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Full Length Research Paper

Ethnobotanical study of medicinal plants used by agro pastoralist Somali people for the management of human ailments in Jeldesa Cluster, Dire Dawa Administration, Eastern Ethiopia

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Ethnobotanical study of medicinal plants in selected kebeles of Jeldesa cluster, Dire Dawa Administration, eastern Ethiopia was carried out with the aim of assessing and documenting the indigenous knowledge of medicinal plants used in the communities and preserves it to be used by the next generations. Ethnobotanical data collection was carried out from September 2015 to March 2016. Three study sites (kebeles) were selected purposefully based on the preliminary survey and recommendations of elders in the study area. Ethno-botanical data were collected using semi-structured interviews, field observations and group discussion. About 24 informants (21 male and 3 female) were involved in this study. A total of 52 medicinal plant species belonging to 43 genera and 30 families were documented for the management of 48 human ailments; with details on their local name, family, habit, habitat, and their mode of preparation and mode of administration. Fabaceae had a relatively high number of species 7(13.5%), followed by Lamiaceae 4 (7.7%). Shrubs constituted 23 species (44%) followed by herbs 19 species (37%). Oral route contributed (57.7%) of the total species, followed by dermal (27.1%). Most of these species (83%) were wild and harvested mainly for their leaves (34%). Most herbal remedies are prepared using fresh plant materials (48%) in the form of crushing (31%). Ailment categories with high ICF value were swollen body parts (Gofla), wounds, and poisonous animal bites that had ICF values of 0.68, 0.66 and 0.64, respectively. Fidelity level index of *Euphorbia somalinsis, Xanthium spinosum* and *Tribulus terrestris* for kidney problem, *Crotalaria laburnifolia* for constipation, *Eulophia petersii* for swollen body part/GOFLA and *Barleria orbicularis, Solanum sepiculum* and *Echidnopsis dammanniana* for snake poison showed a fidelity level of 100% this indicated their outstanding preference for treating the corresponding ailments. The results of the present study also showed that deforestation and human encroachment were ranked 1st and 2nd as threats to conservation of medicinal plants. The present paper represents significant ethnobotanical information on medical plants which provides baseline data for future pharmacological and phytochemical studies.

Key words: Ethnobotanical study, Jeldesa Cluster, Human ailments, Traditional medicine, indigenous knowledge, Eastern Ethiopia.

INTRODUCTION

Ethiopia has a long history of traditional medicine and has developed ways to combat disease through it. It is gifted with a huge potential of medicinal plants and their uses that provide a wide contribution to the treatment of human ailments (Asfaw, 2001; Giday, 2003). About 80% of Ethiopian people rely on traditional medicine to meet their health care needs (Bekele, 2007). The wide spread use of traditional medicine could be attributed to cultural acceptability, perceived efficacy against certain types of diseases, physical accessibility and affordability as compared to modern medicine (Bekele, 2007; Hunde et al., 2006). Nevertheless, little effort has so far been made to properly document the associated knowledge base and conserve medicinal plants in the country (Gidey et al., 2009). Even though encouraging initiatives have emerged in recent years, studies conducted hitherto are far from complete owing to the multiethnic cultural diversity and the diverse flora of Ethiopia (Bekele, 2007; Yineger et al., 2008). Medicinal plants and the associated knowledge are being threatened by ongoing deforestation, environmental degradation and 'modernization' (Balemie et al., 2004; Bekele, 2007). All this necessitates the need to investigate the status of medicinal plant resources and knowledge base associated with it for successful resource conservation and development.

Similar to elsewhere in Ethiopia, Somali people living in Dire Dawa Administration have traditional practices which have passed from generation to generation in order to treat both humans and livestock ailments. A large proportion of the people living in the region depend on direct herbal medicine to treat a wide range of human ailments (Abduljawad et al., 2011). Most of the studies on medicinal plants in Ethiopia have so far concentrated in the south, south west, central, north and north-western parts of the country (Belayneh and Bussa, 2014). Therefore, this study area is selected; because there is no ethnobotanical collection, identification and documentation carried out on medicinal plant species of the area. In addition, most of the natural vegetation of the study area is lost due to natural and human impacts (Abduljawad et al., 2011). Therefore, the current study was conducted to assess and document the indigenous knowledge of medicinal plants and identify the major threats of medicinal plants in the study area. The information generated enhances the ethnobotanical knowledge of the region and provides recommendations that would help to combat problems in the conservation and sustainable use of medicinal plants and serve as baseline information for future pharmacological and phytochemical studies.

MATERIALS AND METHODS

Description of study area

Jeldesa Cluster is consisted of nine rural kebeles (Jeldesa, Ciremiti, Gerba aneno, Mudi aneno, Ayale gumgum Legedini, Debeley, Melkakero and Kulayu) it is located at about 45 km North East of Dire Dawa city. Jeldesa cluster has a population of 30,564 male comprise 51% (15,588) and female comprise 49% (14,976) of the total population (CSA, 2007). The cluster is totally resided by agro pastoralist communities. Metro logically, the region is characterized by an arid climate with low and erratic rainfall and a mean annual temperature which lies between 29 and 32°C. The rainfall pattern is bimodal characterized by small rains in autumn (February to April), big rains in summer (July to September). The mean annual rainfall is 660 mm. However, recently, rainfall pattern has become much more unpredictable with receiving extremely minimum and maximum rainfall per year. The selected study kebeles were Jeldesa, Gerba aneno and Chire miti. These kebeles are relatively wider and have higher number of traditional healers resided in them. Kebele is the smallest administrative unit in Ethiopia. According to Dire Dawa Health Bureau the healthcare coverage of the cluster is 51.52% and the major disease categories recorded by the Health Bureau (2015/2016) gastrointestinal disorders and upper respiratory tract infection.

Traditional healer selection and collection of ethnobotanical data

A total of 24 traditional healers (21 males and 3females) from the age of 28 to 75 years were sampled based on recommendations of local elders and kebele administrators. Ethnobotanical study was conducted between September 2015 to March 2016 in three kebeles of the cluster. Prior to data collection discussion was made with the traditional healers to get their verbal informed consent. Semi-structured interview (was conducted in local language (s), Somali) with the help of interpreter, group discussion (average members of 8 per group), and field observation were employed to collect basic information on the local name (s), diseases treated, parts used, method of preparations and routes of administration. Furthermore, guided field walks with traditional healers were employed to collect specimens of each medicinal plant species. Identification of specimens were made using the published volumes of the Flora of Ethiopia and Eritrea while for unknown plant specimens identification was made by comparing their voucher specimen with authentic specimens deposited in the National Herbarium, Addis Ababa University and by getting assistance from taxonomic personnel.

Data analyses

Ethnobotanical data were analyzed using simple descriptive statistics using Microsoft Excel 2013. The MS Excel Spreadsheet was also utilized for drawing bar graphs. Preference ranking was computed according to Martin (1995). Informant consensus factor (ICF) values were determined following Heinrich et al. (1998). To evaluate the consensus among traditional healers or to evaluate the reliability of the information provided by the

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informants.

$$ICF = \frac{Nur - Nt}{(Nur - 1)}$$

Where,
Nur: Number of use-reports for a particular use category;
Nt: Number of taxa used for a particular use category by all informants.

The Pearson Correlation Test was calculated using SPSS 17.0.1 software package and employed to evaluate whether there was significant ($p < 0.05$) correlation between i) the age of the traditional healers' and the number of medicinal plant species reported, and ii) the educational level of traditional healers' and the number of medicinal plant species reported. The informants who cannot read and write were considered as illiterate while, those respondents attended formal education were considered educated.

The Fidelity Level (FL) index was calculated based on the formula recommended by Friedman et al. (1986), which is used to quantify the importance of a given species for a particular purpose in a given cultural group or to determine the most preferred plants for a treatment of a particular disease and calculated as:

$$FL = \frac{Np}{N} \times 100$$

Where,
Np : Number of use-reports cited for a given species for a particular ailment N : Total number of use-reports cited for any given species

Ranking of threats to medicinal plants

Ranking of threats to medicinal plants that were reported by most of the informants in the study area was conducted using six selected key respondents as described by Martin (1995) and Alexiades (1996). The informants were asked to give seven for the most threatening factor and one for the least threatening factor in the study area. As mentioned by most of the informants' six threats were selected and the informants were asked to give seven for the most threatening factor and one for the least threatening factor in the study area. This information is used to determine the highest threats to traditional medicinal plants in the study area and helps to suggest the necessary appropriate conservation measures.

Ranking of threatened medicinal plants

The ranking of medicinal plants based on the degree of threats was conducted using the method applied by Martin (1995) and Alexiades (1996), five medicinal plants that were reported by the informants as threatened in the study area were ranked with six key informants (knowledgeable traditional healers) by giving 5 for the most threatened and 1 for the least threatened plant species.

RESULT AND DISCUSSION

Characteristics of respondents

A total of 24 traditional healers (21 males and 3 females) from the age of 28 to 75 years were sampled. The respondents were with an average age of 48 years. Males were dominant representing (87.5%) of the respondents. Generally, (66.6%) of the respondents were above 50 years (Figure 1). The majority (50%) of them attended non- formal education (quran) and those who attended formal education constituted (4%) while (46%) were illiterate. Generally, the informants were grouped into three age groups, young (20–35), adult (36–50) and elderly (above 50) to see how the knowledge varies with age as described in Belayneh et al. (2012). There was a significant positive correlation (Pearson correlation coefficient, r =0.27, at α = 0.05, p = 0.04) between the age of informants and the number of species reported by the informants. Differences in medicinal plants knowledge among age groups was also reported in other studies (Gebrezgabiher et al., 2013; Tamiru et al., 2013; Yigezu et al., 2014; Chekole et al., 2015; Tugume et al., 2016). This might be attributed to the current expansion of education and health centers to kebele level which has resulted in the young generation focusing on modern medicines (Belayneh and Bussa, 2014) and advancement in science and technology has changed the social values and therefore, transformed the younger generation at a faster rate into the new tradition (Awas, 2007; Murad et al., 2013).

Medicinal plants reported

A total of 52 plant species distributed among 43 genera and 30 families were documented as traditional medicines against human ailments (Figure 2). Fabaceae had a relatively high number of species 7 (13.5%), followed by Lamiaceae 4 (7.7%), Asclepiadaceae, Capparidaceae, Convolvulaceae and Euphorbiaceae each with 3 (5.8%) species, Acanthaceae, Boraginaceae, Cucurbitaceae, Asteraceae and Solanaceae each with 2 (3.8%) species and the rest 19 families had 1 (1.9%) species each. Family Fabaceae is consistently reported in different ethnomedicinal inventories conducted in Ethiopia (Hunde et al., 2004; Seifu et al., 2006; Gidey et al., 2007; Belayneh et al., 2012; Megersa et al, 2013; Abera, 2014) and other parts of the world (Tugume et al., 2016), which could be attributed to their wider distribution and abundance (Bonet et al., 1999) and rich bioactive ingredient contents (Gazzaneo et al., 2005). Thirty-nine (75%) of the medicinal plants were reported as being used for treating human ailments, 13 (25%) for the treatment of both human and livestock ailments and 1 (1.9%) for livestock aliments only.

Habitat of medicinal plants

Forty-one (79%) species of the medicinal plants were obtained from the wild vegetation followed by 7 (13%) of

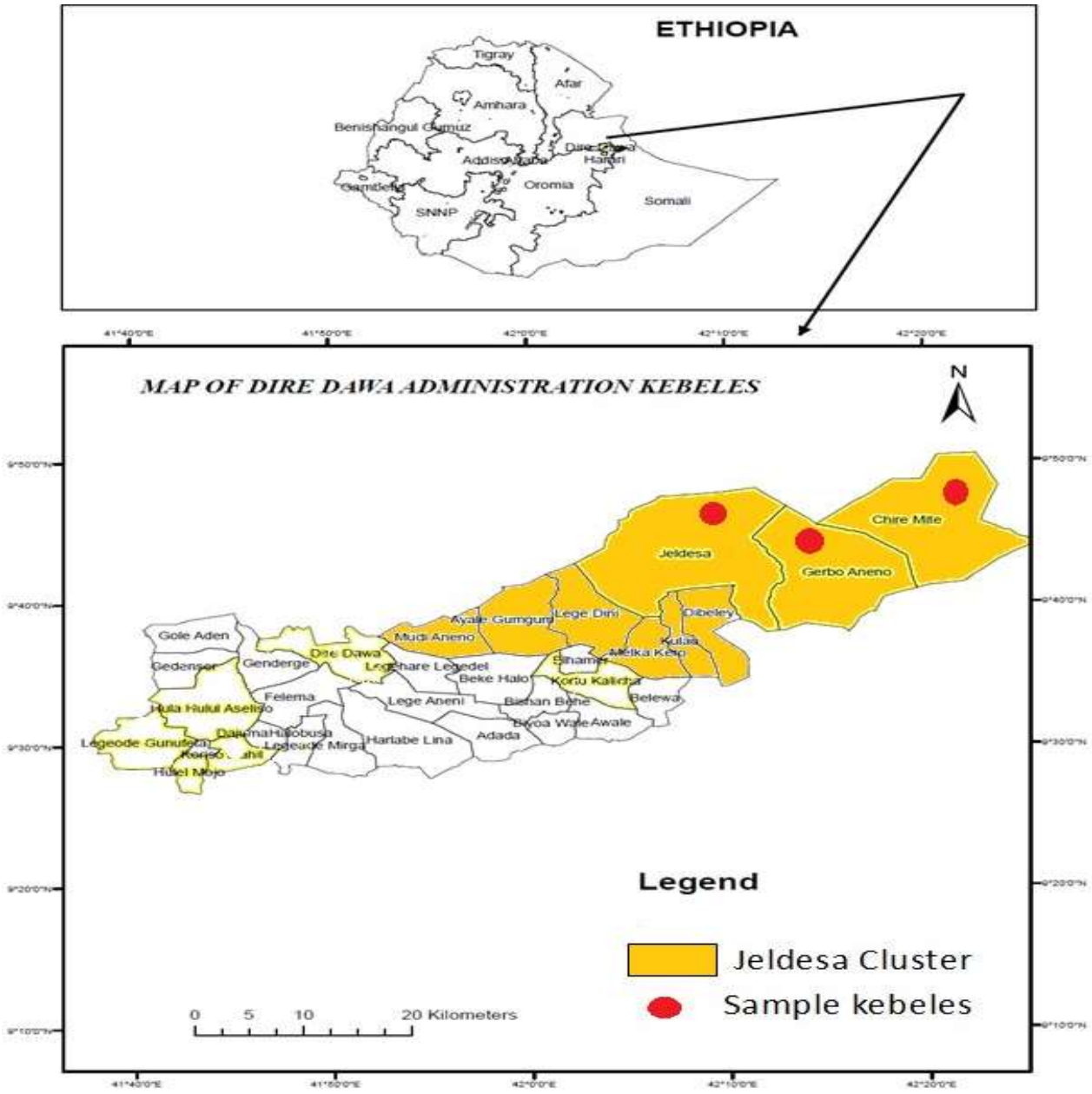

Figure 1. Map of selected kebeles.

medicinal species from Home garden (Figure 3). This result is similar with other studies (Yineger and Yewhalaw, 2007; Lulekal et al., 2008; Yineger et al., 2008; Megersa et al., 2013, Getaneh and Girma, 2014 and Alemayehu et al., 2015) conducted in Ethiopia as well as in other countries such as Pakistan (Ugulu et al., 2009), Uganda (Mugisha and Uriga, 2007; Tugume et al., 2016) and Peru (Bussmann and Sharon,2006), where the majority of the medicinal plants were collected from the wild. This implies that the majority of plants of medical importance were not yet cultivated by traditional healers (Yineger and Yehwalaw, 2007).

Habit of the medicinal plant

Of the total 52 medicinal plants collected from the study area, 23 species (44%) were shrubs followed by 19 species (37%) herbs and 10 species (19%) trees (Figure 4). The highest proportion of growth habit was covered by shrubs and herbs both constitute 81% of the total traditional medicinal plants. This can be related to the floristic composition of vegetation, which is dominated by woodland, bush land and scrubland vegetation types in the study area. Similar patterns were reported by some ethinobotanical studies (Teklehymanot et al., 2007;

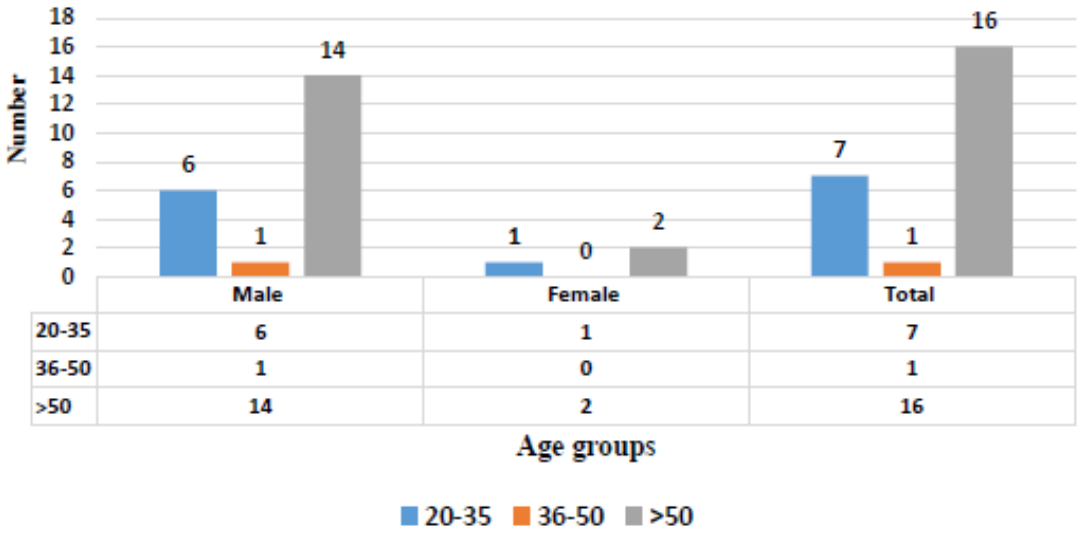

Figure 2. Characteristics of respondents.

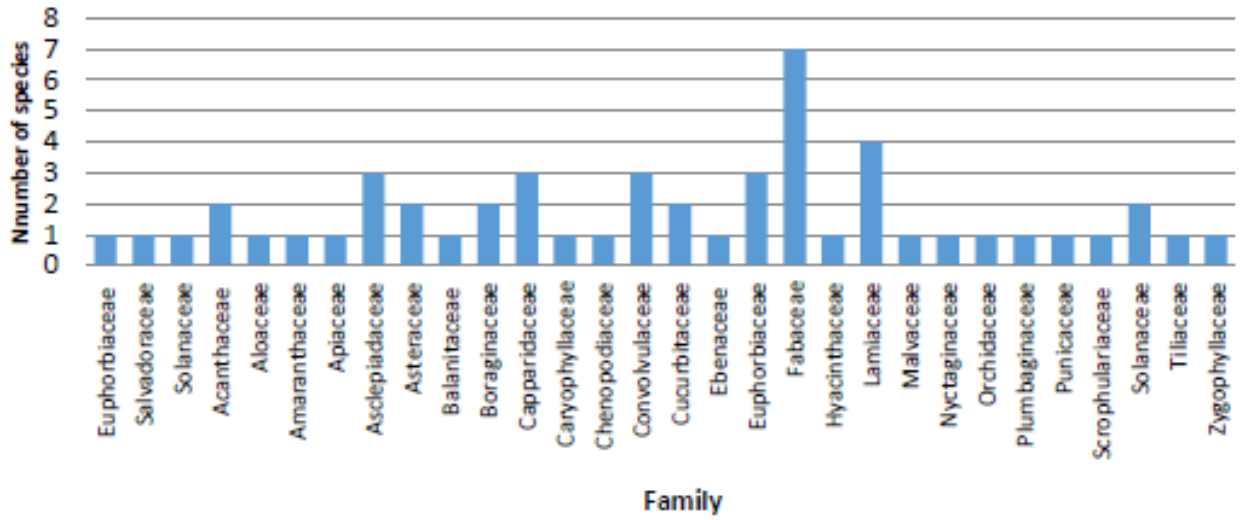

Figure 3. Family distribution of medicinal plants.

Mesfin et al., 2009; Belayneh and Bussa, 2014) where shrubs and herbs are the largest plant growth habits.

Plant parts used for medicine

According to the ethnobotanical data result, leaves are the most commonly used plant parts accounting for 34% of the total, followed by root (33%), seed (9%), all part and fruit constituted (5%) each. Use of other plant parts is as indicated in Figure 5. Latest findings in agreement with this study conducted in Ethiopia indicated that leaf used more than other parts (Megersa et al., 2013; Getaneh and Girma, 2014; Maryo et al., 2015), as well as in other countries such as Pakistan (Murad et al., 2013) and Uganda (Tugume et al., 2016), reported similar findings. Utilization of leaves for drug preparation may not cause detrimental effect on the plants compared to the root or whole plant collections (Megersa et al., 2013; Regassa, 2013; Abera, 2014; Maryo et al., 2015).

Mode of preparations

Local communities employ several methods of

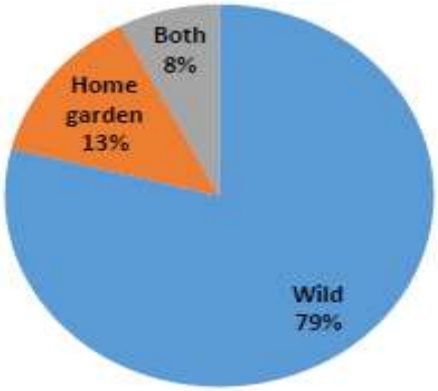

Figure 4. Percentage of medicinal plants on the basis of their habitats.

preparation of plant material for medicinal use including by crushing, squeezing, concoction, smoking, infusion, decoction, pounding, and chewing. Out of the total preparations (31%) are prepared in the form of crushing, followed by pounding (18%), concoction (12%), squeezing constituted (10%), decoction and infusion constituted (8%) each implantation and chewing constituted (4%) each of the total mode of preparations (Figure 6). This agrees with the results of studies carried out by Abdurhman (2010), Regassa (2013) and Megersa et al. (2013) who found that the main mode of preparation is crushing, accounting for 26.2, 29 and 28.2%, respectively.

Route of administration

Different routes were used in administration of herbal preparations. The major routes of administration in the study area are oral, dermal, nasal and optical. Oral route contributed (57.7%) of the total species, followed by dermal (27.1%), nasal and oral and dermal (3.5%) each, optical (2.8%) and smoke bath (2.1%), surgically implanted (1.4%). The least used route of herbal administration were auricular and nasal and auricular which were (0.7%) each (Figure 7). According to Abera (2014), Alemayehu et al. (2015) and Birhanu et al. (2015), oral administration was the dominant route of remedy administration, which constituted 63, 54.21 and 57.1% in their respective study areas (Figure 8). In a similar study by Tugume et al. (2016) on medicinal plants used by Mabira communities in Uganda, it was reported that oral route of administration was commonly used route constituting 53% of the route of administrations used by the local people in the study area. In the present study, lack of agreement among the informant on doses of remedies was the major drawback in the application of traditional medicinal plants in the study area. In a similar study, Belayneh and Busa (2014) reported lack of precision and standardization in the prescription of herbal remedies in the study area and also confirmed that overdose of remedies bring adverse effects like, diarrhea, vomiting, abdominal pain, unconsciousness, and fainting of the patient.

Informant consensus factor (ICF)

ICF for different ailment categories was calculated to test for homogeneity or consistency of informants' knowledge about a particular remedy for an ailment category. ICF indicated which plants are widely used and thus merit further pharmacological and phytochemical studies. In this study ailments with a relatively high ICF value were swollen body parts (Boil, Gofla), wound healing (Korokor, sore, wounds), Poisonous animal bites (snake, scorpion and spider bite), and Organ problems (kidney, liver, heart, eye, nose, ear problems) and that had ICF values of 0.68, 0.66, 0.64, and 0.57, respectively (Table 1). Three ailment categories had ICF of zero (0) since each respondent reported a different species used for the same ailment (Table 2).

Fidelity level (FL) of medicinal plants

The fidelity level of medicinal plants on frequently reported diseases was calculated and summarized in Table 3. Results revealed 100% fidelity level for the following plants; *Euphorbia somalinsis, Xanthium spinosum* and *Tribulus terrestris* for kidney problem, *Crotalaria laburnifolia* for constipation, *Eulophia petersii* for swollen body part/GOFLA and *Barleria orbicularis Hochst, Solanum sepiculum* and *Echidnopsis dammanniana* for snake poison. A fidelity level of 100% for these species indicated their outstanding preference for treating the corresponding aliments. This will also attract pharmacologists for further pharmacological investigation of the traditional plant species.

Threats to medicinal plants in the study area

As mentioned by most of the informants six threats were selected in the study area. This information is used to determine the highest threats to medicinal plants in the study area and helps to suggest the necessary appropriate conservation measures. The results of the present study showed that deforestation and human encroachment were ranked 1st and 2nd, respectively and these were followed by drought and charcoal making in the 3rd and 4th places, respectively as the major threats to the medicinal plants (Table 4). Similar to the current study, Lulekal et al. (2008) confirmed that the main threats to the survival of medicinal plants in the Mana Angetu district were agricultural expansion and

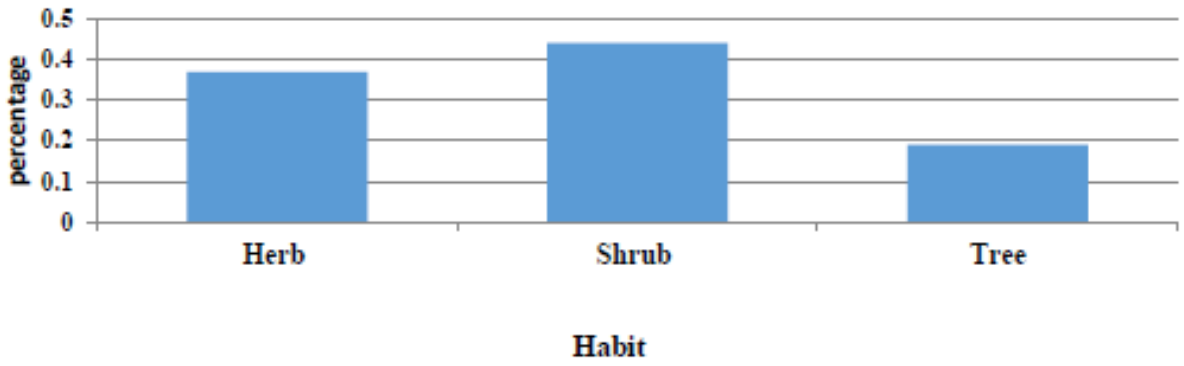

Figure 5. Habit distribution of the reported medicinal plants.

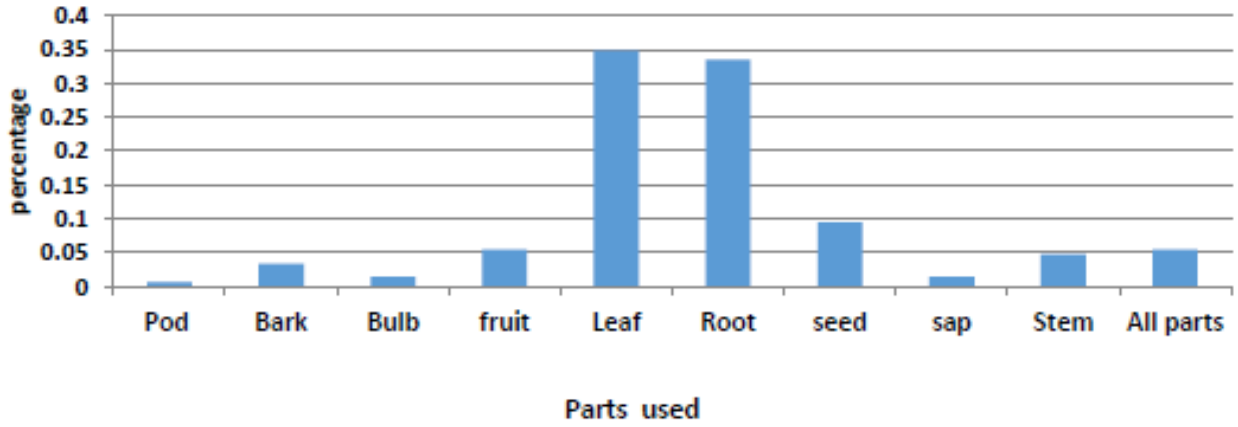

Figure 6. Types of plant parts used in remedial preparation and percentage of preparations per plant part.

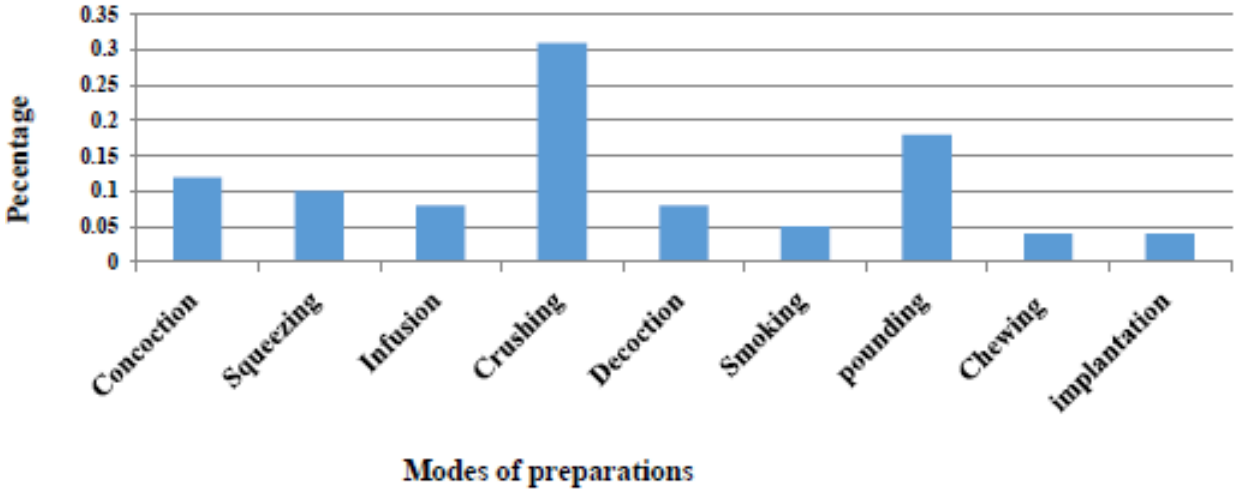

Figure 7. Percentage of method of preparation of traditional medicinal plant remedies.

drought. These anthropogenic and natural factors coupled with very poor conservation efforts threatened

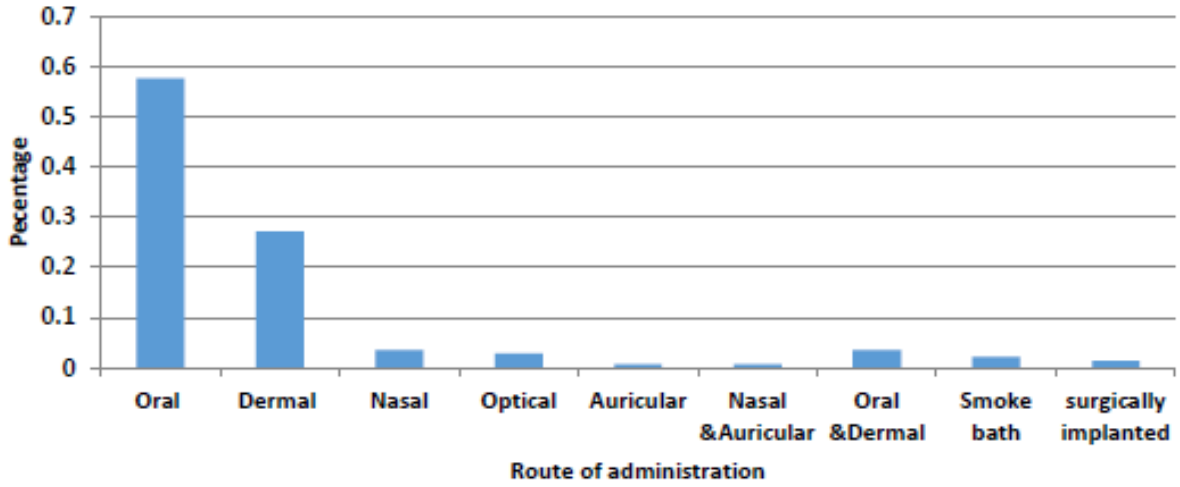

Figure 8. Percentage of administration route of medicinal plants.

medicinal plant survival in the study area.

In addition, improper use of resources such as harvesting the root of a medicinal plant could be a significant threat to medicinal plants as; our result showed that roots were the second major plant parts where 33% of the medicinal plant species were harvested to treat ailments. Root and whole plant harvesting are destructive practice which may result in species extinction. Root as the most commonly used plant part in remedy preparation was reported (Giday et al., 2007, 2009; Lulekal et al., 2013; Maryo et al., 2015).

Threatened medicinal plants

The results (Table 5) indicated that *Balanites aegyptiaca,* is the most threatened followed by *Cadaba farinosa and Tamarindus indica and the least threatened one is Solanum somalensis.*

Medicinal plant conservation efforts of the local people

About 33.62% of the informants reported that they had awareness of the importance of conserving medicinal plant species and were practicing some conservation activities like cultivation in home gardens. The rest of the informants were not practicing any conservation effort. They simply went to the wild to collect medicinal plants as their need arose and did not bother about the long term survival of these plants. It was found that only 13% of the medicinal plants were obtained from home garden about 8% from both wild and home garden this shows that most of the herbalists are not interested to grow medicinal plants in their home garden in order to keep the secrecy of their medicinal value. According to Etana (2010), about 38%, of the medicinal plants collected were reported as found cultivated at home gardens. Some traditional practitioners have started to conserve medicinal plants by cultivating at home garden, such as *Jatropha curcas* L., *Withania somnifera* (L.) *Dunal and Punica granatum* L. The people's culture and spiritual beliefs somehow has helped in the conservation of medicinal plants. For instance, the claim of the traditional healers that medicinal plants are effective only if cut or collected and administered by traditional healers helped in conservation of medicinal plants. Similar cultural and spiritual believes were reported in the study of medicinal plants in Wenago Woreda, SNNPR, Ethiopia (Mesfin et al., 2009).

Conclusions

In the present study, fifty two plant species of medicinal importance were recorded and documented. The majority of the reported medicinal plant species were wild. Many medicinal plant species were also reported to be rare. These demand an urgent attention to conserve such vital resources so as to optimize their use in the primary healthcare system. A rich heritage of indigenous medicinal plant use and knowledge was also recognized. However, awareness creation should be made among the healers so as to avoid erosion of the indigenous knowledge and to ensure its sustainable use and conservation as some healers were not transferring it all. Further phytochemical and biological activity studies should also be conducted on the preferred medicinal plant species so as to utilize them in drug development.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

Table 1. Medicinal plant used for the treatment of human diseases; scientific name, local name, Habit, part (s) used, method of preparation, administration route and diseases treated.

Voucher No.	Scientific name	Family	Plants Local name	Habitat	Habit	Part used	Human disease treated	Mode of preparation (MP)	Mode of administration
DU01	*Seddera hirsuta* Dammer ex Hall. F	Convolvulaceae	Ada'adeyis	W	Sh	L&R	Swelling and infection on the head (Korokor)	Fresh leaf crushed and mixed with oil and applied on the skin.	Dermal
DU02	*Crotalaria laburnifolia* L.	Fabaceae	Adero	W	Sh	L	Nose bleeding	Fresh leaves crushed and squeezed and the juice is added in to the nose drop by drop.	Nasal
DU03	*Salvadora persica* L.	Salvadoraceae	Adey	W	Sh	R	Skin itching	Root boiled in water and washing the body with it.	Dermal
DU04	*Blepharis edulis* (Forssk.) Pers.	Acanthaceae	Ara'ar	W	H	L	After birth retention	Hanging on the ceiling of the house to expel the after birth quickly.	Hanging on roof
						L	Tiredness during labor	Hanging on the ceiling of the house to avoid exhaustion during labor.	Hanging on roof
						R	Scorpion poison	The root is crushed and divided in to two halves and one half mixed with water and consumed the other half is applied on the body part	Oral and Dermal
DU05	*Gomphocarpus purpurascens* A Rich	Asclepiadaceae	Ariyuyo	W	Sh	F	Pneumonia	Crushed and mixed with tenadam, qurqura and oil then applied on the general body	Dermal
DU06	*Acacia tortilis* (Forssk.) Hayne	Fabaceae	Assel	W	T	F	Gastritis	Surgically implanted in the cow dewlap for 3 days.	Implanted surgically
								Dried stem pounded mixed with water and drunk	
						St		The bark is soaked in water over night and consumed. It is consumed when the person is thirsty for one week	
						R	Hepatitis	Crushed and mixed with water and consumed like tea (decoction).	Oral
DU07	*Plectranthus cylinderaceous*	Lamiaceae	Berbarsha	W	Sh	B		Surgically implanted in the cow dewlap for 3 days.	Implanted surgically
DU08	*Grewia* spp	Tiliaceae	Berkule	W	T	St	Swelling and infection on the head (Korokor)	Stem pounded and mixed with goat milk and applied on the wound	Dermal
DU09	*Solanum jubae* Bitter	Solanaceae	Demer-rugad	W	T	R	Abdominal pain	Consumed like tea by being boiled in water.	Oral
DU 10	*Euclea devinoram*	Ebenaceae	Dhadhaho	W	H	L	Mitch	Squeezed	Nasal
DU 11	*Acalypha fruticosa*	Euphorbiaceae	Dhiri	W	Sh	L	diarrhea,	Boiled in the form of tea and consumed.	Oral
						B	lower back pain	Boiled and consumed	Oral
						L	Ear disease	Fresh leaves crushed and squeezed using cloth and applied on the ear drop by drop	Auricular
DU12	*Cucumis* sp.	Cucurbitaceae	Dubdele	W	Sh	St	Diarrhea, vomiting and fever.	Crushed and mixed with goat milk, sugar is added and consumed	Oral
DU13	*Leptadenia* sp.	Asclepiadaceae	Dunkal	W	H	R	Swollen body part/GOFLA	Crushed and mixed with water and consumed	Oral
							Lower back pain	Fresh root crushed and boiled and consumed like tea.	
							Gonorrhea	Fresh root crushed and boiled and consumed like tea.	
							Tonsilitis	Chewing fresh root and the juice is consumed.	
DU14	*Indigofera coerulea* Roxb.	Fabaceae	Gebeldiyo	W	Sh	R	Nosebleed	Fresh leaves crushed and squeezed and the juice is added in to the nose drop by drop.	Nasal

Table 1 cont'd

						L	Paralysis	Leaf pounded and applied on the patient's body.	
						R	Alati	The bark of fresh root is crushed and mixed with coffee pulp and boiled and consumed after addition of sugar or goat milk.	Oral
							Fever	The bark of fresh root is crushed and mixed with coffee ashara and boiled and consumed after addition of sugar or goat milk.	
						R	Epilepsy	Fresh root roasted and fumigated or crushed and mixed with water and consumed	
						L	Skin itching	Fresh leaf crushed warmed for sometimes and mixed with oil and applied on the skin.	Oral
DU15	*Ledebouria* spp.	Hyacinthaceae	Geld ayis	W	Sh	R	Scorpion poison	Fresh root crushed without adding water and the juice is applied on the bite site.	
DU16	*Barleria orbicularis* Hochst. ex T Anders.	Acanthaceae	Get bay	W	Sh	R	Snake poison	Chewing fresh root and swallowing the juice	Oral
						L&R		Fresh leaves crushed and mixed with small amount of water and applied on the body part.	Dermal
						R		Fresh root crushed without adding water and the juice is applied on the bite site.	
						Bu		Crushed and mixed with water and consumed and also applied on the site of bite. Just once.	Oral and dermal
DU17	*Seddra* sp.	Convolvulaceae	Get serey	HG	Sh	R	Diarrhea	Fresh root crushed mixed with milk and consumed, with small sized glass	Oral
DU18	*Capparis tomentosa* Lam	Capparidaceae	Gumero	W	T	R		crushed and mixed with water and taken oral to facilitate nipple pores	Oral
DU19	*Tribulus terrestris*	Zygophyllaceae	Gundo	W	H	Wh	Kidney problem	Fresh whole plant crushed and mixed with water and sugar added and drinks.	Oral
DU20	*Verbasculum sinaiticum* Benth	Scrophulariaceae	Adayoo	W	Sh	R	Bloating	Crushed root mixed with water and taken oral	Oral
						L		Fresh leaves crushed and mixed with water.	
						R		Chewing and swallowing the juice or crushed and mixed with water and drink.	
						R	Sudden illness	Chewing and swallowing the juice or crushed and mixed with water and drink.	Oral
						St	Abdominal pain	Fresh stem crushed and mixed with water and consumed	Oral
DU 21	*Leucas stachydifomis* (Hochst.ex Benth)Briq.	Lamiaceae	Hanun neberhamed	HG	H	Wh	Disease that cut the nose	Fresh or dried whole plant roasted and pounded and mixed with oil or butter and applied on the nose	dermal
DU22	*Xanthium spinosum* L.	Asteraceae	Harbena	W	H	R	Kidney problem	After being squeezed it is mixed with water and drink	Oral
DU23	Aloe pirottae	Aloaceae	Doer	W	Sh	L	Constipation	The juice is squeezed from the leaf and drink	Oral
							Wound healing	Fresh leaves squeezed and the sap is applied on the wound.	Dermal
							Diabetes	Fresh leaves squeezed and the sap is squeezed from the leaf and drunk	Oral

Table 1 cont'd

						Sa	Bloating	Fresh leaves squeezed and the sap is squeezed from the leaf and drunk	Oral
						St	Constipation	Fresh leaves squeezed and the sap is squeezed from the leaf and drunk	Oral
						Sa	Gastritis	Sap concocted with *Zingeber officinale* powder and honey or sugar added and taken oral.	Oral
						St	Eye disease	Fresh leaves squeezed and drop in the eye.	Optical
						Sa	Constipation	Extract the sap and mixed with the flour of *Trigonella foenum-graecum* prepared inf the form of tablet.	Oral
DU24	Leucas neuflizeana COlll'bon	Lamiaceae	Hebrud	W	H	L	Vomiting	Dry or fresh leaf crushed and mixed with water and boiled and taken oral	Oral
DU25	*Withania somnifera* (L) Dunal	Solanaceae	Midox	B	Sh	R	Swollen body part (Gofla)	Crushed and mixed with goat meat soup and drink	Oral
						L	Infertility in women	Fresh leaves crushed and squeezed with water and orally taken.	Oral
						R	Heart problem	Chewing the root and swallowed with water.	Oral
						L	Skin itching	Crushed and mixed with water and boiled the patient wash its body with it.	Dermal
						R	Evil eye	Crushed and squeezed then the juice is added drop by drop	Nasal and Auricular
DU26	*Eulophia petersii*	Orchidaceae	Hola	W	H	L	Swollen knee/GOFLA	Pounded and mixed with water then applied on the wound	Dermal
						Bu		Crushed and applied on the swollen body part.	
DU27	*Foeniculum vulgare*	Apiaceae	Kemona	HG	H	Se	Kidney problem	Seed pounded and mixed with water and the mixture is left to stand for some times and then the supernatant is consumed.	Oral
							Gonorrhea	Pounded and mixed with warm water and taken oral.	
						R	Kidney problem, head ache	The epidermis of the root is dried and crushed and mixed with water	
						Se	Bloating	Crushed and mixed with water	Oral
DU28	*Maerua oblongifolia*	Fabaceae	Je,e	W	Sh	L	Swollen body part/GOFLA	Crushed and mixed with sheep tail fat and taken oral	Oral
						St	Swollen body part /GOFLA	Stem crushed and mixed with sheep tail fat.	
							Fever	Stem crushed and mixed with sheep fat and applied on the body and also small amount of it is consumed.	Dermal
						R	Swollen body part /GOFLA	Crushed and mixed with water and drink	Oral
							Tonsillitis	Chewing the root and swallowing the juice	
							Swollen body part /GOFLA	Fresh root crushed and boiled and drink like tea.	
DU29	*Crotalaria laburnifolia*	Fabaceae	Jelelo	W	Sh	R	Constipation	Fresh root crushed and boiled and consumed like tea.	Oral

Table 1 cont'd

DU30	*Solanum sepiculum*	Solanaceae	Kirir	W	Sh	L	Snake poison	Fresh leaves crushed and mixed with water and consumed	Oral
						R&L	Snake poison	Fresh leaves crushed and mixed with water and consumed and the remaining is used for creaming the body part.	Dermal
DU31	*Parthinum hystrophorus*	Asteraceae	Kuban	W	H	L	Wound healing	Fresh crushed and applied on the wound	Dermal
							Nose bleeding	Fresh leaves crushed and squeezed with cloth and the juice is applied in to the nose.	Nasal
DU32	Balanites aegyptiaca	Balanitaceae	Kulen	W	T	L	Influenza and coughing	Chewing for flue and smoking and inhaling	Nasal
DU33	*Plumbago zeylanica* L.	Plumbaginaceae	Mexres	W	Sh	Se	Intestinal parasites	Pounded and mixed with food and eaten in empty stomach.	Oral
						L	Urinating problem	Fresh leaf crushed and mixed with water and sugar is added.	
							Impotence and gonorrhea	Fresh leaf crushed and mixed with water.	
						R	Gofla (for bone cancer)	The root is boiled and consumed in small amount plus it is also crushed and applied on the surface of the disease part.	Oral and Dermal
						R	Swollen body part /GOFLA	Dried root is crushed and mixed with coffee straw and boiled and consumed.	Oral
DU34	Indigofera sp.	Fabaceae	Mey dah dere	W	Sh	L	Swollen body part /GOFLA	Fresh leaves crushed alone and applied on the body part.	Dermal
DU35	*Halothamnus somalensis*	Chenopodiaceae	Mirow	W	Sh	R	Intestinal parasites	Dry or fresh root crushed and mixed with water and taken oral.	Oral
							Skin itching	It is also used to clean teeth.	
							Intestinal parasites	Dry or fresh root crushed and mixed with water and taken oral.	
						R&L	Constipation	Fresh or dried root and leaf are crushed and mixed together and boiled with water and taken like tea.	
DU36	*Euphorbia* sp.	Euphorbiaceae	Getaro	W	H	L	Spider poison	Dry leaf pounded and mixed with goat milk and taken	Oral
						Wh	Mouth sore	Whole plant pounded and mixed with goat milk and consumed	Oral
							Spider poison	Whole part crushed and squeezed and boiled in water and consumed one or two mouthful it. And the remaining is applied on the wound.	Oral and Dermal
							Spider poison	Fresh Whole plant crushed and mixed with sheep tail fat and applied on the wound for 3 days	Dermal
DU37	*Echidnopsis dammanniana*	Asclepiadaceae	Mesqa	W	H	L	Snake poison	The site of the bite will be tied cut with blade and fresh leaf pounded and tied on the cut body part and also the pounded leaf is mixed with water and consumed	Dermal and oral
							Repel snake	Burning the leaf on fire	Smoking

Table 1 cont'd

						R	Snake poison	Dried root of *Echidnopsis dammanniana* and *Solanum sepiculum* and pounded and mixed with water and consumed.	Oral
DU38	*Heliotropium steudneri* Vatke	Boraginaceae	Dieso/mederis	W	T	L	MICH	Fresh lives crushed and squeezed the juice is added in coffee or tea and consumed.	Oral
							Boil	Fresh leaves crushed and tied with cloth on the boil.	Dermal
							Eye disease	Fresh leaves crushed and squeezed using cloth and applied on the eye drop by drop.	Optical
							MICH	Fresh Leaf squeezed and the juice is added in coffee and consumed.	Oral and Dermal
DU39	*Mentha spicata* L.	Lamiaceae	Nana	HG	H	L	Lung and liver disease	Consumed like tea by boiled in water, or dried leaves pounded and mixed with honey and consumed.	Oral
DU40	*Capparis cartilaginea* Decne.	Capparidaceae	Qelemberur	B	T	L&R	Skin itching	Fresh leaves and root concocted together and mixed with sheep tail fat and painted on the skin.	Dermal
						L	Tonsilits	Dried leaf crushed and mixed with water and taken oral for seven days.	Oral
DU41	*Punica granatum* L.	Punicaceae	Ruman	HG	Sh	F	Gastritis	Fruit coat is crushed and mixed with ½ glass water and 3 spoon sugar and taken oral.	Oral
						R	Ascaris	Dried root s crushed and boiled and consumed empty stomach.	
						L	Diarrhea	Fresh leaves crushed and mixed with water and sugar is added and consumed.	
						Se	Gastric and bad mouth smell	Fresh leaves crushed and mixed with water and sugar is added and consumed.	
							Vomiting, Ascaris and abdominal pain.	Dried seeds crushed and mixed with water and taken oral	
							Evil eye	Dried seeds crushed and mixed with water and taken oral	
DU42	*Tamarindus indica* L.	Fabaceae	Hamer	W	T	F	Eye disease	The fruit is soaked in water and added on the eye drop by drop.	Optical
DU43	*Cadaba farinosa*	Capparidaceae	Melud	W	T	F	Nausea	The fruit is soaked in water and taken oral	Oral
							Constipation	The fruit is soaked in water and taken oral	
						R	Swollen knee	Fresh root crushed and applied on the knee	Dermal
							Swollen body part /GOFLA	Crushed and mixed with water and throat washed and spit out	Oral
								Crushed and mixed with water and applied on the breast.	Dermal
						L	Swollen body part /GOFLA	Fresh leaf crushed and applied on the swollen body part.	Dermal
						R		Root crushed and boiled with water and consumed.	Oral
						Se		Seed crushed and mixed with goat milk and applied on the tumor.	Dermal

Table 1 cont'd

						R	Joint pain	Root crushed and mixed with goat milk and applied on the part.	Dermal
							Swollen body part /GOFLA	Dry or fresh root crushed and applied topically	Dermal
								Dried root is crushed and mixed with pericarp of coffee berry and boiled and consumed.	Oral
DU44	*Euphorbia somalinsis*	Euphorbiaceae	Ubateyis	W	H	St	Kidney problem	Fresh stem crushed and applied on the bite site	Dermal
DU45	*Mirabilis jalapa*	Nyctaginaceae	Udasalim	W	H	R	Fever and general body weakness	Root crushed and mixed with oil and applied on the whole body.	Dermal
DU46	*Ehretia cymosa* Thonn	Boraginaceae	Ulaga	W	T	I	MICH	Leaves of both *Ehretia cymosa Thonn* and *Ocimum lamiifolium Hochst. ex* plants crushed together then squeezed and the juice applied on the skin.	Oral and Dermal
DU47	*Sida ovata*	Malvaceae	Umer kope	B	H	L	Boil	Fresh leaves pounded tied on the swelling.	dermal
DU48	*Cucumis* spp	Cucurbitaceae	Unun	W	H	Se	Snake poison	Dried seeds pounded and mixed with water and consumed.	Oral
DU49	*Aerva javanica*	Amaranthaceae	Wanad	W	Sh	R	Hemorrhage	Seeds pounded and applied on the wart (Kintarot)	Dermal
							Gonorrhea	Crushed and mixed with sheep fat and consumed with spoon morning and evening for three consecutive.	Oral
DU50	*Silene microsolen*	Caryophyllaceae	Wegert	W	H	R&L	Evil eye	Smoking a mixture of *Silene microsolen* and *Silybum marianum*	Smoke bath
DU51	*Seddera bagshawei* Rendle	Convolvulaceae	Tufa	W	H	L	Swelling and infection on the head	Fresh leaf crushed and mixed with oil and applied on the skin.	Dermal
DU52	*Jatropha curcas* L.	Euphorbiaceae	Abetel muluk	B	Sh	pod	Abdominal pain and parasites	Pounded and prepared in the form of tablets	Oral

Habit: Sh-shrub, T-tree, Cl-climber, H-herb; **Part Used:** Wh- Whole, L-leaf, B-bark, Bu-Bulb, St-stem, G-gum, Sa-sap, R-root, Fl-flower, F-fruit, Se-Seed, and P-Pulp; **Habitat:** W-wild, HG-home garden, and Both-B.

Table 2. Informant consensus factor of medicinal plants by aliment categories.

S/No	Aliment category	N_{taxa}	N_{ur}	ICF
1	Swollen body parts (Boil, Gofla)	8	22	0.68
2	Wound healing (Korokor, sore and wounds)	4	9	0.66
3	Poisonous animal bites (snake, scorpion and spider bite)	7	18	0.64
4	Sexual and reproductive health problems (impotence, infertility, STDs)	5	11	0.60
5	Organ problems (kidney, liver, heart, eye, nose, ear problems)	9	20	0.57
6	Spiritual disorder(evil eye, epilepsy)	5	10	0.55
7	General body conditions (Fibril illness (MITCH), general body weakness)	4	7	0.50
8	Gastro intestinal disorders (gastritis, stomach ache, abdominal pain, bloating, diarrhea, vomiting)	17	22	0.23
9	Blood system disorders(diabetes, hypertension)	1	1	0
10	Respiratory tract infections (cough, pneumonia)	3	3	0
11	Skin infections (skin itching, skin rash)	4	4	0

A taxa may fall in more than one ailment.

Table 3. Fidelity value of medicinal plants for the most frequently reported diseases.

Disease treated	Medicinal plants	N_p	N	FL%
Kidney problems	*Foeniculum vulgare*	6	9	66.6
	Euphorbia somalinsis	3	3	100
	Xanthium spinosum L.	4	4	100
	Tribulus terrestris	5	5	100
Constipation	*Aloe pirottae*	3	8	37.5
	Crotalaria laburnifolia	2	2	100
	Tamarindus indica	3	5	60
Swollen body part/Gofla	*Leptadenia sp.*	1	4	25
	Eulophia petersii	2	2	100
	Maerua oblongifolia	4	6	66.6
	Plumbago zeylanica L.	2	7	28.57
	Cadaba sp.	9	13	69.2
Snake poison	*Barleria orbicularis*	4	4	100
	Solanum sepiculum	3	3	100
	Echidnopsis dammanniana	4	4	100
	Cucumis spp	1	2	50
Spider poison	*Euphorbia sp.*	6	7	85.7

Table 4. Ranking of threats to medicinal plants.

Factors	Respondents (R1-R6)							
	R1	R2	R3	R4	R5	R6	Total	Rank
Deforestation	5	6	6	6	6	5	34	**1st**
Charcoal making	2	4	3	3	2	4	18	**4th**
Drought	4	3	4	5	4	3	23	**3rd**
Invasive species	1	2	1	1	3	1	9	**6th**
Overgrazing	3	1	2	2	1	2	11	**5th**
Human encroachment	6	5	5	4	5	5	30	**2nd**

Table 5. Ranking of threatened medicinal plants in the study area.

Plant species	Respondents							Rank
	R1	R2	R3	R4	R5	R6	Total	
Tamarindus indica	3	3	2	4	3	1	16	**3rd**
Cadaba farinosa	4	5	4	2	4	2	21	**2nd**
Balanites aegyptiaca	5	4	5	5	5	5	29	**1st**
Solanum somalensis	1	2	1	3	2	4	13	**5th**
Acacia brevespica	2	1	3	1	1	3	11	**4th**

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Volatile constituents of *Distichochlamys citrea* M. F. Newman and *Distichochlamys orlowii* K. Larsen & M. F. Newman (Zingiberaceae) from Vietnam

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The characterization of chemical constituents of hydrodistilled essential oils from the rhizomes of *Distichochlamys citrea* M.F. Newman and *Distichochlamys orlowii* Larsen & M.F. Newman collected from Pù Mát National Park, Nghệ An Province, Vietnam, was performed by means of gas chromatography-flame ionization detector (GC-FID) and gas chromatography-mass spectrometry (GC-MS) techniques. The main constituents of *D. citrea* oil were 1,8-cineole (23.0%), (*E*)-citral (18.9%) and (*Z*)-citral (15.0%). On the other hand, geranyl acetate (16.5%), β-elemene (9.2%), β-pinene (9.0%) and β-caryophyllene (7.9%) were the principal components of *D. orlowii*. The present paper is the first of its kind aimed at the characterization of the volatile compounds of *D. orlowii*.

Key words: *Distichochlamys citrea, Distichochlamys orlowii,* essential oil composition, monoterpenes, sesquiterpenes.

INTRODUCTION

The aim of the present study was to report the chemical compounds identified in the essential oil obtained from the rhizomes of *Distichochlamys citrea* M.F. Newman and *Distichochlamys orlowii* Larsen & M.F. Newman collected from Pù Mát National Park, Nghệ An Province, Vietnam. This is in continuation of an extensive research aimed at the characterization of the volatile compounds of poorly studied Vietnamese flora (Chau et al., 2015; Huong et al., 2016, 2017). *Distichochlamys* is a genus of plants in the ginger family. It has 4 known species, all endemic to Vietnam (Newman, 1995). The four species are: *D. benenica* Q.B. Nguyen & Skornick, *D. citrea* M.F. Newman, *D. orlowii* K. Larsen & M.F.Newman and *D. rubrostriata* W.J. Kress & Rehse (Newman, 1995; Rehse and Krees, 2003). *D. citrea* was discovered in Bach Ma National Park in Thua Thien Hue province earlier than the

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other species growing in Vietnam (Ty et al., 2015). This species has a distinct aroma and has been employed in traditional medicine in Vietnam as drugs and spices in foods to ameliorate internal disorders and inflammation related diseases (Ty et al., 2015). *Distichochlamys* species are distinguished from each other on the basis of leaf, inflorescence bract, lateral staminode and labellum characters (Rehse and Krees, 2003). They are small herbs forming dense tufts of few-leaved shoots. The inflorescence is terminal arising in the center of the radical leaves. The bracts are distichous, each subtending a few-flowered (Newman, 1995; Larsen and Newman, 2001; Rehse and Krees, 2003). The flowers are white and yellow. In *D. citrea,* the inflorescence bracts are spread and loosely imbricate while the labellum are divided with cleft extending less than half its length. However, in *D. orlowii,* the inflorescence bracts are densely imbricate while the labellum is yellow with purple veins, dark yellow medium band with two emarginated lobes (Larsen and Newman, 2001).

Till moment, scanty information are available in the literature on the chemical constituents of the volatile and non-volatile extracts and biological activity of *Distichochlamys* plants. The authors are aware of one reference describing the essential oil contents of *D. citrea* (Ty et al., 2015). High contents of 1,8-cineole (30.71% - 43.67%), β-citral (1.6% - 13.98%), α-citral (2.47% - 20.88%) and neryl acetate (4.14% - 11.11%) were present in the oils. Also, only one report in the literature describing the volatile and non-volatile compounds identified from rhizome of *D. rubrostriata* (Tuyet, 2012). The phytochemical investigation of the rhizomes of *D. rubrostriata* resulted in the isolation of 3,5-dihydroxy-4',7-dimethoxyflavon, sitosterol palmitate, 3',5-dihydroxy-4',7-dimethoxyflavonol-3-rutinoside and β-sitosterol (Tuyet, 2012). On the other hand, 1,8-cineole (13.20- 22.00%), (*Z*)-citral (14.15-22:26%), (*E*)-geraniol (12.47-12.75%), (*E*)-citral (18.49-22.13%) and geranyl acetate (6.61-14.92%) were the main constituents of the essential oil (Tuyet, 2012).

MATERIALS AND METHODS

Plant materials

Rhizomes of *D. citrea* and *D. orlowii* were collected from Pù Mát National Park, Nghệ An Province in August 2014. Botanical identification was performed by Dr. Dai DN and voucher specimens LTH 26 and LTH 441 respectively were deposited at the Botany Museum, Vinh University. Vietnam. Plant samples were air-dried for a week under room temperature prior to extraction.

Hydrodistillation of the essential oils

About 500 g each of air-dried and pulverized rhizomes (using grinding mill) of each plant were subjected separately to hydrodistillation in an all glass Clevenger apparatus for 4 h at normal pressure, according to an established procedure (Vietnamese Pharmacopoeia, 1997). Briefly, 500 g of the pulverized sample were carefully introduced into a 5 L flask and distilled water was added until it covers the sample completely. Hydrodistillation was carried out in an all glass Clevenger-type distillation unit designed according to the specification. The volatile oils distilled over water and were collected in the receiver arm of the apparatus into a separate clean and previously weighed sample bottles. The processes were done in triplicate. The oil was kept under refrigeration (4°C) until the moment of analysis.

Gas chromatography (GC) analysis of the oils

Gas chromatography (GC) analysis was performed on an Agilent Technologies HP 6890 Plus Gas chromatograph equipped with flame ionization detector (FID) and fitted with HP-5MS column (30 m x 0.25 mm, film thickness 0.25 μm). Temperature parameters: column oven- 40°C, injection port-250°C, detector-260°C. Time programming: 40°C for 2 min, temperature raised to 220°C (10 min hold) at 4°C/min. Carrier gas used was H_2 (1 mL/min), split ratio 10:1, volume injected: 1.0 μL. Inlet pressure was 6.1 kPa. Each analysis was performed in triplicate. Retention indices (RI) value of each component was determined relative to the retention times of a homologous *n*-alkane series (C_4-C_{32}) with linear interpolation on the HP-5MS column. The relative amounts of individual components were calculated based on the GC peak area (FID response) without using correction factors.

Gas chromatography-mass spectrometry (GC-MS) analysis of the oils

GC/MS was performed on HP 5973 MSD mass spectrometer with HP 6890N Plus GC system fitted with a fused silica capillary HP-5 MS column (30 m x 0.25 mm, film thickness 0.25 μm). The conditions were the same as described above for GC with He (1 mL/min) as carrier gas. The MS conditions were as follows: ionization voltage 70 eV; emission current 40 mA; acquisitions scan mass range of 35-350 amu.

Identification of the constituents

Peaks were identified by comparison of relative GC retention indices with standards from literature, retention indices on HP-5 MS column, peak enrichment on co-injection with authentic standard wherever possible and comparison of mass spectra with literature data (National Institute of Science and Technology, NIST, 2001).

RESULTS

The yield of the essential oils were 0.25% (v/w, *D. citrea*), and 0.35% (v/w, *D. orlowii*), calculated on a dry weight basis. Oil samples were light yellow in colouration. Table 1 indicates the chemical constituents present in the oil, their percentages as well as retention indices on HP-5MS column. The classes of compounds obtained in *D. citrea* rhizome oil were mainly the oxygenated monoterpenes (79.4%). The monoterpene hydrocarbons (4.4%), sesquiterpene hydrocarbons (2.3%) and oxygenated sesquiterpenes (5.8%) occurred in much lower amounts. The main constituents of *D. citrea* oil were 1,8-cineole (23.0%), (*E*)-citral (18.9%) and (*Z*)-citral (15.0%). There are significant amounts of geraniol (9.3%), α-cedrol

Table 1. Volatile compounds of *D. citrea* and *D. Orlowii.*

Compounds [a]	Class	RI (Cal.)	RI (Lit.)	Percentage composition (%)	
				D. citrea[b]	*D. orlowii* [b]
α-Thujene	mh	920	921	0.2	0.1
Tricyclene	mh	926	926	-	0.1
α-Pinene	mh	939	932	1.4	2.2
Camphene	mh	953	946	1.1	2.8
β-Pinene	mh	970	976	1.9	9.0
6-Methyl-5-hepten-2-one [c]	nt	988	987	1.9	-
β-Myrcene	mh	990	988	-	0.8
α-Phellandrene	mh	1006	1004	-	0.1
δ-3-Carene	mh	1011	1008	-	0.2
α-Terpinene	mh	1017	1014	0.1	0.1
o-Cymene [c]	mh	1024	1021	-	0.2
Limonene	mh	1032	1030	-	3.1
1,8-Cineole	mo	1034	1032	23.0	-
(*Z*)-β-Ocimene	mh	1043	1037	-	0.1
(*E*)-β-Ocimene	mh	1052	1044	-	0.2
γ-Terpinene	mh	1061	1056	0.3	0.3
α-Terpinolene	mh	1080	1082	-	0.3
Isoterpinolene	mh	1088	1088	-	2.5
Fenchone	mo	1089	1089	0.2	-
Linalool	mo	1100	1095	1.2	3.1
trans-Pinocarveol	mo	1139	1140	0.3	-
Camphor	mo	1145	1141	-	0.3
allo-neo-Ocimene	mh	1147	1147	-	0.8
Citronellal	mo	1153	1158	0.1	-
Borneol	mo	1167	1167	1.8	0.3
Terpinen-4-ol	mo	1177	1177	4.1	-
α-Terpineol	mo	1189	1187	4.6	0.1
α-Thujenal [c]	mo	1189	1189	0.4	-
Myrtenal	mo	1209	1194	-	0.1
Fenchyl acetate	mo	1228	1226	0.2	0.1
Nerol	mo	1234	1239	0.3	-
(*Z*)-Citral (= Neral) [c]	mo	1251	1249	15.0	4.6
Geraniol	mo	1253	1249	9.3	0.9
(*E*)-Citral (= Geranial) [c]	mo	1270	1273	18.9	-
Bornyl acetate	mo	1289	1287	-	2.1
Myrtenyl acetate	mo	1326	1330	-	1.0
Bicycloelemene	sh	1327	1337	0.1	-
Citronellyl acetate	mo	1360	1357	-	0.2
Neryl acetate	mo	1362	1365	-	0.1
α-Copaene	sh	1377	1374	-	0.2
Geranyl acetate	mo	1381	1378	-	16.5
β-Elemene	sh	1391	1387	-	9.2
α-Cedrene	sh	1412	1409	-	0.2
β-Caryophyllene	sh	1419	1417	-	7.9
γ-Elemene	sh	1437	1434	-	0.3
Aromadendrene	sh	1441	1439	0.4	-
α-Humulene	sh	1454	1452	-	4.9
γ-Gurjunene	sh	1477	1479	0.2	3.4
α-Amorphene	sh	1485	1484	-	0,2
β-Selinene	sh	1486	1486	0.8	0.4

Table 1. Cont'd.

Eudesma-4,11-diene	sh	1490	1494	0.2	-
β-Himachalene	sh	1495	1499	-	0.9
Bicyclogermacrene	sh	1500	1500	-	3.6
β-Bisabolene	sh	1506	1502	0.3	-
(*E, E*)-α-Farnesene	sh	1508	1505	-	0.4
δ-Cadinene	sh	1525	1522	-	1.3
γ-Selinene [c]	sh	1529	1532	-	0.5
β-Sesquiphellandrene	sh	1543	1545	0.2	-
Elemol	so	1550	1548	-	0.2
(*E*)-Nerolidol	so	1563	1561	-	0.2
Ledol	so	1565	1561	-	0.2
Spathulenol	so	1578	1577	-	1.9
Caryophyllene oxide	so	1583	1581	0.4	2.7
Viridiflorol	so	1593	1591	0.1	0.8
Guaiol	so	1601	1600	0.1	0.4
α-Cedrol	so	1601	1602	5.2	-
τ-Muurolol [c]	so	1646	1644	-	2.9
α-Cadinol	so	1654	1652	-	0.5
Lepidozene	so	1676	1676	0.1	-
Valerenol	so	1715	1711	-	0.3
(*E,E*)- α-Franesol [c]	so	1718	1722	-	1.1
Mint sulfide [c]	sh	1741	1743	-	0.3
Phytol	dt	2125	2119	-	0.3
Total				93.8	98.5
Monoterpene hydrocarbons				4.4	23.9
Oxygenated monoterpenes				79.4	29.4
Sesquiterpene hydrocarbons				2.3	33.7
Oxygenated sesquiterpenes				5.8	11.2
Diterpenes				-	0.3
Non-terpenes				1.9	-

[a] Elution order on HP-5MS column; (RI Cal.) Retention indices on HP-5MS column; (RI lit.) Literature retention indices; [b] Standard deviation (SD ±) were insignificant and excluded from the Table to avoid congestion; - Not identified; [c] Mode of identification, retention indices, mass spectrum and co-injection; mh, monoterpene hydrocarbons; mo, oxygenated monoterpenes; sh, sesquiterpene hydrocarbons; so, oxygenated sesquiterpenes; dt, diterpenes; nt, non-terpenes

(5.2%) α-terpineol (4.6%) and terpinen-4-ol (4.1%).

However, significant quantity of monoterpene hydrocarbons (23.9%), oxygenated monoterpenes (29.4%), sesquiterpene hydrocarbons (33.7%) and oxygenated sesquiterpenes (11.2%) were identified in the rhizome oil of *D. orlowii*. The oil contained a trace quantity of diterpenes (0.3%). It was observed that geranyl acetate (16.5%), β-elemene (9.2%), β-pinene (9.0%) and β-caryophyllene (7.9%) were the principal components of *D. orlowii*. Other compounds of qualitative importance include α-humulene (4.9%), (*Z*)-citral (4.6%), bicyclogermacrene (3.6%), γ-gurjunene (3.4%), linalool (3.1%) and limonene (3.1%).

DISCUSSION

Of the total of 77 compounds identified in the oil samples, only seventeen of them are common to both oils. Although terpene compounds predominates in the essential oils, it should be noted that each oil sample has its own compositional different from another. For example, high contents of oxygehated monoterpene were observed in *D. citrea*, whereas *D. orlowii* consist of diversed terpene compounds. A noteworthy observation was that 1,8-cineole, (*E*)-citral and α-cedrol, some principal cmpounds of *D. citrea* were not identified in *D. orlowii*. In addition, the content of geraniol (9.3%) in *D. citrea* is much higher than that of *D. orlowii* (0.9%). Also, several compounds such as geranyl acetate, β-elemene, β-caryophyllene, α-humulene which are present in *D. orlowii* were conspicuously absent in *D. citrea*.

The authors are aware of one literature citation on the essential oil of *D. citrea* (Ty et al., 2015) in which the main compounds were identified to be 1,8-cineole (30.71

- 43.67%), β-citral (1.6 - 13.98%), α-citral (2.47 - 20.88%) and neryl acetate (4.14 - 11.11%). Except neryl acetate, all the other compounds mentioned above were also of identified in significant quantity in the present investigated oil sample. The quantitaive and qualitative compositions of 1,8-cineole, (*Z*)-citral and (*E*)-citral in present and previously studied oil samples, confers similarity between *D. citrea* (Ty et al., 2015) and *D. rubrostriata* (Tuyet, 2012).

The biological activity of an essential oil may be due to the main constituents or a synergy between the main constituents and some minor compounds. Literature information has shown that the chemical compounds identified in the essential oils of the studied *Distichochlamys* species possessed some biological potential. For example, 1,8-cineole was known to exhibited several biological activities such a anti-inflammatory (Juergens, 2014) and allelopathic (Nishida et al., 2005). The antitumor activities of β-elemene (Zhan et al., 2012), β-caryophyllene (Legault and Pichette, 2007) and 1,8-cineole (Juergens et al., 2004) against human cell cancer lines have been reported. Geranly acetate ha possessed antinociceptive (Quintans-Júnior et al., 2013), antifungal and anti-inflammatory (Gonçalves et al., 2012) effects. Essential oil with high contents of citral (mixture of neral and geranial) was found to displayed cytotoxic activity on human tumor cell lines, antioxidant activity and the free radical scavenging capacity (Maggi et al., 2013). Thus, a combination of phytochemicals with reported bioactivity in the essential oils of the studied *D. citrea* and *D. orlowii* growing in Vietnam may contribute to their biological activities.

Although little is known about the volatile components of genus *Distichochlamys*, the chemical constituents of essential oils from several species of other genus in the family Zingiberaceae have been widely reported as new species are being discovered. Recently, the leaf volatile components of a newly discovered species, *Zingiber nitens* M.F. Newan, was found to contained δ-elemene (17.0%), β-pinene (12.8%) and β-elemene (8.8%) while the stem comprised mainly δ-elemene (20.1%), germacrene D (8.6%) and bicyclogermacrene (8.1%) with β-pinene (21.0%), δ-elemene (12.8%) and bornyl acetate (11.8%) making up the root (Hung et al., 2017). *Stahlianthus campanulatus* O. Kuzt (Dai et al., 2017) another newly analysed species in Zingiberaceae has its major constituents as stahlianthusone (27.6%), α-copaene (16.7%) and camphor (14.7%). The essential oil compositions of several other plants in the family were newly described in our laboratory (Chau et al., 2015; Huong et al., 2017). It is well known the chemical compositions of an essential depends on several factors such as intra- and inter-specific variations, age of the plants, climatic and environmental conditions, chemotype, handling and processing conditions etc. These factors may have been responsible for the variations in the chemical constituents of essential oils within the family Zingiberaceae.

The present paper provides new information on the chemical constituents of essential oil of *D. orlowii*. In addition, relative differences were observed between the present and previously investigated oil samples of *D. citrea*. Moreover, it was well established that different species of plant may contained different phytochemicals.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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