Ethnobotanical survey of medicinal plants used for Rheumatoid Arthritis treatment in the Sikkim Himalaya, India

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Research

Abstract

Background: Rheumatoid arthritis (RA) is a chronic inflammatory disorder that significantly impairs quality of life and currently lacks fully effective conventional treatments without side effects. Traditional medicinal plants offer promising alternative or complementary therapeutic options, particularly among indigenous populations with rich ethnobotanical knowledge.

Methods: This ethnobotanical study documents the use of medicinal plants for RA management by inhabitants of the Sikkim Himalaya, India, an ecologically diverse and culturally unique region. Data were collected through semi-structured questionnaires administered to 87 informants, including traditional healers and knowledgeable villagers across all four districts of Sikkim, encompassing a broad altitudinal gradient.

Results: A total of 33 plant species representing 24 families and 28 genera were identified as important for RA treatment. Notably, *Equisetum diffusum* exhibited the highest relative frequency of citation (RFC = 0.138), underscoring its therapeutic significance in this region. The predominant plant parts utilized were rhizomes and barks, with traditional remedies most commonly administered topically to affected joints, supplemented by oral applications in selected cases. Ethnomedicinal uses align with existing pharmacological evidence demonstrating anti-arthritic, anti-inflammatory, and antioxidant properties of several documented species.

Conclusions: This study contributes valuable baseline data for future pharmacological validation, conservation policymaking, and integration of traditional knowledge into sustainable RA management strategies.

Keywords: Ethno-medicine, Ethno-botanical survey, Rheumatoid arthritis, Sikkim Himalaya, Traditional medicine

Background

Since prehistoric times, people have been using traditional system of medicine (TSM) to treat various diseases based on their practices, experiences and beliefs. The practitioners of TSM provide substantial contributions to human health both at local and global levels and thus maintain its popularity amongst the people (Jima & Megersa 2018). Developing and underdeveloped countries still depend on TSM for their health care (Sofowora 1982; Hegde 2003) and also provide an ethno-medicinal base for the discovery of novel drugs. TSM is most common and widely used in countries like India, China, Japan, Thailand, Sri Lanka, Pakistan and Korea (Park *et al*. 2012). The World Health Organization (WHO) has also accepted the importance of documenting the TSM of indigenous communities (Buragohain 2011). The Indian traditional system of medicine includes Ayurveda, Siddha, Unani and Folk medicines, among which Ayurveda is considered the most advanced and used extensively (Jaiswal & Williams 2017). In India, about 8000 plant species are used in folk remedies, and around 25,000 effective plant-based therapies are used by the ethnic communities of rural areas for primary healthcare (Sen & Chakraborty 2015). In addition to that, about 2500 species of plants are used as herbal medicines for treating various illnesses, either in the form of folk medicines or modern pharmaceuticals (Choudhary *et al.* 2015). Thus, the traditional knowledge of medicinal plants is of utmost importance as it may lead to the discovery of new potent and cost-effective remedies for curing diseases (Kalita et al. 2012). Folk medicines based on traditional knowledge (TK) play an important role in the indigenous and ethnic communities for maintaining optimum health and treatment of diseases. However, such TK is not documented well and is passed from one generation to another orally (Kala 2003). Therefore, it is important to document the existing rich ethno-medicinal knowledge of the ethnic communities from the region. The documentation of TK not only gives an opportunity to discover novel drugs but also preserves the rich indigenous knowledge of the community (Mahwasane *et al*. 2013), which is depleting due to the accessibility of modern medicines and modern healthcare facilities.

Rheumatoid arthritis (RA) is a chronic, inflammatory autoimmune disease and is considered to be one of the major health problems globally (Guo *et al*. 2018). As per WHO, 0.3-1% of the total populace is affected by Rheumatoid arthritis (RA). It is seen that females are multiple times progressively inclined to the ailment than males (Tripathy *et al.* 2010). The prime symptoms of RA include soreness, swelling, and destruction of ligament and bone. Regular use of modern medicine like NSAIDs (non-steroidal anti-inflammatory drugs) or DMARDs (disease modifying antirheumatic drugs) may result in extreme side effects, including gastrointestinal problems along with peptic ulcers (Reddy et al. 2014). Disappointed with the current medical treatment, several researchers have reported the use of alternative treatments for RA. About 60-90% of arthritic patients are now using complementary and alternative medicine (Rao *et al*. 1999). In this context, there is a need to develop novel anti-RA agents with lesser side effects. Even though numerous studies have reported the use of ethnomedicinal plants in treating RA by ethnic inhabitants of India (Pawar & Patil 2006; Rathore *et al*. 2007; Naidu *et al*. 2008; Sutha *et al*. 2010; Manjula *et al*. 2013; Swamy & Reddi 2016; Shyamala *et al*. 2016) there lacks a comprehensive detailed list of ethnomedicinal plants used by the ethnic peoples of Sikkim Himalaya for the treatment of RA.

In Sikkim Himalaya, three ethnocultural communities, viz. Lepcha, Bhutia, and Nepalese use diverse ethnomedicinal plants for curing various health-related ailments (Singh *et al*. 2002). These ancestral traditional medicinal practices have existed in Sikkim and are well-known to the local tribes (Das 1994). The TMS largely depends on the surroundings and the ethnic expression of the region (Bhasin 2007). The geographic position of Sikkim (bordered by Tibet in the North, Bhutan in the East and Nepal in the West), prohibiting the movement of people, might have led to the development of its own health culture (Panda & Misra 2010). The ethnic people of Sikkim are well aware of the healing properties of their native traditional medicinal plants, but are not reported well to the scientific community. Although reports on the use of folk medicinal plants of Sikkim Himalaya are well documented (Singh *et al*. 2002; Maity *et al*. 2004; Chhetri *et al*. 2005; Chhetri 2005; Pradhan & Badola 2008; Panda & Misra 2010; Das *et al*. 2012; Shrestha *et al*. 2015; Tamang *et al*. 2017; Tamang *et al*. 2020), they lack a comprehensive documentation of ethno-medicinal plants for treating RA. The study was thus undertaken to document the traditional knowledge of medicinal plants used by the inhabitants of Sikkim Himalaya for treating RA.

Materials and Methods

Study Area and Site Description

Sikkim is one of the north-eastern states of India (27˚ 05' to 28˚ 07' N latitudes & 87˚59' to 88˚ 56' E longitude) with an elevation ranging from 300-8500 m asl and has a total area of 7,096 km^2 (Fig. 1). Despite contributing only 0.22% to the country's total geographical area, the state harbors nearly 33% of India's flowering plant diversity. The vegetation of Sikkim exhibits clear altitudinal zonation, ranging from tropical and subtropical forests at lower elevations to temperate and alpine types at higher altitudes, consistent with the classification of Champion and Seth (1968).

The study was conducted across various locations in the state of Sikkim, which is situated in the eastern Himalayas of India. The research covered all four districts of Sikkim — West, East, South, and North — encompassing a diverse range of ecological and geographical settings, from subtropical to alpine zones (Fig 1). A total of 24 locations were surveyed, each represented by specific GPS coordinates (latitude and longitude) for spatial precision. The selection of these sites aimed to capture both the ecological variation and the socio-cultural diversity prevalent across the state. In West Sikkim, sites such as Uttarey, Soreng, Rinchenpong, Hee-Bermiok, Chyakhung, and Darap were included. These areas are known for their rich biodiversity and traditional agricultural practices.

In East Sikkim, the study encompassed locations like Sang-Martam, Phadamchen, Pakyong, 9th Mile (Namli), Assam Linzey, and Rorathang. This district, with a mix of urbanizing and rural pockets, represents transitional landscapes. In South Sikkim, the areas surveyed included Ravangla, Namthang, Wok, Borong, Namchi, and Jorethang. These sites are recognized for their agricultural terraces and community-based conservation efforts. North Sikkim, the most sparsely populated and ecologically fragile district, was represented by sites such as Sankalang, Hee-Gyathang, Shipgyer, Toong Naga, Kabi, and Mangshila. These regions lie in proximity to protected areas and are significant for studying high-altitude ecosystems and traditional knowledge systems. The geographic distribution of the study sites ensured that both remote high-altitude villages and more accessible settlements were included. This comprehensive spatial coverage strengthens the reliability and applicability of the study findings across the organic farming and biodiversity conservation landscape of Sikkim.

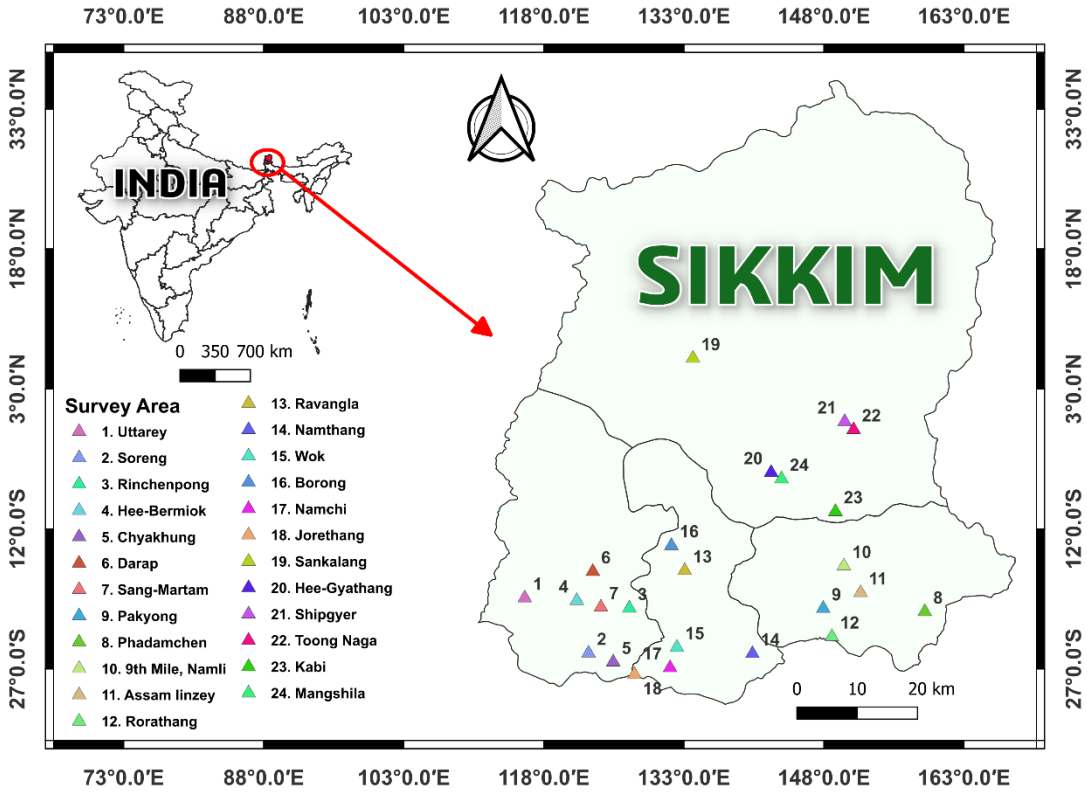


Figure 1. Study area map showing the locations of surveyed sites in Sikkim, India.

Ethnobotanical field survey

A standard semi-structured questionnaire was designed, and thereafter, field surveys were conducted with different indigenous folk healers and local villagers. The survey was conducted in all four districts of Sikkim (North, South, East, and West) irrespective of caste or community. The informants were asked about the local plant names, processing and storage techniques, plant uses either alone or in conjunction with other herbs, preparation methods, and doses, modes of administration, precautions and treatment periods.

Population study

Primary data for the present study were collected through field-based ethnobotanical surveys. Information was obtained directly from local traditional medicine practitioners and knowledgeable villagers through face-to-face interviews using semi-

structured questionnaires. A total of 87 informants participated in the study, including traditional healers and knowledgeable villagers recognized within their communities for their experience and expertise in the use of medicinal plants for treating rheumatoid arthritis. These included approximately 14 key informants (traditional healers) and 73 knowledgeable local villagers with practical experience in the use of medicinal plants for treating rheumatoid arthritis. The informants belonged mainly to the major indigenous communities of Sikkim, including Lepcha, Bhutia, and Nepalese communities (such as Limboo, Rai, Tamang, and Gurung), thereby ensuring broad ethnic representation across the study area. Informants were selected using purposive sampling, targeting traditional healers, experienced farmers, and knowledgeable villagers with recognized expertise in ethnomedicinal practices related to rheumatoid arthritis. This was further supported by snowball sampling, where initial informants identified additional knowledge holders within and across communities.

The study did not aim to sample a fixed percentage of the total population, as ethnobotanical research focuses on knowledge holders rather than population-level representation. Therefore, the number of informants reflects the availability and accessibility of individuals possessing relevant traditional knowledge rather than a proportion of the total population.

Plant collection and authentication

Plant specimens were collected from different regions of the Sikkim Himalaya during field surveys. Preliminary identification was carried out using regional floras, followed by authentication by taxonomists at the Botanical Survey of India (BSI), Eastern Himalayan Circle, Sikkim. The valid and currently accepted scientific names were confirmed using standard taxonomic literature and online databases such as Plants of the World Online (POWO) and The Plant List, following accepted botanical nomenclature. Voucher specimens of each plant were prepared and deposited in the Herbarium of the Department of Botany, Sikkim University, for future reference.

Data analysis

The ethnomedicinal data collected during field surveys were compiled and interpreted specifically in the context of rheumatoid arthritis (RA) treatment practices and knowledge sustainability. Since the study focused exclusively on a single disease, the application of broader ethnobotanical indices such as Use Value (UV), Informant Consensus Factor (ICF), and Cultural Importance Index (CI) was not considered methodologically appropriate. Instead, the Relative Frequency of Citation (RFC) was used as a robust measure of informant consensus and species importance for RA-specific treatment.

The information obtained from the field survey was summarized in Table 4, showing the scientific name, family, local name, and plant parts utilized for the treatment of rheumatoid arthritis. The significance of each plant species was determined based on the RCF (relative frequency of citation) (Tardio & Pardo-De-Santanyana 2008). RFC value differs from 0 (when no one refers to a plant as useful), to 1 (when all the informers referencing it as useful). The RFC was determined by utilizing the equation:

$$RFC = Fc/N,$$

in which Fc is the number of informers who mentioned the utilized of the species and N is the total number of informers. To determine the relative significance of plant families, the Family Importance Value (FIV) was calculated. It was estimated by summing the frequency of citation (FC) of all species belonging to a particular family and divided by the total number of informants (N) (Sulaiman *et al*. 2020).

$$FIV = \sum FC / N \times 100$$

Further, SPSS version 26 was used to perform all the statistical analysis like descriptive analysis, cluster analysis, and ANOVA.

Results

Normality test of the composite index variables

To assess the suitability of parametric statistical analyses, a normality test was conducted on the composite index variables, which were derived by aggregating key indicators such as *Experience, Education Level, Willingness to Share, Knowledge Transfer, Youth Involvement, and Conservation.* These variables were selected based on their conceptual importance in understanding traditional ecological knowledge and conservation behaviours within communities. Only the composite variable was tested for normality as it provides a holistic, statistically robust representation of multi-dimensional constructs, avoiding redundancy and improving interpretability.

Table 1. Normality test of the composite index data

(A)	Tests of Normality					
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
TOTAL	0.117	87	0.005	0.967	87	0.024

[a] Lilliefors Significance Correction

(B)	Descriptives			
			Statistic	Std. Error
TOTAL	*Mean*		12.195	0.227
	95% Confidence Interval for Mean	*Lower Bound*	11.744	
		Upper Bound	12.647	
	5% Trimmed Mean		12.187	
	Median		12.000	
	Variance		4.485	
	Std. Deviation		2.118	
	Minimum		7.000	
	Maximum		17.000	
	Range		10.000	
	Interquartile Range		3.000	
	Skewness		0.000	0.258
	Kurtosis		-0.057	0.511

The results of the Kolmogorov–Smirnov test (statistic = 0.117, df = 87, p = 0.005) and the Shapiro–Wilk test (statistic = 0.967, df = 87, p = 0.024) both indicated significant deviation from normality ($p < 0.05$). Despite these results, descriptive statistics showed that the distribution of TOTAL was approximately symmetric, with a mean of 12.20 (SD = 2.12), a median of 12.00, a range from 7 to 17, and an interquartile range of 3. The skewness (0.000) and kurtosis (–0.057) values were close to zero, suggesting that the distribution was neither skewed nor leptokurtic. However, due to the significant results from both normality tests, the use of non-parametric methods or data transformation was recommended for further inferential analysis involving this composite index.

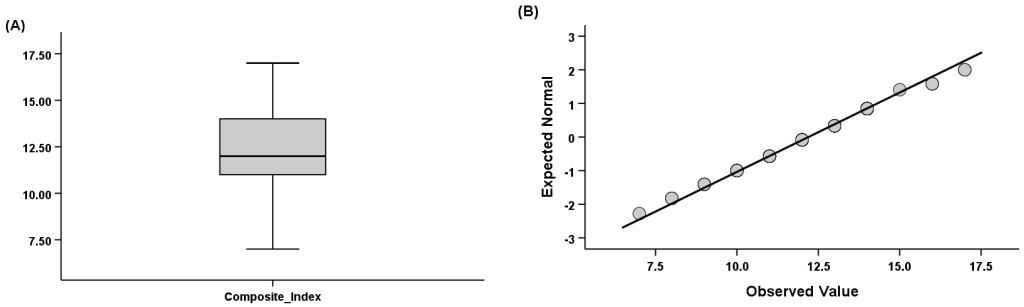


Figure 2. Q-Q plot and Box plot of the composite index data.

Descriptive analysis of Demography

The demographic profile of the 87 respondents was analyzed to understand the composition of the study population involved in traditional ecological knowledge and medicinal plant use. The results are summarized in Table 2.

In terms of age distribution, the majority of participants were older adults. A significant proportion (40.2%) were above 61 years of age, followed by 32.2% in the 51–60 years age group. Those between 41–50 years constituted 19.5%, while only 8% of the respondents were within the 31–40 years bracket. This trend indicates that traditional knowledge is predominantly held by the elderly population, underscoring the urgency of documenting and preserving such knowledge before it is lost with age. With respect to gender, the sample was male-dominated, with 75.9% of the respondents identifying as male and

24.1% as female. This imbalance could reflect gendered roles in knowledge possession, transmission, or community representation in the study area.

Regarding occupation, a vast majority (83.9%) of the participants identified as farmers, while 16.1% were folk healers. This suggests that traditional ecological knowledge is largely embedded within agrarian practices and complemented by specialized knowledge from folk healers. Analysis of education levels revealed that a significant portion of respondents (56.3%) had only basic or no formal education—25.3% had no formal education, and 31% had only primary-level education. A smaller fraction had achieved metric (17.2%), post-metric (19.5%), or graduation-level (6.9%) education. This pattern indicates that traditional knowledge is not necessarily linked to formal educational attainment but may instead be transmitted orally or experientially within the community.

In terms of years of experience with traditional practices, 39.1% of respondents had over 20 years of experience, while 29.9% had between 11–20 years. Those with 6–10 years of experience made up 20.7% of the sample, and only 10.3% had 1–5 years of experience. This distribution confirms that a significant portion of the knowledge holders are long-term practitioners, reinforcing the importance of intergenerational knowledge transfer.

Overall, the descriptive analysis highlights that the traditional ecological knowledge system in the study area is deeply rooted in the elderly, male, agrarian population with limited formal education but extensive experiential knowledge.

Table 2. Demographic details of the current study

Characteristics		Frequency	Percent	Valid Percent	Cumulative Percent
Age Group	*31–40 years*	7	8.00	8.00	8.00
	41–50 years	17	19.50	19.50	27.60
	51–60 years	28	32.20	32.20	59.80
	Above 61	35	40.20	40.20	100.00
	Total	**87**	**100.00**	**100.00**	
Gender	*Male*	66	75.90	75.90	75.90
	Female	21	24.10	24.10	100.00
	Total	**87**	**100.00**	**100.00**	
Occupation	*Farmer*	73	83.90	83.90	83.90
	Folk Healer	14	16.10	16.10	100.00
	Total	**87**	**100.00**	**100.00**	
Education Level	*No formal education*	22	25.30	25.30	25.30
	Primary level	27	31.00	31.00	56.30
	Metric	15	17.20	17.20	73.60
	Postmetric	17	19.50	19.50	93.10
	Graduation	6	6.90	6.90	100.00
	Total	**87**	**100.00**	**100.00**	
Years of Experience	*1–5 yrs*	9	10.30	10.30	10.30
	6–10 yrs	18	20.70	20.70	31.00
	11–20 yrs	26	29.90	29.90	60.90
	Above 20 yrs	34	39.10	39.10	100.00
	Total	**87**	**100.00**	**100.00**	

Association Between Occupation and Ethnomedicinal Knowledge Variables

To examine the strength and significance of association between occupation (farmer vs. folk healer) and various knowledge-related variables on medicinal plant use, Cramér's V test was conducted. The results are presented in Table 3.

The findings revealed that among the tested variables, only *"Form of Administration"* showed a statistically significant association with occupation, with a Cramér's V value of 0.405 and a p-value of 0.046. This indicates a moderate association, suggesting that farmers and folk healers differ significantly in their practices or knowledge regarding the form in which medicinal plants are administered (e.g., decoction, paste, juice, etc.).

Other variables such as Plant Part Used (Cramér's V = 0.257, p = 0.767), Source of Medicinal Plants (Cramér's V = 0.148, p = 0.386), *Route of Administration* (Cramér's V = 0.097, p = 0.662), Plant Availability (Cramér's V = 0.082, p = 0.746), Source of Knowledge (Cramér's V = 0.259, p = 0.211), and Plant Habit (Cramér's V = 0.221, p = 0.373) did not exhibit any statistically significant associations with occupation. These results suggest that for most of the knowledge dimensions assessed, farmers and folk healers share relatively similar levels or types of knowledge.

Table 3. Crammer V test between occupation and knowledge related questionnaire data

Nominal Association		Value	Approximate Significance
Occupation * Plant Part Used	*Phi*	0.257	0.767
	Cramer's V	0.257	0.767
	N of Valid Cases	**87**	
Occupation * Source of Medicinal Plants	*Phi*	0.148	0.386
	Cramer's V	0.148	0.386
	N of Valid Cases	**87**	
Occupation * Form of Administration	*Phi*	0.405	0.046
	Cramer's V	0.405	0.046
	N of Valid Cases	**87**	
Occupation * Route of Administration	*Phi*	0.097	0.662
	Cramer's V	0.097	0.662
	N of Valid Cases	**87**	
Occupation * Plant Availability	*Phi*	0.082	0.746
	Cramer's V	0.082	0.746
	N of Valid Cases	**87**	
Occupation * Source of Knowledge	*Phi*	0.259	0.211
	Cramer's V	0.259	0.211
	N of Valid Cases	**87**	
Occupation * Plant Habit	*Phi*	0.221	0.373
	Cramer's V	0.221	0.373
	N of Valid Cases	**87**	

Association Between Occupation and Ethnomedicinal Practice Variables

To investigate whether occupation influences practice toward the transmission and conservation of ethnomedicinal knowledge, Cramér's V test was conducted between occupation (farmer vs. folk healer) and four key attitudinal variables: *willingness to share knowledge, knowledge transfer practices, youth involvement, and conservation efforts* (Table 4).

The results indicate that none of the tested associations was statistically significant. Specifically, *Willingness to Share* showed a very weak association (Cramér's V = 0.096, p = 0.370), as did *Knowledge Transfer* (Cramér's V = 0.117, p = 0.554), *Youth Involvement* (Cramér's V = 0.092, p = 0.690), and *Conservation Practice* (Cramér's V = 0.036, p = 0.945). These findings suggest that both farmers and folk healers generally hold similar practices regarding the sharing, transmission, and preservation of traditional medicinal knowledge.

Overall, occupation does not appear to significantly influence attitudinal differences in these areas, indicating a community-wide consensus or uniformity in values related to ethnomedicinal knowledge stewardship.

Table 4. Crammer V test between occupation and attitude related questionnaire data

Nominal Association		Value	Approximate Significance
Occupation * Willingness to Share	*Phi*	-0.096	0.37
	Cramer's V	0.096	0.37
	N of Valid Cases	**87**	
Occupation * Knowledge Transfer	*Phi*	0.117	0.554
	Cramer's V	0.117	0.554
	N of Valid Cases	**87**	
Occupation * Youth Involvement	*Phi*	0.092	0.69
	Cramer's V	0.092	0.69
	N of Valid Cases	**87**	
Occupation * Conservation Practice	*Phi*	0.036	0.945
	Cramer's V	0.036	0.945
	N of Valid Cases	**87**	

Cluster Analysis of Knowledge and Practice Variables

The K-means clustering approach classified the respondents into two distinct clusters based on standardized (Z-score) values of variables related to ethnomedicinal knowledge and practices (Fig 3). The heat map of final cluster centres reveal contrasting patterns between the two groups. Cluster 1 exhibited higher Z-scores for variables such as *Source of Medicinal Plants* (0.438), *Form of Administration* (0.374), *Route of Administration* (0.699), *Knowledge Transfer To* (0.401), and *Conservation Practice* (0.108), while Cluster 2 demonstrated negative Z-scores for these same variables, suggesting differing knowledge practices and transmission patterns across the two groups.

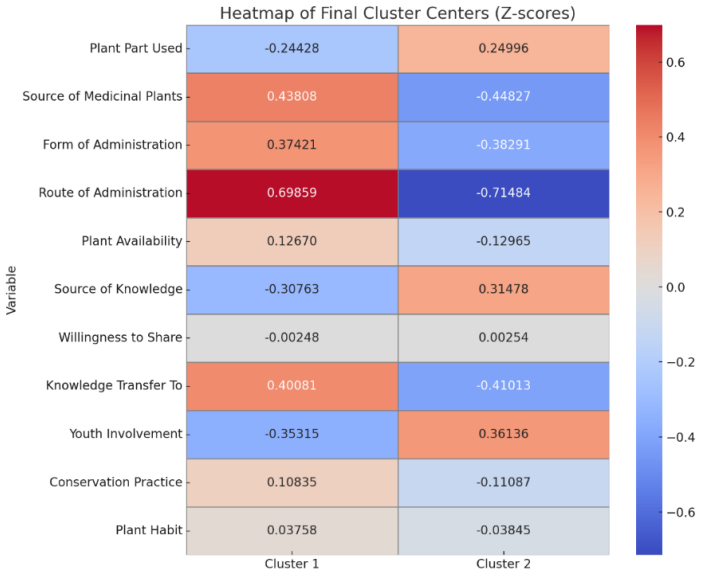


Figure 3. Heat map of final cluster center's Z-score of knowledge variables.

ANOVA results (Table 5) were used descriptively to explore the significance of differences in variable means between clusters. Statistically significant differences ($p < 0.05$) were observed for eight out of eleven variables: *Plant Part Used* ($F = 5.596$, $p = 0.020$), *Source of Medicinal Plants* ($F = 21.072$, $p < 0.001$), *Form of Administration* ($F = 14.410$, $p < 0.001$), *Route of Administration* ($F = 86.783$, $p < 0.001$), *Source of Knowledge* ($F = 9.231$, $p = 0.003$), *Knowledge Transfer To* ($F = 16.954$, $p <$

0.001), and *Youth Involvement* (F = 12.600, p = 0.001). In contrast, variables such as *Plant Availability, Willingness to Share, Conservation Practice,* and *Plant Habit* did not show statistically significant differences between the clusters (p > 0.05). Although normality assumptions were not met, ANOVA results are presented here strictly for descriptive purposes to aid interpretation of cluster characteristics, and not for inferential statistical testing.

Table 5. ANOVA results of cluster analysis

Z-score variables	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Plant Part Used	5.312	1	0.949	85	5.596	0.020
Source of Medicinal Plants	17.085	1	0.811	85	21.072	0.000
Form of Administration	12.466	1	0.865	85	14.410	0.000
Route of Administration	43.446	1	0.501	85	86.783	0.000
Plant Availability	1.429	1	0.995	85	1.436	0.234
Source of Knowledge	8.425	1	0.913	85	9.231	0.003
Willingness to Share	0.001	1	1.012	85	0.001	0.981
Knowledge Transfer	14.301	1	0.844	85	16.954	0.000
Youth Involvement	11.102	1	0.881	85	12.600	0.001
Conservation Practice	1.045	1	0.999	85	1.046	0.309
Plant Habit	0.126	1	1.010	85	0.124	0.725

The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.

Ethnobotanical Diversity of Medicinal Plants Used for Rheumatoid Arthritis

A total of 33 plant species belonging to 24 botanical families were documented in the ethnobotanical survey for the treatment of RA in the Sikkim Himalaya (Figure 4, Table 6). The most dominant families represented were Zingiberaceae (5 species), followed by Lauraceae, Fagaceae, Moraceae, Polygonaceae, and Saxifragaceae (each with 2 species). The remaining families were represented by a single species each (Figure 4).

Habit Distribution

The medicinal plant species used for RA were primarily herbs (n = 13) and trees (n = 13), making up 78.7% of all species recorded. Additionally, shrubs (n = 3), climbers (n = 3), and one parasitic herb were also used in traditional formulations (Figure 5A). Among the various plant parts employed in RA treatment, the rhizome was the most frequently used (10 species), followed by bark (8), fruit (4), whole plant (2), leaves (2), tuber (2), latex (2), and one species each using stem, flower, and root (Fig 5B).

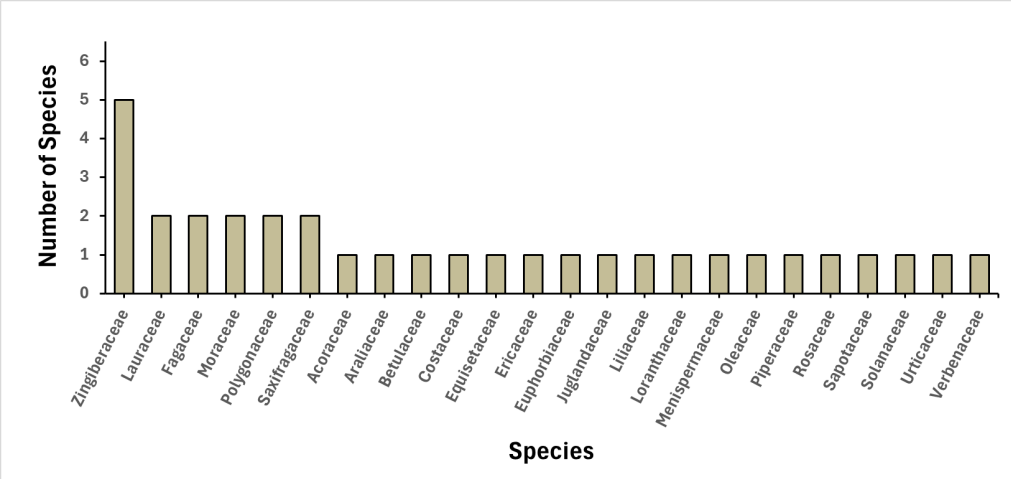
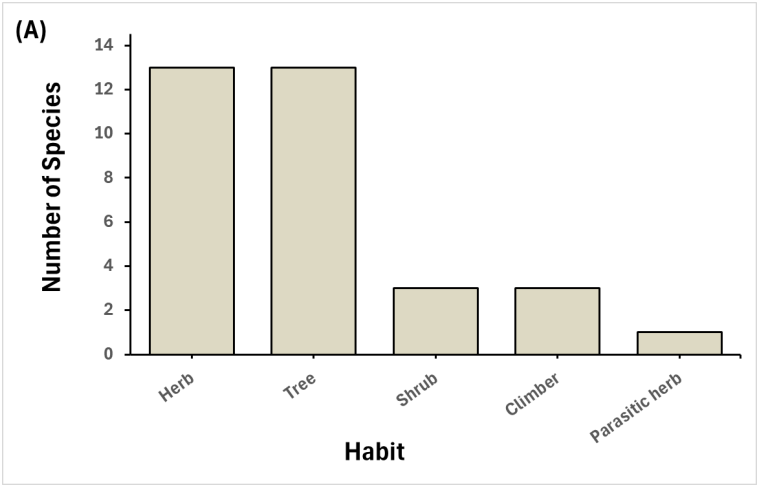


Figure 4. Family-wise use index of documented medicinal plants.

Table 6. Data obtained from ethnobotanical survey of the medicinal plants used in treatment of rheumatoid arthritis (RA) in Sikkim Himalaya

Sl No.	Family	Scientific name (Voucher No.)	Local name	Habit	Part used	Forms of Preparation Method	RFC	No. of Informants who mentioned use of species (FC)
1	Acoraceae	*Acorus calamus* L. (SUH0236)	Bojho	Herb	Rhizome	Poultice	0.091	8
2	Araliaceae	*Pentapanax leschenaultii* (DC.) Seem. (SUH0159)	Chinde	Tree	Bark	Infusion	0.046	4
3	Betulaceae	*Betula alnoides* Buch. -Ham.ex D. Don (SUH0096)	Saur	Tree	Bark	Infusion	0.091	8
4	Costaceae	*Costus speciosus* (J. Koenig) Sm. (SUH0160)	Betlauri	Herb	Stem	Infusion	0.058	5
5	Equisetaceae	*Equisetum diffusum* D. Don (SUH0094)	Salibesali	Herb	Whole plant	Infusion	0.138	12
6	Ericaceae	*Rhododendron arboreum* Sm. (SUH0235)	Laligurans	Shrub	Flower	Infusion	0.023	2
7	Euphorbiaceae	*Ricinus communis* L. (SUH0156)	Dalda	Shrub	Leaves	Paste	0.023	2
8	Fagaceae	*Quercus lamellosa* Sm. (SUH0097)	Bajranth	Tree	Bark	Infusion	0.081	7
9		*Quercus thomsoniana* A. DC. (SUH0238)	Phalath	Tree	Bark	Powder	0.023	2
10	Juglandaceae	*Juglans regia* L. (SUH0205)	Okhar	Tree	Fruit	Poultice	0.023	2
11	Lauraceae	*Litsea cubeba* (Lour.) Pers. (SUH0100)	Siltimur	Tree	Fruit	Oil	0.11	10
12		*Litsea glutinosa* (Lour.) C.B. Rob. (SUH0092)	Awley harchur	Tree	Bark	Poultice	0.092	8
13	Liliaceae	*Asparagus racemosus* Willd. (SUH0237)	Kurilo	Climber	Rhizome	Powder	0.080	7
14	Loranthaceae	*Viscum nepalense* Spreng. (SUH0149)	Harchur	Parasitic herb	Whole plant	Infusion	0.110	10
15	Menispermaceae	*Stephania glabra* (Roxb.) Miers. (SUH0098)	Tamarkey	Climber	Tuber	Powder	0.127	11
16	Moraceae	*Ficus benghalensis* L. (SUH0233)	Baral	Tree	Latex	Latex	0.023	2
17		*Morus macroura* Miq. (SUH0239)	Thulokimbu	Tree	Latex	Latex	0.023	2
18	Oleaceae	*Fraxinus floribunda* Wall. (SUH0154)	Lankhuri	Tree	Bark	Powder	0.091	8
19	Piperaceae	*Piper longum* L. (SUH0158)	Pipli	Climber	Fruit	Infusion	0.023	2
20	Polygonaceae	*Rheum australe* D. Don (SUH0151)	Khokim	Herb	Rhizome	Decoction	0.023	2
21		*Rheum nobile* Hook.f. & Thoms (SUH0152)	Kenju	Herb	Rhizome	Infusion	0.110	10
22	Rosaceae	*Prunus cerasoides* D. Don (SUH0155)	Payung	Tree	Bark	Infusion	0.023	2
23	Sapotaceae	*Diploknema butyracea* (Roxb.) H.J. Lam (SUH0203)	Chewri	Tree	Fruit	Poultice	0.023	2
24	Saxifragaceae	*Astilbe rivularis* Buch. -Ham. ex D. Don (SUH0148)	Budokhati	Herb	Rhizome	Infusion	0.103	9
25		*Bergenia ciliata* (Haw.) Sternb. (SUH0147)	Pakhanbed	Herb	Rhizome	Powder	0.110	10
26	Solanaceae	*Datura metel* L. (SUH0095)	Kalodhaturo	Shrub	Leaves	Paste	0.046	4
27	Urticaceae	*Urtica dioica* L. (SUH0153)	Ghariyasisnu	Herb	Root	Paste	0.069	6
28	Verbenaceae	*Vitex negundo* L. (SUH0093)	Sewali	Tree	Bark	Poultice	0.023	2
29	Zingiberaceae	*Curcuma angustifolia* Roxb. (SUH0234)	Haledo	Herb	Rhizome	Poultice	0.035	3
30		*Curcuma caesia* Roxb. (SUH0150)	Kalohardi	Herb	Rhizome	Poultice	0.081	7
31		*Kaempferia rotunda* L. (SUH0204)	Bhuichampa	Herb	Tuber	Paste	0.046	4
32		*Zingiber capitatum* Roxb. (SUH0157)	Jungaley aduwa	Herb	Rhizome	Infusion	0.023	2
33		*Zingiber zerumbet* (L.) Roscoe ex Sm. (SUH0099)	Phachang	Herb	Rhizome	Poultice	0.069	6



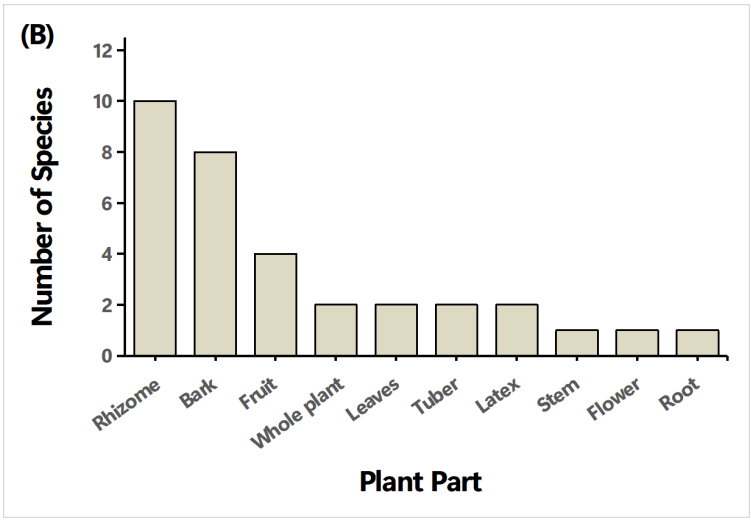


Figure 5. Medicinal Plants Used for the Treatment of Rheumatoid Arthritis in the Sikkim Himalaya: (A) Habit distribution, and (B) Plants-part utilized.

FIV (Family Importance Value)

Family Importance Value (FIV) determines the ethnomedicinal significance of medicinally important plant families. Based on FIV, Zingiberaceae (25.28 %) was observed to be the richest family, followed by Saxifragaceae (21.83 %), Lauraceae (20.68 %), Equisetaceae (13.79 %) and Menispermaceae (12.64 %). Ericaceae, Euphorbiaceae, Juglandaceae, Piperaceae, Rosaceae, Sapotaceae and Verbenaceae have the lowest family importance value, with 2.29 % (Table 7).

Traditional Preparation Methods and Therapeutic Practices

Traditional approaches for the management of rheumatoid arthritis (RA) involved a diverse range of plant-based therapies, including both single-plant remedies and complex polyherbal formulations. In addition to botanical ingredients, several non-plant components, such as honey, milk, egg yolk, and terpene oil, were incorporated to enhance therapeutic efficacy. The primary modes of preparation included decoction, infusion, paste, and poultice, which were administered either orally or applied externally to affected joints until symptomatic relief was achieved. A total of 21 widely practiced formulations were documented based on information provided by traditional healers.

Representative single-plant remedies included species such as *Stephania glabra, Litsea glutinosa*, *Equisetum diffusum*, *Acorus calamus*, and *Vitex negundo*, while additional formulations involved plant parts such as bark, rhizomes, roots, and fruits prepared through various traditional methods. Polyherbal formulations combining multiple plant species, sometimes supplemented with non-plant ingredients, were also commonly employed. Detailed information on individual species, plant parts, and modes of preparation is provided in Table 6.

Comparative analysis with existing ethnomedicinal literature revealed that 10 of the documented species are reported here for the first time for the treatment of rheumatoid arthritis (*Astilbe rivularis*, *Bergenia ciliate*, *Betula alnoides*, *Curcuma angustifolia*, *Equisetum diffusum*, *Pentapanax leschenaultii*, *Quercus lamellosa*, *Quercus thomsoniana*, *Viscum nepalense* and *Zingiber capitatum*).

Table 7. FIV (Family Importance Value) of ethnomedicinal plant Families used for RA

Sl. No	Family	No. of Species	ΣFC	FIV (%)
1.	Acoraceae	1	8	9.19
2.	Araliaceae	1	4	4.59
3.	Betulaceae	1	8	9.19
4.	Costaceae	1	5	5.74
5.	Equisetaceae	1	12	13.79
6.	Ericaceae	1	2	2.29
7.	Euphorbiaceae	1	2	2.29
8.	Fagaceae	2	9	10.34
9.	Juglandaceae	1	2	2.29
10.	Lauraceae	2	18	20.68
11.	Liliaceae	1	7	8.04
12.	Loranthaceae	1	10	11.49
13.	Menispermaceae	1	11	12.64
14.	Moraceae	2	4	4.59
15.	Oleaceae	1	8	9.19
16.	Piperaceae	1	2	2.29
17.	Polygonaceae	2	12	13.79
18.	Rosaceae	1	2	2.29
19.	Sapotaceae	1	2	2.29
20.	Saxifragaceae	2	19	21.83
21.	Solanaceae	1	4	4.59
22.	Urticaceae	1	6	6.89
23.	Verbenaceae	1	2	2.29
24.	Zingiberaceae	5	22	25.28

Some oral formulations included dry powders of *B. ciliata, A. rivularis*, and *V. nepalense,* combined with a glass of milk and 2–4 drops of honey, taken to alleviate joint pain. A decoction from the bark of *Q. lamellosa* and rhizomes of *R. australe* was also used orally (1 glass/day). A multi-ingredient infusion containing *V. nepalense,* rhizomes of *K. rotunda,* barks of *F. benghalensis, F. floribunda, P. cerasoides,* and *B. alnoides* was mixed with honey, milk, and egg yolk and administered in half-glass doses daily. Poultices made from equal quantities of *C. caesia, C. angustifolia,* and *Z. zerumbet* rhizomes were applied externally.

Other commonly used formulations included an oral infusion (as tea) prepared from the rhizome of *Z. capitatum,* bark of *P. leschenaultii,* and bark of *F. floribunda,* taken thrice daily. A unique and culturally significant practice was the creation of artificial hot springs using wooden buckets filled with hot stones and specific medicinal herbs (*V. nepalense,* barks of *F. floribunda, Q. lamellosa,* and *Q. thomsoniana*). Patients would sit in these herbal baths for 1–2 hours weekly.

Notably, certain plants such as *F. floribunda, K. rotunda, A. rivularis, Q. lamellosa,* and *V. nepalense* were frequently employed in diverse therapeutic preparations, highlighting their perceived efficacy. Remedies were typically prepared fresh prior to use. However, dry powdered ingredients could be stored for longer periods, provided they were kept in a cool, dry place away from sunlight. Traditional healers consistently reported the absence of side effects when remedies were used as prescribed. They emphasized the importance of adherence to the treatment regimen and advised patients to avoid specific foods—particularly spicy and sour items, bamboo shoots, and alcoholic beverages—during the treatment period.

Discussion

The dominance of plant families such as Zingiberaceae, Saxifragaceae, and Lauraceae in the current study may be due to well-documented anti-inflammatory and analgesic properties. Previous pharmacological investigations have shown that

members of the Zingiberaceae family, notably *Curcuma caesia*, *Zingiber zerumbet* have strong analgesic and anti-inflammatory properties due to bioactive chemicals such as gingerols, Cineole and curcumene (Sahu *et al*. 2016; Chaudhuri *et al*. 2018). Similarly, Saxifragaceae plants, such as *Bergenia ciliata*, have been traditionally utilized in Himalayan regions to treat inflammatory diseases (Singh *et al*. 2017) and have demonstrated significant pharmacological effectiveness (Ahmad *et al.* 2018). Lauraceae members, including *Litsea cubeba* and *Litsea glutinosa*, contain essential oils and phenolic compounds that contribute to their anti-inflammatory and pain-relieving properties (Tejaswi *et al*. 2010; Kamle *et al*. 2019). These findings support ethnomedicinal importance of these families observed in the present study. The frequent use of herbs and rhizomatous species may be linked to their higher concentration of bioactive secondary metabolites and ease of harvest, while the reliance on bark in tree species likely reflects traditional beliefs regarding potency and sustained therapeutic action. The use of rhizomes has been reported in RA-focused ethnomedicinal studies from other Indian regions (Kaur *et al*. 2012; Chandrasekar and Chandrasekar 2017), indicating convergence of traditional knowledge systems.

Traditional ethnomedicinal knowledge related to rheumatoid arthritis in Sikkim is deeply rooted within local communities and is primarily transmitted orally across generations. Despite a generally positive attitude toward conservation and knowledge sharing among informants, active participation from younger generations remains limited, posing a risk of cultural erosion. This gap may be attributed to increasing modernization and changing healthcare preferences. Additionally, the predominance of male informants reflects prevailing socio-cultural norms, where traditional healing knowledge is largely retained by male elders and folk healers. However, the underrepresentation of female informants suggests that gender-specific knowledge may remain underexplored and warrants further investigation. Certain species, such as *Equisetum diffusum* (RFC = 0.138), were frequently cited, indicating their significance in the management of rheumatoid arthritis. A large proportion of the documented plants, including *Acorus calamus*, *Asparagus racemosus*, *Costus speciosus*, *Curcuma caesia*, and *Vitex negundo*, have also been reported in previous ethnomedicinal and pharmacological studies (see Supplementary Table S1). Comparative analysis with existing literature revealed that 10 plant species are reported here for the first time for their use in rheumatoid arthritis treatment. This novel documentation may be attributed to the geographical uniqueness and ethnic diversity of the study area, which have fostered localized ethnomedicinal knowledge systems. Comparative analysis with previous rheumatoid arthritis–focused ethnomedicinal studies from India (e.g., Rathore *et al*. 2007; Swamy & Reddi 2016) and ethnobotanical investigations from the Himalayan region, including Sikkim, Darjeeling Himalaya, Nepal, and Bhutan (Singh *et al*. 2002; Tamang *et al*. 2017), indicates that 10 of the documented species have not been previously reported for RA treatment. While some of these plants are known for other therapeutic or general anti-inflammatory uses, their specific application in RA management appears to be unique to the traditional healthcare practices of the Sikkim Himalaya.

Most plants reported in this study are supported by a literature review of existing laboratory findings with *in vitro* and *in vivo* pharmacological studies (Table S1). Various plants accounted in this study have been reported by various investigators as having significant anti-arthritic and anti-inflammatory activities (*C. speciosus*, *F. benghalensis*, *L cubeba*, *P. longum*, *U. dioica*, *V. negunda, A. calamus*, *A. racemosus*, *B. alnoides*, *L. glutinosa*, *J. regia*, *C. angustifolia*, *C. caesia*, *D. metel*, *M. macroura*, *P. cerasoides*, *R. australe*, *R. nobile*, *R. arboreum*, *R. communis*, *V. nepalense*, *S. glabra* and *Z. zerumbet*) on different *in vitro* and *in vivo* tests (Table S1) (Matcha *et al*. 2013; Sahu *et al*. 2016; Kuttan *et al*. 2017; Sharma *et al*. 2018). On the other hand, *D. butyracea* has not been investigated on its antiarthritic and anti-inflammatory activities although reported to be used in traditional medicine for treating rheumatism (Table S1) (Khanka *et al*. 2009).

The collected data indicate that traditional healers utilized various parts of medicinal plants in the preparation of remedies for RA. Among these, rhizomes and barks were the most frequently employed components. However, reliance on these specific plant parts raises concerns regarding biodiversity, as their repeated harvesting can contribute to ecological degradation and threaten the survival of certain rare and endemic plant species (Kala 2005). Recognizing these environmental implications, many folk healers have adopted more sustainable practices. For instance, they often cultivate essential medicinal plants near their homes, reflecting an awareness within the ethnic community of the importance of conservation and the sustainable utilization of ethnobotanical resources. Unlike studies in which herbal remedies are administered exclusively through oral routes for the treatment of chronic joint pain (Wambugu *et al*. 2011), the respondents in the present study indicated the prescriptions mainly applied topically over damaged joints. In addition to topical applications, certain folk healers also prescribed oral administration of their herbal remedies. The treatment duration was typically prolonged or continued until noticeable recovery, which is likely attributed to the chronic nature of rheumatoid arthritis. Since RA is not entirely curable, the primary aim of treatment is to alleviate symptoms and slow disease progression (Bullock *et al*. 2018).

The treatment of joint pain and rheumatoid arthritis often involves the use of complex herbal preparations, comprising various plant species, their distinct parts, and diverse preparation techniques (Park *et al*. 2007; Wambugu *et al*. 2011). Such polyherbal formulations may exert broader therapeutic effects through additive or synergistic interactions, offering a promising approach for developing effective, safe, and affordable plant-based therapies on a global scale (Yuan *et al*. 2017). While numerous traditional herbal products have already been commercialized and approved as phytopharmaceuticals (Yuan *et al*. 2016), significant concerns remain regarding the lack of standardized protocols, insufficient safety measures, poor quality control, and instances of adulteration with conventional drugs (Karunamoorthi *et al*. 2013). Therefore, comprehensive scientific validation of phytochemicals, including assessments of their efficacy, safety, and toxicity, is strongly advocated (Sen & Chakraborty 2017).

These findings reveal a robust and culturally rooted knowledge system regarding the use of medicinal plants in the region, particularly those targeting chronic inflammatory conditions such as rheumatoid arthritis. The prominence of herbs and rhizomatous species may reflect both ecological availability and traditional efficacy associated with anti-inflammatory properties.

Conclusion

The present study records 33 medicinal plant species from 24 families using primary field surveys, offering the first thorough ethnomedical documentation of plant-based remedies for rheumatoid arthritis (RA) in the Sikkim Himalaya. Notably, the usage of ten species in RA management has been documented for the first time, demonstrating the diversity and depth of indigenous ethnomedical knowledge. Treatment methods influenced by ecological availability and long-standing traditional experience are reflected in the prevalence of herbs and trees, frequent use of rhizomes and bark, and preference for both topical and oral formulations. The high degree of agreement across informants suggests that these treatments are still useful for treating chronic inflammatory diseases.

The study also faced a number of obstacles, such as challenging terrain, the isolation of high-altitude settlements, and knowledge holders' sporadic unwillingness to share customs, all of which could have affected the volume of data collected. Notwithstanding these limitations, the results offer crucial baseline data on the region's use of medicinal plants for RA. Through methodical recording, sustainable harvesting methods, and community involvement, the project emphasises the necessity of conserving medicinal plant resources and maintaining indigenous knowledge systems. Additionally, future research investigating the medicinal potential of these species through pharmacological and phytochemical analyses may use the described species as a reference. A greater understanding of plant-based methods for treating rheumatoid arthritis may result from combining traditional knowledge with modern research.

Declarations

List of abbreviations: TSM - Traditional System of Medicines; WHO - World Health Organization; TK - Traditional Knowledge; NSAIDs - Non-steroidal anti-inflammatory drugs; DMARDs - Disease modifying anti-rheumatic drugs; RFC - Relative Frequency of Citation

Ethics approval and consent to participate: Before initiating data collection, all participants were clearly informed about the objectives of the study and provided their informed consent to participate. Ethical standards were diligently followed, with explicit permission obtained prior to conducting interviews and recording observations. To maintain confidentiality, all participant contributions were anonymized. Furthermore, the study adhered to the principles of the Nagoya Protocol, ensuring the fair and equitable sharing of benefits arising from the documentation and potential utilization of traditional knowledge. Formal institutional ethical clearance with a protocol number was not required for this non-invasive ethnobotanical interview-based study. However, prior informed consent was obtained from all participants, confidentiality and anonymity were ensured, and the study complied with the principles of the Nagoya Protocol on access and benefit-sharing.

Consent for publication: All authors agreed for submission.

Availability of data and materials: All the information gathered for this research was examined, interpreted, and incorporated into this research.

Competing interests: The authors declare that they have no conflict of interest.

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wrote the protocol, supervised the project, performed the final data interpretation, and wrote the manuscript. All authors read and approved the final manuscript.

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Ethnobotanical Survey of Medicinal Plants Used for Rheumatoid Arthritis Treatment in the Sikkim Himalaya, India

Supplementary information

Table S1: Plant species collected from Sikkim Himalaya based on traditional knowledge on their use in treating RA and cross reference in published literature on their ethnopharmacological uses.

Botanical name and Family	Biological activity/phytoconstituents	Ethnomedicinal uses
Acorus calamus (Acoraceae)	Plant is rich in alpha and beta asarones which is responsible for its therapeutic potential including anti-inflammatory, immunosuppressive, anti-adipogenic, antimicrobial, fungicidal, antidiabetic, neuroprotective, wound healing, mitogenic, insecticidal, anthelmintic, allelopathic, antiepileptic, antispasmodic activities and inhibitor of acetyl cholinesterase (Devi *et al*. 2014).	Rhizomes paste is topically applied to reduce the pains and swelling in rheumatic condition (Imam *et al*. 2013), used as analgesic, antipyretic, tonic, anti-obesity, and healing purposes and to treat skin diseases, neurological, gastrointestinal, respiratory, cold, cough, and fever (Sharma *et al*. 2020), used in the treatment of Jaundice and dental problems (Mukherjee *et al*. 2007).
Asparagus racemosus (Liliaceae)	Antioxidant, anti-inflammatory, antiseptic and antimicrobial activity; steroidal saponins (Selvaraj *et al*. 2019) antiulcer, antioxidant, antidiarrhoeal, antidiabetic, anticancer and immunomodulatory properties; steroidal saponins (Sarasasapogenin, Shatavarins I-IV) (Shaha & Bellankimath 2017).	Roots are used in the treatment of nervous disorders, dyspepsia, diarrhoea, dysentery, tumors, inflammations, hyperdipsia, neuropathy, hepatopathy, cough, bronchitis and hyperacidity (Chawla *et al*. 2011), used to treat rheumatism in Thailand (Potduang *et al*. 2010).
Astilbe rivularis (Saxifragaceae)	Antimicrobial, anti-peptic ulcer, anti-in compounds demonstrated various biological activities including antimicrobial, anti-peptic ulcer, anti-inflammatory and antioxidant activity; aesculetin, astilbic acid, astilbin, aticoside, dimethylaesculetin, daucosterol, eucryphin, palmitine, peltoboykinoleic acid, scopoletin, sitosterol stilbenes, arbutin and bergenin (Timalsena & Lamichhane 2019).	Root is used against diarrhea, dysentery, prolapse of the uterus and hemorrhage, rhizome is used to treat bone fracture, body ache and menstrual disorder (Rajbhandari *et al*. 2011).
Bergenia ciliata (Saxifragaceae)	Antioxidant, antimicrobial, anti-inflammatory, anti-tussive, anti-ulcer and anti-neoplastic activities; phenols, alcohols, terpenoids and fatty acid *(Ahmad et al. 2018)*	Used for dissolution of kidney and gall bladder stones, heart disease, haemorrhoids, stomach disorders and ophthalmia and in Sikkim Himalaya it is used to treat bone fractures, fresh cuts, wounds, diarrhea, pulmonary infections, vomiting, fever, cough and boils (Singh *et al*. 2017).
Betula alnoides (Betulaceae)	Anti-inflammatory activity (Sur *et al*. 2002), antioxidant, antimicrobial and antidiabetic activity (Ghimire *et al*. 2012), anti-HIV and anti-inflammatory activity; Betulinic acid, betulin, Lupeol, Oleanolic acid and Ursolic acid (Chaniad *et al*. 2019). Isolated compounds include arbutin (Thongchai *et al*. 2007).	Bark is used to treat minor bone fracture, dislocation of bone, sore throat and menstrual problem (Rastogi *et al*. 2015).

Costus speciosus (Costaceae)	Antioxidant, anticancer, anti-inflammatory, antidiabetic, hypolipidemic, hepatoprotective, steroidogenic, adaptogenic, and antimicrobial activities; β-amyrin, camphene, costunolide,diosgenin, α-Humulene, lupeol, and zerumbone(El-Far *et al*. 2018), anti-arthritic (Srivastava *et al*. 2012).	Used to treat fever, headache, pneumonia, rheumatism, dropsy, urinary diseases, jaundice, dysentery, cough, dyspepsia, skin diseases, mental disorders, snakebite, rheumatism and bronchial asthma (Shruti Srivastava *et al.* 2011).
Curcuma angustifolia (Zingiberaceae)	Antioxidant, anti-inflammatory, anticancer, antidiabetic, antiproliferative, anti-ulcerogenic and antimicrobial activities; alkaloids, flavonoids, terpenoids, phenols, tannins, saponins, curcumin, steroids, glycosides, and oils (Sharma *et al*. 2019).	Used to treat leprosy, burning sensations, dyspepsia, loss of taste, bronchitis, asthma, fever, thirst, jaundice, anaemia, leucoderma, stones in the kidney and bladder, urinary discharges, ulcers and blood diseases (Sushma *et al*. 2015).
Curcuma caesia (Zingiberaceae)	Analgesic, anti-fungal, antioxidant, smooth muscle relaxant and anti-asthmatic, anti-depressant and hypnotic, anti-Inflammatory, antiemetic and anti-ulcerogenic activities along with neuropharmacological activity, locomotor depressant, anticonvulsant and muscle relaxant effects (Sahu *et al*. 2016). Isolated compounds include 1,8-Cineole, camphor, ar-curcumene, ar-turmerone, (Z)-β-ocimene, α-curcumene, 1,8-cineole and camphene (Dosoky & Setzer 2018).	Rhizomes were used to treat piles, leprosy asthma, cancer, wounds, impotency, fertility, tooth ache, vomiting, allergies, diarrhea, stomachache, rheumatic arthritis, cough, fever, dysentery, worm infection, cancer, epilepsy, snake and insects bite, anti-helmenthic, aphrodisiac and gonorrhoreal discharge (Das *et al*. 2013).
Datura metel (Solanaceae)	Hypoglycemic, antifungal and antioxidant activities; pterodontriol B, disciferitriol, scopolamine, adenosine, thymidine, ilekudinoside C and dioscoroside (Mai *et al*. 2017), anti-inflammatory activity (Matcha *et al*. 2013).	Coughs, bronchial asthma, and rheumatism, skin diseases, piles, fever and diarrhea Monira & Munan 2012).
Diploknema butyracea (Sapotaceae)	Anti-fungal activity; triterpenic saponins (Saha *et al*. 2010).	Barks of tree is used to treat rheumatism, ulcers, itching, hemorrhage, tonsillitis, leprosy and diabetes (Khanka *et al*. 2009).
Equisetum diffusum (Equisetaceae)	Antimicrobial activity (Van *et al*. 2019), isolated compounds include sammangaoside A, kaempferol 3-*O*-sophoroside, L-tryptophan and (3*S*,5*R*,6*S*,7*E*,9*S*)-megastigman-7-ene-5,6-epoxy-3,9-diol3-*O*-β-D-glucopyranoside (Kanchanapoom *et al*. 2007).	Plant powder with mustard oil is used to treat stomach disorders, bone fracture, back ache and muscular pain, decoction of rhizome is used to facilitate fertilization by barren women (Singh & Sinku 2015), bone fracture, kidney trouble (Singh & Upadhyay 2014), in Sikkim Himalaya it is used for treating chest complaints, liver problems, mouth sores, indigestion, kidney stone and dog bite (Panda 2012).
Ficus benghalensis (Moraceae)	Antidiabetic activity (Sharma *et al*. 2007; Edwin *et al*. 2008; Gayathri & Kannabiran 2009; Singh *et al*. 2009), antihyperlipidemic and hypocholesterolemic activity (Shukla *et al*. 2004), anti-inflammatory activity (Wanjari *et al*. 2011; Kothapalli *et al*. 2014), analgesic (Thakare *et al*. 2010), antimicrobial (Alimuddin *et al*. 2010), anti-diarrhoeal activity (Mukherjee *et al*. 1998), antimutagenic and antioxidant activity (Satish *et al*. 2013),	Infusion of the bark is used in dysentery, diabetes, seminal weakness, menorrhagia, leucorrhoea, erysipelas, nervous disorders and burning sensation. Buds' decoction in milk is given in hemorrhages. Aerial roots are antiemetic and also applied topically to pimples. A paste of the leaves or milky juice is applied topically to abscesses and wounds for promoting suppuration. Milky juice and seeds are applied topically to ulcers, sores and rheumatic inflammations (Khaliq 2017).

	hepatoprotective activity (Parameswari *et al*. 2012), anti-arthritic activity (Thite *et al*. 2014), immunostimulatory activity (Verma *et al*. 2012), wound healing potential (Murti *et al*. 2011), Action against inflammatory bowel disease (Patel *et al*. 2010). Phytoconstituents include ketones, flavonols and flavonoids, terpenoids, coumarins, esters, carbohydrates, serine protease (Ahmad *et al*. 2011).	
Fraxinus floribunda (Oleaceae)	Antioxidant activity (Arunika & Palash 2015), anti-inflammatory and hepatoprotective activity (Subba *et al.* 2017), antidiabetic activity (Subba *et al*. 2019), anti-inflammatory and anti-nociceptive activities (Lingadurai *et al*. 2007). Isolated compounds include coumarins, secoiridoids, phenylethanoids, flavonoids, and lignans Kostova & Iossifova 2007).	Traditionally used for the treatment of bone fracture, dislocation of bone and other inflammatory diseases (Gurung 2002; Lingadurai *et al*. 2007).
Juglans regia (Juglandaceae)	Antioxidant, anti-diabetic, lipid-lowering, anti-hypertensive, antimicrobial, liver and kidney protective and anticancer activities; epicatechin, syringetin-o-hexoside, myricetin-3-o-glucoside, myricetin-3-o-pantocid, aesculetin, taxifolin-pantocid, quercetin glucuronide, kaempferol pantocid, and kaempferol rhamnoside (Delaviz *et al*. 2017), anti-inflammatory activity (Erdemoglu *et al*. 2003).	Traditionally roots is used to treat diabetes, its leaves are used to treat rheumatic pains, fever, diabetes, skin diseases and its flowers are used to treat malaria and rheumatic pain (Delaviz *et al*. 2017). In Nepal, the bark paste is used to treat arthritis, skin diseases, toothache and to promote hair growth, seed coat is used for healing wounds (Kunwar & Adhikari 2005). Fruit shell is used to treat malaria in Calabria folk medicine (Tagarelli *et al*. 2010).
Kaempferia rotunda (Zingiberaceae)	Antimicrobial activity (Pratiwi *et al*. 2015), antioxidant activity (Lotulung *et al*. 2008), anti-allergic activity (Madaka & Tewtrakul, 2011), anti-cancer activity and isolated compunds includes- 5-hydroxy-7-methoxyflavanone, 7-hydroxy-5-methoxyflavanone and 5,7- dihydroxyflavanone (Atun & Arianingrum 2013), anti-androgenic activity (Suphrom *et al*. 2017), antihyperglycemic and antinociceptive activities (Sultana *et al*, 2012).	It is used to treat abdominal illness, including dysentery and diarrhoea (Woerdenbag *et al*. 2004), used for gastropathy, inflammations, wounds, ulcers, blood clots, tumours, cancerous swellings (Mustafaanand 2014).
Litsea cubeba (Lauraceae)	Anticancer, anti-inflammatory, antioxidant activity and antimicrobial activity; compounds include alkaloids, monoterpenes, sesquiterpenes, diterpenes, flavonoids, amides, lignans, steroids, and fatty acids (Kamle *et al*. 2019), anti-arthritic activity (Lin *et al*. 2013).	It is traditionally used for curing various gastro-intestinal ailments along with diabetes, edema, cold, arthritis, asthma, and traumatic injury (Kamle *et al*. 2019).

Litsea glutinosa (Lauraceae)	Antimicrobial activity (Hosamath 2011), antioxidant, anti-inflammatory and wound healing activity (Devi & Meera 2010), analgesic activity (Tejaswi *et al*. 2010). Isolated compounds include (E)-p-ocimene, o-pinene, caryophyllene, bicyclogermacrene, germacrene D, etc (Hien *et al*. 2010).	The bark is used to relieve pain, arouse sexual power, produce a soothing effect on the body and arrest bleeding (Ramana & Raju 2017), bark decoction is used as a remedy for diarrhea, dysentery, rheumatism, and as an aid to longevity and in addition, a paste of bark is used as a plaster for sprain, bruises, wounds, inflammation, back pain, rheumatic and gouty joints and bone fractures (Jain *et al*. 2017).
Morus macroura (Moraceae)	Antibacterial activity; 2,4-dihydroxy-3,6-dimethyl-benzoate, norarto-carpanone, moracins B & M, muberroside C, mulberrofuran K (Jasmansyah *et al*. 2019), antigastric ulcer activity; Cinnamic acid derivatives, chlorogenic acid (Farrag *et al*. 2017), antimicrobial activity of endophytic fungi from stem of *Morus macroura* (Handayani *et al*. 2020), antioxidant and anti-inflammatory activity (Dai *et al*. 2004).	Its root barks are used to treat diabetes, arthritis and rheumatism in Chinese herbal medicine (Sun *et al*. 2001).
Pentapanax leschenaultii (Araliaceae)	Spermicidal activity; triterpenoid glucosides (Pant *et al*. 1988).	Tender leaves are edible used as vegetables (Uprety *et al*. 2016).
Piper longum (Piperaceae)	Antitumor activity (Bezerra *et al*. 2006), anti-diabetic activity (Nabi *et al*. 2013), hepatoprotective activity (Gurumurthy *et al*. 2012), antimicrobial (Singh & Rai 2013), anti-inflammatory and anti-arthritic activity; piperine (Yende *et al*. 2010), antioxidant activity (Natarajan *et al*. 2006), antidepressant activity (Lee *et al*. 2008), Cardioprotective activity (Chauhan *et al*. 2010); piperine, piperlongumine, sylvatin, sesamin, diaeudesmin piperlonguminine, pipermonaline, and piperundecalidine (Khushbu *et al*. 2011).	Fruits are used as a stomachic, liver tonic, aboartifacient, pungent, aphrodiasic, stomachic, laxative, anti-diarrhoeal, anti-dysenteric, anti-asthmatic, antibronchitis, abdominal complaints, in urinary discharges, tumours, diseases of the spleen, pains, inflammation, leprosy, insomnia, jaundice, and hiccoughs. The roasted fruits are grounded with honey and given to treat rheumatism, decoction of dried young fruits and root are used to treat acute and chronic bronchitis (Gani *et al*. 2019).
Prunus cerasoides (Rosaceae)	Antimicrobial activity (Arora & Mahajan 2018), antioxidant activity (Joseph *et al*. 2016), benign prostatic hyperplasia (BPH) protective activity (Jena *et al*. 2016), cytotoxic activity (Ahmed *et al*. 2012), anti-inflammatory activity (Sharma *et al*. 2018). Isolated compounds include dihydrotectochrysin, pinocembrin, dihydrowogonin, chrysin, naringenin, kaempferol (Cronenberger 1959), genistein, prunetin, n-pentacosane, triacontane, noctacosanol, β-sitosterol, ursolic acid, oleic, palmitic and stearic acids, afzelin, kaempteritrin, naringenin, β-sitosterol-β-D-glucoside, padmakastein and its derivatives, β-sitosterol behenate, tectochrysin, genistein, leucocynidin, 4´-glucoside of genkwanin, chrysophenol, emodin, 8-β-D glucosides, orientalone,	Bark paste is used to treat bone fracture, burn, indigestion, fever, foot and mouth diseases, dislocations of bone and wound, bark juice is topically applied to backaches. The stems and branches are used for the treatment of gravel, kidney stones, asthma, thirst, leucoderma, leprosy and vomiting. Decoction of stem is applied to cure joint pains. Seeds are chewed to cure kidney stone, bleeding disorders, burning sensation and skin diseases. In China and Malaya peach kernel are used to treat cough, blood diseases and rheumatism (Joseph *et al*. 2018).

	physcion, β- sitosterol glucoside (Jangwan *et al*. 1989), prunol (Ali & Shaheen 2013),	
Quercus lamellosa (Fagaceae)	Antioxidant activity (Subba & Rai 2018).	Bark powder is used as astringent (Chhetri 2005).
Quercus thomsoniana (Fagaceae)	No previous report	Not reported
Rheum australe (Polygonaceae)	Anticancer activity (Rajkumar *et al*. 2010), antidiabetic activity (Radhika *et al*. 2005), antifungal and antimicrobial activity (Aqil & Ahmad 2003), anti-inflammatory activity (Chauhan *et al*. 1992), antioxidant activity (Krenn *et al*. 2003), hepatoprotective activity (Ibrahim *et al*. 2008), immuno-enhancing activity (Kounsar *et al*. 2011), nephroprotective activity (Alam *et al*. 2005). Isolated compounds include aloe-emodin, chrysophanol, emodin, physcion, rhein, (piceatannol, resveratrol, etc, (Rokaya *et al*. 2012).	Rhizomes are used to treat asthma, body pain, boils, bone ache, cold and cough, constipation, cuts and wounds, dysentery, flatulence, headache, joint pain, skin diseases, internal injury, external injury, stomachache, tonsillitis (Pandith *et al*. 2018).
Rheum nobile (Polygonaceae)	Antibacterial, anti-CNS depressant, analgesic, cytotoxic, anti-inflammatory, hypoglycemic and antifertility activities; anthraquinones, coumarins, flavonoids, reducing compounds, tannins, steroids, terpenoids and polyphenols (Gupta *et al*. 2018), antioxidant activity; naphthalene glycosides, stilbene glycosides, flavonols, and anthraquinones (Fei *et al*. 2017).	Rhizomes are used as an astringent, carminative, depurative, diuretic, purgative and tonic (Chopra *et al*. 1956). In Nepal it is traditionally used to treat bone fractures, body ache, stomachache, menstrual problems (Ghimire *et al*. 2008). In folk medicine system of Sikkim, infusion of roots or rhizomes are used to treat rheumatic arthritis, heart complaints and used as tonic after delivery (Maity *et al*. 2004), rhizome is used to treat food poisoning, piles, dysentery (Mandal *et al*. 2013).
Rhododendron arboreum (Ericaceae)	Antidiabetic, adaptogenic, antidiarrhoeal, anti-inflammatory, antinociceptive, antioxidant, anticancer, cardioprotective, hepatoprotective, immunomodulatory, and antimicrobial activities, hypolipidemic effect; phenolics, triterpenoid, flavonols, flavonol glycosides and sterols (Madhvi *et al*. 2019).	Used to treat heart diseases, dysentery, diarrhea, detoxification, inflammation, fever, constipation, bronchitis and asthma (Nisar *et al*. 2013), nose bleeding, diabetes and rheumatism (Krishna *et al*. 2014). Used to treat blood dysentery (Sharma *et al*. 2010), flower juice helps to treat fish bones stuck in the throat (Tiwari & Chauhan 2006).
Ricinus communis (Euphorbiaceae)	Antioxidant, antihistamic, antinociceptive, antiasthmatic, antiulcer, immunomodulatory, antidiabetic, hepatoprotective, antifertility, anti-inflammatory, antimicrobial, central nervous system stimulant, lipolytic, wound healing, insecticidal and larvicidal activities; flavonoids, saponins, glycosides, alkaloids and steroids (Jena & Gupta 2012).	Traditionally used to treat abdominal disorders, arthritis, backache, muscle aches, bilharziasis, chronic backache and sciatica, chronic headache, constipation, expulsion of placenta, gallbladder pain, period pain, menstrual cramps, rheumatism, sleeplessness, and insomnia (Khan Marwat *et al*. 2017).
Stephania glabra (Menispermaceae)	anti-psychotic, anti-diabetic, antipyretic, analgesic, anti-inflammatory, antitumour, antimicrobial, anti-hypertensive, anti-allergic, anthelmintic activities; isolated compounds include tetrahydropalmatine, gindaricine, palmatine, cycleanine, columbamine, jatrorrhizine, magnoflorine, stepharanine,	Traditionally tuber is used to treat asthma, diabetes, cancer, intestinal troubles, tuberculosis, dysentery, sleep disturbances, psycho-disorders, inflammation and fever in many Asian countries (Semwal *et al*. 2015), common fever, filariasis, malaria, pneumonia and typhoid in various parts of India (Singh & Ali 1994), it is used as an anti-dysenteric, antipyretic, anti-asthmatic, anti-tubercular and anti-diabetic agent in India (Semwal *et al*. 2007). In Bangladesh,

	dehydrocorydalmine, pronuciferine, corydalmine, stepholidine, roemerine, palmatrubine, n-desmethylcycleanine, 40,5,7-Trihydroxy-8-C-glucosylisoflavone, 8-(40-Methoxybenzyl)-xylopinine capaurine, corynoxidine, glabradine, gindarudine, 11-hydroxypalmatine, cepharamine, tuduranine, etc. (Semwal & Semwal 2015).	it is also used to treat diabetes, oedema, pain, stomach disorders, helminthiasis, malaria, hepatitis, tuberculosis and hypertension (Jahan *et al*. 2010).
Urtica dioica (Urticaceae)	Antibacterial, antioxidant, analgesic, anti-inflammatory, antiarthritic, analgesic, antidiabetic, hepatoprotective, antiviral, anti-colitis, anthelmintic, immunomodulatory, anticancer, anti-hyperlipidemic, and ant Alzheimer activities; kaempferol, isorhamnetin, quercetin, isoquercitrin, astragalin, rutin (Joshi *et al*. 2014).	Traditionally it is used to treat nephritis, haematuria, jaundice, menorrhagia, arthritis and rheumatism (Asgarpanah & Mohajerani 2012; Joshi *et al*. 2014).
Viscum nepalense (Loranthaceae)	Antioxidant activity; alkaloids, flavonoids, tannins, saponins, sterols, cardiac glycosides, reducing compounds (Murali *et al*. 2011), antitumor and anti-inflammatory activity (Kuttan *et al*. 2017).	It is used as vasodilating, sedative, diuretic and anticancer agent (Jamba & Kumar 2018), it is also used to cure swellings and fractured bone and dislocation (Mukhai *et al*. 2013; Shende *et al*. 2018).
Vitex negundo (Verbenaceae)	Antimicrobial, anti-inflammatory, analgesic, antioxidant, enzyme inhibitory, anticancer, Anticonvulsant, hepatoprotective, drug potentiating, reproductive potential, insecticidal and larvicidal activities; nishindaside, mussaenosidic acids, vitedoin, negundin and vitexin (Basri *et al*. 2014), anti-arthritic and immunostimulatory activities; Phenols, saponins, flavonoids, Phytosterols (Audipudi *et al*. 2014).]	Used to treat eye disease, inflammation, leucoderma, enlargement of the spleen, bronchitis, asthma, biliousness, teeth problems, snake bite, otalgia, arthritis, dyspepsia, colic, rheumatism, leprosy, verminosis, flatulence, dysentery, urinary disorders, wounds, ulcers, bronchitis, cough, malarial fever, haemorrhoids, dysmenorrhoea, leprosy, skin diseases, diarrhoea, cholera, fever, haemorrhages, hepatopathy and cardiac disorders (Venkateswarlu 2012).
Zingiber capitatum (Zingiberaceae)	Antioxidant and antimicrobial activity; alkaloid, cardiac glycoside, tannin, saponin and carbohydrates (Jena *et al*. 2011).	It is used for skin care and as antiseptic (Joshi 2011), asthma (Anjaneyulu & Sudarsanam 2013).
Zingiber zerumbet (Zingiberaceae)	*Anti-inflammatory activity, antioxidant and cytotoxic activity, antimicrobial activity, anticancer activity, antiplatelet activity, antiulcer activity and anthelmintic activity; flavonoids (*afzelin, flavonoid glycosides, essential oils, chlorgenic acid, ferulic acid, curcumin*),* alkaloids (camphene camphor) and monoterpenoids (gigerol, zingeberol, zingerone), sesquiterpenoids including zerumbone and zerumbone epoxide, oxalic acid, kaempferol derivatives (Chaudhuri *et al*. 2018).	Traditionally rhizomes are used to treat stomach pains, diarrhea, inflammation, flatulence, fever, poisoning, allergies, bacterial infections, toothache, infections of ear and additionally in form of herbal tea for treating stomach disease, leaves are used in joint inflammation and pain (Koga *et al*. 2016).