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RESEARCH ARTICLE

Documentation of Wild Edible Plants (WEPs) Consumption in North-Western Himalayas: The Untapped Genetic Resources for Ensuring Nutritional Security

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Abstract

The North-Western Himalayan region (NWHR) spread across Jammu & Kashmir, Himachal Pradesh, and Uttarakhand is a complex physiographical region consisting of glacier mountains, cold deserts, hot springs, and dense forests with unique biodiversity. The region is characterized by extreme weather, intense UV radiation, and low oxygen partial pressures limiting agriculture. Local communities have adapted to these conditions by relying on wild edible plants (WEPs) such as tubers, fruits, berries, and green leafy vegetables (GLVs) for nutrition and livelihood. However, in recent years, the consumption of WEPs and associated indigenous knowledge has been rapidly declining due to the adaptation of Western lifestyles and processed foods. In this context, the present work was taken up to survey and document various WEPs consumed in the NWHR. Nearly, 100 WEPs were recorded and are consumed in the form of curries, soups, sauces, cordials, and pickles. These WEPs contain myriad bioactive molecules such as carotenoids, phenolic acids, flavonoids, anthocyanins, anthraquinones, and terpenoids with therapeutic applications correlating to their traditional medicinal use. Some common uses of WEPs are against inflammation, gastro-intestinal disorders, infection, and hepatoprotection. The study emphasizes the importance of conserving and promoting WEPs for food security and potential therapeutic applications.

Keyboards: Wild edible plants, Bioactive molecules, Nutraceuticals, Phytopharmaceuticals, Value-added products.

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Introduction

Nearly 90% of the calories in the human diet come from a few plant species, such as rice, wheat, maize, sugarcane, and potatoes, with cereals contributing to about 60% of the diet. These crops are water-intensive, have a high environmental footprint, and are vulnerable to environmental fluctuations and diseases (Dwyer *et al.,* 2022). Overreliance on these crops poses a significant threat to global nutritional security in the long run. With the global population expected to reach 9.7 billion by 2050, there is an urgent need to identify alternative crops to ensure nutritional security (Wijerathna-Yapa and Pathirana, 2022). Wild edible plants (WEPs) play a crucial role in meeting global dietary requirements. WEPs are indigenous species that grow and reproduce naturally in their habitats without human intervention or cultivation (Motti, 2022). They include green leafy vegetables (GLVs), fruits, nuts, berries, and tubers gathered from surrounding ecosystems. While 30,000 edible plants have been identified worldwide, only 7,000 species are consistently collected and consumed (Bacchetta *et al.,* 2016). WEPs are nutrient-dense and contain a wide range of bioactive molecules such as polyphenols, terpenoids, fatty acids, carotenoids, and alkaloids with myriad health benefits (Ray *et al.,* 2020). They have been shown to help in recovering from malnutrition, including iron deficiency anemia and protein deficiency in rural communities (Knez *et al.,* 2023). Additionally, WEPs exhibit great genetic diversity, resilience to drought and changing climates, and resistance to pathogens and pests (Bacchetta *et al.,* 2016; Dwyer *et al.,* 2022). Therefore, WEPs have the potential to be a valuable source of future food, and there is a critical need to reintroduce them into human diets (Motti, 2022; Knez *et al.,* 2023).

Approximately 100 million people from 705 different ethnic communities in India rely on WEPs for their livelihood. These communities, mainly tribal and rural, produce a variety of value-added products from WEPs, such as juices, jams, pickles, and wines (Mishra *et al.,* 2021). In India, 1403 WEPs from 44 families have been identified as commonly consumed, with leafy shoots and fruits being the most consumed parts (Ray *et al.,* 2020). WEPs are particularly prevalent in mountainous regions like the Indian Himalayan region (IHR), which is known for its rich biodiversity and unique cultural practices centered around agro-pastoralism and WEP consumption (Thakur *et al.,* 2017; Hegde *et al.,* 2023). The North-Western Himalayan region (NWHR) spread across Jammu & Kashmir, Himachal Pradesh and Uttarakhand is a complex physiographical region consisting glacier mountains, cold deserts, hot springs and dense forests with unique biodiversity. The region is characterized by extreme weathers, intense UV radiation and low oxygen partial pressures limiting agriculture. Local communities have adapted to these conditions by relying on WEPs for nutrition and livelihood. Several authors have reported the use of WEPs as a source of bioactive molecules and essential nutrients from this region (Thakur *et al.,* 2017; Ray *et al.,* 2020; Pereira *et al.,* 2020; Hegde *et al.,* 2023). In recent years, there has been an overall consensus on the importance of WEPs and their conservation and value addition (Mishra *et al.,* 2021). Despite the growing recognition of WEPs, their consumption, and associated indigenous knowledge are declining due to the influence of Western lifestyles and processed foods. Further, the region is significantly influenced by the tourist population, often creating a negative impact on the local ecosystem, especially the food and culinary diversity (Pereira *et al.,* 2020). This trend poses a threat to biodiversity conservation and the preservation of traditional knowledge (Mishra *et al.,* 2021). In this context, we aimed to survey and document the understudied lesser-known genetic resources, i.e., WEPs in the North Western Himalayas across different seasons. Information such as the diversity of WEPs, plant parts used for edible applications, major bioactive molecules, and traditional medicinal uses have been recorded through extensive respondent surveys among the local populations. The study emphasizes the importance of conserving and promoting WEPs for food security and potential therapeutic applications. We envisage that comprehensive documentation and subsequent characterization would validate the traditional uses of these WEPs and promote their use as mainstream foods.

Materials and Methods

Study Area

The study area encompasses the North Western Himalayas comprising politically delineated states *viz*., Himachal Pradesh, Jammu & Kashmir (J&K) and Uttarakhand. Geographically the region is spread between 28° 43′-37° 05′ N latitude and 72° 40′ -81° 02′ E longitude covering an approximate area of 33 million ha. The representative study locations from each state and their and geographical coordinates are presented in Figure 1 and Table 1, respectively. The region is characterized with a tropical to temperate climate owing to the altitudinal variations ranging from 100 m to above 6000 m asl covering sub-tropical to cold temperate alpine zones. Geologically, the region comprises three ranges, the Greater Himalaya, the outer Himalaya and the lesser Himalaya. The mean rainfall in the region is approximately 800, 1200 and 1500 mm for Jammu & Kashmir, Himachal Pradesh and Uttarakhand, respectively. However certain regions of NWHR such as the Trans-Himalayan zone encompassing areas like Ladakh in J&K, Lahaul & Spiti in Himachal Pradesh, and Nelong valley of Uttarakhand are considered cold deserts with very low annual rainfall (~40 mm) and extreme temperatures ranging from -45°C in winters to 40°C in summers. Owing to the wide range of climatic conditions, the region is characterized by abundant plant diversity, particularly medicinal plants. The primary occupation of the tribal communities residing in the NWHR region is agro-pastoralism and primarily depends on the resources available from surrounding ecosystems.

Surveys

The work comprised field surveys, interactions with the locals of the study sites, data recording, analyses, and interpretation of the gathered information. Filed surveys were conducted between February 2022 to May 2022 in Himachal Pradesh, J&K and between November 2022 to January 2023 in Uttarakhand covering summer and winter seasons respectively. In the following year (2023), survey and data collection were conducted vice-versa, i.e., during winter months (Nov-Jan 2023) in Himachal Pradesh and J&K and summer months in Uttarakhand (Feb-April 2024). The study locations were shortlisted based on earlier reconnaissance surveys in a few representative sites. Intensive interviews such as door-to-door surveys and fieldwork were conducted at these sites (Table 1). Information such as age, gender, and literacy were recorded after taking the consent of the respondent. Information such as knowledge and use of WEPs were collected using structured interviews as described

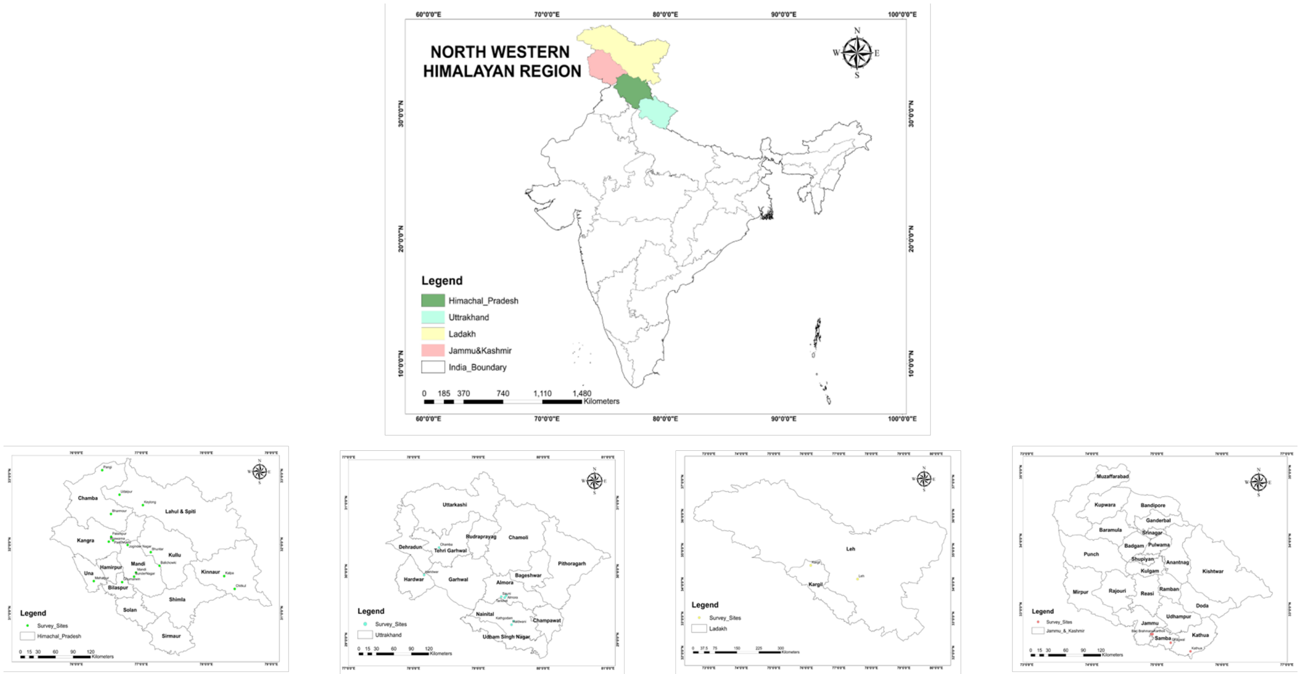

Figure 1: Location maps of study sites in the North Western Himalayan region

Table 1: Details of survey sites in the North Western Himalayan region

S. No.	*Name of the village*	*State*	*Latitude*	*Longitude*	*Altitude (m)*
1	Keylong	Himachal Pradesh	32.5710	77.0320	3080
2	Udaipur	Himachal Pradesh	32.7243	76.6651	2743
3	Bhuntar	Himachal Pradesh	31.8862	77.1455	2050
4	Balichowki	Himachal Pradesh	31.6886	77.2800	2000
5	Mandi	Himachal Pradesh	31.7087	76.9320	780
6	Sunder Nagar	Himachal Pradesh	31.5299	76.8889	1174
7	Joginder Nagar	Himachal Pradesh	31.9912	76.7899	1220
8	Ghumarwin	Himachal Pradesh	31.4491	76.7048	700
9	Pangi	Himachal Pradesh	32.9882	76.5303	2100
10	Bharmour	Himachal Pradesh	32.4428	76.5329	2100
11	Palampur	Himachal Pradesh	32.1109	76.5363	1355
12	Panchrukhi	Himachal Pradesh	32.0566	76.5647	1053
13	Bhawarna	Himachal Pradesh	32.0398	76.4997	1254
14	Mehatpur	Himachal Pradesh	31.4078	76.3435	393
15	Kalpa	Himachal Pradesh	31.5377	78.2754	2960
16	Chitkul	Himachal Pradesh	31.3508	78.4366	3450
17	Haridwar	Uttarakhand	29.9457	78.1642	314
18	Ranikhet	Uttarakhand	29.6434	79.4322	1869
19	Sauni	Uttarakhand	29.6278	79.3543	1679
20	Tarikhet	Uttarakhand	29.6141	79.4071	345
21	Haldwani	Uttarakhand	29.2183	79.5130	424
22	Kathgodam	Uttarakhand	29.2693	79.5441	554
23	Chamba	Uttarakhand	30.3455	78.3947	1524
24	Leh	Ladakh	34.1526	77.5771	3524

25	Kargil	Ladakh	34.5539	76.1349	2676
26	Kathua	Jammu & Kasmir	32.3863	75.5173	393
27	Kartholi	Jammu & Kasmir	32.6380°	74.9342°	340
28	Bari Brahmana	Jammu & Kasmir	32.6365°	74.9141°	340
29	Ghagwal	Jammu & Kasmir	32.5122	75.2129	370

by Thakur *et al.* 2017. Besides this, group discussions were held with locals in each site consisting mixed population of diverse age groups. The information on ethnic cuisines and ingredients utilized was primarily obtained from discussions with womenfolk while information on the availability of the WEPs, and their distribution was obtained from men. All the respondents were made aware of the purpose and nature of the study and data were recorded upon oral consent and agreement. The record of WEPs used by the local people such as parts used, and dishes prepared from the WEPs were collated based on household surveys (n = 524). The WEPs were categorized based on the purpose of use, such as vegetables, fruits, flavoring agents, raw food, and beverages (brew). The data on the usage of WEPs were further categorized season-wise *viz*., WEPs consumed in summer, winter, and rainy seasons. The information collated was evaluated for taxonomic diversity, species richness, and the plant part used for edible purposes (Table 2). The major metabolites identified in these WEPs were listed based on earlier published reports (Table 3).

Results

Wild Edible Plants and Their Consumption Pattern

Nearly 100 WEPs were identified to be consumed in the study region covering Himachal Pradesh, J&K and Uttarakhand. These 100 WEPs belonged to 51 different families; with members of Amaranthaceae (n = 8), Polygonaceae (n = 8), and Rosaceae (n = 8) being the predominant ones followed by Asteraceae members (n = 6). These were followed by Fabaceae, Aracaceae, Moraceae, and Eleagnaceae with 4 species in each of them being consumed. The rest of the families contained either one or two plants that are edible and consumed across the NWHR. In the majority of the cases, leaves and tender shoots (n = 43) was the predominant form of consumption as green leafy vegetables (GLVs) closely followed by fruits (n = 41), roots and tubers (n = 11), flowers and buds (n = 7), seeds (n = 4) and whole plant (n = 1) (Figure 2). Some of the common GLVs consumed in the NWHR, particularly Himachal Pradesh are *Amaranthus tricolor, Chenopodium album, Colacasia esculena, Nasturtium officinale, Brassica juncea, Zanthoxylum armatum, Urtica dioica, Portulaca oleracea, Oxalis latifolia, Rheum austral* are primarily used in the preparation of curries, sauces (chutney) and stuffed flat bread. In Uttarakhand, the following leaves are commonly utilized viz., *Boerhavia diffusa* L., *Antidesma montanum., Achyranthes aspera* L., *Polygonum aviculare* L., in addition to the aforesaid leaves that are consumed in Himachal Pradesh. Apart from its use as a food ingredient, the leaves of the aforesaid plants are primarily used in traditional medicine mainly for gastro-intestinal disorders, and for treating ulcers and infections (Thakur *et al.,* 2017). In the cold desert regions encompassing, Ladakh, Lahaul, and Spiti, a variety of wild leaves are consumed as food, medicine, and flavoring agent. *C. foliosum, Rumex hastatus, R. emodi,* and *Urtica tibetica* are commonly utilized leaves as vegetables. Leaves of *Allium jacquemontii, Murraya koennigii*, and *Mentha longifolia* are used as flavouring agents due to the presence of essential oils and aromatic compounds (Farzaei *et al.,* 2017).

The next form of WEP widely consumed are fruits and berries. These are consumed raw or cooked as vegetables or converted into a variety of products such as juices, jams, sauces, and pickles. Among wild fruits and berries, *Aegle marmelos*, *Artocarpus lacucha, Berberis sp. (B. aristate, B. asiatica)* DC., *Cornus capitata, Diospyros lotus, Ficus auriculata, Ficus palmata* (Wild Figs), *Myrica esculenta, Morus alba, Physalis peruviana, Punica granatum, Pyrus pashia, Ribes alpestere, Rubus sp. (R. elipticus, R. niveus), Prunus sp. (P. americana*, *P. mira), Hippophae rhamnoides* are few popular wild edible fruits from the NWHR. Among these fruits, seabuckthorn (*H. rhamnoides*), apricot (*P. americana*), pomegranate (*P. granatum*), and bael (*A. marmelos*) are valued highly owing to their medicinal properties (Bachheti *et al.* 2023).

Following leaves and fruits, tubers and roots are another important form of consumption of WEPs. Tubers of *Colacasia esculenta*, *Pueraria tuberosa, Typhonium diversifolium, Arisaema speciosum, Dioscorea sp.* (*D. bellophyla, D. bulbifera, D. oppositifolia*) are a few commonly consumed tubers. They are primarily used as vegetables for stuffing breads and used as curries and pickles. Apart from these, aerial parts of

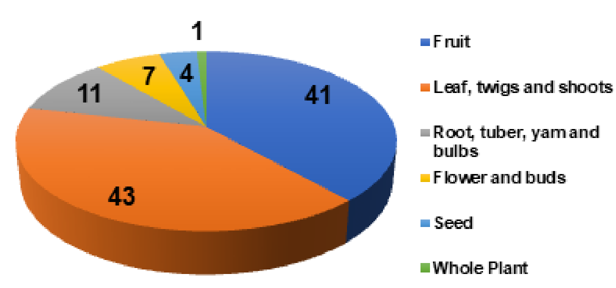

Figure 2: Statistics of different plant part used

several WEPs are primarily used as vegetables mainly curries. Flowers constitute a significant component of traditional foods in NWHR. The major seasonal flowers consumed are *Bauhinia variegeta, B. purpurea*, *Rhodeodendron arboreum*, *Viola odorata,* and *Bombax ceiba*. *Bauhinia* sp. (*B. variegeta* and *B. purpurea*) is used in the preparation of snacks (fritters) and stuffed flat breads. In addition, they have been used for treating infections and boosting immunity (Hegde *et al.,* 2023). Rhododendron sp. is used for the preparation of sauces and squash, cordial, and consumed during summers. They are primarily used as coolant and possess significant commercial value providing livelihood to the locals (Singh and Chatterjee, 2022). *V. odorata* flowers are dried and used as tea and preparation for decoction while *B. ceiba* flowers are used as a source of natural color and used for the treatment of anemia, haematuria, and hemorrhoids (Jain *et al.,* 2009).

Apart from Angiosperms, fiddlehead fern, *Diplazium* sp. (*D. esculentum* and *D. maximum*) are used as an important vegetable in the rainy season in Himachal Pradesh and Uttarakhand. The tender stalks of the fern are consumed as vegetables and used in curry preparations. Although not a plant, the locals consider it a plant (Sareen *et al.* 2021). Likewise, wild edible mushrooms, *Morchella esculenta* (Gucchi) and *Termitomyces* sp. (*T. heimii* and *T. microcarpus*) are commonly used as vegetables and preparation of curries across Himachal Pradesh, Uttarakhand and J&K (Atri *et al.,* 2019). A snapshot of various wild edibles distributed in the NWHR is presented in the Figure 3.

Bioactive Molecules from WEPs

Apart from their use as vegetables and raw foods, WEPs possess excellent bioactive properties owing to the presence of myriad bioactive molecules. The major class of bioactive molecules are phenolic acids, flavonoids, anthocyanins, terpenoids, carotenoids, anthraquinones, phenylethanoids and phenylpropanoids (Bhatt *et al.,* 2017; Bachheti *et al.,* 2023; Hegde *et al.,* 2023). The list of major classes of metabolites reported in the WEPs is presented in Table 3. The GLVS are a rich source of micronutrients, particularly iron, zinc and magnesium, and carotenoids, primarily lutein and beta carotene (Sarkar *et al.,* 2023). Fruits and berries are primarily rich sources of polyphenols. Some commonly detected metabolites in wild edible fruits from NWHR are 3-O-caffeoylquinic acid, 5-*O*-caffeoylquinic acid. Quercetin-3-*O*-glucoside, *p*-coumaric acid, 3-*p*-coumarylquinic acid, kaempferol glycosides, isorhamnetin, myricetin, catechins, gallic acid, and apigenin glucosides (Hegde *et al.,* 2023; Bachheti *et al.,* 2023). These polyphenols have been attributed with a wide range of bioactive properties viz., antioxidant, anti-inflammatory, hypocholesterolaemia and cardioprotective, and anti-cancerous (Pereira *et al.,* 2020). Some high-value and commercially important molecules from WEPs in NWHR are quercetin-3-O-glucoside from

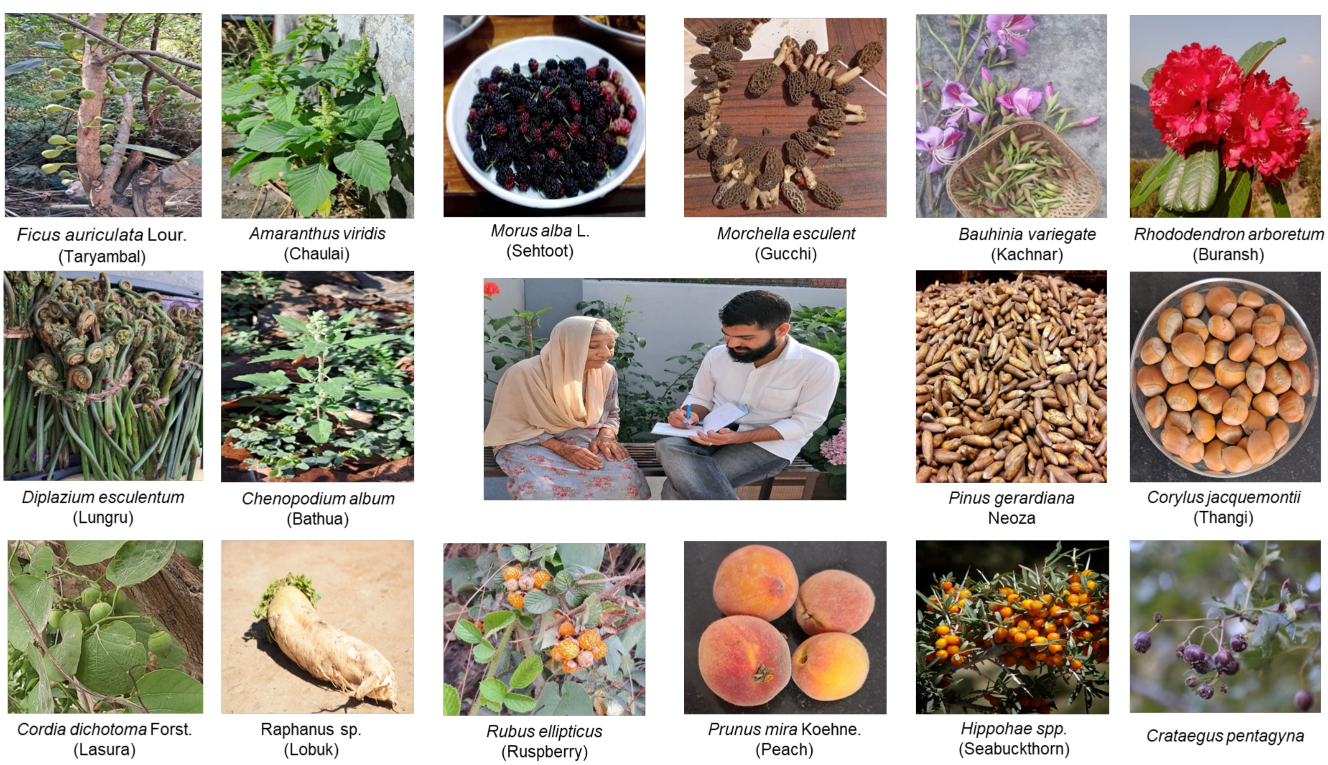

Figure 3: Photographs of wild edible plants consumed in North Western Himalayan region

Table 2: Wild edible plants (WEPs) consumed in the North Western Himalayan Region

S. No.	*Botanical name*	*Local name*	*Family*	*Part used*	*Method of consumption*
Himachal Pradesh					
Summer season					
1	*Rhododendron arboreum* Sm.	Buransh	*Ericaceae*	Flower	Chutney, juices and cordial
2	*Bauhinia variegeta* L.	Kachnar	Fabaceae	Buds and flowers	Fritters and kachru (Stuffed Indian flat bread)
3	*Cordia dichotoma* Forst.	Lasura	Boraginaceae	Raw fruits	Vegetable, pickle
4	*Amaranthus viridis* L.	Chulai	Amaranthaceae	Leaf	Leafy vegetable, curries
5	*Ficus palmata* Forssk	Fegra	Moraceae	Fruit	Ripe fruit, Vegetable curries
6	*F. auriculata* Lour.	Taryambal	Moraceae	Fruit	Ripe fruit, Vegetable curries
7	*Artocarpus lacucha* Buch.-Ham.	Dheu	Moraceae	Fruit	Ripe fruit, Vegetable curries
8	*Viola odorata* L.	Banfsa	Violaceae	Flower	Flavouring agent to tea
9	*Sechium edule* (Jacq.) Swartz	Lonku	Cucurbitaceae	Fruit	Vegetable curries
10	*Fagopyrum dibotrys* (D.Don) Hara	Kathu	Polygonaceae	Leaf and seeds	Leafy Vegetable curries
11	*Morchella esculenta* (L.) Pers.	Gucchi	Morchellaceae	Arial part	Vegetable curries
12	*Aegle marmelos* Correa.	Bael or wood apple	Rutaceae	Fruit	Ripe fruit, marmalade
13	*Berberis aristata* DC.	Kasmale	Berberidaceae	Fruit	Ripe fruit
14	*Carissa spinarum* L.	Garne or Conkerberry	Apocynaceae	Fruit	Ripe fruit
15	*Morus alba* L.	Wild toot or Shehtoot	Moraceae	Fruit	Ripe fruit, chutney
16	*Myrica esculenta* Buch-Ham. Ex D. Don	Kaphal	Myricaceae	Fruit	Ripe fruit
17	*Phyllanthus emblica* L.	Amla	Phyllanthaceae	Fruit	Ripe fruit, chutney, juice and pickle
18	*Rubus ellipticus* Sm.	Aakhe or Yellow Himalayan Raspberry	Rosaceae	Fruit	Ripe fruit
19	*Ziziphus mauritiana* Lamk.	Ber or Indian Jujube	Rhamnaceae	Fruit	Ripe fruit
20	*Fragaria indica* Andr.	Wild Strawberry	Rosaceae	Fruit	Ripe fruit, juice
21	*Prunus armeniaca* L.	Apricot	Rosaceae	Fruit	Ripe fruit, juice and jam
22	*B. asiatiica* Roxb. ex DC.	Indian/Asian Barberry	Berberidaceae	Fruit	Ripe fruit
23	*Crataegus pentagyna* Waldst. & Kit. ex Willd	Black Fruit Hawthorn	Rosaceae	Fruit	Ripe fruit
Rainy season					
24	*Colocasia esculenta* (L.) Schott	Patrode	Araceae	Leaf	Patrode, leafy vegetable curry
25	*Diplazium esculentum* (Retz.) Sw.	Lungru	Athyriaceae	Fern	Vegetable curry
26	*Portulaca oleracea* L.	Kulfa	Portulacaceae	Twigs	Leafy vegetable curry
27	*Termitomyces microcarpus* (Berk. & *Broome) R. Heim, Mem*.	Tatmor/Bhatoliyan	Lyophyllaceae	Arial Part	Vegetable curry, pickle
28	*Crataegus songarica* K. Koch	Van-Sangli or Ramjag	Rosaceae	Fruit	Ripe fruit
29	*Elaeagnus umbellate* Thumb.	Chinder	Elaeagnaceae	Fruit	Ripe fruit
30	*Pyrus pashia* Buch.-Ham ex D.Don	Kainth	Rosaceae	Fruit	Ripe fruit, pickle and marmalade

31	*Ribes alpestre* Wall. ex. Decne.	Chalendra or Asian gooseberry	Grossulariaceae	Fruit	Ripe fruit
32	*Rubus niveus* Thunb.	Akhe or Hill Raspberry	Rosaceae	Fruit	Ripe fruit
33	*Viburnum mullaha* Buch.-Ham ex. D. Don	Ghenu or Himalayan Viburnum	Adoxacea	Fruit	Ripe fruit
34	*Corylus jacquemontii Decne.*	Himalayan Hazelnut	Betulaceae	Fruit	Nuts, oil extraction
35	*Murraya koennigii* L.	Gandhelu or Metha Neem	Rutaceae	Fruit	Ripe fruit
36	*Elaeagnus umbellate* Thunb.	Ghain, Chindar	Elaeagnaceae	Fruit	Ripe fruit
Winter season					
37	*Brassica juncea* L.	Mustard Leaf	Brassicaceae	Leaf	Leafy vegetable curry, fritters and kachru (stuffed indian flat bread)
38	*Chenopodium album L.*	Bathua	Amaranthaceae	Twigs	Leafy vegetable curry, fritters and kachru (stuffed indian flat bread)
39	*Momordica dioica* Roxb.	Ban Karela	Cucurbitaceae	Fruit	Vegetable curry
40	*Colocasia esculenta* (L.) Schott	Colocasia tubers	Araceae	Tuber	Vegetable curry and pickle
41	*Cornus capitata* Wall. ex Roxb.	Tharbal or Himalayan strawberry tree	Cornaceae	Fruit	Ripe fruit
42	*Diospyros lotus* L.	Amlook or Date plum	Ebenaceae	Fruit	Ripe fruit
43	*Physalis peruviana* L.	Rasbhary	Solanaceae	Fruit	Ripe fruit
44	*Pinus gerardiana* Wall. ex D.Don	Neoza	Pinaceae	Fruit	Nuts, oil extraction
45	*Punica granatum* L.	Wild Pomegranate (Darhu)	Punicaceae	Fruit	Chutney
46	*Prunus mira* Koehne.	Pit Aaru (Smooth Pit peach)	Rosaceae	Fruit	Ripe fruit and jam
47	*Solanum nigrum* L.	Kali Makoi or Black Nightshade	Solanaceae	Fruit	Ripe fruit
48	*Olea ferruginea* Royle	Indian Olive	Oleaceae	Fruit	Ripe fruit
49	*Flacourtia indica* (*Burm. f.) Merr.*	Indian Plum or Governor's plum	Salicaceae	Fruit	Ripe fruit
Uttarakhand					
Summer season					
50	*Achyranthes aspera* L.	Chaff- flower	Amaranthaceae	Leaf, seed	Leafy vegetable curry
51	*Elaeagnus latifolia* L.	Khasi Cherry or Bastard oleaster	Elaeagnaceae	Fruit	Ripe fruits
52	*Bombax ceiba* L.	Semal	Bombacaceae	Flower	Vegetable curry and chutney
53	*Agave americana* Linn.	Ramban	Asparagaceae	Shoots	Vegetable curry
54	*Asparagus filicinus* Buch.-Ham.ex D.Don	Kairua	Asparagaceae	Shoots	Vegetable curry
55	*Dioscorea bulbifera* Linn.	Genthi	Dioscoreaceae	Tuber	Vegetable curry and pickle
56	*Urtica dioica* L.	Bichchu ghas	Urticaceae	Leaf	Leafy vegetable curry
Winter season					
57	*Bauhinia purpurea* L.	Khair-wal	*Fabaceae*	Flower, buds and fruit	Flower and buds as vegetable curry Ripe fruit
58	*Boerhavia diffusa* L.	Punarnava	Nyctaginaceae	Leaf	Leafy vegetable curry

59	*Polygonum aviculare* L.	Jhangar/Wild Buckwheat	Polygonaceae	Twigs	Leafy vegetable curry
60	*Pueraria tuberosa* DC.	Bilikand	*Fabaceae*	Tuber	Vegetable curry
Rainy season					
61	*Antidesma montanum* Blume	Amli	Phyllanthaceae	Leaves and fruit	Chutney and pickle
62	*Costus speciosus* (Koen ex. Retz) Sm.	Keu	*Costaceae*	Tuber	Vegetable curry
63	*Phytolacca sp.*	Jarag twigs	Phytolaccaceae	Twigs	Leafy vegetable curry
64	*Arisaema speciosum* Mart.	Bankh	Araceae	Tuber	Vegetable curry
65	*Chaerophyllum villosum* Wall. Ex DC.	Ganziadi	Apiaceae	Rhizome	Vegetable curry
66	*Dioscorea glabra* Roxb.	Tarur	Dioscoreaceae	Arial root yam	Vegetable curry
67	*Typhonium diversifolium* Wall. Ex Schott	Rugi	Araceae	Tuber	Vegetable curry
Jammu & Kashmir					
Summer season					
68	*Allium cepa* var. proliferum	Tree Onion/Praan Praand	Amaryllidaceae	Shoots, bulb	Flavouring agent and vegetable
69	*Celosia argentea* L.	Moval	Amaranthaceae	Leaf	Flavouring agent
70	*Malva sylvestris* Linn.	Soochal	Malvaceae	Leaf	Leafy Vegetable curry
71	*Nasturtium officinale* R. Br.	Nagbabur	Brassicaceae	Leaf	Leafy Vegetable curry
72	*Orobanche alba* steph.	Subzgul	Orobanchaceae	Whole plant	Vegetable
73	*Polygonum alpinum* All.	Tsokladar	Polygonaceae	Leaf	Leafy Vegetable curry
74	*Taraxacum officinale* Weber	Hand	Daisy family Asteraceae	Leaf	Leafy Vegetable curry
Rainy season					
75	*Amaranthus retroflexus* L.	Ganhaar/Redroot pigweed	Amaranthaceae	Seeds	Flavouring agent
76	*Amaranthus spinosus* Linn.	Charleree	Amaranthaceae	Leaf	Leafy vegetable curry
77	*Angelica glauco* Edgew.	Chorak	Apiaceae	Twigs and roots	Flavouring agent and leafy vegetables
78	*Commelina benghalensis* Linn.	Chura	Commelinaceae	Leaf	Leafy vegetable curry
79	*Medicago sativa* Linn.	Ispit	Fabaceae	Leaf	Leafy vegetable curry
80	*Polygonum aviculare* Linn.	Endrani	Polygonaceae	Leaf	Leafy vegetable curry
81	*Solanum nigrum* Linn.	Kainkothi	Solanaceae	Leaf	Leafy vegetable curry
Ladhak					
Summer Season					
82	*Saussurea gossypiphora* D.Don.	Ldums	Asteraceae	Leaf	Leafy vegetable curry
83	*Capparis spinosa* L.	Kabra	Capparaceae	Leaf and fruit	Leafy vegetable curry and pickle
84	*Chenopodium foliosum* Asch.	Sneou	Amaranthaceae	Leaf	Flavouring agent
85	*Sedum ewersii* Ledeb.	Churuppa	Crassulaceae	Twigs	Leafy vegetable curry
86	*Polygonum chinensis* L.	Jangli Palak	Polygonaceae	Leaf	Leafy vegetable curry
87	*Allium prezewalskianum* Regel.	Wild onion	Amaryllis	Shoots and bulb	Flavouring agent and vegetable curry
88	*Artemisia brevifolia* Wall. ex DC.	Kamchu	Asteraceae	Leaf	Flavouring agent

89	*Mentha longifolia* (L.) Huds.	Pholoing	*Lamiaceae*	Leaf	Flavouring agent
90	*Hippohae spp.*	Chharma or Seabuckthorn	Elaeagnaceae	Fruit, Leaf	Ripe fruit, chutney, juice and decoction
Rainy season					
91	*Carum carvi* L.	Caraway/Ambuk Konsnyot	Apiaceae	Leaf, seed	Flavouring agent
92	*Chenopodium botrys* L.	Sagani	Amaranthaceae	Leaf	Leafy vegetable curry
93	*Arnebi euchroma* (Royle ex Benth.) I.M.Johnst. A	Troma	Boraginaceae	Roots	Vegetable curry
94	*Crepis tectorum* L.	Remang	Asteraceae	Twigs	Leafy vegetable curry
Winter season					
95	*Fagopyrium esculentum Moench*	Tyat/Kuttu	Polygonaceae	Leaf	Leafy vegetable curry
96	*Rheum emodi* Wall	Lachu	Polygonaceae	Leaf	Leafy vegetable curry
97	*Lactuca sativa* L.	Dums	Asteraceae	Leaf	Leafy vegetable curry and flavouring agent
98	*Raphanus sp.*	Lobuk	Brassicaceae	Leaf	Chuney, pickle
99	*Lactuca dolichophylla* Kitam.	Khala	Asteraceae	Leaf	Leafy vegetable curry
100	*Oxyria digya* (L.) Hill	Lamanchu	Polygonaceae	Leaf	Leafy vegetable curry and eaten fresh

Bauhinia variegeta (Hegde *et al.,* 2023) cyanidin-3-O-glucoside from *Rhododendron arboreum* (Sendri *et al.,* 2022), berberine from *B. asiatica* and *B. aristata* (Chander *et al.,* 2017), naphthoquinone (shikonin) from *Arnebia euchroma* (Kumar *et al.,* 2021) polyunsaturated fatty acid such as alpha-linolenic acid and carotenoids from *Hippophae rhamnoides* (Wani *et al.,* 2016), apigenin derivatives from *Mentha longifolia* (Farzaei *et al.,* 2017), betalins from *Amaranthus* sp. (*A. tricolor and A. viridis*) (Hussain *et al.,* 2018). The structure of a few important bioactive metabolites identified in the WEPs distributed across the NWHR is presented in Figure 4. The motivation behind the consumption of WEPs among locals could be directly correlated with the lifestyle and environmental conditions they live in. High-altitude regions, specifically the cold desert regions of NWHR such as Ladakh, Lahaul, and Spiti are characterized by extreme cold climate, high UV irradiation, and hypobaric hypoxia (Bharti *et al.,* 2017). Such harsh living conditions are known to induce severe oxidative stress in the body and lead to the accumulation of reactive oxygen species (ROS) (Aranda-Rivera *et al.,* 2022). Oxidative stress is associated with several pathological conditions such as inflammation, neurological disorders, and cancer (Aranda-Rivera *et al.,* 2022). Several WEPs that are consumed in NWHR have been reported to counter oxidative stress owing to the presence of aforesaid bioactive molecules. For example, the widely consumed stinging nettle (*U. dioica*), and seabuckthorn (*H. rhamnoides*) contain strong antioxidants such as quercetin-3-O-glucoside, alpha-linolenic acid, β-carotene offering strong radioactive protection (Wani *et al.,* 2016). Similarly, other polyphenols such as apigenin and rutin derivatives are known to enhance endogenous antioxidant systems in the body and protect against radiation-induced damage (Choi *et al.,* 2014). The presence of antioxidant polyphenols in almost all the WEPs suggests the importance of these WEPs in maintaining the health of the locals. Certain medicinal herbs unique to cold desert regions have been used by the locals such as the leaves and shoots of *Rhodiola heterodonta*, *Potentilla ansernia,* and *Hippophae* sp. for the preparation of brews and tea (Chen *et al.,* 2023). *Rhodiola* contains phenylethanoids and phenylpropanoid metabolites such as salidroside and aromatic molecules such as tyrosol that have been reported to possess neuroprotective functions under hypoxic conditions (Li and Chen, 2017).

Challenges and Future Prospects in the Consumption of WEPs in NWHR

Although the WEPs play an important role in the subsistence of the local people, their consumption prevalence and traditional knowledge behind their utilization are slowly declining due to several reasons. One of the major factors affecting the continued consumption of WEPs among locals is urbanization and adaptation to modern lifestyle. In addition, the availability of packaged food and high

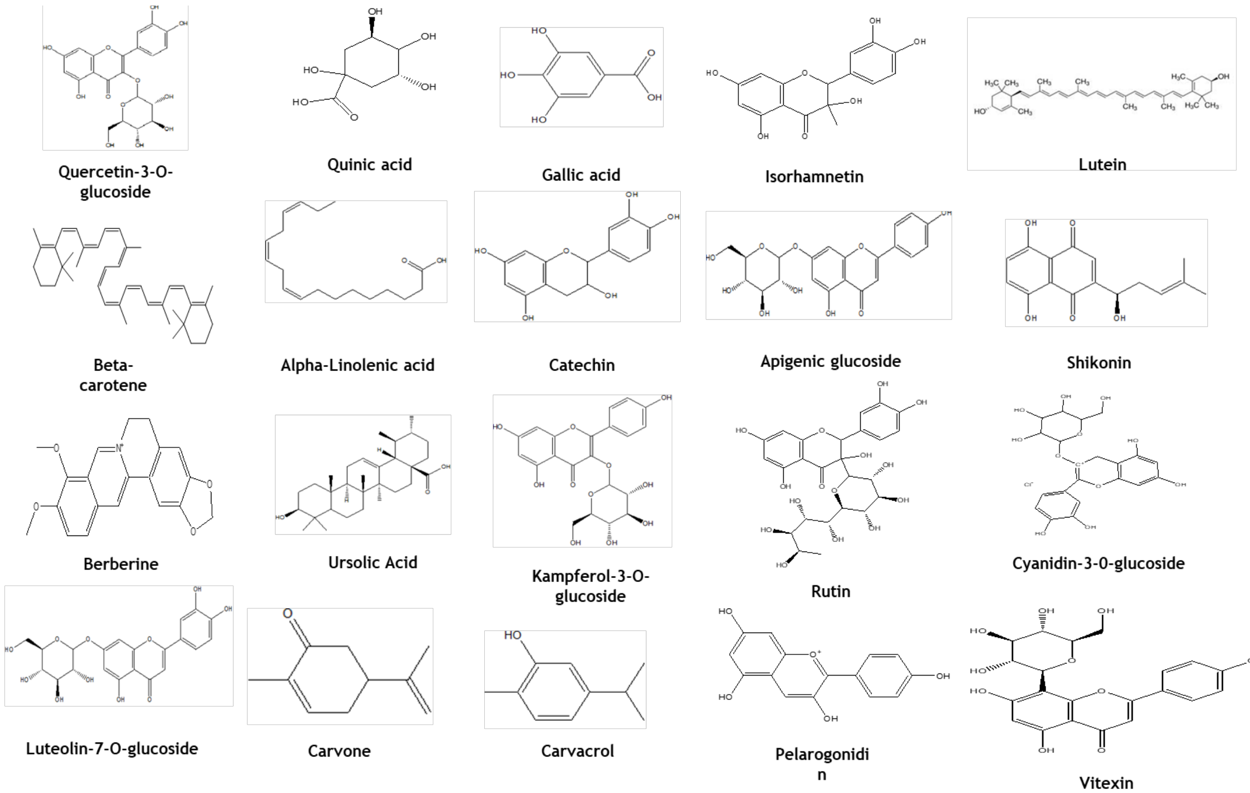

Figure 4: Major bioactive molecules in present in the WEPs distributed in the North Western Himalayan region

Table 3: Major metabolites and bioactive molecules

S. No.	*Latin name of the WEP*	*Major metabolites*	*Bioactive molecules*	*References*
1	*Rhododendron arboreum* Sm.	Flavonoids, flavonoid glycoside, organic compounds	Quercetin-3-rhamnoside, Rutin, Coumaric acid, naringenin and taxifolin	Kumar *et al.* 2019
2	*Bauhinia variegeta* L.	Flavonoid glycosides	Kaempferol-3-*O*-glucosyl-7-*O*-glucoside, kaempferol-3-*O*-rutinoside, kaempferol-3-*O*-glucoside, kaempferol-3-*O*-robinoside, quercetin-3-*O*rhamnoside, quercetin-3-*O*-glucosyl-7-*O*-glucoside, and quercetin-3-*O*-rutinoside, apigenin, myricetin, and luteolin	Hegde *et al.* 2023
3	*Cordia dichotoma* Forst.	Flavonoids polyphenols, tannins, and alkaloids	Kaempferol, quercetin and isorhamnetin	Raghuvanshi *et al.* 2022
4	*Amaranthus viridis* L.	Flavonoids, carotenoids, organic compunds	β-carotene and lutein, Kaempferol, kaempferol 3-O-β-glucoside, kaempferol 3-O-β-diglucoside, kaempferol-3-O-arabinoglucoside, quercetin, quercetin 3-O-xylosylglucoside, quercetin-3- O rhamnoglucoside, 2,4-Di-tert-butylphenol, Dioctyl phthalate	Poonia and Upadhayay, 2015
5	*Ficus palmata* Forssk	Alkaloids, tannins, flavonoids, terpenoids, cardiac glycosides	NR	Joshi *et al.* 2014
6	*F. auriculata* Lour.	Alkaloids, Saponins, glycosides, phytosterol, resins, phenols, tannins, diterpenes, Flavonoids	Quercetin, epigallocatechin	Mehra and Tandon, 2021
7	*Artocarpus lacucha* Buch.-Ham.	Flavonoids, phenols, saponins, tannins and coumarins	Kaempferol, Rutin, Quercetin, Luteolin7Oglucoside	Pertiwi *et al.* 2024

8	*Viola odorata* L.	Phenylpropanoids, stigmastanes, fatty alcohols, fatty acid and fatty acid ester	Eugenol, gamma-sitosterol, tetradecanoic acid, hexadecanoic acid, octacosanol, Octadecanoic acid, methyl ester	Jasim *et al.* 2018
9	*Sechium edule* (Jacq.) Swartz	Phenolic acid, flavonoids, alkaloids	Hydrobenzoic acids (galic, protocatechuic, syringic, p-hydroxybenzoic), hydroxycinnamic acid (cafeic, ferulic, p-coumeric, clorogenic), flavones, apigenin, Flavanonols (quercetin, myricetin, rutin) flavonones (naringenine), cucurbitane α-Amyrin, cycloartenol, β-amyrin, 24-methylenecycloartanol	Gavia-García *et al.* 2023
10	*Fagopyrum dibotrys* (D.Don) Hara	Flavonoids, phenols, terpenes, steroids, triterpenoids	Quercetin, rutin, catechins, catechin, epicatechin, benzoic acid, 3,4-dihydroxy benzoic acid, gallic acid, succinic acid, syringic acid, ferulic acid, glutinone, glutinol, 3α,21β-dihydroxy-olean-12-ene, olean-12-ene-3β,7β,15α,28-tetraol, ursolic acid, 3α-hydroxy-urs-12,15-dien, hecogenin, β-sitosterol, *N*-butanol-β-d-furan methylglycoside, *n*-butyl-β-d-fructopyronoside, β-daucosterol, daucosterol	Zhang *et al.* 2021
11	*Morchella esculenta* (L.) Pers.	Flavonoids, phenolic compounds, steroids	Flavones, flavonoids, quercetin, benzoic acid, cinnamic acid, gallic acid, phydroxybenzoic acid, Phydroxybenzoic acids, Protocatechuic acid, Vanillic acid, Sterol, Ergosterol	Singh *et al.* 2022
12	*Aegle marmelos* Correa.	Polyphenols, coumarins Tannins, alkaloids, pectin, phenolic acids, organic acids, flavonoids, tocopherols, carotenes	Alloimperatorin, zanthotoxol, imperatorin, xanthotoxol, isoimperatorin, umbelliferone, marmelide, scopoletin, marmelosin, scopolentin, marmesin, psoralen-a, scoparone, marmin, methyl ether, psoralen, 4,7,8-trimethoxyfuroquinoline, Skimminianine, aegelenine, halfordinol, aegeline, ethyl cinnamate, aegelinosides A, ethyl cinnamamide, aegelinosides B, dictamine, fragrine, gallic acids, p-coumaric acid, 2,3-dihydroxy benzoic acid, vanillic acid, chlorogenic acid, rutin	Sharma *et al.* 2022
13	*Berberis aristata* DC.	Alkaloids, berberine, palmatine, columbamine, quercetin	Berberamine, Aromoline, Jatrorrhizine, Oxyberberine, Tetrahydropalmatine, Oxycanthine, Lupeol, Oxycanthine	Jahan *et al.* 2022
14	*Carissa spinarum* L.	Polyphenols, flavonoids	Syringic acid, Resveratrol, Chlorogenic acid, Epicatechin, Myricetin, Quercetin, Luteolin, Apigenin	Nazareth *et al.* 2021
15	*Morus alba* L.	Flavonoids, polyphenol, anthocyanins, terpenes, carotenoids, and alkaloid	Quercetin (Quercetin 3-O-rutinoside, Quercetin 3-O-glucoside, Quercetin3-O-galactoside), Kaempferol (Kaempferol 3-O-glucoside, and Kaempferol 3-O-rutinoside), Guinic acid, Rutin, Catechin, Cyandin-3-glucoside, Chlorogenic acid, Gallic acid, Ferulic acid, p-coumaric acid, o-coumaric acid, Cinnamic acid, and Caffeic acid	Zhou *et al.* 2022
16	*Myrica esculenta* Buch-Ham. Ex D. Don	Tanins, phenolic acid, flavonoids, terpens, triterpenoids, steroids	Catechin, Gallic acid, Chlorogenic Acid, Coumaric acids, Gallic acid, Ferulic acid, 1-ethyl-4-methylcyclohexane, Myo-inositol, methyl-d-lyxofuranoside, 2-furancarboxyaldehyde, 2,5-furandionedihydro-3-methylene, furfural, oxirane	Kabra *et al.* 2019
17	*Phyllanthus emblica* L.	Phenolic acids, flavonoids, Tannins, alkaloids	Hydroxybenzoic acids (4-hydroxybenzoic acid, coumaric acid, gallic acid, protocatechuic acid, syringic acid, vanillic acid, flavonols, flavones, flavanones, and flavan-3-ols, Kampferol, quercetin, apigenin, luteolin, myricetin, ellagitannins, Ellagic acid, phyllantine and phyllantidine	Gul *et al.* 2022
18	*Rubus ellipticus* Sm.	Polyphenols, flavonoids, anthocyanins, tannins, terpenoids	Quercetin, rutin, Quercetin 3-O-glucuronide, Phloridzin, Epicatechin, Epigallocatechin, Chrysin, Cyanidin, Pelargonidin, Malic acid, Ellagic acid, Chlorogenic acid, Citric acid, Ascorbic acid, Quinic acid, m-Coumaric acid, p-Coumaric acid, β-Carotene Gallic acid, Catechin	Lamichhane *et al.* 2023

19	*Ziziphus mauritiana* Lamk.	Cyclopeptid alkaloids, sterols, flavonoid, terpenoids	Berberine, quercetin, kaempferol, sitosterol, stig-masterol, lanosterol, diosgenin, 2α-aldehydo-A (1)-norlup-20(29)-en-27, 28-dioic acid (zizyberanal acid), Zizyberanone, Zizyberanalic acid, Ursolic acid, Colubrinic acid, Alphitolic acid, 3-O-cis-p-coumaroyl alphitolic acid, 3-O-trans-pcoumaroyl alphitolic acid, Betulinic acid, Betulonic acid, 3-O-cis-pcoumaroyl maslinic acid, 3-O-trans-p-coumaroyl maslinic acid, Oleanolic acid, Oleanonic acid, Quercetin 3-O-rutinoside, Quercetin 3-O-robinobioside, Quercetin 3-O-galactoside, Quercetin 3-O-glucoside, Quercetin 3-O-rhamnoside, Quercetin 3-O-pentosylhexoside, Quercetin 3-O-6-malonylglucoside, Quercetin 3-O-malonylglucoside, Luteolin 7-O-6-malonylglucoside, Luteolin 7-O-malonylglucoside, Myricetin 3-O-galactoside, Naringenin triglycoside	Prakash *et al.*, 2021
20	*Fragaria indica* Andr.	Phenolics, phenolic acid, flavonoids, tannins, ellagic acid, glycoside, flavonols, proanthocynidins and benyl derivatives	NR	Bahukhandi *et al.* 2023
21	*Prunus armeniaca* L.	Organic acid, carotenoids, polyphenols, carotenoids, polysachharides	β-carotene, β-cryptoxanthin, γ-carotene, Lycopene, Chlorogenic, Neochlorogenic acids, Catechin, Epicatechin, Rutin, Pectin	Erdogan-Orhan and Kartal, 2011
22	*Berberis asiatiica* Roxb. ex DC.	Alkaloids, tannins, flavonoids, Terpenoids, sterols	Berberine, Berbamine, Palmatine, Columbamine, Jatrorrhizine, and Oxyacanthine	Semwal *et al.* 2023
23	*Crataegus pentagyna* Waldst. & Kit. ex Willd	Phenolics, proanthocyanidins flavonoid glycosides,	Quercetin, Isoquercetin, Rutin, Hyperoside, Epicatechin, Chlorogenic acid, Protocatechuic acid, gallic acid, caffeic acid, and chlorogenic acid, coumaric acid, chlorogenic acid, caffeic acid, ferulic acid, quercetin 3-O-glucoside (isoquercetin), quercetin, quercetin 3-O-rutinoside (rutin), (-)-epicatechin, kaempferol 3-O-glucoside, hyperoside, apigenin, cyanidin 3-O-glucoside, luteolin and procyanidins B1 and B2	Taleghani *et al.* 2024
24	*Colocasia esculenta* (L.) Schott	Alkaloid, flavonoid, tannin, glycoside	Tarin, Vicenin-2, iso-vitexin, iso-vitexin 3′-O-glucoside, vitexin X′-O-glucoside, iso-orientin, orientin-7-O-glucoside, luteolin 7-O-glucoside	Sharma *et al.* 2020
25	*Diplazium esculentum* (Retz.) Sw.	Alkaloids, flavonoids, glycosides, phenolic, tannins, terpenoids, steroids	Pentadecanoic acid, β-sitosterol, neophytadiene, α-linolenic acid, methylpalmitate, diisobutylphthalate, phytol and 10,12 hexadecadien-1-ol	Semwal *et al.* 2021
26	*Portulaca oleracea* L.	Flavonoid, alkaloids, terpenoids, fatty acid	Kaempferol, apigenin, luteolin, myricetin, and quercetin, N-trans-feruloyltyramine, dopa, dopamine, noradrenaline, omega-3 fatty acids	Iranshahy *et al.* 2017
27	*Termitomyces microcarpus* (Berk. & *Broome) R. Heim, Mem*.	Phenolic compounds, flavonoids	Tannic acid and gallic acid, gentisic acid, and protocatechuic acid, pyrogallol vanillic acid, syringic acid, pcoumaric acid, caffeic acid, ferulic acid, cinnamic acid, myricetin, kaempferol, quercetin,	Mitra *et al.* 2016
28	*Crataegus songarica* K. Koch	Phenols, flavonoids, anthocyanin	NR	Gania *et al.* 2014
29	*Elaeagnus umbellate* Thumb.	Polyphenols, anthocyanins	Lycopene, lutein, phytoene, phytofluene, β-cryptoxanthin, β-carotene, and α-cryptoxanthin	Gamba *et al.* 2020
30	*Pyrus pashia* Buch.-Ham ex D.Don	Sterols, triterpines	β-sitosterols, β-sitosterol-3-D glucoside, Lupeol	Ali and Juyal, 2018
31	*Ribes alpestre* Wall. ex. Decne.	Flavonoids	NR	Sun *et al.* 2021
32	*Rubus niveus* Thunb.	Polyphenols, flavonoids	NR	Moreno-Medina *et al.* 2018
33	*Viburnum mullaha* Buch.-Ham ex. D. Don	Polyphenols, flavonoid	Acetyl salicyclic acid, Clorogenic acid, Dihydroquercetin, Dihydrorobinetin, Dihydromyricetin, 2-isoprenylemodin, Rutin, Cosmosiin hexaacetate, Pectolinarin, Eriodictyol, Iriginol hexaacetate, Theaflavin, Epicatechin-pentaacetate, Lomatin, Peucenin	Singh *et al.* 2017

34	*Corylus jacquemontii Decne.*	Tannins, carotenoids, polyphenols	Apigenin, Dimethyl ellagic acid, Quercetin rhamnoside, Quercetin hexoside, Kaempferol rhamnoside	Kumar *et al.* 2016
35	*Murraya koennigii* L.	Flavonoids, phenolics, organic acid	Chlorogenic acid, Catechin, Rutin, Myricetin	Aroor *et al.* 2023
36	*Elaeagnus umbellate* Thunb.	Polyphenols, organic acids, monoterpenes,	Limonene, phellandrene, sabinene, terpinene, terpinolene citric, malic, oxalix, quinic, succinic, and tartaric	Gamba *et al.* 2020
37	*Brassica juncea* L.	Phenolic acids, flavonoids and glucosinolates, carotenoids	Sinigrin, Glucoiberin, progoitrin, glucoraphanin, gluconapin, 4-hydroxyglucobrassicin, glucoerucin, glucobrassicin, 4-methoxyglucobrassicin, gluconasturtiin, and neoglucobrassicin, β-carotene, lutein, violaxanthin, and neoxanthin	Frazie *et al.* 2017
38	*Chenopodium album L.*	Flavonoids	Kaempferol, kaempferol 3-O-βglucoside, kaempferol 3-O-β-diglucoside, kaempferol-3-Oarabinoglucoside, quercetin, quercetin 3-O-xylosylglucoside, and quercetin-3- O rhamnoglucoside	Poonia and Upadhayay, 2015
39	*Momordica dioica* Roxb.	Alkaloids, steroids, triterpenoids, saponins	Momordicin, lectins, β-sitosterol, saponin glycosides, ursolic acid, hederagenin, oleanolic acid, α-spinasterol, stearic acid, gypsogenin, momodicaursenol, 3β-o-benzoyl11-oxo-ursolic acid, 3β-o-benzoyl-6-oxo-ursolic acid, and 3o-β-D-glucuronopyranosyl gypsogenin	Talukdar and Hossain, 2014
40	*Colocasia esculenta* (L.) Schott	Polyphenols, polysaccharides	1-O-feruloylD-glucoside, 3, 5-DiCQ acid, vitexin, isovitexin, cyanidin-3-glucoside, luteolin-7-O-rutinoside, vicenin-2; caffeic acid, cyanidin-3-rhamnoside, chlorogenic acid, quercetin and hyperoside, Tarin, taro-4-I polysaccharide, taro polysaccharides 1 and 2 (TPS-1/TPS-2), A-1/B-2 α-amylase inhibitors, monogalactosyldiacylglycerols (MGDGs), and digalactosyldiacylglycerols (DGDGs)	Ribeiro *et al.* 2020
41	*Cornus capitata* Wall. ex Roxb.	Anthocyanin, flavonoid, phenolic acid, triterpenoid	NR	Badoni *et al.* 2024
42	*Diospyros lotus* L.	Polyphenols, flavonoids	Gallic acid, Catechin, Epicatechin Chlorogenic, Vanillic acid, Caffeic acid, Syringic, p-coumaric acid, Ferulic acid, Salicylic acid, sinapic acid, Quercetin-3-glucoside, Protocatechuic acid, Myricetin, 3,4-dihydroxybenzoic acid, Quercetin, 4-hydroxybenzoic acid, Salicylic acid, and Resveratrol	Hassan *et al.* 2022
43	*Physalis peruviana* L.	Phenolic acids, flavones, flavonols, flavanones, orthodipheols, anthocyanins	Campesterol, β-sitosterol, Stigmasterol	Puente *et al.* 2010
44	*Pinus gerardiana* Wall. ex D.Don	Phenolic acid, Phytosterol	Lycopene, Catechin, Oleic acid, Campesterol, Oleic acid, Gallocatechin, Linolenic acid, β-sitosterol	Singh *et al.* 2021
45	*Punica granatum* L.	Flavonoids, phenolic acids, ellagitannins, gallotannins	Apigenin, Tricetin, Luteolin, Kaempferol, Quercetin, Myricetin, Gallic acid, Ellagic acid, Ellagic acid pentoside, Ellagic acid-arabinoside, Ellagic acid rhamnoside, Brevifolincarboxylic acid, p- coumaric acid, Galloyl-HHDP-glucoside, Digalloyl-glucoside	Yisimayili and Chao, 2022
46	*Prunus mira* Koehne.	Flavonoids	NR	Ying *et al.* 2019
47	*Solanum nigrum* L.	Polyphenols, alkaloid	4 steroidal alkaloid glycosides, Solamargine, Solasonine, α and β- solanigrine	Wang et al., 2017
48	*Olea ferruginea* Royle	Polyphenols, quinones, flavonoids, Catechins, coumarins, terpenoids	NR	Bachheti *et al.* 2014
49	*Flacourtia indica* (*Burm. f.) Merr*.	Organic acid, flavonoids	Caffeic acid, ferulic acid and p-coumaric acid	Ndhala *et al.* 2007

50	*Achyranthes aspera* L.	Alkaloids, saponins, tannins, flavonoids, glycosides, steroids, Phenolic acids	27-cyclohexyheptacosan-7-ol, 16-hydroxy-26-methyl heptacosan-2-one, 17-pentatriacontanol, Isobetanin and betanin, eupatorin, chrysin, quercetin and kaempferol, 6-prenyl apigenin, bisdesmosidic saponin, sapogenin, β-sitosterol and spinasterol, gallic acid, vanillic acid, ferulic acid, isoferulic acid, protocatechuic acid, syringic acid, salicylic acid, gentisic acid, p-coumaric acid, trans-cinnamic acid, p-hydroxybenzoic acid, chlorogenic acid, sinapic acid and caffeic acid	Raju *et al.* 2022
51	*Elaeagnus latifolia* L.	Terpenoids, Triterpenoids, Anthraquinones	NR	Bachheti *et al.* 2014
52	*Bombax ceiba* L.	Flavonoids, alkaloids, phenolic acid, xanthones	Kaempferol, isorhamnetin, quercetin, and herbacetin Scopolamine, protocatechuic acid, esculetin, isomangiferin, mangiferin, isovitexin, vitexin, rutin, chlorogenic acid, methyl chlorogenate, vanillic acid, quercetin, fraxetin, palmitic acid, ethyl palmitate, β-sitosterol	Yasien *et al.* 2022
53	*Agave americana* Linn.	Phenols, flavonoids, phytosterols, and saponins	Quercetin, isorhamnetin, kaempferol, glycosylated derivates ellagic acid glycoside, Apigenin, p-coumaric acid, puerarin, Cantala-saponin-1	Bermúdez-Bazán *et al.* 2021
54	*Asparagus filicinus* Buch.-Ham.ex D.Don	Saponins and flavonoids	Filicinin A and B, Filiasparoside A and B, Aspafilioside C, Aspafilisine, kaempferol, quercetin, and rutin	Sobhy *et al.* 2022
55	*Dioscorea bulbifera* Linn.	Naphthofurans, Flavonoids, Steroids and steroid derivative	Diosbulbin, Daucosterol, β-sitosterol, Kaempferol-3,5-dimethylether, Caryatin, Myricetin, Kaempferol, Diosgenin, Quercetin, Stigmasterol, Pennogenin	Kundu *et al.* 2021
56	*Urtica dioica* L.	Flavonoids, Phenolic acids	Amentoflavone, apiin, apigenin, apigenin 7-O-*b*-D-glucoside, baicalin, baicalein, catechin, epicatechin, epigallocatechin gallate, chrysoeriol, genestein, isorhamnetin, kaempferol, keampferol 3-O-*b*-D-glucoside, luteolin, luteolin 7-O-*b*-D-glucoside, myrecetin, naringenin, quercetin, quercetin 3-O-*b*-D-glucoside, quercetin 3-O-*b*-D-galactoside, rutin, vitexin, Gallic acid, vanillic acid, syringic acid, protocatechuic acid, gentisic acid, Cinnamic acid, caffeic acid, p-coumaric acid, ferulic acid, chlorogenic acid, sinapic acid	Devkota *et al.* 2022
57	*Bauhinia purpurea* L.	Flavonoids and phenolic compounds	Flavone glycosides, dimeric flavonoids, 6-butyl-3-hydroxy flavanone, amino acids, phenyl fatty ester, lutine and β-sitosterol, B. purpurea lectin (in seeds)	Negi *et al.* 2012
58	*Boerhavia diffusa* L.	Tannins, flavonoids, alkaloids, glycosides, steroids, terpenoids, phenolic compounds	Quercetin 3-O-(2″-rhamnosyl)-robinobioside D-pinitol, fructofuranose, β-d-glucopyranose,	Juneja *et al.* 2020
59	*Polygonum aviculare* L.	Flavonol glucuronides	Myricetin 3-O-β-D-glucuronide, quercetin 3-O-β-D-glucuronide, isorhamnetin 3-O-β-D-glucuronide and kaempferol 3-O-βD-glucuronide	Granica *et al.* 2013
60	*Pueraria tuberosa* DC.	Alkaloids, carbohydrates, steroids, glycosides, tannins, terpenoids, flavonoids, coumarins and anthocyanidins	Puerarin, daidzein, genistein, phytosterols (β-sitosterol, stigmasterol, p-coumaric acid, arachidonic acid, eicosanoic acid, hexadecanoic acid, tetracosanoid acid,	Maji *et al.* 2014
61	*Antidesma montanum* Blume	Tannins, polyphenols, flavonoids, saponins and steroid glycosides	9-octadecenoic acid, n-hexadecanoic acid, and 9,12-octadecadienoic acid, carpusin, geraniin, antidesmin A, lupeolactone	Ismail *et al.* 2019
62	*Costus speciosus* (Koen ex. Retz) Sm.	Alkaloids, glycosides, steroids, phenolics, flavonoids, tannins, terpenoids, and saponins	Curcumin, curcuminoids, aliphatic hydroxyl ketones, triterpenes, starch mucilage, oxa-acid, fatty acid, abscisic acid, corticosteroids, tigogenin	Maji *et al.* 2020
63	*Phytolacca sp.*	Saponin, flavones, phytosterols	Esculentosides, phytolaccosides, cochliophilin A and α-spinasterol	Bailly, 2021
64	*Arisaema speciosum* Mart.	NR	NR	
65	*Chaerophyllum villosum* Wall. Ex DC.	Phenolic compounds, monoterpenes	Carvacrol methyl ether, thymol methyl ether, myristicin, γ-terpinene, p-cymene	Joshi, 2013

66	*Dioscorea glabra* Roxb.	Steroidal saponins, flavonoid, polyphenols, allantoin	Rutin, quercetin	Wang *et al.* 2023
67	*Typhonium diversifolium* Wall. Ex Schott	NR	NR	
68	*Allium cepa* var. proliferum	Flavonoid, organosulfur compounds, polyphenols and organic acids	Kuwanon K, ferulic acid, rhamnazin, leucopelargonidin and xanthomicrol	Zhou *et al.* 2020
69	*Celosia argentea* L.	Phenols, flavonoids, anthocyanins, diterpenes, saponins, cyclic-peptides, phenols, tannins	Isoflavones, latlancuayin, lutin, epigallocatechin, gallic acid, caffeic acid, rosmarinic acid, quercetin, triterpenoid saponins (celosin A-G, celosin I-II and celosin H-J, cristatain), Cycpeptide (morodin, celogentin A –K and celogenamide A)	Thorat, 2018
70	*Malva sylvestris* Linn.	Flavonoids, terpenoid, phenols, coumarin	Gossypetin 3-sulphate-8-O-β-$_D$-glucoside (gossypin), hypolaetin 3′-sulphate, 3-O--dglucopyranosyl-8-O-β-$_D$-glucuronopyranoside, hypolaetin 4′-methyl ether 8-O-β-$_D$-glucuronopyranoside, hypolaetin 8-O-β-$_D$-glucuronopyranoside, isoscutellarein 8-O-β-$_D$-glucuronopyranoside, malvone, 4-hydroxybenzoicacid, 4-methoxybenzoicacid, 4-hydroxy-3-methoxybenzoicacid, 2-hydroxybenzoic acid, 4-hydroxy-2-methoxybenzoic acid, 4-hydroxybenzyl alcohol, 4-hydroxydihydrocinnamic acid, 4-hydroxy-3methoxydihydrocinnamic acid, 4-hydroxycinnamic acid, ferulic acid, tyrosol, 7-hydroxy-6methoxycoumarin (scopoletin) and 5,7dimethoxycoumarin	Gasparetto, 2012
71	*Nasturtium officinale* R. Br.	Alkaloids, flavonoids, saponins, terpenoids/steroids, glycosides, tannins, glucosinolates	Gluconasturtin, gallic acid derivative, ferrullic acid derivative, proanthocynidin B1, p-coumaric acid derivative, apigenin, phydroxybenzoic acid, sinapic acid, p-coumaric acid, caftaric acid, quercetin-3- (cafferoyldiglucoside)-7glucoside, kaempferol-3-(caffeoyl diglucoside)- 7-rhamnoside, caffeoylmalic acid, coumaric acid derivative, β-carotene, 2-phenylethyl isothiocyanate, 4-phenylbutyl isothiocyanate, pulegone, sec-butyl isothiocyanate	Al-Snafi, 2020
72	*Orobanche alba* steph.	Terpenoids, organic acids and their derivatives	Linalool, geraniol, nerol, (Z)-iso-citral, geranylacetate, neral, neryl acetate, p-menthone, Pinocamphone, limonene, γ-terpinene, p-cymene, 1,8-cineol, α-copaene, Isobornyl-2-methyl-butyrate, δ-cadinene, Trans-caryophyllene, β-bourbonene, Caryophyllene oxide, Manool, Linoleic acid, Linolenic acid, Hexadecanoic acid, Palmitic acid, Myristic acid,	Shi *et al.* 2020
73	*Polygonum alpinum* All.	Flavonoids	Quercetin 3-*O*-arabinofuranoside, quercetin 3-*O*-β-glucuronopyranoside, quercetin 3-*O*-a-rhamnopyranosyl (1→6)-b-glucopyranoside, quercetin 3-*O*-β-galacturonopyranoside, quercetin 3-*O*-β-glucopyranoside, kaempferol 3-*O*-b-galactopyranoside, quercetin 3-*O*-β-galactopyranoside, and myricetin 3-*O*-β-galactopyranoside	Demirezer *et al.* 2006
74	*Taraxacum officinale* Weber	carotenoids; flavonoids, phenolic acids, sesquiterpene lactones, sterols, triterpenes	Quercetin, chrysoeriol, luteolin-7-glucoside, cafeic acid, chlorogenic acid, chicoric acid, taraxinic acid, taraxacoside, 11β,13-dihydrolactucin, ixerin D, taraxacolide-O-β-glucopyranoside, taraxasterol, β-sitosterol, stigmasterol, α-amyrin	Napoli and Zucchetti, 2021
75	*Amaranthus retroflexus* L.	Flavonoids, alkaloids, sesquiterpenes, phenolic acids, *O*-prenylated phenylpropanoids	Rutin and quercetin, amaranthine, ferulic acid, umbelliferone apigenin, boropinic acid, 4 -geranyloxyferulic acid (GOFA), 7-isopentenyloxycoumarin, auraptene, and umbelliprenin	Fiorito *et al.* 2017
76	*Amaranthus spinosus* Linn.	Betalains, hydroxycinnamates, saponins, steroids and flavonoids	Rutin, quercetin, amaranthine, isoamaranthine, hydroxycinnamates, quercetin and kaempferol glycosides, 7-p-coumaroyl, apigenin, 4-O-β-D-glucopyranoside, α-xylofuranosyl uracil, β-D-ribofuranosyl adenine and β-sitosterol glucoside	Tanmoy *et al.* 2014
77	*Angelica glauco* Edgew.	Terpene hydrocarbons, coumarins, phthalides	α-phellandrene, β-pinene, thujene, β-caryophyllene, γ-terpinene, β-bisabolene, germacrene D, trans-carveol, β-caryophyllene oxide, nerolidol, decursin, decursinol angelate, bergapten, phthalides ((*E*)- and (*Z*)-ligustilides, (*Z*)-butylidene phthalide	Kumar *et al.* 2022

78	*Commelina benghalensis* Linn.	Polyphenols, flavonoids, tannins, and alkaloids	Salicylic acid, p-coumaric acid, 8-hydroxyquinoline, caffeic acid, quinolones, catechol, resorcinol, tannic acid, chlorogenic acid n-octacosanol, n-triocotanol, stigmasterol, campesterol, hydrocyanic acid, beta-sitosterol and campesterol	Ghosh *et al.* 2019
79	*Medicago sativa* Linn.	Saponins, flavonoids	Triterpenic pentacyclic glycosides, zanhic acid, medicagenic acid, glucuronic acid, glycosides apigenin, luteolin, chrysoeriol, tricin and methyltricetin, medicarpin, melilotocarpan E, isoflavane millepurpan	Rafińska *et al.* 2017
80	*Polygonum aviculare* Linn.	Flavonoids	Quinic acid, quercitrin, myricetin, epicatechin, ellagic acid, kaempferol, iso-rhamnetin	Pawłowska *et al.* 2023
81	*Solanum nigrum* Linn.	Alkaloids, flavonoids, tannins, saponins, glycosides, coumarins, phytosterols	Solamargine, Solasonine, α and β- solanigrine, tigogenin, solasodine, solanine, sapogenin, diosgenin, tigogenin, solanidin, uttronin A, uttroside-A	Saleem *et al.* 2009
82	*Saussurea gossypiphora* D.Don.	Steroids, tannins, flavonoids, phenolics, saponins	Apigenin and luteolin	Mishra *et al.* 2021
83	*Capparis spinosa* L.	Flavonoid, polyphenol, alkaloids	Leaves: Rutin and quercertin Fruit: Capparine A, capparine B, flazin, guanosine, 1H-indole-3-carboxaldehyde, 4-hydroxy-1H-indole-3-carboxaldehyde, apigenin, kaempferol, thevetiaflavone, capparisine A, capparisine B, capparisine C, Tetrahydroquinoline acid	Zhang and Ma 2018
84	*Chenopodium Foliosum* Asch.	Phenolic compounds, monoterpenoid, sesquiterpenoids	Limonene, α-terpinene, γ-isomer, p-cymene, Carvacrol, thymol, α-pinene, camphor, β-caryophyllene	Kokanova-Nedialkova *et al.* 2009
85	*Sedum ewersii* Ledeb.	NR	NR	
86	*Polygonum chinensis* L.	Flavonoids, anthraquinones, phenylpropanoids, proanthocyanidines, coumarin, phenolic compound	1,2-benzenedicarboxylic acid, squalene, mono(2-ethylhexyl) ester, 8-methyloctahydrocoumarin	Ezhilan and Neelamegam, 2012
87	*Allium prezewalskianum* Regel.	NR	NR	
88	*Artemisia brevifolia* Wall. ex DC.	Phenolic acids, flavonoids c	chlorogenic acid, caffeic acid, coumaric acid, catechin and picein	Nataraj *et al.* 2022
89	*Mentha longifolia* (L.) Huds.	Flavonoids, ester flavonoid, phenol, monoterpene, terpenoid	Apigenin-7-o-glucoside, Luteolin 7-o-glucoside, Iso-orientin Eriodictyol-7-rutinoside, Rosmarinic acid, Tricetin 3′-o-glucoside 5′-o-rhamnoside, Carvone, 1,8- cineole, Pulegone, Menthol, Menthone, Piperitenone oxide, Sabinene	Farzaei *et al.* 2017
90	*Hippohae rhamnoides* L.	Phenolics, flavonols glycosides	Aglycones quercetin, Isorhamnetin, Myricetin, Kaempferol, I-3-O-glucoside-7-O-rhamnoside, I-3-O-rutinoside, I-3-O-β-sophoroside-7-O-α-rhamnoside, I-3-Oglucoside, Q-3-O-glucoside, Q-3-Orutinoside, Q-3-O-sophoroside-7-O-rhamnoside	Wani *et al.* 2016
91	*Carum carvi* L.	Flavonoids	Carvacrol, Carvone, α-pinene, limonene, γ-terpinene, linalool, carvenone, and p-cymene	Sachan *et al.* 2016
92	*Chenopodium botrys* L.	Terpenes	Camphor, δ-3-carene, fenchone, linalool, menthone, nerol, β-pinene, pulegone, terpineol-4 and thujone) and sesquiterpenes (β-elemene, elemol and β-eudesmol)	Morteza, 2015
93	*Arnebi euchroma* (Royle ex Benth.) I.M.Johnst. A	Naphthoquinone, purpurin	Shikonin, alkannin, shikometabolin H, epoxyarnebinol, and iso-hexyl-naphthopurpurin	Chawla, 2021
94	*Crepis tectorum* L.	NR	NR	
95	*Fagopyrium esculentum Moench*	Flavonoids, phenolic compounds, fagopyritols, triterpenoids,	Rutin, quercetin, orientin, vitexin, isovitexin, isoorientin, (´)-Epicatechin, (´)-epicatechin-3-O-p-hydroxybenzoate, (´)-epicatechin-3-O-(3,4-di-Omethyl)-gallate, (+)-catechin-7-O-glucoside, phenylpropanoids, olean-12-en-3-ol, urs-12-an-3-ol	Jing *et al.* 2016

96	*Rheum emodi* Wall	Anthraquinone	1,8-dihydroxyanthraquinones, rhein, aloe emodin, emodin, emodin glucosides, chrysophanol glucosides, Sulfemodin 8 O Glucoside, chrysophanol and physcion, Revandchinone 1, 2,3,4	Zargar *et al.* 2011
97	*Lactuca sativa* L.	Organic acids, alkaloids, terpenoids, phenolic compounds	Hydroxybenzoic, hydroxycinnamic acid, glycosylated quercetin, luteolin, lactucin, apigenin	Yang *et al.* 2018
98	*Raphanus sp.*	NR	NR	
99	*Lactuca dolichophylla* Kitam.	NR	NR	
100	*Oxyria digyna* (L.) Hill	Flavonol	5, 7, 3'-trihydroxy-4-methoxyflavanone-7-O-(2»-O-beta -D-glucopyranosyl)-alpha -L-rhamnopyranoside and 5, 7, 2', 3', 4'-pentahydroxyflavone-8-C-glucopyranoside, Vitexin, Orientin, Hesperidin, Quercetin-3-O-beta-D-glucopyranoside and Stigmasterol	Ahmad *et al.* 2022

revenue through the cultivation of cash crops have resulted in a significant reduction in the utilization of WEPs, rather than the inclination (Thakur *et al.,* 2017). Upon survey, it was observed that locals were more inclined towards the sale of the WEPs for hard cash instead of consuming themselves, similar to the observation of Thakur *et al.* 2017; Chacha *et al.* 2022. From a scientific standpoint of view, the lack of *ex-situ* conservation, domestication strategies, and management practices would endanger the continued availability of WEPs. However, there is an urgent need to promote the domestication of underutilized WEPs owing to several benefits they offer, namely reduced carbon footprint in their production owing to lower fertilizer inputs, climate and pest resilience, multiutility use of single crop as food, fodder, fibre, and fuel.

Strategies for Introducing WEPs into Mainstream Agriculture

Although there is very limited knowledge of the conservation strategies for WEPs, efforts are being made towards their domestication to bring more diversity to our diet. Some potential strategies for domestication could be (i) captive cultivation of endangered WEPs and reintroducing them in natural populations, (ii) intercropping with cash crops, (iii) identification of soil microorganisms that promote WEP's growth and introducing them in their domestication, (iv) introducing drought resilient WEPs in degraded and dry lands and other novel environments, (v) use of new generation techniques such as high throughput phenomics, next generation sequencing, genome-wide association studies (GWAS), interactome big data analysis and machine learning for understanding the behaviour of WEPs under stress environments and utilizing the data for domestication process (Krug *et al.,* 2023).

Conclusion

The present work reiterates the importance of WEPs in bringing dietary diversity to humans. Dependence on fewer number of crops have resulted in significant volatility in crop yields impacting economies on a global scale. In addition, the high environmental footprints and vulnerability to pest and pathogenic attacks make these crops unsustainable for the future. Underutilized WEPs can offer a sustainable alternative to these crops and NWHR possess a great diversity of WEPs. In the present study, nearly 100 WEPs were identified and characterized for their consumption pattern season-wise in the NWHR. Green leafy vegetables and fruits were the predominant forms of WEP consumption. The health benefits derived from these WEPs are discussed through their phytochemical composition, polyphenols and terpenoids were the predominant class of molecules present across the groups responsible for their bioactive properties. The WEP consumption and environmental conditions such as that of cold desert regions are highly correlated. There is an urgent need for devising strategies to domesticate these WEPs. Use of novel technologies such as high throughput phenomics, next generation sequencing, genome wide association studies (GWAS), interactome big data analysis and machine learning would augment the conservation strategies for these unique WEPs. Introduction of underutilized genetic resources such as WEPs would enhance the regional food security and improve the health and well-being of the population.

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