Regional State (SNNPR). During a reconnaissance survey, overall information on the study areas was obtained. Eight study areas were identified based on the distribution of medicinal plants, biological and cultural diversity and rich traditional knowledge of the community [7,8]. In addition to the above-mentioned regions, sector-based data were collected from Ethiopian Public Health Institute, Wondo Genet Agricultural Research Center, Wondo Genet College of Forestry and Natural Resources, Regional States of Oromiya, Southern Nations, Nationalities and Peoples (SNNPR), Amhara Investment Agencies, Regional Agricultural Bureaus, College of Veterinary Medicine, Addis Ababa University and Hawassa University.

Sampling technique and sample size

Purposive sampling method as recommended by Dolores and Tongco [9] was employed to select potential informants. A total of 60 key informants were selected with the help of local administrators and elderly people from 8 woredas/districts/ (five from each) for ethno-biological data collection. A total of 60 informants were also selected from the targeted sectors (five from each) for sector based secondary data collection and detailed study [9].

Data collection

Techniques such as group discussion (for preference ranking, direct matrix ranking and paired comparisons), semi-structured interviews and field observations were used as recommended by Martin [10] and Cotton [11]. The interviews were based on a checklist of questions prepared beforehand in English and local languages. Sector based data were collected from targeted sectors by using the questionnaires.

Ethno-botanical data were collected by using semi-structured interviews, field observation, ranking and scoring methods [10,11]. Interviews and discussions were conducted in local language using a checklist of topics.

Data analysis

The key informant data of distribution and use, habits, sources and abundance, market accessibility and availability, and bioprospecting potentials of the medicinal plants were analyzed using descriptive statistical methods such as frequency and percentage as recommended by Dolores and Tongco [9]. The key informant data about the potential medicinal plants and multi-purpose plants were analyzed using descriptive statistical methods such as preference ranking and direct matrix ranking methods as recommended by Martin [10].

Results and Discussions

Distribution and diversity of medicinal plants

A total of 78 medicinal plants belonging to 69 genera and 52 families were named by key informants/traditional healers in the study areas. In terms of family distribution, Solanaceae 6(11.76%), Asteraceae 5 (9.80%) and Rosaceae 4 (7.84%) species were frequently reported and other families consisted of one to three representative species. Out of the listed medicinal plants, 36 species (46.75 %) were used to treat human ailments, 15 species (19.48 %) were used for the treatment of animal diseases (livestock such as cattle, sheep and poultry) and 26 species (33.76%) were used to treat both human and animal diseases.

Habits of medicinal plants used by informants

Regarding the habit diversity, herbs were the most commonly used with 29 species (38%), followed by shrubs with 28 species (36%), trees with 17 species (22%) and climbers accounted for 4% (Figure 1). The dominance of herbs may be due to easy availability to local people and their abundance in the area. The data also showed that the majority of medicinal plants in the home gardens were also herbs. This finding is in line with most inventories documented in Ethiopia on medicinal plants [12,13].

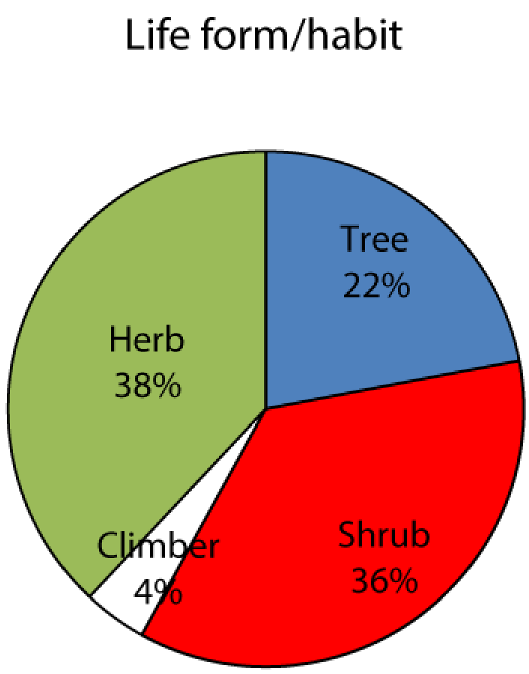

Figure 1: Habits of medicinal plants.

According to the informants, the most commonly used plant parts in the study area, for remedial preparations were roots (50.01%), followed by stems (27%) and leaves (10.81%). The parts of medicinal plants were prepared in various ways such as crushing into powder, mixing with water and/or other solvents and additives.

The highest knowledge transfer on traditional medicinal plants in the study areas were from parents or close relatives (79%) followed by self-trial and error methods (9.3%). Among the interviewed healers, fewer than 2% were ready to transfer the knowledge without incentives. Most healers believed that traditional medicine was more effective if practiced within a family or within a close relative. Such a trend was also reported from elsewhere [14,15].

Sources and abundance of medicinal plants

The present study showed that the medicinal plants were collected from various sources. Figure 2 shows the percentage of medicinal plants collected and used by traditional healers from the wild, homegardens and market. These data indicated that the local people obtained medicinal plant species more from wild vegetation than from homegardens and markets. These results agree with data documented by Debela Hunde et al. [12] and Ermias Lulekal et al. [13].

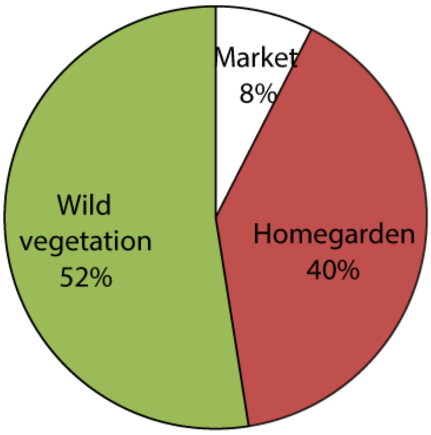

Figure 2: Sources of medicinal plants' collection.

Market accessibility and availability

Fifty three percent of informants reported that medicinal plant species were more abundant in wild vegetation than in the homegardens of study areas. With regard to accessibility in markets, 60% of traditional healers cited that medicinal plants were not accessible in local markets. Sixty eight percent of informants reported that medicinal plant species were available in the study areas. However, in most study areas, it was observed that medicinal plants usually associated with spices and herbs displayed for vending on roadsides, around churches and mosques during religious ceremonies. This is in line with findings of Dawit Abebe and Ahadu Ayehu [16] and Marshal [17].

Potential medicinal and multi-purpose plants

When different species are prescribed for the same health problem, people showed preference of one to the other. Preference ranking of seven medicinal plants that were reported based on abundance and frequent use for treating common diseases was recorded by asking five selected key informants. *Stephania abyssinica*, *Ensete ventricosum* and *Urtica simensis* ranked highest from each study areas, which indicated that these species were most abundant and effective for treating common diseases. *Calpurnia aurea*, *Eucalyptus globulus*, and *Olea europaea L. ssp.* cuspidata ranked last, which indicated that the species were the least effective in each study area (Table 1).

Woreda	Medicinal plants	Key informants (R)						
		R-1	R-2	R-3	R-4	R-5	Total	Rank
Zege and Banja	*Croton macrostachyus*	8	7	7	6	5	33	6
	Stephania abyssinica	10	10	10	10	8	48	1
	Verbascum sinaiticum	10	9	7	7	10	43	4
	Calpurnia aurea	4	5	7	4	3	23	7
	Ocimium lamiifolium	7	7	7	7	7	35	5
	Plantago lanceolata	10	10	7	10	7	44	2
	Verbena officinlis	10	9	8	7	10	44	2
Wondo Genet and Wonago	*Croton macrostachyus*	7	8	8	9	9	41	5
	Vernonia amygdalina	8	7	10	9	9	43	2
	Ensete ventricosum	10	10	6	10	10	46	1
	Phytolacca dodecandra	8	10	10	5	10	43	2
	Artemisia annua	10	10	10	1	7	38	6
	Ruta chalepensis	8	8	7	10	10	43	2
	Eucalyptus globulus	5	6	5	6	5	27	7
Goba and Dinsho	*Croton macrostachyus*	7	10	10	6	6	39	2
	Thymus schimperi	6	7	7	5	10	35	5
	Hagenia abyssinica	8	8	9	7	6	38	3
	Urtica simensis	10	10	10	10	10	50	1
	Oleaeuropaea L. ssp. cuspidata	4	4	4	4	5	21	7
	Hypericum revolutum	3	10	5	10	10	38	3
	Aloe macrocarpa	5	1	3	9	5	23	6

Table 1: Preference ranking of medicinal plants used for common diseases in the study areas. Note: R – denotes key informants /elderly traditional healers of the woredas (districts) that are purposely selected by the researchers.

The majority of the community in the study areas relies on plants for various purposes such as medicinal, cosmetic, food, fencing and construction. To assess the relative importance and identify the potential plant genetic resources (multi-purpose genetic resources) in the study area, direct matrix ranking was used. Fifteen (five selected from each study area) key informants claimed that tree species were with great versatility of use based on five use criteria. *Arundinaria alpina* was found to be with a total score of 94 informants, *Hypericum revolutum* with a total score of 85.5 and *Ensete ventricosum* with a total score of 102. These 3 species were ranked first from each study area. The data indicated that these species were with the highest versatility of use by local people (Table 2).

Woredas	Medicinal plants	Key informants						
		Food	Medicine	Cosmetic	Soil fertility	Construction	Total	Rank
Zege and Banja	*Mimusops kummel*	20	6	22	21	21	90	2
	Cordia africana	14	7	17	19	25	82	3
	Croton macrostachyus	0	12	14	18	20	64	5
	Podocarpus falcatus	0	13	15	15	22	65	4
	Vernonia amygdalina	0	9	4	9	13	35	7

	Millettia ferruginea	0	9	4	20	15	48	6
	Arundinaria alpina	4	4	30	30	30	94	1
Goba and Dinshu	*Oleaeuropaea L. sub spcuspidata*	10	17	14	13	18	72	3
	Eucalyptus camaldulensis	0	12	7	0	20	39	7
	Urtica simensis	24	13	3	11	0	51	4
	Hagenia abyssinica	7	18	12	18	20	75	2
	Thymus schimperi	22	14	9	3	0	48	5
	Hypericum revolutum	16	16	18	16	19	85	1
	Syzygium guineense	5	14	8	14	1	42	6
Wondo Genet and Wonago	*Syzygium guineense*	20	13	18	24	21	96	2
	Eucalyptus camaldulensis	0	9	22	0	20	51	5
	Ensete ventricosum	25	25	2	25	25	102	1
	Prunus africana	0	19	11	0	10	40	6
	Croton macrostachyus	0	25	0	24	25	74	4
	Ruta chalepensis	23	17	0	0	0	40	6
	Olea europaea L. sub spcuspidata	0	21	24	17	20	82	3

Table 2: Direct matrix ranking of seven multi-purpose species with five major uses by respondents in the study areas.

Genetic Resources with Bioprospecting Potential

Yushania alpine/ Bamboo

The study revealed that bamboo (Yushania alpine) was reported with very high frequency (100%) and distributed in Banja, Goba and Dinshu districts. It was found in a relatively fewer distribution in Wonago woreda (66.67%). According to Brias and Tesfaye Hunde [18], Yushania alpine is a multi-purpose plant with countless applications, of which, construction materials, furniture, fences, handicrafts, pulp and paper, edible shoots, and animal fodder are most common. Most of the alpine bamboo in Ethiopia grows naturally in highland forests like Awi Zone, Injibara (private plantations) and Bale Zone (natural stands).

Urtica simensis / 'Samma'

According to the data from the key informants, Samma /*Urtica simensis* has the highest distribution in Goba and Dinshu woredas (100%) and the lower distribution in Banja (80%) and lowest in Wonago (50%) woreda. In many of the study woredas, *Urtica simensis* is used as food and medicinal plant (e.g. to treat gastric ailments). Eskedar Getachew et al. [19] reported that it has a high nutritional value when compared to many green leafy vegetables commonly cultivated and consumed in Ethiopia. Its protein and mineral content is exceptionally high which makes this vegetable an inexpensive but high source of quality nutrition. Its potential contribution to food security, nutrition, health, and income generation is still largely underexploited. The potential of spreading its use across regions and cultural groups is not yet looked into.

Thymus schimperi/ 'Tosign'

According to the report from the key informants, Thymus schimperi/Tosign has higher distribution in Goba and Dinshu woredas (100%) and lower distribution in Banja (80%) and lowest in Wonago (50%). It is extensively used in making teas and coffees. Ermias Dagne et al. [20] reported that *Thymus schimperi* is an indigenous spice used in Ethiopia to flavor a wide range of food products and has also medicinal properties.

Mushrooms

According to the data taken from the key informants, Mushroom has the highest distribution in Wondo (100%) and Wonago (80%). Dawit Abate [21] reported the three most commonly cultivated mushrooms in Ethiopia to be *Agaricus bisporus* (button mushroom), *Pleurotus ostreatus* (oyster mushroom) and *Lentinula edodes* (shiitake mushroom). These cultivated mushrooms are sold as fresh to supermarkets, restaurants and hotels in Ethiopia. These mushrooms are used as nutritious food sources as they are richer in protein, vitamin and mineral contents. They are also known to have substances that enhance the immune system, fight infectious diseases, and lower blood pressure and cholesterol levels.

In addition to genetic resources identified by the key informants, a total of 81 plant species were studied in research centres and higher institutions. Out of 81 plant species, 51 species (63%) were reported to have commercial value. Of these, only 8.64% including *Cymbopogon citrullus*, *Cymbopogon winterianus*, *Rosemaryinus officinalis*, *Menthax piperita, Mentha spicata*, *Mentha arvensis*, *Moringa stenopetala* have been well studied by various researchers [22-27].

Conclusions and Recommendations

Ethiopia is rich in biodiversity but poor in terms of socio-economic development. The growing trend of bioprospecting can be a good opportunity for Ethiopia to make use of its diverse biological resources and to enhance its socio-economic developments.

In the present study, various genetic resources especially medicinal plants have been identified from different areas. Some of these plants reported both from the studied districts as well as the scientific community working on them to be potentially important species for bioprospecting. Although some of these genetic resources are currently being used in the local markets, access and benefit sharing agreement (ABS) with bioprospecting companies is believed to accrue much more benefit to the development of the country.

However, some challenges were also identified and require due attention for the success of ABS and related studies in the future. Some of these challenges include: lack of awareness by district officials and the scientific community of international and national legal systems, access and benefit sharing principles; lack of awareness on institutes mandated for the implementation of these principles; limited study on bioprospecting for base line information; lack of suitable schemes for equitable sharing of benefits arising from biological resources; lack of participation and full cooperation from traditional healers; threat of extinction of medicinal plants through misuse; inadequate collaboration between the mandated Institute, Ethiopian Institute of Biodiversity, and different stakeholder institutions; and absence of clear distinction between bio-trade and bioprospecting.

Thus, further and similar studies on bioprospecting should be encouraged to identify more potential genetic resources from wider range of areas. Participation and collaboration of traditional healers is highly solicited. Since biodiversity is crucial to mankind, stakeholders and all concerned bodies should collaborate for the effective conservation, bioprospecting and fair and equitable sharing of benefits out of the use of these genetic resources.

Acknowledgments

The work is part of an annual research project. Financial support of the Ethiopian Institute of Biodiversity is greatly acknowledged. Key informants of the local and scientific community who willingly shared their valuable traditional and scientific knowledge and provided information about the potential genetic resources of the study areas are also to be duly acknowledged.

References

1. Gemedo Dalle (2010) Access and Benefit Sharing Agreement on Teff (Eragrostis tef) and its implementation and challenges. In:Teff: The Story of Ethiopia's Biodiversity. Occasional Report 5. Forum for Environment. Central Printing Press. Addis Ababa, Ethiopia : 19-37.
2. McGown J (2006) Out of Africa: Mysteries of Access and Benefit Sharing, A report. The Edmonds Institute 20319-92nd Avenue West Edmonds, Washington 98020 USA : 33-34.
3. Andersen R, Winge T (2012) The Access and Benefit-Sharing Agreement on Teff Genetic Resources Facts and Lessons. FNI Report 6.
4. CBD (2001) Convention on Biological Diversity, Secretariat for the Convention on Biological Diversity. UN Environment Programme.
5. Ministry of Environment and Forests India (2002) Biotechnology and Bioprospecting for Sustainable Development. India's presentation for the Ministerial Meeting of Mega-biodiversity Countries. Ministry of Environment and Forests Government of India.
6. Vavilov NI (1951) The origin, variation, immunity and breeding of cultivated plants. Selected Writings. Translated from the Russian by Chester, S. K. The Ronald Company, New York.
7. Zemede Asfaw (1999) Ethnobotany of Nations Nationalities and Peoples in Gambella, Benishangul-Gumuz and Southern regions of Ethiopia. A research report submitted to the Research and Publications Office of Addis Ababa University, Addis Ababa: 172.
8. Giday M, Asfaw Z, Elmqvist T, Woldu Z (2003) An ethnobotanical study of medicinal plants used by the Zay people in Ethiopia. J Ethnopharmacol 85: 43-52.
9. Dolores Ma, Tongco C (2007) Purposive sampling as a tool for informant selection. Ethnobotany Research and Applications 5: 147-158.
10. Martin GJ (1995) Ethnobotany. A methods manual. Chapman and Hall. London: 268.
11. Cotton CM (1996) Ethnobotany: Principles and applications. Chichester, New York: John Wiley and Sons Ltd.
12. Debela Hunde, Zemede Asfaw, Ensermu Kelbessa (2004) Use and management of ethno-veterinary medicinal plants by indigenous people in Boosat, Welenchi area. Ethiop. J. Biol. Sci. 3: 113-132.
13. Lulekal E, Kelbessa E, Bekele T, Yineger H (2008) An ethnobotanical study of medicinal plants in Mana Angetu district, southeastern Ethiopia.Ethnobiol Ethnomed 4: 10.
14. Abbink J (1995) Medicinal and ritual plants of the Ethiopian South West. An account of recent research, indigenous knowledge and development. Monitor 3: 6-8.
15. Mesfin F, Demissew S, Teklehaymanot T (2009) An ethnobotanical study of medicinal plants in Wonago Woreda, SNNPR, Ethiopia. See comment in PubMed Commons below J Ethnobiol Ethnomed 5: 28.
16. Dawit Abebe, Ahadu Ayehu (1993) Medicinal plants and enigmatic health practices of Northern Ethiopia. Berhanena Selam Printing Enterprise, Addis Ababa.
17. Marshal N (1997) Trade in medicinal plants: Consideration for conservation of medicinal plants. In: Kinyua A, Kofi-Tsekpo W and Dangana L. UNESCO, Nairobi: 113-118.
18. Brias V, Tesfaye Hunde (2009) Guidelines for cultivating Ethiopian highland bamboo. Bamboo cultivation manual. Ministry of Agriculture and Rural Development and Kenya Forestry Research Institute. United Nations Industrial Development Organization.
19. Eskedar Getachew, Gulelat Desse, Getachew Addis (2013) Nutritional profile of samma (Urtica simensis Steudel) leaves grown in Ethiopia. International Journal of Science Innovations and Discoveries (IJSID) 3: 153-160.
20. Ermias Dagne, Solomon Hailu, Daniel Asrat, Tadelu Worku (1998) Constituents of the essential oil of Thymus schimperi. Bull.Chem.Soc.Ethiop. 12: 79-82.
21. Dawit Abate (2010) Mushroom Cultivation–Ethiopia. In: Experiences in developing capacity for sustainable development 17: 109-116.
22. Abuye C, Urga K, Knapp H, Selmar D, Omwega AM, et al. (2003) A compositional study of Moringa stenopetala leaves. East Afr Med J 80: 247-252.
23. Solomon Abate, Beemnet Mengesha (2010) Row spacing and harvesting age affect agronomic characteristics and essential oil yield of Japanese Mint (Mentha arvensis L.). Medicinal and Aromatic Plant Science and Biotechnology 5:74-76.
24. Beemnet Mengesha, Teixeira da Silva JA, Solomon Abate (2011) Agronomic characters, leaf and essential oil yield of peppermint (Mentha piperiata L.) as influenced by harvesting age and row Spacing. Medicinal and Aromatic Plant Science and Biotechnology 5: 49-53.
25. Solomon Abate, Beemnet Mengesha (2011) Effect of row spacing and harvesting time on growth and essential oil yield of spearmint (Mentha spicata L.). International Journal of Sustainable Agriculture 3: 39-43.
26. Solomon Abate, Fikiremariam Haile (2012) Essential oil content response of lemongrass, palmarosa and citronella to post harvest wilting and chopping. The African Journal of Plant Science and Biotechnology 6(Special issue 1): 1-4.

27. Zewdinesh Damtew, Beemnet Mengesha, Tsion Tesema (2012) Effects of harvesting age and spacing on leaf yield and essential oil yield of rosemary (Rosmarinus officinalis L.). The African Journal of Plant Science and Biotechnology 6 (Special issue 1): 9-12.

This article was originally published in a special issue, entitled: **"Genetic Diversity and Molecular Evolution",** Edited by Zayed University, UAE