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Knowledge and demand for medicinal plants used in the treatment and management of diabetes in Nyeri County, Kenya

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ABSTRACT

Ethnopharmacological relevance: Non communicable diseases are currently a major health challenge facing humanity. Nyeri County has one of the highest diabetes prevalence in Kenya (12.6%), compared to the country's prevalence of 5.6%. The purpose of the study was to document; diabetes knowledge, medicinal plants and demand for the services of traditional medicine practitioners, in the management and treatment of diabetes.

Methods: A cross-sectional study was carried out in the six constituencies in Nyeri, using pre-tested semi-structured questionnaires. Thirty practicing traditional medicine practitioners were purposively selected for the study. Field observation and identification was carried out on all plants that were cited during the interview. Plant samples were collected and voucher specimen deposited in the University of Nairobi Herbarium in the – School of Biological Sciences.

Results: The study revealed 30 plant species in 28 genera and 23 families that are used by the traditional medicine practitioners to treat and manage diabetes. Demand for traditional medicine practitioners' services in the treatment of diabetes is low and often occurs when conventional drugs fail.

Conclusion: Interaction with the TMPs unveiled significant diversity of potential anti diabetic medicinal plants and in-depth ethnobotanical knowledge that they possessed. Preference for traditional herbal medicine was low despite wide ethnobotanical knowledge in the face of high prevalence of diabetes in the locality. The findings form the basis of pharmacological studies for standardization of the documented ethnomedicine used in the treatment and management of diabetes in the study area.

1. Introduction

In the recent past, humanity has faced a growing and overwhelming healthcare challenge due to the devastating burden of non-communicable diseases (NCDs). Diabetes has become one of the leading NCDs in both the developed and currently developing countries. Complications related to diabetes reduce a person's productivity with consequent loss of economic growth whilst placing a very heavy social-economic and health care burden on the community (IDF, 2013; Michael and Alethea, 2006). About 415 million and 14.2 million adults have diabetes worldwide and Africa, respectively. Additionally, 66.7% of diabetic persons are unaware of their hyperglycemic status (IDF, 2015). According to WHO; old age, cigarettes, excessive consumption of alcohol or refined foods and lack of regular physical activity are significant determinants of diabetes (WHO, 2002). However, disparities in predisposing factors in diabetes vary from one local or regional community to the other, due to demographic and social-economic pattern changes (Laakso et al., 1988).

About 50% of all adult hospital admissions in Kenya have been related to NCDs which accounts for 55% of hospital deaths, diabetes being among the leading (El-busaidy et al., 2014). Currently, Kenya has 478 thousand persons estimated to have diabetes (IDF, 2015) and a treatment expenditure of USD 61 per person (IDF, 2013).

In Kenya, studies have recorded a prevalence of 4.2%, 2.2% and 12.2% in the general population, rural areas and urban areas,

Abbreviations: SPSS, statistical package for the social science; TMPs, traditional medicine practitioners; ENT, ear, nose and throat; NCDs, non-communicable diseases; RBG, random blood glucose

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respectively (Dirk et al., 2009). The study about diabetes prevalence revealed an alarming increase in impaired glucose tolerance that ranged from 8.6% in the rural population to 13.2% in the urban. Diabetes prevalence in Kenya was also affected by gender with, 60.3% being women compared to 19.5% in men in the urban areas. In the rural areas, Diabetes mellitus was 22.6% and 10% in women and men, respectively (Christensen et al., 2009).

A study carried out in eight provinces of Kenya showed that 10.3% of the medical camp attendees had diabetes out of which 28.4% were recorded from Central Kenya and only 2.4% accounted for Rift Valley region (Karekezi et al., 2011). The mean random blood glucose (RBG) recorded from 51% of patients that attended Nyeri County general hospital was 8.0 Mmol/l, in another 31%, it was over 10.0 Mmol/l. Some patients had lived with the disease for over thirty years. The age of patients with diabetes complications ranged from ages 32–93 years. Moreover, overall rate of glycemic control was sub-optimal, notably, 60% had high blood pressure above 130/80 mmHg and a mean BMI of 27.6 which is a strong indicator of obesity and overweight (Kibachio et al., 2013). Results from another study in Nyeri County revealed high prevalence of diabetes, about 13.5% among HIV infected individuals as compared to 6.18% in HIV negative population, the mean blood glucose level was 7.6 ± 5. l and 4.4 ± 1.1, respectively (Njagi, 2012).

There have been concerns over the alarming incidences of diabetes prevalence in Nyeri County (12.6%), compared to the country's prevalence of 5.6%, Kirinyaga County at 6.8% and, both Murang'a and Nyandarua at 10%. This prompted the need to establish a Diabetes Specialist Unit that would serve as the coordination Centre for all the 259 community health units (Nyawira, 2013).

While such efforts by the County leadership were appreciable, awareness about Diabetes mellitus may have served as a prerequisite for activities aimed at preventing and controlling the disease effectively by either the individual or a community. This was tied to the fact that, choices about treatment and management approaches related to the health and well-being of people with diabetes were neither made by their physician or health professional but themselves (Anderson and Funnell, 1999).

For an individual to make rationally correct choices, adequate background information was necessary. Consequently, diabetes education aiming at improving knowledge, attitudes and skills was a widely accepted integral part of comprehensive diabetes care (Maina et al., 2011). Further, prior information on attitude, past behavior, affective believes of a community were shown to play a crucial role during awareness campaigns and patient counseling (Conner and Armitage, 1998; Norris et al., 2001). Study findings from Kisii County revealed that, Type II diabetic patients poorly failed to control their dietary behavior despite showing a positive attitude (Omondi et al., 2010). Diabetic patients and health care professionals continued to seek alternative treatment approaches related to antihyperglycemic medicinal herbs as they were believed to cause few side effects compared to synthetic drugs (Huang et al., 1992; Dey et al., 2002). But effective use of traditional medicine as an alternative approach towards treatment and management of diabetes ultimately depends on an individual or community's background knowledge, understanding, attitude, perception and treatment prevalence.

In Kenya, traditional knowledge on the use of antidiabetic medicinal plants was documented among various tribes. Notably, eight plants used by the Mbeere and Kisii communities were documented (Kareru et al., 2007; Maobe et al., 2013). In Central Kenya, information on the use of traditional medicinal plants was documented (Gachathi, 2007; Kokwaro, 1976; Sindiga et al., 1990; Sindiga et al., 1995). However, a detailed account of the current use of traditional antidiabetic herbs in Nyeri County was not documented. Yet, rapid epidemiology of diabetes was accompanied with emergence of herbal treatment centers especially in the urban centers such as Nyeri town, Narumoru, Mukurweini, Karatina and Othaya (Culture and Social Services Department, 2013). The purpose of the current study was to establish, from traditional herbal practitioners, the level of diabetes knowledge and awareness and, treatment seeking behavior in relation to the use of traditional antidiabetic medicinal plants among the Kikuyu community in Nyeri County.

2. Materials and methods

2.1. Description of the study area and ethnographic background

Nyeri County is located in Central Kenya and borders; Laikipia County to the North, Meru to the North East, Kirinyaga to the East, Murang'a to the South, and Nyandarua to the West. It lies between 0° 09′S, 36° 30′E and 0° 50′S, 37° 20′E coordinates, within an area of 3337 km^2 and a population of 693,558 (Male – 49%, Female – 51%). It is divided into six constituencies; Tetu, Kieni, Mathira, Othaya, Mukurwe-ini and Nyeri town (Fig. 1). Temperatures range from a mean annual minimum of 12 °C to a mean maximum of 27 °C, with rainfall amounts of between 550 mm and 1500 mm per annum.

The long rains occur from March to May while the short rains come in October to December. Nyeri leads nationally with a forest cover of 38.5% compared to a national cover of 6.9%. The main physical features of the County are Mount Kenya (5199 m) to the east and the Aberdare ranges (3999 m) to the west; both densely forested with rich plant species diversity. Much of the land is used for agriculture which forms a mainstream source of livelihood, predominating economic activities include; tea and coffee grown for exports; large scale horticultural flower farms, greenhouse farming by small scale vegetable farmers and dairy farming. The predominant tribe is Kikuyu community; others include the Luo, Meru, Kamba, Embu, Borana and Somali. Majority of people living in Nyeri County are Christians. Nyeri County has one level 5 hospital, three level 4, 18 level 3 and 75 level two health facilities. It has also three mission and three private hospitals, one nursing home, one hospice and 228 private clinics spread across the County. The doctor/population ratio is about 1:6459 apopulation ratio of /population ratio of 1:143 (Commission of Revenue Allocation (CRA), 2012). According to African Palliative Care Association (APCA) database; Nyeri County has a high prevalence of hypertension, diabetes and heart diseases (http://integratepc.org/hospitals/kenya-only/). Diabetes prevalence is about 12.6% and ranks highest in Kenya and sub-Saharan Africa (Nyawira, 2013). However, despite the overwhelming level of non-communicable diseases, the County has constantly been at the forefront in discrediting the use of herbal medicine (Muigai, 2004).

2.2. Ethical approval

The survey study was carried out after permit to carry out the research was obtained from National Commission for Science, Technology and Innovation (NACOSTI).

2.3. Data collection

The study was carried out in the month of April 2014 after a permit to carry out the research was obtained from National Commission for Science, Technology and Innovation (NACOSTI). Respondents who willingly consented were selected to participate in the study by signing consent of agreement form. The study design was a cross sectional survey, 30 respondents were recruited for the study. Recruitment was done in consultation with the

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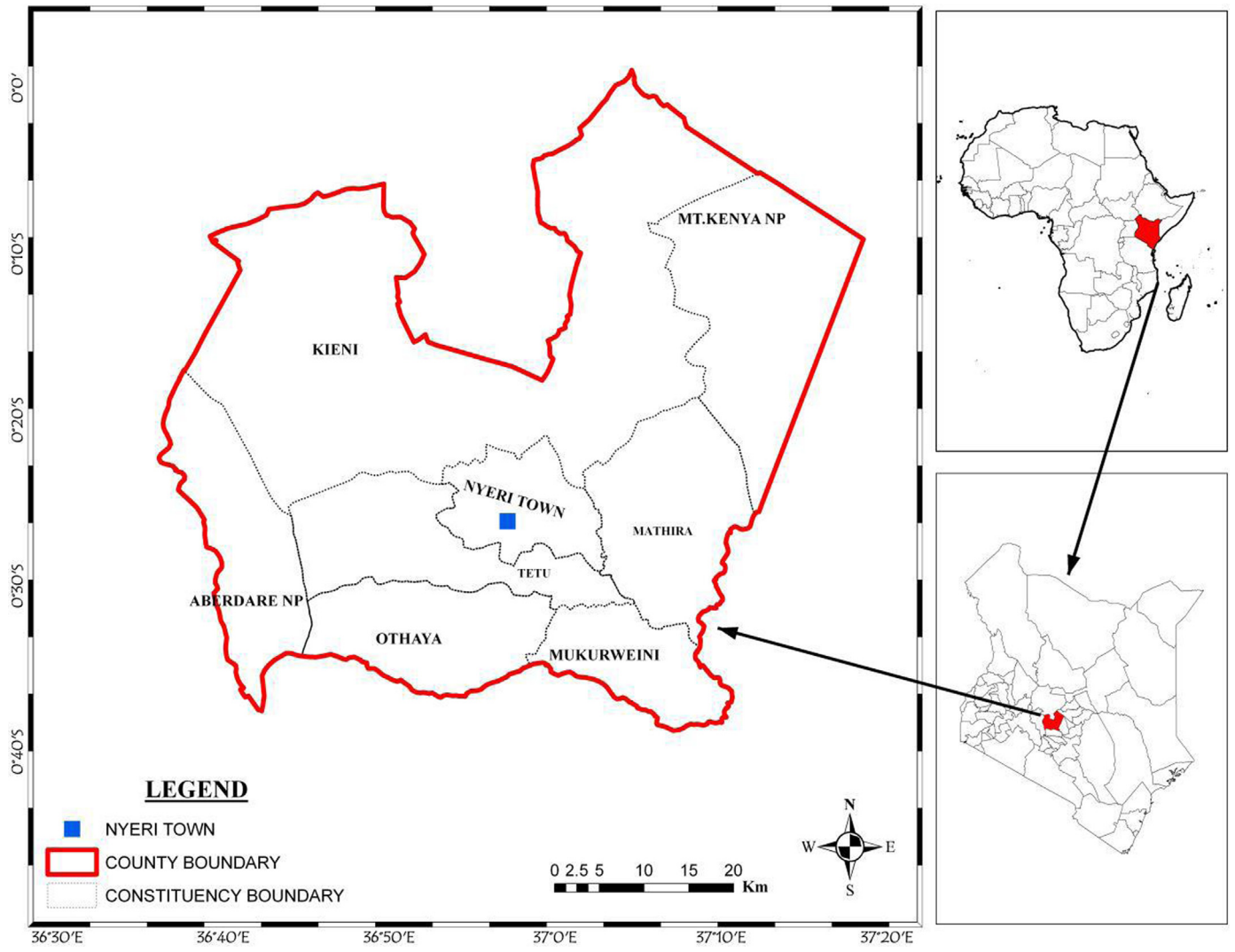

Fig. 1. Map of study area. Top right: Map of Africa illustrating physical position of Kenya. Bottom right: map of Kenya illustrating geographical position of Nyeri County. Left: Nyeri County showing constituency boundaries.

Ministry of Culture and Social Services. Data was collected through interviews; transect walk and administration of semi-structured questionnaires. The questionnaires constituted both open-ended and close-ended items, aimed at obtaining a detailed account of ethno-therapeutic approaches in treatment and management of diabetes. The questionnaires were pilot tested and thereafter used by the researchers and a team of trained research assistants to gather the information on; diabetes prevalence, control and treatment approaches, demand for the services and traditional knowledge about antidiabetic herbal medicine. The interviews were conducted in the vernacular language and translated by the research team. Medicinal plants cited during the interviews were observed from the study field, identified , photographed and collected through the assistance of TMPs and the taxonomist from the University of Nairobi, voucher specimens were deposited in the University of Nairobi Herbarium - in the School of Biological Sciences. Although most of the plants were identified in the field, a few were identified from the University of Nairobi Herbarium using taxonomic records and existing literature.

3. Data analysis

Ethnobotanical data that was collected was entered into SPSS programme version 20. The data was analyzed and summarized into proportions and percentages using descriptive statistics. Some responses were quoted verbatim and content analyzed. Relative importance of antidiabetic plant species among traditional medicine practitioners in Nyeri County was calculated as $UVs = (\Sigma UV_{is})/(n_i)$, where UVs is the total Use Value of the species for all informants, UV_{is} is the Use Value of the species for a single informant, while n_{is} is the number of interviews by the informant (in this study, one interview was conducted per respondent) (Hoffman and Gallaher, 2007; Phillips and Gentry, 1993).

4. Results and discussion

Diabetes in Nyeri County was described as “Mũrimũ wa cukari”, 30 TMPs (100%) acknowledged that diabetes was very common and they were aware of its occurrence. Each cited at least 1–5 diabetic persons within their local area and 1–5 deaths related to diabetes complication(s). Eighty nine (89%) of TMPs understood what diabetes was and gave a valid explanation of its cause(s). The other 11% in particular those that were old or illiterate did not understand the disease. Previous studies classified Central Kenya as one of the regions with the highest record of diabetes knowledge, education being a major determinant (Maina et al., 2011). A higher level of education was associated with better knowledge

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(Al Shafaee et al., 2008; Agu et al., 2014; Mohd et al., 2014). About 67% and 33% of the TMPs reported that diabetes was common among the old people and adults, respectively. Similarly, a mean age of 57 ± 12 years among diabetic patients from Nyeri County was recorded, with some being as old as 93 years of age (Kibachio et al., 2013). Seventy eight (78%) of TMPs reported that most of diabetic persons within their locality were men, the other 22% reported a high prevalence in women. A similar study showed high diabetes prevalence in men (9.8%) compared to 9.2% in women (Danaei et al., 2011), but this contradicts separate results that indicated a high prevalence in men than women (Christensen et al., 2009).

Concerning causes of diabetes in Nyeri County, 89% of TMPs related it to diet, obesity, inactivity and stress, only 11% believed that, it was caused by inheritance. These observations concurred with other findings (Mehta et al., 2006; WHO, 2007; Ziraba et al., 2009). In particular, diet was highly cited as a major contributor (95%), due to consumption of refined foods such as; sugar, maize, wheat and fats in addition to meat. Related findings established that, poor dietary habits were major predisposing factors in diabetes (WHO, 2007; Mehta et al., 2006). Similarly, high fat diet (59.4%), abdominal obesity 43.7% and sedentary lifestyle (46.8%) were linked to predisposing factors for diabetes (Chege, 2010; Elbusaidy et al., 2014). Conversely, in Murang'a County, inheritance was cited by 50.4% of diabetic patients as a major predisposing factor. Notably, the county had lower diabetes prevalence than Nyeri (Mwangi and Gitonga, 2014). Considering that only a small percentage of diabetes in Nyeri County was caused by inheritance as reported by the TMPs, it was evident that, inheritance was not a major predisposing factor among Nyeri community. Doubtlessly, diabetes prevalence in Nyeri County could be significantly lowered by managing diet and body weight through proper lifestyle practices. Indeed, WHO, emphasizes that although overweight and obesity are common factors underlying NCDs, they can be preventable through dietary lifestyles (WHO, 2009).

About 89% of the TMPs cited personal responsibility and commitment as a prerequisite in the control and prevention of diabetes. They advocated for reduced consumption of meat, refined foods and fats, and instead supplement the diet with consumption of traditional foods and vegetables. This was in agreement with other reports; which underscored the centrality of traditional lifestyle which consisted of whole grain, vegetables and fruits, because they contained high fiber content (Christensen et al., 2009; IDF, 2009).

The TMPs emphasized that, local herbs were superior to conventional drugs as they rarely produced side effects. A cross-sectional survey among some Palestinian diabetic patients showed that, 70% confessed that use of CAM therapy had demonstrated greater efficacy than the allopathic remedies. Additionally, CAM had slowed down the disease progression, reduced both the disease symptoms as well as pathological effects caused by the allopathic therapies (Ali-Shtayeh, 2012). The TMPs in the current study recommended assimilation of modern technology in order to enhance correct diagnosis. Before administering any antidiabetic herbs and during subsequent review visits, 88% of the TMPs requested the patient to obtain a medical laboratory test report about the level of their blood sugar. This finding contradicted IDF (2006) report showing that TMPs rarely referred their patients to public health facilities due to ignorance. Further, the current study revealed challenges faced by the TMPS in their practice such as; although diabetic patients sought conventional medical services from the time of diagnosis; rarely did the medical practitioners refer these cases to TMPs. Only one herbalist acknowledged of having treated a case of diabetes referred to him by a medical practitioner. Moreover, unless probed by the TMP, the patients were unwilling to disclose any previous medical treatment. Therefore, to avoid double treatment, the TMPs had to inquire from the patients about use of any other form of medication, before they administered any treatment. The major reasons that were given about why patients would switched from conventional therapy to herbal medicine included; the patient realizing that their condition had become chronic, started experiencing side effects from the conventional drugs and therefore lost faith in them and lack of any other treatment option.

The TMPs reported that, patients did combine conventional and herbal medicine but they rarely informed the herbalist. Nevertheless, the TMPs always advised them to switch from conventional drugs to herbal medicine. Others preferred the patient to take herbal medicine for some period of time, like one week/month, and if there was no noticeable improvement, revert back to conventional medicine. A study carried out in Murang'a showed that, 7% of diabetic patients combined both herbal and conventional medicine as their diabetes management regime (Mwangi and Gitonga, 2014). Similar studies showed that, patients shy off from disclosing use of herbs and drugs; out of 17% of patients that used both herbs and drugs, 73% did not inform their doctors (Al-Rowais, 2002). Similarly, 68% of patients attending outpatient clinic in 7 Palestine government hospitals declined to declare to the medical practitioner that they had used Complementary and Alternative Medicine (CAM) (Ali-Shtayeh et al., 2012). This contradicted a study carried out in Jordan which revealed that, most patients (80.2%) had willingly disclosed information on CAM use to their physicians (Otoom et al., 2006). In the present study, all TMPs interviewed strongly believed that, such actions could result in herb- drug interaction leading to a dangerous state of hypoglycemia, toxicity and serious physiological side effects. Herb-drug interactions have been cited as a potential physiological risk factor (Fugh-Berman, 2000; Izzo, 2005).

The present study showed that, 78% of the TMPs treated diabetes; and in a year, 67% had treated a diabetic case. However, the numbers of diabetic patients that had sought TMPs services was low compared to the high diabetes occurrence in the area. In a month, 11% of the TMPs had treated a diabetic patient, the other 89% had not. The average number of diabetic patients both per month and year ranged from 1 to 5 patients indicating low demand for their services in the treatment and management of diabetes. The low turnout of diabetic patients seeking herbal treatment was attributed to factors such as; association of TMPs with witchcraft (Mwangi and Gitonga, 2014) and easy access to medical health facilities (http://www.kenya-information-guide.com/nyeri-county.html).

The TMPs used a variety of treatment practices to improve efficiency of herbal medicine; 90% administered more than one antidiabetic herbs in addition to other forms of treatment approaches such as; recommending change of diet to one that included traditional and none fatty foods and, administration of herbs that enhanced digestive and blood circulatory system. Polyherbal therapy was proved to produce a higher antidiabetic effect than single herb therapy (Ebong et al., 2008). One TMP included herbs that rejuvenated the nervous system; he believed that, diabetes was partly caused by nervous communication breakdown. He added that, *"to effectively treat diabetes one should treat stress"* which according to him was *"a major diabetes contributing factor"*. This was supported by evidence from a study which indicated that there is a relationship between regeneration of the pancreas and the neural activity (Takayoshi, 2004). Additionally, there exists a strong link between depression and poor hyperglycemic control (Lustman et al., 2000); which validated the approach undertaken by this particular TMP. The most preferred method of administering herbal medicine as a decoction was the oral route.

The TMPs displayed extensive knowledge on antidiabetic herbs; each cited 1–5 herbs and, those that referred to other

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Table 1
Commonly used antidiabetic medicinal plant combination.

Combination	Name of the herbs	Part (s) used	Preparation and dosage
1	*Mangifera indica* *Persea americana* *Sonchus luxurian/ Launaea cornuta / Lactuca inermis* (Mũthũnga)	Leaves	Decoction
2	*Rotheca myricoides* *Prunus africana*	Leaves or bark Bark	Decoction. Take one cup three times a day for 2months
3	*Rhamnus prinoides* *Acacia nilotica* *Myrsine africana* *Dracaena steudneri*	Root or bark Bark or root Fruits Bark, root	Decoction

sources of information named 6–10 plants. However, the main challenge that faced the present study was the TMPs unwillingness to disclose the dosage. Although the TMPs acknowledged that, they combined more than one antidiabetic herb in addition to other therapeutic approaches, only three were willing to disclose the constituent herbs within the combination (Table 1). Notably, literate TMPs regularly referred to other sources of information purposely to understand; which was the most appropriate herb to administer, its efficacy and side effects. That revelation underscored the importance of documenting therapeutic uses of traditional herbs and the need to validate their efficacy and safety using scientific methods.

A total of 30 plant species within 23 plant families and 28 genera believed to possess antidiabetic property were documented (Fig. 2; Table 2). The plant family with the highest proportion of antidiabetic species was Asteraceae (8); a similar trend was observed elsewhere (Heinrich et al., 1998). Interestingly, from the interviews, an herb locally known as "Mũthunga" had the highest citation (13.9%), however, during specimen identification in the field with the TMPs, the researchers together with the botanist identified it as botanically different herbs which comprised of five species namely; *Launaea cornuta*, *Lactuca inermis, Sonchus luxurian*, *Sonchus oleraceus and Sonchus asper*. In practice, it was *Launaea cornuta*, *Lactuca inermis,* and *Sonchus luxurian* that were prescribed during treatment depending on the availability of the

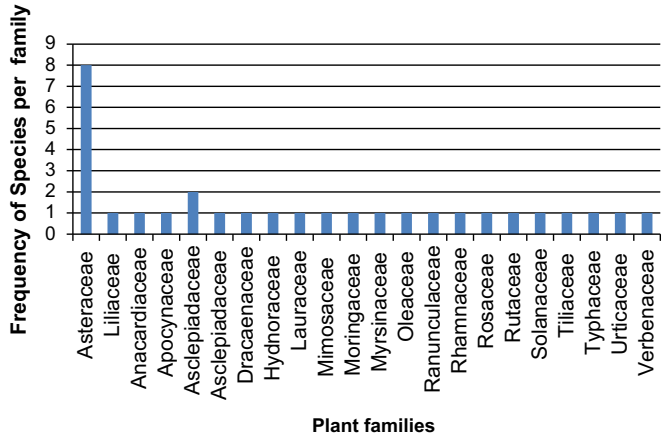

Fig. 2. Families of medicinal plants commonly used in the treatment and management of diabetes in Nyeri County

species. *Sonchus oleraceus* and *Sonchus asper* were used as a nutritional supplement in the management of diabetes. Other antidiabetic herbs included; *Mangifera indica* (8.3%). *Galinsonga parviflora* (5.6%), *Rotheca myricoides* (5.6%), *Prunus africana* (5.6%), *Persea americana* (5.6%), *Hydnora abyssinica* (5.6%), *Periploca linearifolia* (5.6%), *Dracaena steudneri* (5.6%), *Rhamnus prinoides* (5.6%) and *Clematis hirsuta* (5.6%). A study carried out in Israel, documented 16 hypoglycemic plants (Yaniv et al., 1987), but none was similar to what is used in the present study area, possibly due to ecological diversity. A similar report carried out in South -eastern Morocco documented 45 medicinal plants used to manage diabetes (El-Hilaly et al., 2007), it included *Olea europoea* which was also cited in the current study. In South-western Nigeria, Abo and Fred-Jaiyesimi (2008) documented 31 antidiabetic plants and only *Rutaceae* family was similarly cited in the present study. Ketera and Mutiso (2012), identified 39 plant species used to manage diabetes in the lower eastern region of Kenya which included; *Allium sativum*, *Olea africana*, *Urtica massaica* and *Rotheca myricoides,* that were also cited in the present study. From the foregoing survey report, it was evident that diverse ecological regions provided a unique variety of medicinal plants which met the therapeutic needs of each community in the treatment and management of diabetes. A high prevalence of diabetes in the study area could explain why the present study revealed a large number of medicinal plants used to treat and manage diabetes.

Several studies revealed that, some of the plants were used to manage various diseases (Table 3) as well as possessing antidiabetic activity (Table 3). The antidiabetic effect of most of the plants was attributed to their hypoglycemic (El-Fiky et al., 1996; Ferheen et al., 2009; Ranilla et al., 2010), α-amylase inhibitory (Odhav et al., 2010), antiglucosidase (Ferheen et al., 2009; Ranilla et al., 2010; Gallardo-Williams et al., 2002), hypolipidemic (Ashraf et al., 2011; Eidi et al., 2006; Arulmozhi et al., 2010), lipid peroxidation inhibition (Singh et al., 2009), antioxidant (Singh et al., 2009; Al-Fatimi et al., 2015; Mosa et al., 2014; Jaiswal et al., 2009; Gupta et al., 2012; Jemai et al., 2009; Catherine and Edward, 2009; Asmamaw et al., 2007; Omwenga, 2011; Arulmozhi et al., 2010; Rahmat et al., 2012; Xiaa et al., 2011; http://www.Iitg.ac.In/rakhi_chaturvedi/pdf/books/b1.pdf; Gallardo-Williams et al., 2002) and anti-inflammatory activity (Koko et al., 2015; Cáceres et al., 1992; Catherine and Edward, 2009; http://www.Iitg.ac.In/rakhi_chaturvedi/pdf/books/b1.pdf) and, improved insulin resistance (Somova et al., 2003). Plant phytochemicals such as; flavonoids, saponins, terpenes and alkaloids were reported in most of the cited plants (Table 3). Flavonoids were associated with improved insulin secretion, prevention of beta-cell apoptosis (Montserrat et al., 2008), potentiated glucose-induced insulin secretion, inhibition of α-amylase and α-glucosidase activity and glucose uptake from the intestines and, hypoglycemic effect (Mohan and Nandhakumar, 2014). Studies showed that, terpenes inhibited α-amylase activity (Ljiljana et al., 2014) and ameliorated the alterations of cardiomyopathy (Gong et al., 2012). Saponins were reported to possess antioxidant, antiglycation (Yun-Fang et al., 2011), hypocholesterolemic, hypoglycemic and anti-obesity effect (Olusola et al., 2014). Alkaloids were reported to possess hypoglycemic and hypolipidemic activity (Sharma et al., 2010; Zhou et al., 2012). The pharmacological activities of the chemicals isolated from the cited plants (Table 3) validated the traditional use of most of the medicinal herbs used by the TMPs to manage diabetes.

Seventeen (17) plant species which included; *Clematis hirsuta*, *Dracaena steudneri*, *Gomphocarpus fruticosus*, *Grewia similis*, *Hydnora abyssinica*, *Lactuca inermis*, *Myrsine africana*, *Ornithogalum tenuifolium*, *Periploca linearifolia*, *Rhamnus prinoides*, *Rotheca myricoides*, *Sonchus asper*, *Sonchus luxurian*, *Spilanthes mauritiana*, *Teclea simplicifolia*, *Urtica massaica* and *Vernonia lasiopus*, were not investigated for their antidiabetic activity in the previous studies

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Table 2
Medicinal plants used in the treatment and management of diabetes in Nyeri County.

Family	Botanical name and voucher number	Name in Kikuyu	Growth form	Habitat	Part used	Preparation and dosage	Citations	Use value (UVs)
ANACARDIACEAE	*Mangifera indica* L. LNM14/07	Mũembe	Tree	Cf Cp	Leaves	Slice the leaves and then prepare an infusion for 24 h (tea color) Take 1 glass per day for 28days	*3*	0.1
APOCYNACEAE	*Carissa edulis* (Forssk.) Vahl. LNM14/24	Mũkawa	Shrub	Bu	Leaves Bark Root	Decoction	1	0.03
ASCLEPIADACEAE	*Periploca linearifolia* Quart.-Dill. LNM14/06	Mwemba-iguru	Liana	Bu	Stem Leaves	Decoction	2	0.07
ASCLEPIADACEAE	*Gomphocarpus fruticosus* (L.) W.T. Aiton LNM14/14	Mũkangarithi	Herb	Cf Bu Cp	Seeds Roots	Prepare a decoction, take 250 ml twice daily for 2 months	1	0.03
ASTERACEAE	*Sonchus luxurian* (R. E. Fries)C. Jeffrey LNM14/04	Mũthũnga	Herb	Cf Bu Cp	Leaves	Chew the leaves or boil the whole plant. Take one cup for one month	5	0.17
ASTERACEAE	*Launaea cornuta* (Hochst. ex Oliv. and Hiern) C. Jeffrey. LNM14/03	Mũthũnga	Herb	Cf Bu Cp	Leaves	Chew the leaves or boil the whole plant. Take a cup for one month	5	0.17
ASTERACEAE	*Lactuca inermis Forssk* LNM14/01	Mũthũnga	Herb	Cf Bu Cp	Leaves	Chew the leaves or boil the whole plant. Take a cup for one month	5	0.17
ASTERACEAE	*Sonchus oleraceus* L. LNM14/02	Mũthũnga		Cf Bu Cp	Leaves	Chew the leaves or boil the whole plant. Take a cup for one month	5	0.17
ASTERACEAE	*Sonchus asper* L. Hill LNM14/05	Mũthũnga	Herb	Cf Bu Cp	Leaves	Chew the leaves or boil the whole plant. Take a cup for one month	5	0.17
ASTERACEAE	*Galinsonga parviflora* Cavanilles. LNM14/08	Mũng'ei	Herb	Cf	Leaves Roots	Decoction taken for a month	2	0.07
ASTERACEAE	*Vernonia lasiopus* O. Hoffm. LNM14/23	Mũchatha	Shrub	Bu	Leaf	Decoction	1	0.03
ASTERACEAE	*Spilanthes mauritiana* (A. Rich. ex Pers.) DC. LNM14/30	Gatharia ita	Herb	Bu Cf	Whole plant	Decoction	1	0.03
DRACAENACEAE	*Dracaena steudneri* Schweinf. Ex. Engl. LNM14/11	Ithare	Tree	Cp	Bark Root	Decoction	2	0.07
HYACINTHACEAE	*Ornithogalum tenuifolium* F. Delaroche LNM14/22	Mũgwace	Herb	Sma	Rhizome	Decoction	1	0.03
HYDNORACEAE	*Hydnora abyssinica* A. Braun ex Schweinf. LNM14/17	Mũthigira	Herb	Sma	Stem	Decoction	2	0.07
LAURACEAE	*Persea americana* Mill. LNM14/19	Mũkũrobia	Tree	Cf Cp	Leaves Bark	Decoction	*2*	0.07
LILIACEAE	*Allium sativum* L. LNM14/13	caumu	Herb	Mkt	cloves	Decoction	1	0.03
MIMOSACEAE	*Acacia nilotica* (L.) Delile LNM14/16	Ngirũriti	Shrub	Bu	Bark Root	Decoction	1	0.03
MORINGACEAE	*Moringa oleifera* Lam. LNM 14/28	Moringa	Tree	Cf Cp	Seeds	Chew 2 seeds per day for a month	1	0.03
MYRSINACEAE	*Myrsine africana* L. LNM14/26	Mũgaita	Shrub	Bu	Fruits	Decoction	1	0.03
OLEACEAE	*Olea africana* Mill. LNM14/27	Mũtero	Tree	Bu Cp	Leaf Root	Decoction	1	0.03
RANUNCULACEAE	*Clematis hirsuta* Guill. and Perr. LNM14/10	Mũgaya ng'ũndũ	Shrub	Bu	Leaves Roots	Decoction	2	0.07
RHAMNACEAE	*Rhamnus prinoides* L Hér. LNM14/18	Mũkarakinga	Shrub	Bu	Roots Bark	Decoction	2	0.07
ROSACEAE	*Prunus africana* Hook. f.) Kalkman LNM14/20	Mũiri	Tree	Cf Bu Cp	Leaves Bark	Decoction	*2*	0.07
RUTACEAE	*Teclea simplicifolia* (Engl.) Verdoorn LNM14/25	Mũnderendu		Bu	Leaves	Decoction	1	0.03
SOLANACEAE	*Solanum nigrum* L. LNM14/29	Managu	Herb	Cf	Leaves	Infusion	1	0.03
TILIACEAE	*Grewia similis* K. Schum. LNM14/21	Mũtheregendu	Shrub	Bu	Leaves	Decoction	1	0.03
TYPHACEAE	*Typha domingensis* Pers. LNM14/15	Ndothua	Herb	Wl	Rhizomes	Decoction	1	0.03
URTICACEAE	*Urtica massaica* Mildbr. LNM14/12	Thabai /Hatha	Herb	Cf Bu	Leaves	Decoction	1	0.03
VERBENACEAE	*Rotheca myricoides* (Hochst.) Steane and Mabb. LNM14/09	Munjuga-iria	Shrub	Bu	Leaves Roots Bark	Decoction taken for a month	2	0.07

Table 3
Cross – reference of plant species used to treat and manage diabetes in Nyeri County with published literature.

Botanical name	Phytochemical constituents/pharmacological activity	Ethnotherapeutic uses
Acacia nilotica (Mimosaceae)	It contains saponins, anthraquinones, tannins, flavonoids and cardiac glycosides (Deshpande and Kadam, 2013). It has antibacterial (Deshpande and Kadam, 2013) and antidiabetic (Mukundi et al., 2015), antimutagenic (Arora et al., 2003) and antioxidant activities and inhibits lipid peroxidation (Singh et al., 2009). It contains proanthocyanidins which increases insulin sensitivity (Lerman et al., 2008).	The stem and bark is used as a stimulant and appetizer (Kimondo et al., 2015; Muthee et al., 2011). Whole plant is used to manage chronic pain (Wambugu et al., 2011), GIT complications and Babesiosis (Nanyingi et al., 2008).
Allium sativum (Liliaceae)	It contains alkaloids, tannins, carotenoids, saponin, flavonoids, steroids and cardenolides (Otunola et al., 2010). It has antimicrobial (Benkeblia, 2004; Pundir et al., 2010), antidiabetic (Ojo et al., 2015; Aiyeloja and Bello, 2006; Thomson et al., 2007; Younas and Hussain, 2014), antilipidemic (Ashraf et al., 2011; Eidi et al., 2006), antibiotic and anti-hypertension (Aiyeloja and Bello, 2006) activity.	The bulbs are used in managing; asthma, colic, constipation, flatulence, and cardiovascular ailments (Khan and Khatoon, 2008).
Carissa edulis (Apocynaceae)	It contains; alkaloids, flavonoids, steroids, saponins, cardiac glycosides, phenolics and terpenoids (Maina et al., 2015a,b). It has antipyretic, antinociceptive (Maina et al., 2015a,b) and hypoglycemic activity (El-Fiky et al., 1996).	The roots and leaves are used to treat gonorrhea, syphilis (Muthee et al., 2011), ENT diseases (Njoroge and Bussmann, 2006a), fever, malaria, measles, helminth infection (Okullo et al., 2014), peptic ulcers and diabetes (Kigen et al., 2014).
Clematis hirsuta (Ranunculaceae)	It contains sterols and triterpenes (Maged et al., 2008). It has insignificant hepato-protective activity (Saleh et al., 2008).	It is used to treat ear pain and headache (Berhane et al., 2014) and anthrax. The leaves are crushed together with those from *Dodonia angustifolia* and used to treat *Herpes zoster* (Abraha et al., 2013).
Dracaena steudneri (Dracaenaceae)	It contains alkaloids, terpenoids, phenolics, tannins, flavone, steroids and saponins. The bark has antifungal activity against; *Cryptococcus neoformans*, *Aspergillus niger* and *Candida albicans* (Mbwambo et al., 2010 and Kisangau et al., 2009).	The dried powder is applied on wound (Fisseha et al., 2009). The bark is used to treat oral candidiasis, cryptococcal meningitis and tuberculosis (Kisangau et al., 2007) and leaves to manage diarrhea (Jane et al., 2013).
Galinsoga parviflora (Asteraceae)	It contains galinsosides A and B (flavanone glucosides), chlorogenic acid and hydroxycinnamic acid derivatives. It possesses antioxidant, α-glucosidase inhibitory (Ferheen et al., 2009; Ranilla et al., 2010) and α-amylase inhibitory (Odhav et al., 2010) activities.	Whole plant decoction is used to treat the wound (Jena and Satapathy, 2015)
Gomphocarpus fruticosus (Asclepiadaceae)	It contains triterpenoids, cardiac glycosides like cardenolides (Amani et al., 2016) and flavonol glycosides (Samia et al., 2006). It possesses growth inhibitory activity against cancer cell lines and antibacterial activity against gram-positive bacteria (Mothana et al., 2009). Acetone extract has strong (> 70%) *anti*gonoccol activity (Mulaudzi et al., 2015) but the methanol extract demonstrates less activity against *Staphylococcus aureus*, *Bacillus subtillis*, *Salmonella typhi*, *Escherichia coli* and *Pseudomonas aeroginosa*. It has no antifungal activity (Omwenga et al., 2012).	It is used to treat sexually transmitted diseases (Mulaudzi et al., 2015).
Grewia similis (Tiliaceae)	It has antimicrobial activity and contains steroids; 3β-sitosterol and 3β-stigmasterol (Muithya, 2013).	
Hydnora abyssinica (Hydnoraceae)	It contains tannins, cardiac glycosides, terpenes and flavonoids (Mosa et al., 2014) and phenols (Al-Fatimi et al., 2015). It has antioxidant and antibacterial activity against gram-positive bacteria (Al-Fatimi et al., 2015). The root aqueous extract has anti-diarrheal activity (Mohammed, 2015). It has anti-inflammatory, immunosuppressant (Koko et al., 2015) and antioxidant activity.	It is used to treat malaria (Njoroge and Bussmann, 2006b). The flowers are used to manage gastric ulcers, stomach diseases and cancer (Al-Fatimi et al., 2015).
Lactuca inermis (Asteraceae)	It contains sesquiterpene lactones (Klaudia et al., 2009), alkaloids, phenols, tannins and steroids. It has antibacterial activity (Jaurès et al., 2013).	It is used to manage pain caused by inflamed joints (Wambugu et al., 2011), amoebiasis (Getnet et al., 2015) constipation and as a diuretic (Olowokudejo et al., 2008). The leaf decoction is taken orally to manage ENT (ear, nose and throat) diseases (Njoroge and Bussmann , 2006a).
Launaea cornuta (Asteraceae)	It contains; isoquinoline alkaloids, phytosterols, terpenoids, coumarins (Karau et al., 2014a,b), flavonoids, glycosides, and tannins (Misonge et al., 2015). It has antidiabetic (Karau et al., 2014a,b) and antimalarial activity and, it is toxic to brine shrimp (Musila et al., 2013).	The shoot and whole plant is used in the management of chronic pain (Wambugu et al., 2011), breast and prostate cancer and, diabetes (Kareru et al., 2007). The stem is chewed to treat throat cancer (Kigen et al., 2014). The leaves are eaten as traditional vegetable (Chweya and Eyzaguirre, 1999).
Mangifera indica (Anacardiaceae)	It has antidiabetic (Bhowmik et al., 2009), antihyperglycemic (Kemasari et al., 2011) and antibacterial (Bbosa et al., 2007) activity.	The leaf decoction is used to treat ENT diseases (Njoroge and Bussmann, 2006a) and to manage diabetes by the Embu community (Kareru et al., 2007)
Moringa oleifera (Moringaceae)	It contains; tannins, steroids, triterpenoids, flavonoids, saponins, anthraquinones and alkaloids (Kasolo et al., 2010). It has antidiabetic and antioxidant (Jaiswal et al., 2009; Gupta et al., 2012), antispasmodic, antiinflammatory and diuretic activity (Cáceres et al., 1992).	It is used as a medicine for skin, digestive, respiratory and joint diseases (Cáceres et al., 1991).
Myrsine africana (Myrsinaceae)	The leaves contain flavonoids; myricetin, quercetin, kaempferol, gallic acid (Arot et al., 1996) and the fruits contain benzoquinone derivatives; methylvilangin and methylanhydrovilangin (Manguro et al., 2003). It has antibacterial, haemagglutination (Bashir et al., 2011) and antispasmodic activity (Sadiq et al., 2011).	It is used to treat tuberculosis, polio and as a strong anthelmintics (Bussmann, 2006). The fruit juice is used to treat taeniasis (D'Avigdor et al., 2014) and the leaves to manage jaundice and liver diseases (Sadia et al., 2015).
Olea africana (Oleaceae)	It contains; triterpenoids (oleuafricein and oleanolic acid) which improves insulin resistance (Somova et al., 2003). Hydroxytyrosol and Oleuropein possess antidiabetic and antioxidant effects (Jemai et al., 2009).	The stem bark and leaves are used to deworm, expel retained afterbirth, treat respiratory diseases and anaplasmosis (Muthee et al., 2011), manage chronic pain (Wambugu et al., 2011), helminthosis, asthma, rheumatism, and lumbago (Nanyingi et al., 2008). The sap is used in bone setting (Kareru et al., 2007). The stems bark and roots are used to manage diabetes (Ketera and Mutiso, 2012).
Ornithogalum tenuifolium (Hyacinthaceae)	It contains steroidal sapogenin (Orde et al., 2006).	

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Table 3 (*continued*)

Botanical name	Phytochemical constituents/pharmacological activity	Ethnotherapeutic uses
Periploca linearifolia (Asclepiadaceae)	It possesses antimalarial (Nyangasi, 2014) and antibacterial activity; It has no antifungal activity (Asmamaw et al., 2007).	It is used manage postpartum haemorrhage (D'Avigdor et al., 2014) hemorrhoid (Getnet et al., 2015) and malaria (Muthaura et al., 2007). The root decoction is used to treat colds, *Herpes zoster* and oral thrush (Amuka et al., 2014).
Persea americana (Lauraceae)	It contains protocatechuic acid, clorogenic acid, rutin, syringic acid, kaempferide and kaempferol (Pahua-Ramos et al., 2012). It has anti-diabetic, diuretic (Gondwe et al., 2008) and hypolipidemic (Pahua-Ramos et al., 2012) activity.	It is used in the management of hypertension and diabetes (Gbolade, 2012; Kpodar et al., 2015).
Prunus africana (Rosaceae)	It contains; β-sitostenone, campesterol, β-sitosterol, palmitic acid, (3.β., 5.α) - stigmast-7-en-3-ol, stigmastan-3, 5-diene, lup- 20 (29)-en-3-one and α-tocopherol compounds (Nyamai et al., 2015). It has GLP-1 secretory activity (Singh et al., 2015).	The stem bark, roots and flowers are used to treat prostate cancer and urinary tract infections (Muthee et al., 2011; Focho et al., 2009). The bark decoction is taken to treat pimples, skin itches (Njoroge and Bussmann, 2007) and, breast and prostate cancer (Kareru et al., 2007).
Rhamnus prinoides (Rhamnaceae)	It contains anthraquinones and flavonoid (Berhanu and Martin, 1995). It has anti-inflammatory, antioxidant and acetylcholinesterase inhibitory (Catherine and Edward, 2009) and anti-mutagenic activities (Verschaeve et al., 2004).	Root decoction is taken orally to manage ENT diseases (Njoroge and Bussmann , 2006a), treat tonsillitis (Moa et al., 2013; Getnet et al., 2015), pneumonia, bacillary dysentery, amoebiasis and as a tonic (Amuka et al., 2014), hepatitis (in formula) (D'Avigdor et al., 2014) and herpes (Getnet et al., 2015).
Rotheca myricoides (Verbenaceae)	It contains polyphenols, alkaloids, anthraquinones, terpenes (Nasser et al., 2010) and tannins (Omwenga, 2011). It possesses antiplasmodial (Mekonnen et al., 2012), antimutagenic (Reid et al., 2006), antioxidant (Asmamaw et al., 2007; Omwenga, 2011) and antibacterial activity (Asmamaw et al., 2007) against *P. aeruginosa* and *S. aureas* (Omwenga, 2011). It does not possess antifungal activity (Asmamaw et al., 2007; Omwenga, 2011).	It is used to manage pain caused by inflamed joints (Wambugu et al., 2011), stem bark to manage abdominal colics, malaria and febrile convulsions (Mainen et al., 2012) and roots to treat gonorrhea and syphilis (Muthee al., 2011).
Solanum nigrum (Solanaceae)	It contains alkaloids, saponins, tannins and flavonoids (Gogoi and Islam, 2012). It has antioxidant, antihyperlipidemic (Arulmozhi et al., 2010) and hypoglycemic effect (Tiwari and Jain, 2012).	The decoction of the whole plant is taken to treat erectile dysfunction (Kareru et al., 2007), liver cirrhosis and, as a diuretic, laxative and antispasmodic (Mahroof et al., 2009).
Sonchus asper (Asteraceae)	It contains proanthocyanidins, flavonoids, flavonols, total phenols and low levels of alkaloids, saponins, and phytate. It has antibacterial, antioxidant (Florence et al., 2011), hepatoprotective (Khan et al., 2012) and brain antioxidant activities. It increases cognitive performance (Rahmat et al., 2012) and protects the kidneys against oxidative stress (Rahmat et al., 2010).	The plant decoction is cathartic; it is used to treat ascites and hydrothorax. The leaves and roots are used in indigestion and as a vermifuge and febrifuge (Mahroof et al., 2009).
Sonchus luxurian (Asteraceae)	It contains alkaloid, glycosides, terpenoid, steroid, flavonoids, tannins, trace amounts of saponins (Waiganjo et al., 2013) and, triterpenes. It does not have molluscicidal activity (Kindiki, 2014).	It is used as a vegetable (Hassan, 2014).
Sonchus oleraceus (Asteraceae)	It contains phenolics and flavonoids (Xiaa et al., 2011). It has antioxidant and antibacterial activity.	The root decoction is taken to manage ENT diseases (Njoroge and Bussmann , 2006a) and sap to treat tonsils (Kaluwa et al., 2014).
Spilanthes mauritiana (Asteraceae)	It contains alkylamides, phenolics, caumarin and triterpenoids (Mithilesh and Rakhi, 2015). It has antibacterial activity against (Werner et al., 1998) against *Helicobacter pylori* (Fabry et al., 1996a), larvicidal activity against Aedes aegypti mosquito (Jondiko, 1986), antifungal activity against *Aspergillus* spp. but not *candida* spp. (Fabry et al., 1996b), anti-inflammatory, antioxidant, antimicrobial and diuretic activities (Mithilesh and Rakhi, 2015).	Whole plant crushed is used to treat toothache, oral thrush and manage craniotomy (Kipkore et al., 2014). The shoot is used as a vegetable and, the flower paste to treat sore throat, jaundice (Jain et al., 2011) and cough (Manju et al., 2010)
Teclea simplicifolia (Rutaceae)	It contains alkaloids; ribalinine, montrifoline, skimmianine, isoplatydesmine and edulinine, isohaplopine (8-hydroxy-4, 7-dimethoxyfuroquinoline) , 3,3-dimethylallylether (Assefa et al., 1988) and triterpenes. It has analgesic (Njeru, 2015) and antiplasmodial activity (Rukunga et al., 2009).	It is used to treat malaria (Njoroge and Bussmann, 2006b).
Typha domingensis (Typhaceae)	It has wound healing (Akkol et al., 2011), antioxidant and anti-glucosidase activity. There is presence of polyphenols, flavonoids (Chai et al., 2014), linoleic acid and α-linolenic acid (Gallardo-Williams et al., 2002).	It is used in wound healing (Sharma et al., 2014).
Urtica massaica (Urticaceae)	It contains tannins in large quantity and, terpenes, saponosides, flavonoids and anthocyanes in small quantities (Nahayo et al., 2008).	Leaf decoction is taken orally to manage ENT diseases (Njoroge and Bussmann , 2006a), treat malaria (Njoroge and Bussmann, 2006b) and diarrhea (Nahayo et al., 2008).
Vernonia lasiopus (Asteraceae)	It has hepatotoxic (Marie-Jeanne et al., 2010), antimalarial (Francis et al., 2007) and anthelmintic activity (Njonge et al., 2013).	It is used to manage ENT diseases (Njoroge and Bussmann, 2006a) malaria, stomachache, cough, migraine and to delay delivery (Patience et al., 2016).

(Table 3) and were therefore mentioned for the first time in the present study as potential antidiabetic herbs.

5. Conclusion and recommendation

The present study revealed that, traditional practitioners from Nyeri County possessed in-depth knowledge about traditional medicine used to manage diabetes. Seventeen (17) plants were identified and documented for the first time as potential antidiabetic medicine. Polyherbal treatment was the preferred mode of treatment, which promotes synergistic activity of herbal medicine. Further, some of the cited plants were reported to possess hypoglycemic, antioxidant and inhibition of α-amylase and α-glucosidase activity and, improved insulin secretion. The TMPs in this area demonstrated extensive conventional knowledge about diabetes occurrence, symptoms, prevention and control and, appreciated the need to assimilate modern medical laboratory

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technology in the treatment of diabetes. Notably, services from the TMPs were rarely sought because of the low attitude among members of the community; indicating that, herbal medicine was not well accepted. Therefore, traditional knowledge from the TMPs traditional healers from Nyeri County should be documented so that it does not become eroded due to natural attrition of the present custodians. Moreover, findings from the present study form the basis for further pharmacological studies of the cited medicinal plants, with a purpose of validating their efficacy and safety as well as developing drugs to be used in the management of diabetes.

Author's contribution

LNK carried out the study, analyzed the data and wrote the manuscript, MPM, JMM, GPK and SGK designed the study, carried out field work, supervised the study and revised the manuscript.

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