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Ethnobotanical study of Nutraceutical Plants in Machakel District, Amhara, Ethiopia

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Abstract

A nutraceutical is a food or food-derived product of plant or animal origin that provides health benefits and helps prevent or treat diseases. This study documented indigenous knowledge of different nutraceutical plants in four kebeles selected based on vegetation cover. Eighty one (81) informants were participated for the data collection activities. The method used semi-structured interviews, field observations, and market surveys. The collected data was analyzed using Informant consensus, preference ranking, paired comparison, and direct matrix ranking. Fifty two (52) nutraceutical plant taxa belonging to different genera (46) and families (27) were recorded, with Poaceae as the most dominant family. The largest growth habit collected in the study area was herbs. The most cited plant part from cultivated and wild sources were Seeds and fruits respectively. *Allium sativum* and *Embelia schimperi* were the most cited species from cultivated and wild habitats. *Hordeum vulgare* was the preferred species for treating gastritis, while *Guizotia abyssinica* and *Cordia africana* ranked first in overall importance. The study reports the growing importance of nutraceutical plants and the need for further research across different cultural settings. Highly cited and preferred species indicate promising candidates for further nutritional, pharmacological, and conservation studies. Therefore, integrating indigenous knowledge with scientific research and conservation strategies is essential to promote sustainable use and enhance the role of nutraceutical plants in improving food and health security.

1. Introduction

Ekta K. Kalra defines nutraceuticals as food-derived products that extend beyond basic dietary supplementation by offering health-enhancing, disease-preventive, or therapeutic benefits. Unlike conventional foods, functional foods, or simple dietary supplements, nutraceuticals are intended for oral consumption in forms such as tablets, capsules, pills, or liquids. They are not promoted as regular foods or complete dietary items and are specifically meant to support nutrition while also contributing to the prevention and/or treatment of diseases or health disorders [1, 2].

The term **nutraceutical** denotes products obtained from processed foods such as cereals, soups, beverages, herbs, dietary supplements, specialized diets, and that serve both nutritional and medicinal roles. These products are capable of restoring, supporting, or altering physiological functions in the human body [3, 4].

Several studies conducted in Ethiopia indicate that nutraceutical research is largely embedded within ethnobotanical, medicinal, and wild edible plant studies. Ethnobotanical investigations across different regions, such as Raya-Azebo District, Dibatie District, and southern Ethiopia, have documented numerous plant species used both as food and for health benefits, reflecting their

nutraceutical potential [5, 6, 7 and 8]. Plants such as *Moringa stenopetala*, *Balanites aegyptiaca*, and *Acacia* species are widely reported for their nutritional value and therapeutic uses, including management of gastrointestinal disorders, infections, and metabolic diseases [6, 7]. In addition, recent reviews of Ethiopian medicinal plants highlight the presence of bioactive compounds with antioxidant, antimicrobial, and anti-ulcer properties, further supporting their role as nutraceuticals [8]. Overall, although the term “nutraceutical” is rarely used explicitly, existing Ethiopian literature demonstrates substantial traditional knowledge and plant resources with strong nutraceutical relevance, indicating the need for focused and integrated nutraceutical research.

In rural Ethiopia, particularly in Machakel district, the use of nutraceuticals is widespread, with communities relying on locally available foods and traditional remedies passed down through generations for health care. However, this indigenous knowledge is rapidly declining due to lifestyle changes, occupational shifts, and the loss of knowledgeable elders. To help preserve this valuable heritage, ethnobotanical research is essential. Accordingly, this study documents indigenous knowledge of nutraceutical plants used in Machakel district.

METHODS

Geographical location

The Machakel district is absolutely located between 10°19'75"–10°41'00" N latitude and 37°16'46"–37°45'42" E longitude. Relatively found in East Gojjam zone Amhhara region

and lies approximately 270 km south of Bahir Dar, the regional city and about 30 km from Debre Markos, the capital of East Gojjam Zone. Amanuel town serves as the administrative capital of the district [Figure 1].

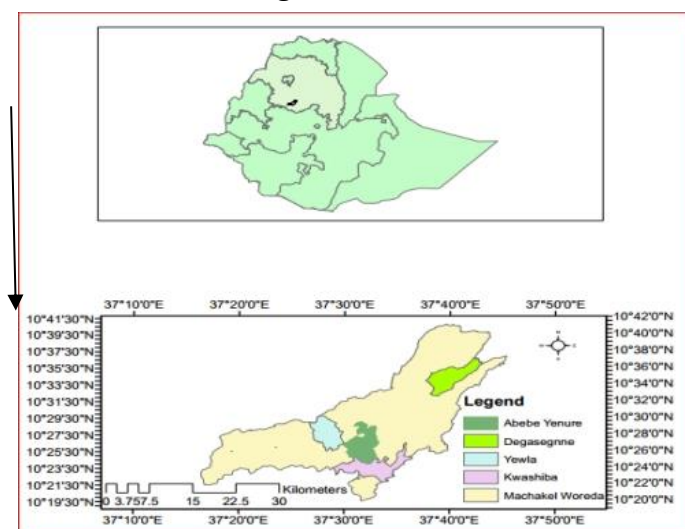


Figure 1: Map showing Amhara Region and Machakel District

Population

According to the 2021 budget year population projection, Machakel District had a total population of 145,121. Of this population, 128,323 (88.4%) resided in rural areas and 16,798 (11.6%) in urban areas. The rural population comprised 63,552 males and 64,771 females, while the urban population consisted of 8,399 males and 8,399 females. The overall sex ratio of the district was approximately one male per female. In terms

of religious affiliation, the population was predominantly Orthodox Christian (99.9%), with Muslims accounting for 0.1% of the total population.

Health care status

The study area people have access health care service from six health centers and twenty-four health posts. The ten most prevalent human diseases reported in the district are presented in [Table 1].

Table 1: Top ten human disease in Machakel **District**.in 2018.

No.	Types of Disease	No. of Patient
	Typhoid	449
	Lower respiratory tract infection	389
	Acute gastrointestinal disorder	355
	Urinary tract infection	301
	unspecified disease	249
	Injury	199
	Malaria	196
	Hypertension and other related disease	139
	Diabetes	69
	Trauma and bone fracture	55

Source: (MWHO, 2021/2022)

Livestock diseases in the district are addressed through a network of 26 government veterinary clinics and 20 private veterinary institutions, comprising 7 private clinics and

13 veterinary pharmacies (MWWHO, 2021).

The top ten animal diseases reported in the district are presented in [Table 2].

Table 2: The top ten animal diseases in the district

No	Types of Disease	No. of patient
	Anthrax (Bacterial diseases)	2347
	Pneumonic pasteurollsis (Bacterial diseases)	1967
	Brucellosis (Viral infection)	1233
	Mastitis (viral Breast diseases)	1227
	New castle (Viral infection for poultry)	942
	Rabies (Viral infection)	62
	AHS (African horse sickness)viral infection	357
	Sheep and Goat pox (Viral infection)	654
	Liver fluke (Liver worm)	489
	Mengmites (Skin diseases)	425

Source: Machakel **District** Veterinary Health Office (MWWHO, 2018).

Preliminary Survey and Study Site Identification

A preliminary survey was conducted in Machakel District from 5 to 25 December 2021 to gather initial information for the selection of sampling sites. The district comprises 24 kebeles, which are distributed across three agro-ecological zones: highland (9 kebeles), midland (14 kebeles), and

lowland (2 kebeles), as classified by [9]. This survey facilitated the identification of representative kebeles from each agro-ecological zone for subsequent detailed study. Based on this stratification, representative kebeles were purposively selected from each zone: Kwashiba from the lowland, Yewula and Abebyeyenure from the mid land, and Degasegnin from the highland. The selection

of kebeles for detailed study was carried out with the help of elders and development agents ensuring representative coverage of each agro-ecological zone and facilitating the collection of nutraceutical plant data

Study Population and Sampling Procedures

A total of 3,357 household heads were recorded, comprising 2,958 males and 399 females. Household heads were considered the primary unit of analysis because they are typically responsible for household-level decision-making and possess substantial knowledge regarding local socio-economic and environmental conditions.

From this population, 81 household heads were selected as study participants. Aged between 24 and 75 years range was chosen to ensure inclusion of individuals with adequate experience and long-term familiarity with the study area. The total participant was determined using a standard formula to ensure representativeness, and household heads were selected through systematic or random sampling to minimize bias and enhance reliability.

In addition to household surveys, key informant interviews were conducted to obtain in-depth qualitative information. Ten (10) key informants were purposively selected following the approach described by [10]. Purposive sampling was employed because key informants were required to have specialized knowledge, long-term experience,

and a recognized role in the community. These individuals included elders and other knowledgeable persons who were identified based on recommendations from community elders, local administrative officials, and religious leaders. This triangulated selection process helped ensure the credibility and relevance of the information obtained.

The remaining informants were selected based on the calculated sample size to balance quantitative, representativeness with qualitative depth following [11]. The combination of household surveys and key informant interviews allowed for methodological triangulation, thereby strengthening the validity and robustness of the study findings

$$n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2(N-1) + z^2 p q}$$

Where,

n: Sample size

z: Standard normal value at 95%

confidence

p : Sample proportion → 0.05

q : 1 - p.

e : Margin of error → 0.05;

N : Total population

$$\begin{aligned} &= \frac{(1.96)^2 \cdot (0.05)(1-0.05)3357}{(0.05)^2(3357-1) + (1.96^2)(0.05)(1-0.05)} \\ &= \frac{612.571932}{8.57497} \\ &= 71 \end{aligned}$$

These 71 informants were distributed proportional to each selected kebeles. Then the allocated households were selected systematically

Methods for Documenting Ethnobotanical Information

Ethnobotanical information was collected using standard methods as described by [12-14]. Semi-structured interviews, focus group discussions one per kebele with 5-7 participants selected purposively, direct observations, guided field walks, and market surveys from 2 market sites were used.

Plant identification

The collected plant materials were authenticated by a qualified taxonomist at the Department of Botany, Debre Markos University. Species identification was performed using standard taxonomic keys and consulting the *Flora of Ethiopia and Eritrea* [15]. Collected plant specimens were prepared

Results and discussion

Diversity of Nutraceutical plant

Fifty two (52) nutraceutical plant taxa distributed to 27 families and 46 genera were documented (Appendix 1). The Poaceae family comprising five species exhibited the highest species richness, followed by Brassicaceae, Fabaceae, Rosaceae, and Lamiaceae, each represented by four plant taxa [Table 3]. Most nutraceutical plant species were sourced from cultivated habitats, such as home gardens and farmlands (43

and stored in the mini herbarium of the Department of Botany to serve as a reference for future studies.

Methods for analyzing Ethnobotanical information

Ethnobotanical information on documented nutraceutical plant species and their corresponding traditional knowledge was analyzed employing descriptive statistical techniques, including frequency distributions and relative percentages. A simple preference ranking was carried out for the eight nutraceutical plant species considered most important, following the methodology described by [12]. Additionally, multiple uses of the selected species were analyzed using a direct matrix ranking exercise. For the most frequently utilized nutraceutical plants, Informant Consensus Factor (ICF) values were calculated with the procedure outlined by [16].

species; 82.7%), whereas a smaller fraction originated from wild habitats (9 species; 17.3%). The predominance of Poaceae and Brassicaceae reflects their global and regional importance as plant families that include numerous crop species widely utilized for both nutritional and medicinal purposes. Previous ethnobotanical and nutritional studies have consistently reported the dual role of these families in food security and traditional healthcare systems across different regions [17-20]. Members of Poaceae, such as

cereal crops, are primary sources of carbohydrates and essential nutrients, while Brassicaceae species are well recognized for their bioactive compounds, including glucosinolates, vitamins, and antioxidants that contribute to disease prevention and health promotion.

A similar trend was observed in the present study, where local communities utilized all documented nutraceutical plant species for both dietary and health management purposes. The integration of food and medicine in plant

use reflects the holistic nature of indigenous knowledge systems, in which nutrition and health are closely interconnected. The dominance of cultivated nutraceutical plants further suggests deliberate domestication and management practices aimed at ensuring continuous access to both food and therapeutic resources. This finding underscores the importance of agro-biodiversity conservation and the role of traditional knowledge in sustaining community health and nutritional well-being in the study area.

Table3: Family and Genus-Level Distribution of Nutraceutical Plant Species

Family	Species	Percentage	Genera	Percentage
Poaceae	5	9.62	5	10.87
Brassicaceae	4	7.69	1	2.17
Fabaceae	4	7.69	4	8.7
Rosaceae	4	7.69	4	8.7
Lamiaceae	4	7.69	4	8.7
Apiaceae	3	5.77	3	6.52
Astraceae	2	3.85	2	4.35
Rutaceae	3	5.77	1	2.17
Alliaceae	2	3.85	1	2.17
Solanaceae	3	5.77	3	6.52
18families/one species only	18	34.62	18	39.13
Total =28	52	100	46	100

Habits (growth forms) of nutraceutical plants

Herbs were the predominant growth form among nutraceutical plants in the study area, representing 34 species (65.38%), followed by trees with 11 species (21.15%) [Fig. 2]. Most of the herbs were obtained from cultivated habitats, including home gardens and

farmlands, whereas trees and shrubs were predominantly collected from wild habitats.

The dominance of herbs as nutraceutical resources reflects their widespread cultivation, ease of access, and faster growth cycles, which make them readily available for both

dietary and medicinal use. Herbs, which contribute to their therapeutic value are also more amenable to local management practices and often exhibit a higher diversity of bioactive compounds, such as alkaloids, flavonoids, and phenolics. In contrast, trees and shrubs, which are frequently wild-collected, tend to provide long-term and multipurpose resources, including fruits, bark, seeds, and leaves, but require longer maturation periods, making them less abundant in cultivated systems.

Comparable studies conducted by [21, 22] reported a higher proportion of shrubs and

trees among nutraceutical species in other regions, indicating that growth form diversity can vary according to ecological, cultural, and management factors. The variation may be influenced by the agro-ecological setting, the degree of domestication, and community preferences for certain plant forms. In the present study, the predominance of herbaceous species highlights the importance of cultivated plant management and the reliance of local communities on fast-growing, easily accessible nutraceutical resources for both nutrition and health maintenance.

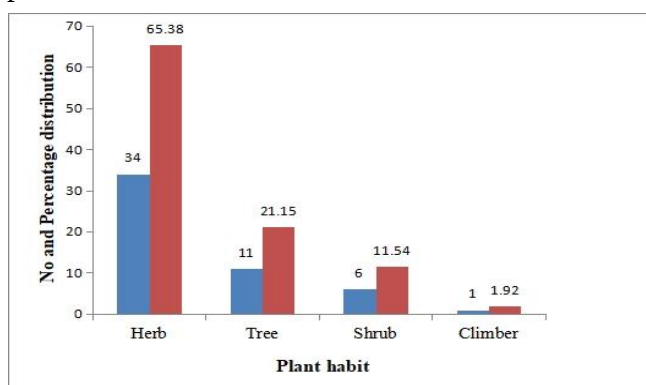


Figure 2: Habits of nutraceutical plants

Parts of the Plant Harvested for Nutraceutical Value

Local communities utilize various plant parts of nutraceutical species for both food and medicinal purposes. Among cultivated plants, seeds were the most frequently used part, accounting for 13 species (30.23%), followed closely by fruits, also representing 13 species (25.4%) (Fig. 3). The primary role of cultivated plants is nutritional; however, local people also employ these crops for

therapeutic purposes, reflecting the dual function of many domesticated species in indigenous knowledge systems.

The prominent use of seeds and fruits can be attributed to their high nutrient density and the concentration of bioactive compounds, such as proteins, essential fatty acids, vitamins, and phytochemicals, which contribute to both health maintenance and the

prevention or treatment of common ailments. Leaves, roots, and other plant parts were also utilized in substantial quantities, consistent with reports from similar ethnobotanical studies [23–25].

This pattern underscores the integrative nature of local ethnonutritional practices, where food and medicine are interlinked.

Cultivated species are especially valued not only for their accessibility and abundance but also for their recognized therapeutic properties.

The reliance on multiple plant parts highlights the importance of conserving both plant diversity and associated indigenous knowledge to ensure sustainable nutrition and healthcare within the community

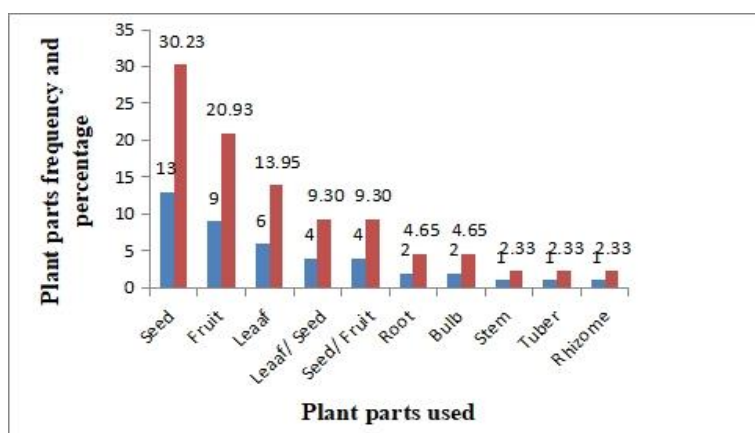


Figure3: Cultivated nutraceutical plant parts used in the study area

Conversely, for wild-sourced nutraceutical plants, fruits were the predominantly used plant part, constituting 66.66% of utilization, followed by leaves, leaf–seed combinations, and roots, each contributing 11.11%. The predominance of fruits in wild species may reflect their seasonal abundance, ease of harvest, and high nutritional and medicinal value. Leaves, roots, and other parts are collected less frequently, likely due to their lower availability or the labor required for harvest. Similar ethnobotanical studies have

Mode of Application of nutraceutical plant remedies in Machakel District

Traditional nutraceutical preparations in the study area were applied through various methods. The most common mode of

reported variations in plant part utilization, where leaves are often collected more frequently than fruits for both food and medicinal purposes [23]. These differences are influenced by cultural preferences, ecological availability, and local knowledge systems. The observed pattern in the study area highlights how local communities strategically use wild plant resources, prioritizing those parts that are most accessible, palatable, and therapeutically effective

administration was direct consumption by eating, accounting for 40.43% of reported uses, followed by drinking, which represented 35.10%. Inhalation and fumigation were the

least frequently employed methods, each accounting for only 1.06% of use [Table 4].

Participants in this study, as well as reports from other ethnobotanical investigations, indicated that nutraceuticals are commonly prepared as soups, teas, and fermented beverages, with oral consumption remaining the predominant method of intake [26-28].

This pattern reflects the integration of nutraceuticals into everyday diets, where foods serve both nutritional and therapeutic roles. Oral administration, especially through eating and drinking, likely enhances the bioavailability of active compounds while aligning with local culinary practices and cultural acceptability

Table 4: Methods of Administration of Prepared Nutraceuticals

Application Method	Usage Frequency of Application	Percentage
Eating	38	40.43
Drinking	33	35.10
Creaming	5	5.31
Pasted on	4	4.26
Tying	2	2.13
Sucking	2	2.13
Drinking/ creaming	2	2.13
Inhaling	1	1.06
Fumigate	1	1.06
Drinking or eating	2	2.13
Rubbing	2	2.13
Others	2	2.13
Total	94	100

Dosage and Delivery Methods of Nutraceutical Plant Preparations

Dosages of traditional nutraceutical preparations were estimated using local measuring units, including spoons ('Mankia'), cups ('Sini'), and glasses ('Birchiko') for liquids, and spoons or handfuls ('Efeign') for powdered materials (Appendix 2). The most commonly route of administration employed was oral, accounting for 81.91% of reported uses, whereas application to the tooth surface was the least common at 1.06% [Table 5].

The predominance of oral administration aligns with observations by Kim and De Jesus, who noted that the oral route is convenient, cost-effective, and widely adopted for nutraceutical use. The efficacy of orally administered functional foods and nutraceuticals largely depends on their absorption in the small intestine, with bioavailability being influenced by the extent of compound absorption across the intestinal epithelium [29]. This emphasizes the importance of both local dosing practices and the physiological factors that affect the therapeutic outcomes of traditional nutraceutical

Table 5: Ethnobotanical Study of Nutraceutical Plant Administration Routes

Route of administration	Frequency	Percentage
Oral	77	81.91
Dermal	11	11.70
Neck	2	2.13
Oral /Nasal	2	2.13
Oral / Dermal	2	2.13
Tooth surface	1	1.06
Total	94	100

Human Ailments Treated by Nutraceutical Plants

Within the research site, fifty-two nutraceutical plant taxa were recorded as being employed to treat forty-five human health conditions (Appendix). Of these, 25 ailments were treated with two or more plant species, reflecting the use of synergistic combinations in traditional healthcare, whereas 20 ailments were addressed by a single species. Nutraceutical plants deliver a twofold advantage by supplying vital nutrients alongside bioactive constituents that exert medicinal effects, thereby promoting general well-being [30].

The medicinal efficacy of nutraceuticals is attributed to their abundant phytochemical profile, encompassing vitamins, minerals, polyphenols, flavonoids, and diverse secondary metabolites that function as oxidative stress-reducing agents, immune regulators, and inflammation-reducing agents. These compounds not only enhance nutritional status but also target underlying physiological pathways correlated with long-term diseases such as diabetes mellitus, high blood pressure, and cardiovascular pathologies, and gastrointestinal conditions, several of which are among the top ten prevalent ailments in the study area.

This dual functionality of nutraceuticals—as both food and medicine—has played a significant role in accelerating the expansion of the international nutraceutical market into a multimillion-dollar industry [27] [31]. Nutraceuticals are increasingly recognized for their health promoting, disease preventive and therapeutic potential, leading to a surge in scientific research and global interest from both the biomedical and nutrition science communities. Recent reviews highlight that nutraceuticals—which include nutritionally enhanced foods, food supplements, and health-promoting compounds—are gaining substantial attention for their roles in chronic disease prevention and health promotion, and their study has expanded considerably in modern healthcare research [32]

Informant consensus

The most frequently cited nutraceutical plant for preventing, treating, and curing specific diseases in the study area was *Allium sativum*, reported by 71 informants (87.65%) [Table 6]. This species is widely used as a food ingredient and, concurrently, utilized as a folk remedy for the management of multiple health disorders including cardiovascular disorders, infections, and digestive ailments. Similar

findings have been recorded in prior investigations, highlighting the medicinal capacity and multifaceted uses of *A. sativum* [33-35]

Another commonly utilized species, *Embelia schimperi*, collected from wild habitats, was reported by 54 informants (66.67%) for its curative purposes. The medicinal efficacy of

E. schimperi is further supported by experimental studies demonstrating its antimicrobial, antioxidant, and anti-inflammatory activities [36-38]. These observations underscore the reliance of local communities on both cultivated and wild nutraceutical plants for health maintenance and disease management.

Table6:Top ten commonly known cultivated and nine wild nutraceutical plant taxa which employed to manage diverse illnesses with informant lists in Machakel District

Nutraceutical plants (cultivated)	No.of informants	% of informants	Nutraceutical plants (Wild)	No.of informants	% of informants
<i>Allium sativum</i>	71	87.65	<i>Embelia schimperi</i>	54	66.67
<i>Ruta chalepensis</i>	65	80.25	<i>Rubus steudneri</i>	46	56.79
<i>Avena sativa</i>	62	76.54	<i>Foeniculum vulgare</i>	31	38.27
<i>Hordeum vulgare</i>	57	70.37	<i>Carissa spinarum</i>	29	35.80
<i>Lupinus albus</i>	53	65.43	<i>Cordia africana</i>	28	34.57
<i>Eragrostis tef</i>	48	59.26	<i>Ficus sur</i>	26	32.1
<i>Guizotia abyssinica</i>	39	48.15	<i>Rosa abyssinica</i>	23	28.4
<i>Linum usitatissimum</i>	38	48.15	<i>Urtica simensis</i>	22	27.16
<i>Capsicum annum</i>	36	44.44	<i>Rumex abyssinicus</i>	19	23.46
<i>Citrus × aurantiifolia</i>	33	40.74			

Paired comparison for nutraceutical plants to treat gastritis

Gastritis was identified as one of the 45 human ailments reported in the study area, with most community members managing it at home using traditional nutraceutical plants according to their own prescriptions. A pairwise comparison of the six most commonly used nutraceutical species for gastritis indicated that *Hordeum vulgare* was the most preferred by informants, whereas *Cucurbita pepo* and other species were the least preferred [Table 7]. The beneficial effects on health of *H. vulgare* are primarily linked to its high

dietary fiber content, which promotes gastrointestinal health by enhancing digestion, regulating bowel movements, and supporting gut microbiota. In addition, its phytochemical constituents including polyphenols, flavonoids, and other bioactive compounds—exhibit antioxidant, inflammation reducing, anti-inflammatory, and protective effect on the mucosal layer, which could help prevent and manage chronic digestive disorder [39-41]. These findings highlight the dual role of *H. vulgare* as both a nutritional and therapeutic resource in the local community.

Table7: Pair wise comparison of Nutraceutical plants for gastritis treatment

Nutraceutical plants	Key Informants (I ₁ -I ₁₀)										Total Score	Rank
	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	I ₈	I ₉	I ₁₀		
<i>Linum usitatissimum</i>	2	2	4	3	3	4	2	5	3	3	31	3 rd
<i>Saccharum officinarum</i>	3	3	3	4	4	3	4	3	4	4	35	2 nd
<i>Trigonella foenum- graecum</i>	4	4	3	3	3	2	2	2	2	2	27	4 th
<i>Hordeum vulgare</i>	5	5	4	4	4	4	4	4	5	4	43	1 st
<i>Cucurbita pepo</i>	0	1	0	0	0	0	2	0	1	1	5	6 th
<i>Vicia faba</i>	1	0	1	1	1	2	1	1	0	1	9	5 th

*I= informants

Direct matrix ranking for cultivated nutraceutical plants

Local people described that nutraceutical plant taxa possess diverse uses, as summarized in Appendix 4. Direct matrix ranking of cultivated nutraceutical plants revealed that *Guizotia abyssinica* was the most widely used species for multiple purposes, followed by *Hordeum vulgare* [Table 8]. The multifunctional use of these species reflects the familiarity of study participants with plants grown in their vicinity, allowing them to utilize a single species for diverse nutritional, medicinal, and other household purposes.

The multifunctionality of *G. abyssinica* and *H. vulgare* is consistent with findings from other studies [42-45], which highlight their roles as

staple foods, sources of oil, and contributors to health management through their bioactive compounds. This pattern underscores the importance of domesticated nutraceutical plants in local livelihoods, food security, and traditional healthcare, demonstrating the integration of nutritional and therapeutic functions within the same species.

Table8: Direct matrix analyses of selected nutraceutical plant species were cultivated in Machakel District (Nutraceutical value-Nu), (Forage-Fo), (Green fertilizer- Gf), (Traditional house roof cover-Thr), (Fence-Fe), (Fire wood- Fw), (Work of mud-wm),(Source of income-Si).Values indicate total score of 10 key informants presented for each use categories.

Nutraceutical plant Species(cultivated)	Use category								Total	Rank
	Nv (I ₁₋₁₀)	Fo (I ₁₋₁₀)	Gf (I ₁₋₁₀)	Thr (I ₁₋₁₀)	Fe (I ₁₋₁₀)	Fw (I ₁₋₁₀)	Wm (I ₁₋₁₀)	Si (I ₁₋₁₀)		
<i>Avena sativa</i>	50	46	0	45	12	7	44	23	227	3 th
<i>Hordeum vulgare</i>	50	46	8	46	10	6	45	40	251	2 nd
<i>Guizotia abyssinica</i>	42	48	50	25	25	22	0	50	262	1 st
<i>Eragrostis tef</i>	50	47	7	1	0	2	50	50	207	5 th
<i>Lupinus albus</i>	50	5	50	0	8	22	0	15	150	6 th
<i>Vicia faba</i>	50	32	50	0	7	21	0	50	210	4 th

Direct matrix ranking for wild nutraceutical plant taxa

Among the documented wild plant taxa, *Cordia africana* emerged as the most widely used species for multiple purposes, whereas *Foeniculum vulgare* was the least utilized [Table 9]. The multiple uses of *C. africana* include medicinal applications, food provision, fuelwood, construction materials, and other cultural functions. Such multifunctionality highlights the ecological, nutritional, and socioeconomic importance of this species within the community.

Understanding and recognizing the multiple uses of plants within a given culture often serve as a driver for community-led, use-based conservation strategies. When a species provides diverse benefits, local people are more likely to cultivate, protect, or sustainably harvest it, ensuring its availability for future generations. This concept aligns with the principles of ethnobotany and sustainable resource management, which emphasize the link between traditional knowledge and biodiversity conservation.

The observations from this investigation also indicate that the multipurpose utility of species such as *C. africana* is not unique to the study area; corresponding outcomes have been documented in other regions, where wild nutraceutical plants provide a combination of medicinal, nutritional, and ecosystem services [41–43] [46–48]. These observations underscore the critical role of wild nutraceutical plants in supporting community health, livelihoods, and cultural practices, and they highlight the need to integrate ethnobotanical knowledge into conservation planning and sustainable resource management.

Table9: Direct matrix analysis of wild nutraceutical plant uses in Machakel District, were Nutraceutical value(Nv), Forage (Fo), Fire wood collection (Fi), Charcoal (ch), construction (Co), Tool making (To) and Shade (Sh).Values indicate total score of 10 key informants for each use categories

Wild nutraceutical plants	Use category							Total	Rank
	Nv (I ₁ -I ₁₀)	Fo (I ₁ -I ₁₀)	Fi and Ch (I ₁ -I ₁₀)	Co (I ₁ -I ₁₀)	Fe (I ₁ -I ₁₀)	To (I ₁ -I ₁₀)	Sh (I ₁ -I ₁₀)		
<i>Ficus sur</i>	38	15	26	8	25	31	41	184	2 nd
<i>Rubus steudneri</i>	41	13	12	0	35	0	22	123	3 rd
<i>Foeniculum vulgare</i>	45	25	6	0	0	0	3	79	5 th
<i>Cordia africana</i>	35	34	45	50	37	46	50	297	1 st
<i>Embelia schimperi</i>	42	40	13	0	3	0	18	116	4 th

Conclusions and recommendations

The study documented 52 nutraceutical plant species in Machakel District, predominantly herbs, used to manage 45 human ailments, with key species such as *Allium sativum*, *Hordeum vulgare*, *Guizotia abyssinica*, and *Cordia africana* highly valued for both nutritional and medicinal purposes. Seeds, fruits, and leaves were the most commonly used parts, and the chief route of administration was via the oral route. Multipurpose use of these plants underscores their cultural, economic, and health significance, while also highlighting the need for conservation. It is recommended to promote sustainable harvesting and cultivation of key species, document and transfer indigenous knowledge, and carry out chemical and pharmacological studies to confirm traditional use and support the development of nutraceuticals.

Availability of research data: The data utilized in this study are accessible in the appendices or via the link provided by the editors

Competing Interests

The authors declare that there are no conflicts of interest regarding the publication of this study

Contributions of the Authors

All authors contributed to the study design, data collection, analysis and manuscript writing and approved the final manuscript

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Appendix:

Nutraceutical plants used by the local people in the study area with scientific name, family, local name, habit or Ha (Climber- CI, Herb- H, Shrub- S and Tree- T), parts used or Pu (Leaf- L, Root- R, stem- Sm, bulb- Bu, Seed- Se ,shoot-So) and Fruit- Fr), Crop categories or Cc (Vegetable-V, Seed –Se, Spice-SP, Vegetable and Spice-V + SP, Fruit-Fr , Pulse-Pu, Stimulant-St Cereal-Ce , Oil seed-Os and Rhizome- R), condition of preparations or Cp (fresh- F, dried- D and fresh or dried- F/D), disease treated, preparation and application and route of administration(Ra)(Oral-O, Dermal-De ,Nasal-N).

No	Scientific Name	Family	Local Name	Cc	Ha	Pu	C P	Diseases Treated	Formulation and Administration	R A
1	<i>Allium cepa</i> L.	Alliaceae	Key shinkur	V + Sp	H	Bu	F	Tinea nigra	The bulb of <i>Allium cepa</i> was halved, and the cut surface was applied to the infected area. The infected site was then repeatedly rubbed with the <i>Allium cepa</i> bulb	De
					H	Bu	F	Tinea versicolor	The bulb of <i>Allium cepa</i> and the root of <i>Rumex abyssinicus</i> were crushed and combined with <i>Citrus × aurantiifolia</i> juice and salt to form a paste, which was then applied topically to the affected area.	De
2	<i>Allium sativum</i> L.	Alliaceae	Nech shinkurt	V+s p	H	Bu	F	Common cold	A decoction was prepared by boiling crushed <i>Allium sativum</i> bulbs and <i>Ruta chalepensis</i> leaves in water. One cup, sweetened with sugar, is recommended to be consumed each evening before bedtime	O
				V+s p	H	Bu	F	Evil eye	The bulb of <i>Allium sativum</i> and <i>Ruta chalepensis</i> were crushed, wrapped in fresh cotton cloth, and inhaled for their aroma	N
					H	Bu	F	Malaria	The bulbs of <i>Allium sativum</i> and <i>Capsicum annuum</i> were sliced, soaked in water, and consumed with injera after 24 hours.	O
					H	Bu	F	Dry cough	The clove of garlic, peeled and crushed, combined with a teaspoon of honey, and consumed in the morning on an empty stomach, regularly	O
					H	Bu	F	Typhoid	The bulbs of <i>Allium sativum</i> (garlic) and <i>Allium cepa</i> (onion) are finely grated, and <i>Capsicum annuum</i> (chili) is chopped. They are soaked in a small amount of water with salt for 3–5 minutes, and 2–3 spoonfuls are eaten	O

									with injera	
3	<i>Avena sativa</i> L.	Poaceae	Engido	Ce	H	Se	D	Bone fracture and general weaknes	The seeds of <i>Avena sativa</i> (oats) are powdered and mixed with the powders of <i>Hordeum vulgare</i> (barley) and <i>Triticum dicoccum</i> (emmer wheat). This mixture is boiled with water or milk, with a small amount of sugar and a pinch of salt added according to taste, to make 'atmit' (gruel). The atmit is then consumed repeatedly by drinking it from a glass	O
					H	Se	D	Diabetes	Powdered seeds of <i>Avena sativa</i> (oats) are mixed with the powders of <i>Hordeum vulgare</i> (barley) and <i>Triticum dicoccum</i> (emmer wheat). The mixture is boiled with water or milk, with a little sugar and a pinch of salt added to taste, to make 'atmit' (gruel). It is then repeatedly consumed by drinking from a glass	O
4	<i>Beta vulgaris</i> L.	Chenopodiaceae	Keysr	V	H	R	F	Hypertension	The tap root of <i>Beta vulgaris</i> washed, peeled, chopped then cooked for few minutes and eaten with injera.	O
				V	H	R		Anemia	Eating cooked <i>Beta vulgaris</i> or drinking the water of it after washed, peeled, chopped, boiled and decanted.	O
5	<i>Mutarda carinata</i> (A.Braun) D.A.German	Brassicaceae	Gomen zer/kitel	V	H	Leaf	F	Constipation and intestinal cancer	The leaf of <i>Mutarda carinata</i> chopped and cooked for few minutes by adding <i>Allium cepa</i> , few drop of oil and very small amount of salt and then eaten with injera at least once a day in human meal.	O
6	<i>Mutarda nigra</i> (L.) Bernh.	Brassicaceae	Senafich	Sp	H	Se	D	Malaria	The seed crushed and homogenized with dry cheese (metata ayib) together with other condiments including salt and then eaten with injera after seven years by diluting with hot water or raw milk.	O
					H	Leaf		Kidney diseases	The leaf of the plant chopped and cooked for few minutes with <i>Allium cepa</i> , no oil added is eaten by injera continuously	O
					H	Se	D	Intestinal parasites	Crushed substance mixed with water and then consumed by a cup	O
					H	Se	D	Bloating	Crushed and blended with water, then drunk from a cup, or eaten as sprouted <i>Vicia faba</i> seasoned with black mustard (<i>Mutarda nigra</i>) during bloating.	O
7	<i>Brassica oleracea</i> L.	Brassicaceae	Tkl gomen	V	H	L	F	Gastritis	The leaf of <i>Brassica oleracea</i> chopped boiled with water and decants the residue and then drunk one glass of the solution.	O
8	<i>Brassica rapa</i> L.	Brassicaceae	Kosta	V	H	L	F	Constipation	The leaf of <i>Brassica rapa</i> chopped and cooked by adding <i>Allium cepa</i> , few drop of oil, salt and <i>Capsicum</i>	O

									<i>annuum</i> and then eaten with injera	
					H	L	F	Loss of appetite	The leaf of <i>Brassica rapa</i> chopped and cooked by adding <i>Allium cepa</i> , few drop of oil, salt and <i>Capsicum annuum</i> and then eaten with injera	O
9	<i>Capsicum annuum</i> L.	Solanaceae	Karia	V+S p	H	Fr	F	Malaria	The fruit of <i>Capsicum annuum</i> and the bulb of <i>Allium sativum</i> are chopped, soaked in water, and eaten with injera after one day	O
					H	Fr	F	Headache	The fresh fruit is eaten with injera.	O
					H	Fr	F	The loss of appetite	The fruit is eaten with enjera.	
10	<i>Carica papaya</i> L.	Caricaceae	Papaya	Fr	T	Fr	F	Gastritis	The raw fruit is peeled and eaten by removing the seeds.	O
11	<i>Carissa spinarum</i> L.	Apocynaceae	Agam		Sh	Fr	F	Tooth ach	A handful of raw fruit <i>Carissa spinarum</i> is eaten.	O
12	<i>Cicer arietinum</i> L.	Fabaceae	Shimbra	pu	H	Se	D	Malaria	The germinated seeds are dried, crushed, mixed with <i>Allium sativum</i> , soaked in water for three days, and the filtrate is consumed with skimmed milk, once a day by glassfuls	O
				Pu	H	Se	D	Wart	The seed washed, soaked in water for one day and wash the wart by the filtrate with new cotton cloth for up to five days	De
13	<u><i>Citrus</i> × <i>aurantiifolia</i> (Christm.) Swingle</u>	Rutaceae	Lomi	Fr	T	Fr	F	Tinea vesicular	The fruit of <i>Citrus</i> × <i>aurantiifolia</i> is juiced, combined with crushed <i>Allium cepa</i> bulbs, <i>Rumex abyssinicus</i> roots, and salt, then applied as a paste on the affected area until the skin is free of the condition	De
				Fr	T	Fr	F	Ascaries and intestinal parasite.	It is recommended to drink one cup of juice from the fruit of <i>Citrus</i> × <i>aurantiifolia</i> in the morning before breakfast for one or two days	O
				Fr	T	Fr	F	Blooding of gum	The fruit of <i>Citrus</i> × <i>aurantiifolia</i> squeezed and drunk repeatedly and also wash the mouth with it (one fruit per day is enough).	O
14	<u><i>Citrus</i> × <i>aurantium</i> f. <i>aurantium</i></u>	Rutaceae	Birtukan	Fr	T	Fr	F	Common cold	It is recommended to drink a cup of juice from the fruit of <i>Citrus</i> × <i>aurantium</i> , either fresh or boiled, with the boiled juice taken after dinner	O
15	<i>Coffea arabica</i> L.	Rubiaceae	Bunna	St	T	Se	D	Headache	The seeds are washed, roasted, crushed, and boiled in water, and the resulting decoction is drunk by the cup during pain	O
					T	L	F	Common cold	The leaves are boiled in water, and the resulting liquid is drunk.	O
					T	L	D	Wound	Washed, roasted, and crushed seeds are applied as a	De

									paste to the wound	
					T	L	D	Diarrhoea	The seeds are washed, roasted, and crushed, then either the powder is mixed with hot water and the filtrate drunk by the cup, or the powder is eaten with honey before breakfast	O
16	<i>Cordia Africana</i> Lam.	Boraginaceae	Wanza		T	Fr	F	Gastritis	The raw fruit is eaten	O
17	<i>Coriandrum sativum</i> L.	Apiaceae	Dnblal	Sp	H	Se	D	Intestinal parasite	The seed roasted with little heat and boiled in water mixed with <i>Allium sativum</i> , <i>Nigella sativa</i> then drunk the filtrate repeatedly.	O
					H	Se	D	Ascaris	The seed boiled with seven cup or glass of water up to one cup or glass remains then decanted and drunk the filtrate.	O
18	<i>Cucurbita pepo</i> L.	Cucurbitaceae	Duba	V	C	Fr	F	Gastritis	The <i>Cucurbita pepo</i> fruit peeled, chopped and cooked by adding <i>Allium cepa</i> , oil, salt and ate with injera.	O
						Fr	F	Tooth ache	The seed dried, crushed, put on fire and fumigate the smoke through tube directly to the tooth.	O
19	<i>Daucus carota</i> L.	Apiaceae	Karrot	V	H	R	F	Eye diseases	Raw <i>Daucus carota</i> washed and eaten	O
20	<i>Embelia schimperi</i> Vatke	Myrsinaceae	Enkoko		Sh	Se	F	Tape worm	The seed dried, pounded, diluted with water or TELA and drunk by a glass.	O
21	<i>Eragrostis tef</i> (Zucc.) Trotter	Poaceae	Dabbotef	Ce	H	Se	D	Anemia	The seed powdered and back as “injera” kita” or boiled as “atmit” gruel and then ate the injera or drunk the “atmit” repeatedly.	O
22	<i>Ficus sur</i> Forssk	Moraceae	Shola		T	Fr	F	Constipation	Eat the raw fruit of <i>Ficus sur</i> .	O
23	<i>Foeniculum vulgare</i> Mill	Apiaceae	Inslal	Sp	H	L/so	F	Kidney stone diseases	The leaves or shoots are simmered in water, and a cup of the strained liquid is consumed orally	O
				Sp	H	L/so		Bloating	Crush the leaves or shoots, mix with water, and drink the filtrate.	O
24	<i>Guizotia abyssinica</i> (L. f.) Cass	Asteraceae	Nug	Os	H	Se	D	Dry cough	Pound the seeds, mix with water, boil, and drink a glass of the filtrate after dinner each evening until recovery	O
				Os	H	Se	D	Constipation	Roast and pound the seeds, mix with kolo, and eat.	O
25	<i>Helianthus annuus</i> L.	Asteraceae	Yeferenge suf	Os	H	Se	D	Dry cough	Roast and pound the seeds, mix with water, boil, and drink a glass of the filtrate.	O
				Os				Constipation	Pound and boil the seeds, mix with water, salt, and <i>Ruta chalepensis</i> seeds, and eat with injera.	O

26	<i>Hordeum vulgare</i> L.	Poaceae	Gebbs	Ce	H	Se	D	Gastritis	Roast the seeds and eat as 'kolo,' or powder them, mix with water, salt, and sugar to take as 'beso,' or cook into 'genfo' porridge.	O
				Ce	H	Se		General weakness	The roasted , powdered seed of <i>Hordeum vulgare</i> mixed with powder of <i>Triticum dicocoon</i> , <i>Avena sativa</i> and boiled as“atimit” by adding sugar(honey), salt then a glass of the solution taken orally in continuous way.	O
27	<i>Linum usitatissimum</i> L.	Linaceae	Telba	Os	H	Se	D	Gastritis	Boil <i>Linum usitatissimum</i> seeds in water, add sugar, and drink during pain.	O
28	<i>Lupinus albus</i> L.	Fabaceae	Gbto	Pu	H	Se	D	Hypertensi on	The seed of <i>Lupinus albus</i> roasted ,soaked in water one-five days to remove the bitter taste and eaten by mixing with <i>Allium cepa</i> , <i>Capsicum annuum</i> and salt or eaten without any mix. <i>Lupinus albus</i> drunk in the form of local alcoholic drinks “Gbto areki” , the seed roasted, soaked ,dried, hulled and powdered and then prepared by the way in which local areki synthesized.	O
					H	Se	D	Wound	Crush <i>Lupinus albus</i> seeds, mix with <i>Allium sativum</i> , and apply to the wound as a paste.	De
29	<i>Lycopersicon esculentum</i> L.	Solanaceae	Timatim	V	H	Fr	F	Anemia	The fruit washed, chopped spiced with <i>Allium cepa</i> , <i>Capsicum annuum</i> , and salt and eaten by injera.	O
30	<i>Malus sylvestris</i> (L) Mill.	Rosaceae	Apple	Fr	T	Fr	F	Diabetes	Eating the raw fruits	O
31	<i>Mangifra indica</i> L.	Anacardaceae	Mango	Fr	T	Fr	F	Gastritis	Eating the raw fruits	O
32	<i>Mentha spicata</i> L.	Lamiaceae	Nana	Sp	H	L	F	Head ache	Boil the leaves and drink with tea	O
33	<i>Musa x paradisiacal</i> L.	Musaceae	MuZ	Fr	H	Fr	F	Stress	Eating the raw fruits of it is recommended	O
				Fr	H	Fr	F	Gastritis	Eating raw fruits	O
34	<i>Nigella sativa</i> L.	Ranunculaceae	Tkurazmud	Sp	Sp	Se	D	Asthma	The seed of <i>Nigella sativa</i> crushed, the powder mixed with crushed <i>Allium sativum</i> , honey and taken orally by spoon	O
					Sp	Se	D	Kidney diseases	The seed of <i>Nigella sativa</i> washed dried, remove any unwanted things and mixed with honey then eaten by spoon.	O
35	<i>Ocimum bacilicum</i> L.	Lamiaceae	Besobla	Sp	H	Se/Fr	F	Melisma	The seed and its part crushed and then creamed the affected part of the skin for up to three days, then after start another cycle until the skin recovered.	De
36	<i>Persea Americana</i> Mill.	Lauraceae	Avocado	Fr	T	Fr	F	Rough skin and hair	The skin or hair creamed by raw fruit and washed by water.	O
					T	Fr	F	Thinning	The raw fruit is peeled and taken orally.	O

37	<i>Prunus persica</i> (L.) Batsch	Rosaceae	Kok	Fr	T	Fr	F	Gastritis	The raw fruit is eaten during starvation	O
38	<i>Psidium guajava</i> L.	Myrtaceae	Zeytun	Fr	T	Fr	F	Abdominal pain	Eaten the raw fruits	O
				Fr	T	Fr	F	Tonsillitis and Common cold	Boiling the leaf and drunk in the form of tea.	O
39	<i>Rhamnus prinoides</i> L' Herit.	Rhamnaceae	Gesho	Sp	S	L	F	Tonsillitis and uvultia	Cutting seven leaves from the apical meristems of the plant and chewed, hold in mouth for up to five or more minutes and then reject the fluid.	O
40	<i>Rosa abyssinica</i> C.H . Wright	Rosaceae	Kega		S	Fr	F	Rheumatism	Hand full of raw <i>Rosa abyssinica</i> fruit is eaten	O
					S	Fr	F	Ascaries	The raw fruit is eaten	O
41	<i>Salvia rosmarinus</i> Spenn	Lamiaceae	Rosmiary	Sp	H	L/So	F / D	Hypertension	The shoot with its leaf inserted in to hot wote or tibs for better taste and also medicinal advantages when it taken orally or the leaf inserted in to hot water and drunk it in the form of tea.	O
42	<i>Rubus steudneri</i> Schweinf	Rosaceae	Engory		S	Fr	F	Gastritis, Stomach ache and Ascaries	The raw fruit is eaten	O
					S	Fr	F	Fever	Crush the fruit, mix with water, and drink the mixture.	O
43	<i>Rumex abyssinicus</i> Jacq.	Polygonaceae	MekmeKo		S	R	D	Hypertension	Dry and crush the root of <i>Rumex abyssinicus</i> , add to hot water, and drink as tea	O
44	<i>Ruta chalepensis</i> L.	Rutaceae	Tenadam	Sp	S	L	F	Evil eye	Pound <i>Ruta chalepensis</i> leaves and <i>Allium sativum</i> bulbs, tie in a cloth around the neck, and smell	O
				Sp	S	Fr	F	Stomach ache	Pound and boil the fruit in water and drink, or eat the fruit directly	O
				Sp	S	Fr	F	Common cold	Immerse <i>Ruta chalepensis</i> leaves in hot water, boil with <i>Camellia sinensis</i> , drink with sugar, and inhale the vapor.	O
45	<i>Saccharum officinarum</i> L.	Poaceae	Shenkor Ageda	V	H	Sm	F	Gastritis	Peel the stem bark, chew the stem, swallow the juice, and discard the rest	O
				V	H	Sm		Common cold	The stem bark is put on fire, when it hot, peeled the stem, chewed and the juice only swallowed.	O
46	<i>Solanum tuberosum</i> L.	Solanaceae	Dinic	V	H	R		Scar on the skin	The root tuber washed, chopped in to large pieces and pasted the pieces on the injured part (noon bloody).	De

47	<i>Thymus schimperi</i> Ronnger.	Lamiaceae	Tosign	Sp	H	L	F	Common cold	The leaf of <i>Thymus schimperi</i> immersed in hot water for few minutes, decanted and taken a cup of filtrate by adding sugar.	
48	<i>Trigonella foenum-graecum</i> L.	Fabaceae	Abish	Sp	H	Se	D	Gastritis ,wart and hypertension	The seed is powdered, soaked with water through a night, decanted the water in to another material to remove the bitter taste and add other water, sugar (honey), mixed it well, and then drunk the solution.	O
				Sp	H	Se	D	Thinning	The seed of <i>Trigonella foenumgraecum</i> germinated, dried, powdered, mixed with powder of <i>Hordium vulgare</i> , boiled taken as “atimit ‘by adding sugar or honey specially for children.	O
49	<i>Triticum dicocoon</i> Schrank.	Poaceae	Aja	Ce	H	Se	D	General weakness	The powder of the seed mixed with water, boiled, add sugar or honey and taken orally.	O
50	<i>Urtica simensis</i> Hochst ex A. Rich	Urticaceae	Sama		H	L	F	Heart diseases and Gastritis	Cut <i>Urtica simensis</i> leaves and shoots with protective hands, rub on a flat surface to remove stinging, boil, squeeze, grind with a little <i>Hordenum vulgare</i> flour, boil again, salt, and eat with injera	O
					H	L	F	Eczema	Cut <i>Urtica simensis</i> leaves with protective hands, dry and pound them, mix with fresh butter, and apply to the affected area	De
51	<i>Vicia faba</i> L.	Fabaceae	Bakela	Pu	H	Se	D	Wound	Powder dried <i>Vicia faba</i> seeds, mix with <i>Lupinus albus</i> powder, and apply to the infected area.	De
				Pu	H	Se	D	Gastritis	Boil <i>Vicia faba</i> seeds and drink the water	De
				Pu	H	Se	D	Boils	Chew <i>Vicia faba</i> seeds and apply the paste to the infected area.	De
52	<i>Zingiber officinale</i> Roscoe	Zingiberaceae	Zingible	Rh	H	Rh		Bad mouth odor	Chew the rhizome and rinse your mouth with water.	O
					H	Rh		Common cold	Add pieces of <i>Zingiber officinale</i> to hot water, strain, and drink.	O
					H	Rh		Stomach ache	Crush a few pieces of <i>Zingiber officinale</i> , mix with a little water, strain, and drink the filtrate	O