

AN ETHNOBOTANICAL STUDY ON WILD EDIBLE PLANTS OF DISTRICT DODA, J&K AND ANALYSIS OF NUTRITIONAL CONTENT OF SOME SELECTED PLANTS

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**in
BOTANY**

**By
SANIA HAMID**

Registration Number: 42000164

Supervised By

Dr. Devendra Kumar Pandey

(UID: 15673)

Department of Botany

(Professor)

School of Bioengineering and Biosciences

Lovely Professional University

Co-Supervised by

Dr. Anju Koul

(UID: NA)

Department of Botany

(Associate Professor)

Govt. Degree College Akhnoor, J&K



LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2026

DECLARATION

I, hereby declared that the presented work in the thesis entitled “An Ethnobotanical Study on Wild Edible Plants of District Doda, J&K and analysis of nutritional content of some selected plants” in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of **Dr. Devendra Kumar Pandey** working as Professor in the School of Biosciences and Bioengineering of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.



(Signature of Scholar)

Name of the scholar: Sania Hamid

Registration No.: 42000164

Department/school: School of Biosciences and Bioengineering

Lovely Professional University,

Punjab, India

CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled “An Ethnobotanical Study on Wild Edible Plants of District Doda, J&K and analysis of nutritional content of some selected plants” submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Botany, School of Bioengineering and Biosciences, is a research work carried out by **Sania Hamid** (Registration No. 42000164), is bonafide record of her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.



(Signature of Supervisor)

Name of supervisor:

Dr. Devendra Kumar Pandey

Designation: Professor

Department/school:

School of Biosciences and Bioengineering

Lovely Professional University, Punjab



(Signature of Co-Supervisor)

Name of Co-Supervisor:

Dr. Anju Koul

Designation: Associate Professor

Department of Botany

Government Degree College

Akhnoor, J&K

Abstract

Ethnobotany is an interdisciplinary science bridging traditional knowledge of plants with contemporary biological research, providing critical insights into the cultural, nutritional, and therapeutic roles of plants within human societies. Among its most important domains is the study of wild edible plants (WEPs), which continue to serve as vital sources of micronutrients, seasonal foods, and livelihood support in many rural and indigenous communities. This research work titled “An Ethno-botanical Study of Wild Edible Plants of District Doda of J&K and Nutritional Analysis of some selected Plants” was carried out in two parts i.e., field work and laboratory analysis. The field work, consisting of collection of plants and documentation of ethno-botanical data was done during the years 2021-2023. The analysis part was subsequently carried out during 2023 to 2025. A total of 85 plants being used as wild edibles were collected and identified. The specimens were deposited in Herbarium, University of Jammu. Some of the wild leafy vegetables were analyzed for their nutrient content, minerals, oxalates (anti-nutrients), presence of phytochemicals and anti-oxidant activity. The taxa evaluated were *Taraxacum officinale*, *Phytolacca acinosa*, *Urtica dioica*, *Malva neglecta*, *Eremurus himalaicus*, *Diplazium esculentum*, *Fagopyrum esculentum*, and *Cichorium intybus*. The evaluation of nutrient content was done by using standard AOAC methods including micro-Kjeldahl method for protein estimation, phenol sulfuric acid method for determination of total carbohydrate content, soxhlet method for lipids and gravimetric method for crude fibre content. The estimation of mineral content was done by Energy-dispersive X-ray fluorescence (EDXRF) technique using a benchtop EDXRF spectrometer. The determination of oxalate content was done by potassium permanganate titration method. Fourier Transform Infrared (FTIR) spectroscopy was employed to investigate the phytochemical composition of these plant species. Estimation of tannins and flavonoids was done by using UV spectrophotometry. Anti-oxidant activity of the plant samples was studied by 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay. The tests were performed in triplicate and three readings were recorded for each. The data were analyzed using one-way analysis of variance (ANOVA) with IBM SPSS Statistics (version 22.0) software (Armonk, NY: IBM Corp.).

The results obtained through analysis revealed that these wild edible plants represent a diverse reservoir of nutrients, essential minerals and medicinally important phytochemicals. Proximate analysis revealed considerable interspecific variation in macronutrient profiles. Moisture content ranged from 78.27% (*P. acinosa*) to 92.53% (*E. himalaicus*), while crude protein was highest in *C. intybus* (12.50%) and *D. esculentum* (10.28%). *F. esculentum* exhibited the highest fat content (11.40%) and calorific value (344.88 kcal/100 g), whereas *D. esculentum* showed maximum crude fibre (34.7%) levels. Elevated ash content was observed in *M. neglecta* (19.4%) and *P. acinosa* (16.8%) indicating substantial mineral richness.

Elemental analysis performed using Energy Dispersive X-Ray Fluorescence (EDXRF), revealed substantial interspecific variation in both macro- and microelements on dry weight basis. Among the macroelements, potassium (2.57–5.86 g/100 g) was the most abundant, followed by calcium (0.27–4.02 g/100 g), phosphorus (0.29–0.72 g/100 g), and magnesium (0.44–0.95 g/100 g). Microelements such as iron (19.3–219 mg/100 g), zinc (1.9–7.3 mg/100 g), manganese (2.2–9.0 mg/100 g), and copper (0.9–3.2 mg/100 g) were also detected in nutritionally significant quantities.

The results indicated that *Malva neglecta* sample contained exceptionally high iron (219.0 mg/100 g) and zinc (7.3 mg/100 g), while *Urtica dioica* exhibited the highest calcium concentration (4.02 g/100 g). *Diplazium esculentum* and *Phytolacca acinosa* were particularly rich in potassium and phosphorus. Oxalate concentrations were quantified and were found to be ranging from 4.27 to 15.75 mg/g on dry weight basis. The lowest oxalate content was observed in *D. esculentum* (4.27 mg/g), whereas *T. officinale* and *F. esculentum* exhibited the highest levels (15.75 mg/ g). *M. neglecta*, *U. dioica*, and *D. esculentum* emerged as promising sources of bioavailable iron, calcium, and potassium, with minimal anti-nutritional interference owing to their low oxalate content. On the other hand, high-oxalate species like *F. esculentum* and *T. officinale* indicated requirement of processing interventions to optimize nutrient bioavailability.

FTIR spectral signatures highlighted that all species are chemically rich in constituents bearing hydroxyl and glycosidic groups, alongside secondary phenolic compounds and minimal lipid fractions. The technique effectively differentiated the biochemical nature of each species with spectra broadly recorded in the 4000–600 cm^{-1} range. It revealed broad absorption bands corresponding to hydroxyl and amino stretching vibrations (3700–3200 cm^{-1}), aliphatic C–H stretches (3000–2800 cm^{-1}), carbonyl and aromatic C=C stretching (1740–1500 cm^{-1}), and glycosidic/carbohydrate-associated C–O linkages (1260–950 cm^{-1}). Semi-quantitative interpretation showed that hydroxyl and N–H groups were the most dominant (30–35%), followed by carbohydrate C–O bonds (20–25%), carbonyl and aromatic functional groups (15% each), and a minor contribution from aliphatic and overtone bands (<10%).

Among the examined taxa, *T. officinale* and *P. acinosa* exhibited strong O–H/N–H and glycosidic absorptions, confirming the prevalence of polysaccharides, glycosides, and polyphenolic compounds. *U. dioica* and *D. esculentum* displayed comparable spectral patterns with abundant hydroxyl and carbohydrate peaks, moderate carbonyl intensity, and aromatic features indicative of phenolics and esters. *M. neglecta* presented additional amide and carboxylate bands (1543–1398 cm^{-1}), confirming the presence of proteinaceous and mucilaginous components. *E. himalaicus* showed notable aromatic and nitrogen-related (C–N) vibrations with minor conjugated (C $\equiv$ C/C $\equiv$ N) signals, suggesting the presence of unique secondary metabolites. *F. esculentum* demonstrated balanced intensities of polysaccharide and aromatic groups, aligning with its known flavonoid, rutin and starch-rich composition, whereas *C. intybus* exhibited distinct carbonyl and carbohydrate peaks corresponding to inulin-type fructans and phenolic esters.

The quantitative estimation of tannin content among eight selected wild edible and medicinal plant species revealed notable interspecific variation, reflecting differences in their phytochemical composition and ecological adaptations. The tannin content ranged from 20.04 mg/g in *M. neglecta* to 65.96 mg/g in *F. esculentum*, indicating a broad biochemical diversity among the studied taxa. *F. esculentum* (65.96 mg/g), *T. officinale* (63.17 mg/g), *D. esculentum* (63.00 mg/g), and *C. intybus* (62.53 mg/g)

exhibited the highest tannin concentrations, signifying their potential as strong antioxidant and antimicrobial agents, as tannins are known for their phenolic nature and bio-protective effects. Moderate levels were observed in *P. acinosa* (40.18 mg/g), *U. dioica* (42.49 mg/g), and *E. himalaicus* (30.83 mg/g), suggesting balanced nutraceutical potential with lesser antinutritional implications related to tannins. The lowest tannin content in *M. neglecta* (20.04 mg/g) revealed enhanced palatability and digestibility, making it suitable for regular dietary use.

The quantitative estimation of total flavonoid content in the studied species also revealed marked interspecific variation in phenolic metabolism and antioxidant potential. The flavonoid content ranged from 0.44 mg/g in *E. himalaicus* to 2.05 mg/g in *P. acinosa*, signifying substantial biochemical diversity among the examined taxa. The highest concentrations in *P. acinosa* (2.05 mg/g) and *U. dioica* (2.002 mg/g) underscore their strong antioxidant and anti-inflammatory properties, validating their traditional ethnomedicinal use. Moderate levels in *T. officinale* (1.70 mg/g), *C. intybus* (1.46 mg/g), and *F. esculentum* (1.41 mg/g) indicate appreciable nutraceutical value, supporting their inclusion in functional food formulations. Lower concentrations in *M. neglecta* (0.96 mg/g), *D. esculentum* (1.16 mg/g), and *E. himalaicus* (0.44 mg/g) suggest relatively reduced flavonoid biosynthesis. The variation in flavonoid accumulation could be attributed to differences in metabolic pathways, light exposure, altitude, edaphic factors and stress physiology. These findings highlight the rich tannin-flavonoid diversity among these Himalayan species, reflecting their adaptive biochemical strategies and ecological significance.

The antioxidant potential of these plants was evaluated using the percentage radical scavenging activity (RSA) as an indicator of free radical neutralization efficiency. The results demonstrated substantial interspecific variation, with RSA values ranging from 32.13% in *P. acinosa* to 74.92% in *E. himalaicus*. The highest antioxidant activity observed in *E. himalaicus* signifies its strong free radical quenching capacity. *F. esculentum* (56.60%) and *T. officinale* (42.68%) also exhibited considerable antioxidant activity, aligning with their ethnomedicinal roles. Moderate activities were recorded in *D. esculentum* (40.73%), *C. intybus* (39.82%), *U. dioica* (34.80%), and *M. neglecta* (34.69%), whereas *P. acinosa* (32.13%) displayed relatively lower

scavenging potential, indicating species-specific variations in phenolic metabolism. The pronounced activity of *E. himalaicus* and *F. esculentum* highlights their potential as potent sources of natural antioxidants suitable for nutraceutical and therapeutic applications.

The overall findings of this research validate the traditional usage of the studied species and contribute to the growing evidence supporting Himalayan wild edibles as reservoirs of bioactive compounds with significant health-promoting potential. These edible wild plants exhibit remarkable nutritional diversity, with each species offering unique mineral strengths as well as phytochemicals of medicinal importance. Incorporating them into human diets could address multiple micronutrient deficiencies, support chronic disease prevention, and enhance overall health. The results provide a scientific basis for the valorization of these species as natural sources of antioxidants, supporting their potential utilization in pharmaceutical, nutraceutical, and food industries. This comparative assessment adds valuable insight into the phytochemical composition of regional wild edibles and offers a foundation for future bioactivity-guided research and functional product development.

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Abstract

Ethnobotany is an interdisciplinary science bridging traditional knowledge of plants with contemporary biological research, providing critical insights into the cultural, nutritional, and therapeutic roles of plants within human societies. Among its most important domains is the study of wild edible plants (WEPs), which continue to serve as vital sources of micronutrients, seasonal foods, and livelihood support in many rural and indigenous communities. This research work titled “An Ethno-botanical Study of Wild Edible Plants of District Doda of J&K and Nutritional Analysis of some selected Plants” was carried out in two parts i.e., field work and laboratory analysis. The field work, consisting of collection of plants and documentation of ethno-botanical data was done during the years 2021-2023. The analysis part was subsequently carried out during 2023 to 2025. A total of 85 plants being used as wild edibles were collected and identified. The specimens were deposited in Herbarium, University of Jammu. Some of the wild leafy vegetables were analyzed for their nutrient content, minerals, oxalates (anti-nutrients), presence of phytochemicals and anti-oxidant activity. The taxa evaluated were *Taraxacum officinale*, *Phytolacca acinosa*, *Urtica dioica*, *Malva neglecta*, *Eremurus himalaicus*, *Diplazium esculentum*, *Fagopyrum esculentum*, and *Cichorium intybus*. The evaluation of nutrient content was done by using standard AOAC methods including micro-Kjeldahl method for protein estimation, phenol sulfuric acid method for determination of total carbohydrate content, soxhlet method for lipids and gravimetric method for crude fibre content. The estimation of mineral content was done by Energy-dispersive X-ray fluorescence (EDXRF) technique using a benchtop EDXRF spectrometer. The determination of oxalate content was done by potassium permanganate titration method. Fourier Transform Infrared (FTIR) spectroscopy was employed to investigate the phytochemical composition of these plant species. Estimation of tannins and flavonoids was done by using UV spectrophotometry. Anti-oxidant activity of the plant samples was studied by 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay. The tests were performed in triplicate and three readings were recorded for each. The data were analyzed using one-way analysis of variance (ANOVA) with IBM SPSS Statistics (version 22.0) software (Armonk, NY: IBM Corp.).

The results obtained through analysis revealed that these wild edible plants represent a diverse reservoir of nutrients, essential minerals and medicinally important phytochemicals. Proximate analysis revealed considerable interspecific variation in macronutrient profiles. Moisture content ranged from 78.27% (*P. acinosa*) to 92.53% (*E. himalaicus*), while crude protein was highest in *C. intybus* (12.50%) and *D. esculentum* (10.28%). *F. esculentum* exhibited the highest fat content (11.40%) and calorific value (344.88 kcal/100 g), whereas *D. esculentum* showed maximum crude fibre (34.7%) levels. Elevated ash content was observed in *M. neglecta* (19.4%) and *P. acinosa* (16.8%) indicating substantial mineral richness.

Elemental analysis performed using Energy Dispersive X-Ray Fluorescence (EDXRF), revealed substantial interspecific variation in both macro- and microelements on dry weight basis. Among the macroelements, potassium (2.57–5.86 g/100 g) was the most abundant, followed by calcium (0.27–4.02 g/100 g), phosphorus (0.29–0.72 g/100 g), and magnesium (0.44–0.95 g/100 g). Microelements such as iron (19.3–219 mg/100 g), zinc (1.9–7.3 mg/100 g), manganese (2.2–9.0 mg/100 g), and copper (0.9–3.2 mg/100 g) were also detected in nutritionally significant quantities.

The results indicated that *Malva neglecta* sample contained exceptionally high iron (219.0 mg/100 g) and zinc (7.3 mg/100 g), while *Urtica dioica* exhibited the highest calcium concentration (4.02 g/100 g). *Diplazium esculentum* and *Phytolacca acinosa* were particularly rich in potassium and phosphorus. Oxalate concentrations were quantified and were found to be ranging from 4.27 to 15.75 mg/g on dry weight basis. The lowest oxalate content was observed in *D. esculentum* (4.27 mg/g), whereas *T. officinale* and *F. esculentum* exhibited the highest levels (15.75 mg/ g). *M. neglecta*, *U. dioica*, and *D. esculentum* emerged as promising sources of bioavailable iron, calcium, and potassium, with minimal anti-nutritional interference owing to their low oxalate content. On the other hand, high-oxalate species like *F. esculentum* and *T. officinale* indicated requirement of processing interventions to optimize nutrient bioavailability.

FTIR spectral signatures highlighted that all species are chemically rich in constituents bearing hydroxyl and glycosidic groups, alongside secondary phenolic compounds and minimal lipid fractions. The technique effectively differentiated the biochemical nature of each species with spectra broadly recorded in the 4000–600 cm^{-1} range. It revealed broad absorption bands corresponding to hydroxyl and amino stretching vibrations (3700–3200 cm^{-1}), aliphatic C–H stretches (3000–2800 cm^{-1}), carbonyl and aromatic C=C stretching (1740–1500 cm^{-1}), and glycosidic/carbohydrate-associated C–O linkages (1260–950 cm^{-1}). Semi-quantitative interpretation showed that hydroxyl and N–H groups were the most dominant (30–35%), followed by carbohydrate C–O bonds (20–25%), carbonyl and aromatic functional groups (15% each), and a minor contribution from aliphatic and overtone bands (<10%).

Among the examined taxa, *T. officinale* and *P. acinosa* exhibited strong O–H/N–H and glycosidic absorptions, confirming the prevalence of polysaccharides, glycosides, and polyphenolic compounds. *U. dioica* and *D. esculentum* displayed comparable spectral patterns with abundant hydroxyl and carbohydrate peaks, moderate carbonyl intensity, and aromatic features indicative of phenolics and esters. *M. neglecta* presented additional amide and carboxylate bands (1543–1398 cm^{-1}), confirming the presence of proteinaceous and mucilaginous components. *E. himalaicus* showed notable aromatic and nitrogen-related (C–N) vibrations with minor conjugated (C $\equiv$ C/C $\equiv$ N) signals, suggesting the presence of unique secondary metabolites. *F. esculentum* demonstrated balanced intensities of polysaccharide and aromatic groups, aligning with its known flavonoid, rutin and starch-rich composition, whereas *C. intybus* exhibited distinct carbonyl and carbohydrate peaks corresponding to inulin-type fructans and phenolic esters.

The quantitative estimation of tannin content among eight selected wild edible and medicinal plant species revealed notable interspecific variation, reflecting differences in their phytochemical composition and ecological adaptations. The tannin content ranged from 20.04 mg/g in *M. neglecta* to 65.96 mg/g in *F. esculentum*, indicating a broad biochemical diversity among the studied taxa. *F. esculentum* (65.96 mg/g), *T. officinale* (63.17 mg/g), *D. esculentum* (63.00 mg/g), and *C. intybus* (62.53 mg/g)

exhibited the highest tannin concentrations, signifying their potential as strong antioxidant and antimicrobial agents, as tannins are known for their phenolic nature and bio-protective effects. Moderate levels were observed in *P. acinosa* (40.18 mg/g), *U. dioica* (42.49 mg/g), and *E. himalaicus* (30.83 mg/g), suggesting balanced nutraceutical potential with lesser antinutritional implications related to tannins. The lowest tannin content in *M. neglecta* (20.04 mg/g) revealed enhanced palatability and digestibility, making it suitable for regular dietary use.

The quantitative estimation of total flavonoid content in the studied species also revealed marked interspecific variation in phenolic metabolism and antioxidant potential. The flavonoid content ranged from 0.44 mg/g in *E. himalaicus* to 2.05 mg/g in *P. acinosa*, signifying substantial biochemical diversity among the examined taxa. The highest concentrations in *P. acinosa* (2.05 mg/g) and *U. dioica* (2.002 mg/g) underscore their strong antioxidant and anti-inflammatory properties, validating their traditional ethnomedicinal use. Moderate levels in *T. officinale* (1.70 mg/g), *C. intybus* (1.46 mg/g), and *F. esculentum* (1.41 mg/g) indicate appreciable nutraceutical value, supporting their inclusion in functional food formulations. Lower concentrations in *M. neglecta* (0.96 mg/g), *D. esculentum* (1.16 mg/g), and *E. himalaicus* (0.44 mg/g) suggest relatively reduced flavonoid biosynthesis. The variation in flavonoid accumulation could be attributed to differences in metabolic pathways, light exposure, altitude, edaphic factors and stress physiology. These findings highlight the rich tannin-flavonoid diversity among these Himalayan species, reflecting their adaptive biochemical strategies and ecological significance.

The antioxidant potential of these plants was evaluated using the percentage radical scavenging activity (RSA) as an indicator of free radical neutralization efficiency. The results demonstrated substantial interspecific variation, with RSA values ranging from 32.13% in *P. acinosa* to 74.92% in *E. himalaicus*. The highest antioxidant activity observed in *E. himalaicus* signifies its strong free radical quenching capacity. *F. esculentum* (56.60%) and *T. officinale* (42.68%) also exhibited considerable antioxidant activity, aligning with their ethnomedicinal roles. Moderate activities were recorded in *D. esculentum* (40.73%), *C. intybus* (39.82%), *U. dioica* (34.80%), and *M. neglecta* (34.69%), whereas *P. acinosa* (32.13%) displayed relatively lower

scavenging potential, indicating species-specific variations in phenolic metabolism. The pronounced activity of *E. himalaicus* and *F. esculentum* highlights their potential as potent sources of natural antioxidants suitable for nutraceutical and therapeutic applications.

The overall findings of this research validate the traditional usage of the studied species and contribute to the growing evidence supporting Himalayan wild edibles as reservoirs of bioactive compounds with significant health-promoting potential. These edible wild plants exhibit remarkable nutritional diversity, with each species offering unique mineral strengths as well as phytochemicals of medicinal importance. Incorporating them into human diets could address multiple micronutrient deficiencies, support chronic disease prevention, and enhance overall health. The results provide a scientific basis for the valorization of these species as natural sources of antioxidants, supporting their potential utilization in pharmaceutical, nutraceutical, and food industries. This comparative assessment adds valuable insight into the phytochemical composition of regional wild edibles and offers a foundation for future bioactivity-guided research and functional product development.

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Chapter1

INTRODUCTION

The diversity of life on this earth is supported by plants which form the basis of all ecosystems. Human beings are dependent on plants, not only for their survival but for their sustenance and well-being also in the form of food, medicine, shelter, etc (Knapp, 2019). The scientific study of all these interactions between human-beings and plants is known as Ethnobotany (Schaal, 2019), a term given in 1895 by Dr. J.W. Harshberger, an American botanist (Rahman *et al.* 2019). The word Ethnobotany is composed of two terms; i.e., ‘ethno’ meaning ‘study of people’ and ‘botany’ meaning ‘study of plants’. It is a multi-disciplinary science which is part of a broad discipline called Ethnobiology (Pandey and Tripathi, 2017) and deals with all facets of human-plant relationship. Ethnobotany has high relevance to global issues such as biodiversity conservation, climate change, food security and human health; therefore, it has received considerable attention from researchers during recent years (Palchetti *et al.* 2023). The study of Wild Edible Plants (WEPs) is an important aspect of ethnobotanical research, as food is the basic necessity of life. These plants have integrated with the local traditional knowledge over decades, assuming great cultural importance in different societies.

1.1 Wild Edible Plants: An Overview

Wild edible plants (WEPs) are defined as the species of native plants that grow as well as reproduce in their natural habitats without cultivation and are directly obtained from the wild for human consumption. The whole plants or their parts are collected for food from their natural populations. These plants grow spontaneously in forests and even on farmland or uncultivated land (Duguma, 2020) forming an important part of the local ecosystems. Humans have been foraging for WEPs since their existence on this planet, integrating them into diets and traditional food systems. Distributed across diverse evolutionary lineages, WEPs are particularly well represented in families such as Rosaceae, Fabaceae, Asteraceae, Lamiaceae, Polygonaceae, Brassicaceae, Apiaceae, and Amaranthaceae, reflecting the repeated human selection of lineages possessing favourable nutritional, sensory, and functional traits (Samant &

Dhar, 1997; Alrhoun *et al.*, 2025). Their present diversity and biochemical characteristics are the products of long-term evolutionary processes operating across contrasting environments, from alpine and temperate ecosystems to tropical, Mediterranean, and semi-arid habitats. Evolutionary relatedness may influence the distribution of functional traits, and closely related taxa can share nutritional, phytochemical, or ecological characteristics because of common ancestry and phylogenetic conservatism. For example, Rosaceae contain numerous antioxidant-rich edible fruits, Fabaceae include many nitrogen-fixing taxa with protein-rich seeds, Polygonaceae comprise several mineral-rich edible species that may also accumulate oxalates, while Lamiaceae are widely recognized for essential oils and antioxidant phenolic compounds. At the same time, adaptive evolution under environmental pressures such as drought, cold, salinity, ultraviolet radiation, herbivory, and pathogen attack has promoted stress tolerance, efficient resource acquisition, and the production of secondary metabolites, including phenolics, flavonoids, tannins, and terpenoids, many of which also contribute to the nutritional and medicinal value of wild plants (Vanzani *et al.*, 2011).

During the course of civilization, gradually there was domestication of crop plants, and the cultivated plants became main source of food. Unlike intensively domesticated crops, most WEPs have undergone relatively limited artificial selection; nevertheless, their continued use has been shaped by ecological availability, repeated harvesting, cultural preferences, traditional ecological knowledge, human migration, and the historical exchange of food traditions (Alrhoun *et al.*, 2025). But the use of WEPs was never discontinued; even today these plants form an integral part of the human diet mostly in rural and semi-urban areas across the globe. They are natural food reserves for mankind providing nutrition even to the tribal communities living in less accessible areas. They contribute significantly towards food security and livelihood of tribes, but have not gained much scientific recognition (Mahapatra and Panda, 2012). WEPs have also been used as food sources during famines when there was food shortage and crop failure due to adverse environmental conditions like floods, droughts and pest infestation of domesticated crops (Singh and Mathew, 2021).

The earlier ethno-botanical research was mainly focused on medicinal plants and WEPs were studied only with respect to ‘phytoalimurgy’ which mainly refers to their importance as famine foods or emergency foods. But in the recent years, there has been renewed interest in the study of WEPs and they are referred to as ‘new functional foods’ because of their beneficial phytochemical and nutrient content (Ceccanti *et al.*, 2018).

1.2 Functional Foods and Nutraceuticals

WEPs are crucial for enhancing dietary diversity in various regions and can also be consumed for their health benefits as many of them are utilized as herbal medicines in traditional practices (Shin *et al.* 2018). Due to their positive health impacts, these plants are often classified as functional foods. They have higher levels of beneficial components such as minerals, vitamins, antioxidants, phenolics, flavonoids, and fibre as compared to many conventional crops (Benitez *et al.* 2017, Motti, 2022). Additionally, wild plants are seen as healthier alternatives to cultivated vegetables that may contain pesticides and other chemicals. Recent research has increasingly highlighted the connection between diet and disease prevalence. One such widely recognized diet is the Mediterranean Diet, which exemplifies a healthy dietary pattern that is nutrient-dense and flavorful while promoting heart health, blood pressure regulation, offering protective benefits against incommunicable diseases such as cancer, diabetes, etc. It is deep rooted in biodiversity as WEPs are integral to this diet alongside cultivated fruits and vegetables, historically serving as primary food sources in rural communities (Motti *et al.* 2020, Delgado *et al.* 2023).

WEPs are also being explored as source of nutraceuticals because of the popular traditional use of these plants for therapeutic purpose. The observation of local ethno-botanical traditions with respect to medicinal utilization of these plants is important as it may provide leads for their possible introduction into modern diets. In many European regions and also other parts of the world, recently, there has been considerable revival of interest in the use of WEPs and some of these are even available in the local markets. (Marrelli *et al.* 2020). These plants are considered to be potential sources of natural constituents beneficial for human health in addition to the

major nutrients. They are easy to access, have unique chemo-diversity which is responsible for anti-microbial activity of extracts derived from these plants (Porras *et al.* 2020). Many other beneficial aspects of WEPs have been revealed by current research going on in this area. These include anti-diabetic and anti-cancer potential of the phytochemical constituents of some WEPs. Various factors have led to a worldwide increase in the number of individuals with diabetes mellitus and according to the WHO, and within a few years the number is likely to cross 300 million (Alam *et al.* 2020). Some of the traditionally used WEPs have been assessed for their anti-diabetic activities and the results have confirmed their α -glucosidase as well as α -amylase inhibitory property (Rana *et al.*, 2019; Mzoughi *et al.* 2019, Alam *et al.*, 2020). The anti-cancer activity of WEP extracts has been studied and it has shown positive results (Tuzcu *et al.*, 2017, Abu-Lafi *et al.*, 2019, Neipihoi *et al.*, 2020). Numerous other studies have shown that WEPs possess potentially beneficial active principles, though there have been reports of the presence of some undesirable compounds as well. Therefore, adequate research is necessary to evaluate not only the benefits, but also the unwanted effects associated with the use of these edible plants (Marelli *et al.* 2020).

1.3 Food Security

Food security is one of the most pressing issues of the 21st century encompassing not only the availability of sufficient food but also its accessibility and nutritional adequacy. Despite advances in agriculture and the wide capacity of global food systems, many people still face hunger or lack access to nutritious diets. The rise in consumption of highly processed foods poses health risks, while malnutrition (encompassing both under nutrition and over nutrition) alongside climate change, represents a significant global challenge. This underscores the urgent need for a food system which is healthier and highly sustainable. The global population is estimated to reach around 10 billion by the year 2050 and at present humanity is facing the challenges of food insecurity and malnutrition. Almost 750 million individuals in the world were exposed to severe levels of food insecurity in 2019 according to FAO whereas the total food insecurity including the severe and moderate levels accounted to a total of 2 billion people worldwide. There has been a rise in food insecurity from

2014 to 2019 in all continents of the world except Europe and Northern America. According to FAO estimates, in 2019 there has been prevalence of undernourishment in approximately 690 million people in the world and half of these undernourished people live in Asia accounting to around 381 million (FAO, 2021). There has been negligible improvement in the food insecurity levels during the years 2022 and 2023 (FAO, 2024). This evidence clearly reveals that the world is far from achieving the UN Sustainable development Goal 2 (UNSDG-2 ‘End hunger, achieve food security and improved nutrition, and promote sustainable agriculture’) by 2030. Encouraging the use of WEPs can play a vital role in addressing global food insecurity by providing nutrient-rich and diverse dietary options.

Diversity or heterogeneity in diets has been recommended for proper human nutrition and health. One of the main reasons for malnutrition is that the world’s 51% of caloric intake is from rice, wheat and maize which dominate the world markets; as a result the diets are becoming increasingly homogenous (Borelli *et al.* 2020). In addressing this global challenge, a better understanding of the natural food resources is required, and WEPs are a part of it. As per the current estimates, there are around 7,039 total edible plant species in the world including 7,014 higher plants. But comparatively, a quite smaller number of food crops is being widely cultivated for providing major calorific and nutrient intake of human beings. Only 417 of edible plant species from 168 genera belonging to 62 families, appear in the FAO list, 2015 (Diazgranados, 2020). This means we are dependent upon a very narrow range of crop genetic diversity. Many of the left-out crops have been neglected and under-utilized and are under threat because of habitat destruction and lack of documentation (Ulian *et al.* 2020).

In India also the number of wild edible species is quite high. There is record of around 1,403 wild plant species from 184 families that are consumed across India. Though numerous edible plant species remained semi-wild or wild, and were not domesticated; however, they have the potential for transforming our food systems towards being more nutritious, more sustainable, and resilient to climate change (Ray *et al.* 2020). By integrating them into modern food systems, WEPs have the potential to contribute to a more secure and equitable food future.

The research for identifying new potential crops which can serve as alternative sources of food and study of their nutrient profile will be of great significance in the management of food shortage issues and nutritional problems. Wild plants have been subjected to numerous studies regarding the nutritional composition, and many have been found to be very rich sources of nutrients. There is emerging interest in the evaluation of nutritional values of the WEPs and there are many such plants which are commonly used by indigenous people whose nutritient content is yet to be evaluated (Kumar and Shiddamallaya, 2021). Since there is increase in evidence of the nutritional value and biocultural importance of the wild edible plant species, they can be used to enhance nutrition and make diverse and sustainable foods available to all. This can be done by creating the market for orphan crops and WEPs at the local as well as global level (Borelli *et al.* 2020). Therefore there is an urgent need to systematically document, conserve and promote the use of WEPs.

1.4 Socio-economic Aspects

Wild food plants play a crucial socio-economic role in many regions by supplementing house-hold nutrition, generating income and sustaining traditional food practices. They contribute to local cultural heritage as well as environmental sustainability through their gathering and consumption (Karabak 2017, Moksia *et al.* 2019). In recent years, there has been growing interest in studying WEPs among rural populations, with numerous floristic inventories produced across various continents. Some research has examined variations in ethno-botanical knowledge across different linguistic communities or historical borders. These inventories are crucial not only for local plant use knowledge but also for conserving agro biodiversity and protecting land resources. Increasing awareness of WEPs can positively impact agriculture in marginal areas by promoting crops that can withstand extreme environmental conditions due to climate change. These species can play a crucial role in mitigating agricultural insecurity resulting from a shifting climate. However, the natural resilience of wild species to swift climate changes, a trait often absent in non-native species, suggests that they may become increasingly vital during times of agricultural decline linked to climate-related events (Bharucha and Pretty, 2010).

1.5 Sustainable Development Goals

Wild Edible plants and underutilized crop species represent a vast, largely untapped resource with profound implications for achieving multiple Sustainable Development Goals (SDGs). These plant species, whether crop wild relatives, native plants in natural ecosystems, or neglected traditional food plants, possess genetic diversity, nutritional profiles, and adaptive traits that can be utilized for significant contributions to food security, climate resilience, biodiversity conservation, and social equity (Singh *et al.* 2020). The strategic integration of wild food plants into agricultural systems and conservation programs creates multidimensional benefits that directly support at least eight of the seventeen SDGs, including zero hunger, good health, gender equality, climate action, and biodiversity conservation (Singh *et al.*, 2019). This relationship between WEPs and sustainable development necessitates increased research, policy support, and community engagement to fully realize the potential of these valuable biological resources.

Considering the various evidences, it is apparent that encouraging the use of WEPs aligns with the aim of various Sustainable Development Goals 2030 (Fig.1.1). WEPs apart from providing food to the tribal communities, hold the potential for supplementing the homogenous diets to reduce malnutrition across the world. They can be utilized to develop nutraceuticals, anti-microbial, anti-diabetic and anti-cancer medicines. Moreover, they can be used for boosting the rural economy also. WEPs can play an indispensable role in improving food security and providing balanced diets especially to people in the under-developed and developing countries (Amente *et al.*, 2017).

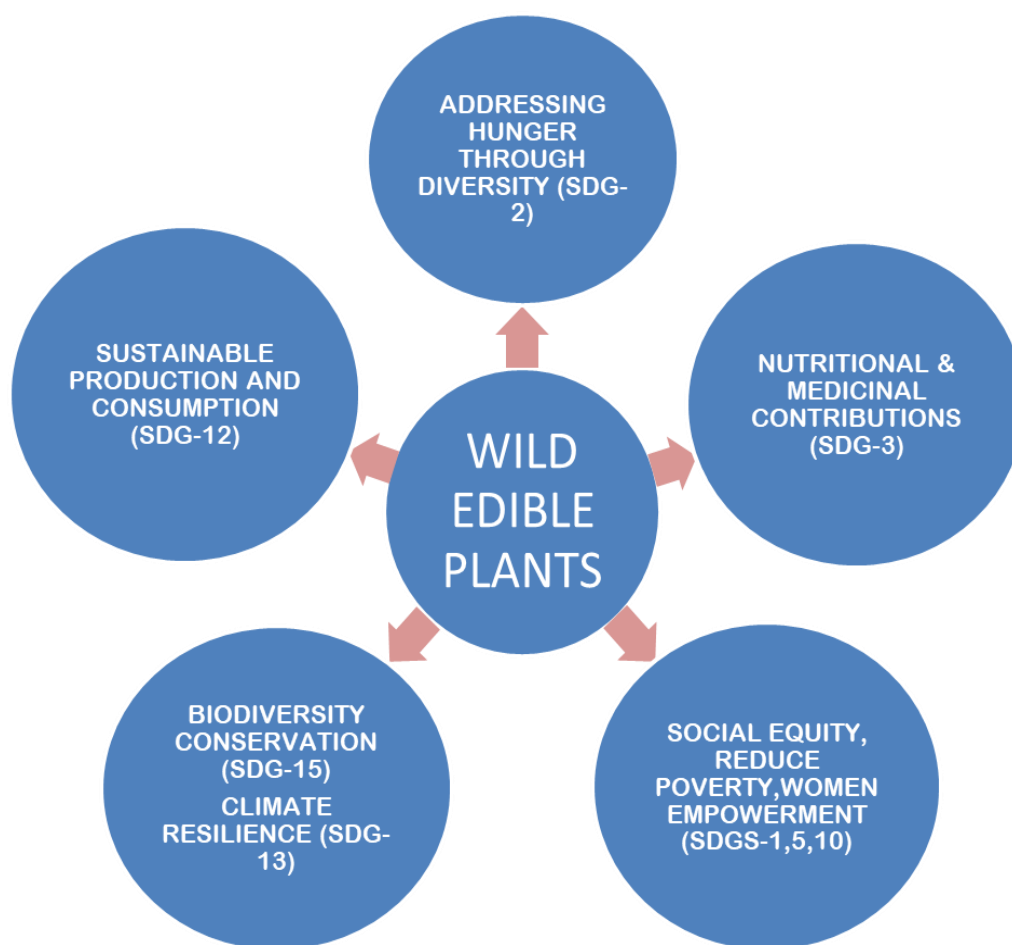


Fig 1.1: Wild Edible Plant Research and Sustainable Development Goals

1.6 Need for exploration and evaluation of WEPs

The above mentioned discussion clearly indicates that wild edible plants are not only a vital component of human diets but are indispensable natural resources with multi-faceted benefits. There is a need for increased research on these plant species to better understand their potential contributions to sustainable development. This includes efforts to document and preserve traditional knowledge about these plants, as this knowledge represents a valuable resource for sustainable development that is at risk of being lost. Many studies have raised concerns regarding erosion of traditional knowledge due to factors such as urbanisation, change in land use-patterns, change in diversity, habitat fragmentation, abandonment of use. Recently a study was conducted by Nabhan *et al.* (2022) in indigenous Seri communities of Mexico. They observed that the traditional Comaac diet of the inhabitants had lost its species diversity due to

loss of traditions and shifts in livelihood. It was documented by them, that only 43% of the wild edible plants were being used at present as compared to earlier times when around 95 to 100 species were being utilised by them for food (Nabhan *et al.* 2022). Therefore documentation of traditional knowledge of these plants is essential as it will ensure not only conservation of biodiversity and preservation of local cultural heritage but also future utilization of these natural resources (Arjona-Garcia *et al.* 2021). Additionally, investigations of their nutritional and phytochemical properties, adaptive traits, and optimal cultivation practices are essential.

Micronutrient deficiencies pose a significant global public health challenge, affecting over two billion individuals, predominantly in low to middle-income countries (Kumar *et al.*, 2019). Vulnerable groups include young children, pregnant and lactating women, and the elderly, who are at higher risk due to increased nutritional demands (Tribaldos *et al.*, 2018). Research on micronutrient deficiencies is underrepresented despite their disproportionate contribution to global malnutrition in low- and middle-income countries, raising concerns over whether current research priorities adequately address SDG-2 (Akpojevwe *et al.*, 2025). In this context, the investigation on wild edible plants becomes crucial, as these underutilized taxa offer rich reservoirs of micronutrients and bioactive compounds. This can enable sustainable, culturally embedded nutritional interventions capable of mitigating hidden hunger where conventional dietary diversification is limited. It is also important for present and future botanical research to focus on diversity of WEPs, associated traditional practices, agricultural knowledge, bio-conservation strategies, and sustainable utilization. As wild food plants gain recognition as sources of natural health products, it is vital to support biochemical evaluation that documents not only their nutrient content and bioactive compounds but also anti-nutrients as well as potentially toxic elements. Understanding processing methods and nutrient profiles of wild plants is just as essential as documentation of the species because it helps in assessing their mechanisms of action, safety, and efficacy for evaluating the overall health benefits and physiological effects of these plants. Interdisciplinary approaches that bridge ethno-botany, agronomy, ecology, nutrition, and social sciences can provide comprehensive insights into the multi-dimensional values of wild plants.

After going through literature survey on floral diversity of The Union Territory of Jammu and Kashmir (J&K), it has been found that the focus of researchers has been mainly on medicinal plants. Moreover the studies conducted on WEPs of the region including research on their nutritional or anti-nutritional aspects are limited. The present study is an attempt to document ethnobotanical knowledge regarding usage of wild edible plants in District Doda of J&K and also analyses of some selected species for their nutritional potential. This research can provide a valuable foundation for integrating wild edible plants into agroforestry or in cultivated landscapes, while also aiding the selection of further species for nutritional assessment and nutraceutical evaluation.

1.7 Objectives of the present work

1. Collection, identification and documentation of the wild edible plant species of District Doda.
2. Herbarium preparation and assessment of the identified plants for selection of the most important species.
3. Evaluation of some selected species for nutrient composition, mineral profile and presence of anti-nutrients.
4. Anti-oxidant activity of selected plant species.

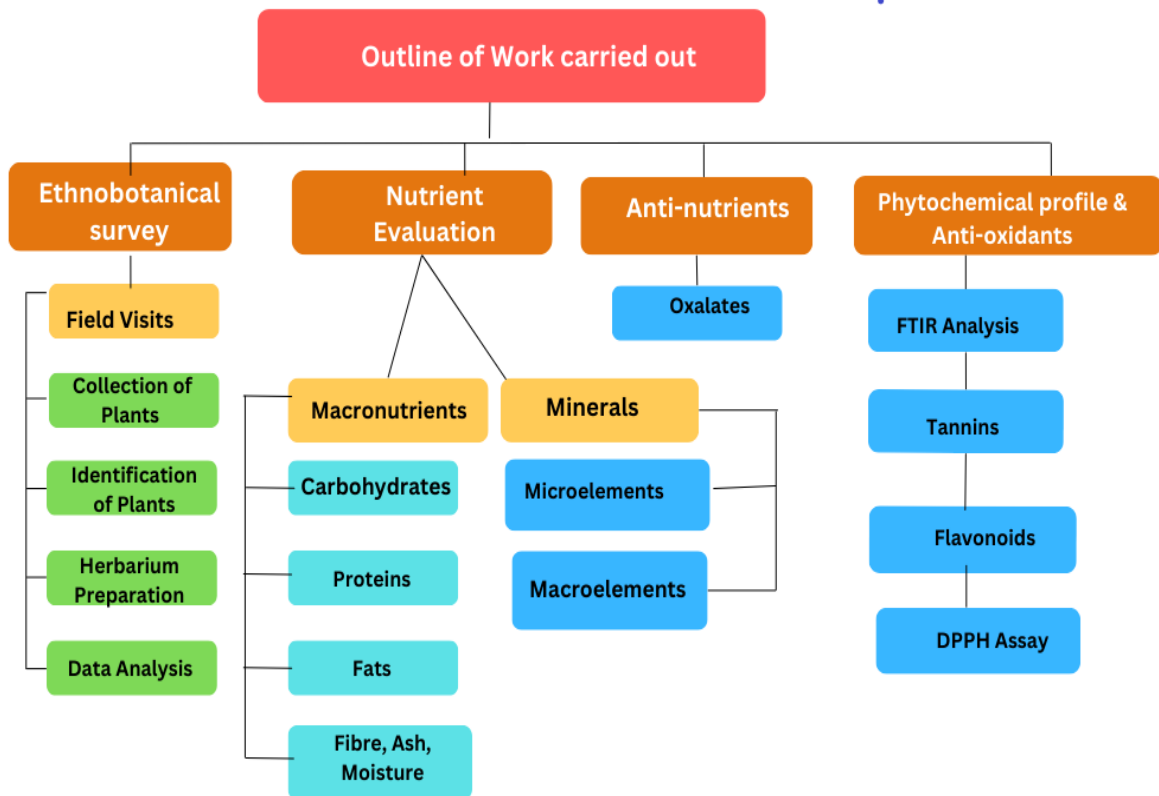


Fig 1.2: Outline of the research work undertaken

Chapter-2

REVIEW OF LITERATURE

WEPs are an important component of human diet, the people residing in rural areas and the tribes particularly, are more dependent on these natural sources of food. These plants have historically served as dietary staples for indigenous and rural populations across diverse geographical regions. This natural resource represents a crucial yet underutilized component of global food systems, providing essential nutrients and sustenance to communities worldwide. Scientific interest in these plants initially developed through botanical exploration, economic botany, and ethnographic documentation. The emergence of ethnobotany as a formal discipline at the end of the nineteenth century provided a systematic framework for studying traditional plant knowledge and human-plant relationships.

During much of the twentieth century, WEP research remained largely descriptive, focusing on species inventories, vernacular names, edible parts, preparation methods, and famine-food traditions. From the 1970s onward, systematic ethnobotanical surveys expanded across Europe, Asia, Africa, and the Mediterranean, documenting both the diversity of wild foods and the gradual erosion of associated traditional knowledge. Historical ethnobotanical studies, such as those of Kalle and Sõukand (2012) and Łuczaj *et al.* (2012), demonstrated major transformations in wild-food use under changing socioeconomic conditions.

WEP research in recent years has increasingly moved beyond documentation toward scientific validation. There has been resurgence of interest in these plants owing to their exceptional nutritional profiles, medicinal properties, and potential contributions to sustainable food security as supported by scientific research. The integration of ethnobotany with food chemistry and nutritional science is particularly evident in Mediterranean research (Tardío *et al.*, 2016), while Himalayan studies have emphasized the dietary and cultural importance of underutilized wild foods (Abbasi *et al.*, 2013). Contemporary WEP research therefore represents a multidisciplinary field linking traditional knowledge with nutrition, biodiversity conservation, dietary diversification, and sustainable food systems. The review of literature related to

WEPs has revealed that lot of research has been carried out in this regard and currently various aspects of these plants are being investigated not only in India but also across various parts of the world. This comprehensive analysis examines the current state of knowledge regarding wild edible plants, their significance for rural and tribal communities, and emerging research trends that highlight their importance in addressing contemporary nutritional challenges.

2.1. Ethno-botanical studies of WEPs across the globe:

2.1.1 Africa:

The utilization of wild plants as source of food has been an integral component of indigenous African cultural practices for countless generations (Pitso and Lebese, 2014). The reliance on these plants is higher in rural and tribal populations where access to conventional agricultural products may be limited or inconsistent. For many African communities, wild edible plants represent preferred food security resources because they are naturally produced without artificial intervention or costly inputs. Ethno-botanical research on wild edible plants across Africa employs diverse methodological approaches to document traditional knowledge and assess utilization patterns (Abera and Belay, 2022). The nutritional contributions of WEPs to African diets have also received increasing scientific validation through contemporary research (Adamu *et al.* 2022, Nyero *et al.* 2023).

Amente (2017) has done an extensive ethno-botanical survey of the WEPs consumed by the people of Gumuz community in Western Ethiopia. The informants were selected randomly from different ethnic groups. The data were collected by conducting semi-structured interviews, group discussions and field study. Analysis of the data was done by using direct matrix ranking and informant consensus factor. This study revealed a total of 60 species belonging to 49 genera belonging to 35 families used as wild edibles. Many of these species were found to be under threat due to various anthropogenic factors, therefore, suggesting the need for awareness of local people and community-based management at all levels. The author also proposed urgent collection of germplasm by the professionals to ensure conservation of these natural resources.

Belahsen *et al.* (2017) have studied the food security in Moroccan Berber communities. They observed decline in the wild edible plant consumption because of nutritional transitions and gradual loss of related traditional knowledge of the diverse dietary habits.

An ethnobotanical survey of wild edible fruit tree species among various ethnic groups was done by Dejene *et al.* (2020) in lowland areas of Ethiopia. They identified 88 species of WEPs out of which 52 species from 40 genera were wild edible fruit trees. The consumption of WEPs was observed to be more during food shortage periods when the stored grain was consumed, and new crop was not harvested. They also observed that some of the WEPs were under threat though some of them were conserved by traditional conservation practices.

Fils *et al.* (2020) conducted an ethnobotanical survey of WEPs used by Baka community of southeastern Cameroon and documented usage of 88 species in the region including new reports for 17 wild edible plant species.

Fongnzossie *et al.* (2020) did an ethnobotanical assessment of WEPs and mushroom species of the Bamenda Highlands in Cameroon and pointed out their potential for enhancing food security. They recorded use of 41 species including mushrooms, leafy vegetables, spices, beverages and root tubers. Their results also showed that the WEPs in the region were threatened due to excessive collection and habitat degradation.

Maroyi (2020) undertook an ethno-botanical investigation of wild as well as cultivated vegetables in the Eastern Cape Province of South Africa. The data were collected through field surveys in different seasons, interviews of informants and as a result 32 species of vegetables were identified. The results showed that both wild as well as conventional crops played important role in diet of the people. Ethno-botanical indices such as relative frequency of citation (RFC) and informant consensus factor (ICF) were also determined for each species to evaluate their respective importance for the local people.

Aparicio *et al.* (2021) did an ethnobotanical survey of edible and medicinal plants used in Nhamacoa area, Manica province–Mozambique. They recorded 106 different

species of WEPs from 86 genera and 52 families. Based on the cultural value index and factor informant consensus, three species were identified with potential as livelihood alternative for the local people. Moreover, some species of WEPs having medicinal importance were recommended by the authors for further phytochemical evaluation.

Hassen (2021) surveyed North Wollo in Ethiopia to study the diversity of WEPs. He observed that WEPs contributed significantly to sustainable food security in the region. Based on the data collected and field observations a total of 66 local wild plants were enumerated. The threats to conservation of WEPs and challenges in their domestication were also recorded which included unsustainable harvest, taboos and strong cultural beliefs of indigenous people.

Kidane and Kejela (2021) documented the use of wild and semi-WEPs in Berek Natural Forest, Oromia special zone, Ethiopia and identified 43 such species most of which were trees. Some of the edible plants had multipurpose use within the local community. They also observed declining diversity of these plants and also decline of associated traditional knowledge. The authors, therefore, recommended cultivation of these plants by the locals and setting up of botanic gardens at least at the level of kebele which are the smallest administrative units in Ethiopia.

Aboukhalaf *et al.* (2022) worked on the local knowledge and traditional utilization of WEPs in Central Morocco. In region named Sidi Bennour, 56 plant species were documented, which have medicinal importance, food value, or both. In addition, it was observed that there was decline in the natural populations of many species commonly used as food or medicine in the study area. The indigenous people were also observed to practice safe use of plants which are otherwise known for their toxic properties e.g. *Arisarum vulgare* and *Citrullus colocynthis*. The authors recommended further research on WEPs in other regions of Morocco also, in order to develop methods and work out various strategies for the conservation of these plants. They also suggested the transmission of traditional ethno-botanical knowledge related to their local uses.

Oluoch *et al.* (2023) devised an integrated participatory approach to analyse perceived local availability of WEPs by three communities of North-west Kenya. They conducted focus group discussions to identify the factors influencing availability of WEPs. They also focussed on the need to document threats to sustainable use of these plants. The findings are significant as they can be utilized in formulation of programs and policies for including these plants in the fight to combat food insecurity and malnutrition in pastoral communities in Africa.

Biri *et al.* (2024) conducted an ethno-botanical study of Wild Edible Plants of Arsi Zone of Ethiopia. The data collection tools used for this survey included guided field visits, semi-structured interviews and survey of market. The study led to the documentation of 36 wild plant species consumed in the region including two novel species. The major threats affecting the diversity of wild plants in the study were also identified and the authors suggested prioritization of domestication and cultivation of the identified wild edible plants.

2.1.2 Europe:

An interesting ethno-botanical work was carried out by Vorstenbosch *et al.* (2017) to identify the plants used as ‘Famine food’ during World War II in Netherlands. They interviewed 78 elderly Dutch informants and documented the 38 plant species which were used as emergency food at that time. The identified species included 21 species of WEPs and 3 species of wild edible fungi. They described their study as a case of ‘salvage ethno-botany’ and concluded that the information regarding WEPs as famine foods is still present in the Dutch Society though some part of it might have disappeared over the years.

Žuna Pfeiffer *et al.* (2020) undertook an ethno-botanical study of wild plants used in the north-eastern region of Croatia and recorded use of 44 taxa mostly as medicine but some as wild edibles also. Their results indicated disappearing ethno-botanical knowledge in the region.

Motti *et al.* (2020) undertook an ethno-botanical case study in Southern Italy in which they investigated the wild edible plants included in the famous Mediterranean diet.

They conducted field trips in the region thereby interviewing 69 informants and as a result documented 85 species with relative frequency of citation (RFC) for each.

A detailed systematic review was also published by Motti (2021) based on 34 ethno-botanical studies conducted on Wild Edible herbaceous plants and spices of Italy. He documented use of 78 wild taxa which could be utilized not only for enriching the diet but also to boost the local economy. The distribution of these plants in the area was also analyzed along with their main phytochemical properties.

Benitez *et al.* (2023) reviewed the uses of Wild edible plants of Andalusia in Southern Spain which is one of the most diverse regions of Europe. The resulting data showed high diversity of wild plants consumed in the region i.e. around 336 species, 24% of which were consumed for medicinal purposes also. An additional list of 166 potential edible species from other Spanish territories was also prepared by reviewing the relevant data.

2.1.3 Australia:

Canning (2022) worked out agriculture models based on environmental suitability for growing 177 native wild food and forage plants in Australia in order to diversify production for enhancing overall food security. He identified the regions where agriculture could be transformed using regenerative practices of cultivating native food plants.

Hay *et al.* (2022) carried out an assessment of the local edible flora of Australia for identification of some natural food color and flavour additives. They identified 17 potential species which could be utilized for benefit to remote communities by industrial application. They concluded that these natural additives from wild foods could be promoted as new sector after proper investigations such as market survey, ethical implications and technical risks such as food safety evaluation.

2.1.4 South-America:

Gori *et al.* (2022) studied the diversity, distribution and taxonomic aspects of underutilized wild edible species of Columbia. The cataloging was done to shortlist

the species-rich genera and biogeographic analysis was done to identify the diversity hotspots. They further stressed on need of targeted ethno-botanical studies in order to achieve the full characterisation of these resources as well as future prioritisation of efforts toward their conservation and sustainable utilization.

Leon-Lobos *et al.* (2022) reviewed the use pattern of WEPs of Chile by assessment of their taxonomic diversity, life forms, methods of preparation, consumption mode, traditional as well as modern uses along with their nutritional properties. They reported that the local population consumed 330 native plant species, distributed across 196 genera and 84 botanical families accounting for nearly 8% of the total regional flora. They highlighted the need to deepen studies on Chilean wild edible plants, particularly in two directions i.e, biochemical assessments to better define their nutritional profiles, and agricultural research to support domestication and breeding efforts aimed at developing potential new crops.

2.1.5 North-America:

Narváez-Elizondo *et al.* (2021) compared the traditional knowledge about edible plants among different groups of young people from Southern Tepehuans of Durango which is an ethnic group of Mexico. They reported the disappearance of traditional knowledge about edible plants in this tribe and attributed it to various factors like lifestyle changes, nutritional transitions and declining use of the indigenous languages. They suggested formulation of new approaches for preservation of the valuable traditional knowledge.

2.1.6 Asia:

Cakir (2017) has explored the traditional knowledge of WEPs of Igdir Province in Turkey. Their study has revealed information about uses of 154 species of WEPs belonging to 27 families. Some of the plants were considered to be toxic and were found to be consumed only after special traditional preparation methods to avoid the harm. This is indicative of the fact that along with the documentation of WEPs, the method of consumption should also be recorded.

Kayabaş *et al* (2018) have studied the traditional use of WEPs in the human nutrition in Manyas (Turkey). They observed use of 58 plant species some of which were recorded for the first time in Turkey. Many of these plants were collected and traded in the open markets of this region.

Silalahi and Nisyawati (2018) conducted an ethno-botanical study of medicinal and edible flora of the home gardens of Batak Karo sub-ethnic groups in North Sumatran region of Indonesia. They found that alongwith the cultivated plants many wild plants were also grown for their medicinal and edible uses. They identified a fruit plant and one low calorie sugar plant with high cultivation potential.

Mukhtar (2019) has explored the diversity of wild edible fruit plants and indigenous knowledge related to them in West Aceh, Indonesia. He recorded 44 species of fruit plants including some with multiple traditional uses which although not domesticated but were often traded in the local traditional markets.

Yeşil *et al.* (2019) conducted first ethnobotanical study of WEPs in Mardin which is a multicultural area of Turkey. They collected the information by interviewing informants and analysed the data by determining the factor informant consensus (FIC) and cultural importance index (CI). A total of 74 species belonging to 57 genera from 31 families were documented as a result of this survey. Among these species, 12 taxa of WEPs were reported for the first time and many of them were found to be of nutraceutical importance.

Cao *et al.* (2020) conducted an ethnobotanical investigation of wild edible plants traditionally used by three cross-border ethnic communities viz. the Hani, Dai, and Yao in Jiangcheng County located in southwest China. They conducted extensive survey in twenty villages of the region and also calculated use value index of the WEPs. They recorded 211 species of WEPs from 151 genera belonging to 71 families. They also identified some threatened edible plants sold in the markets and selected the most important 30 plants for cultivation in local villages.

Sun *et al.* (2020) studied the medicinal dietary plants of the Yi which is the largest ethnic group in Yunnan Province of China. They performed field investigations for

data collection and also analyzed the use value index and frequency of utilization index for wild edible species consumed in the region. The study led to documentation of 124 species from 102 genera belonging to 52 families including angiosperms, gymnosperms, pteridophytes and fungi. Among the documented species 40 plants were having edible parts with medicinal value whereas 82 species had other medicinally important parts apart from the edible parts. They also observed commercial potential of some of the identified medicinal edibles.

Wang *et al.* (2020) conducted an ethno-botanical survey of WEPs used by the Yi community living in Liangshan Prefecture, Sichuan Province of China. They reported use of 105 species of WEPs from 97 genera belonging to 62 families. In addition, they also reported 49 species of medicinal edible plants including some with multiple medical applications. They also observed that the traditional communities were involved in the conservation of some wild medicinal edibles as they collected seedlings from the forests and planted them in their courtyards.

An ethnobotanical investigation of medicine and food yielding plants utilized by the people of Lhoba community inhabiting Medog County region of Tibet, China was done by Yang *et al.* (2020). They collected the data by using qualitative as well as quantitative ethnobotanical methods. They recorded 57 species of WEPs and 37 medicinal plant species which were being used traditionally. They suggested urgent action to conserve the threatened traditional knowledge of the region and further assessment of the species for potential nutritional and medicinal value.

Al-Fatimi (2021) conducted first ethno-botanical survey of the traditionally important WEPs used by rural people of Southern Yemen. This research led to documentation of 58 plant species out of which 12 were found to be unique to the region. The results indicated that these plants are an important part of the cultural heritage as well as the traditional food security of this region.

Ding *et al.* (2021) carried out a study on traditional knowledge of Wild edible plants used by Sherpa people in Tibet, China. The research focused on diversity as well as collection calendar for these plants especially during food shortage periods in the region. The field study was done with the help of local informants in six Sherpa

communities of the region. The study led to collection of 84 plant species for which use-value and cultural importance indices were also determined. A collection calendar for each of these species was also prepared.

Cheng *et al.* (2022) interacted with 127 informants to understand the ethno-botany of plants used by Dulong ethnic group in China and also the traditional knowledge associated with these plants. They reported 148 WEPs in total, whose multiple uses were also analysed. The most culturally significant WEPs were identified by quantitative methods. The authors suggested that, wild fruits and vegetables having economic potential such as *Angiopteris esculenta*, *Cardiocrinum giganteum*, *Caryota obtuse* and *Maianthemum atropurpureum* could be utilized to develop an income source for local residents. They also impressed upon the need for protecting local traditional knowledge of WEPs in the region and carrying out studies on biochemical as well as nutritional aspects of these plants.

An analysis of home gardens of South Korea was done by Hong and Zimmerer (2022) to study the ethno-botany and habitat conversion of wild edible plants in the region. This was the first investigation in Jeju region of South Korea to study wild edible plants which are grown non-commercially. The study was conducted in the home gardens of twelve villages located in Jeju Province; as a result of which 164 species were observed including 52 wild plant taxa. The authors also observed significance of home gardens in conservation of wild plant taxa.

Fullilove (2022) analysed importance of biodiversity preservation methods in Israel-Palestine with special focus on famine foods such as *Anchusa strigosa* which is having medicinal properties in addition to local food value. The study highlighted role of traditional practices in the conservation of diversity of these plants.

Amin *et al.* (2023) conducted research on utilization of wild plants for food by three linguistic groups of Upper Khyber Pakhtunwala in Pakistan which is an important hotspot of traditional plant knowledge. The authors recognized the study area as ‘biocultural refugia’ as use of many wild plants was found to be overlapping among the studied groups viz. Gujjars, Kohistanis and Shinakis, and documentation of total 64 species was done. The authors suggested use of traditional gastronomy for

promoting food tourism in the region which could elevate the economic status of local communities.

A cross-cultural investigation on traditional knowledge of WEPs by various ethnic groups of semi-arid region of Punjab in Pakistan was done by Waheed *et al.* (2023). In this study they assessed the cultural importance of 71 wild food plants in the region. Some of these plants were found to be common between different ethnic groups and 20 new wild food plants were also reported which were not reported earlier from Pakistan. Nineteen plant species were found to have market value and thus had potential for enhancing regional economy.

Osawa (2024) reviewed the ethno-botanical use of WEPs in Japan. This analysis reported use of 268 wild plant taxa including ferns and bamboos. Similarities for preferences of wild plant foods were also found on comparison with ethno-botany of these plants in other Asian countries.

2.1.6.1 India:

Thakur *et al.* (2017) have observed the patterns of consumption of WEPs in a tribal inhabited region of Western Himalayas in India. The study was conducted through field surveys, household surveys, group discussions and structured questionnaires. Trends of use of these plants were also studied and it was found that there was considerable decline in the use of wild edible plant since last 5 to 10 years. The results also revealed that fifty plant species are utilized by the local people for edible purposes.

Aryal *et al.* (2018) studied the use and diversity of non-cultivated wild edible plants in Western Himalayan trans-boundary region shared by India, Nepal and China. The methodology used by them included focus group discussions, informant interviews, observation of species in nature and market surveys as well as household surveys. As a result of this study 99 species of wild edible plants were documented including *Dryopteris cochleata* having the highest use-value in the region. They also observed some challenges in ensuring management and conservation of these species.

In their studies on the WEPs consumed by ethnic communities in Kalimpong district of West Bengal in India, Bhujel *et al.* (2018) documented species from 47 families. A total of 86 species belonging to 71 genera were identified which included different life forms. They also did market survey and identified the economic potential of many of these WEPs and concluded that they could be used for rural upliftment.

A detailed review of diversity, distribution and uses of WEPs of Uttarakhand, India has been done by Joshi *et al.* (2018). They observed that the region has rich traditional knowledge of WEPs and emphasized on the need for proper biochemical and nutritive evaluation of the underutilized taxa as well as development of agrotechnological methods for their propagation.

Mallick *et al.* (2020) carried out an ethno-botanical survey of wild food plants utilized by the local rural and tribal people of Odhisha for livelihood and food security. The research work was carried out on different tribes of Odhisha by conducting extensive field surveys to explore, collect and identify the wild food plants. The data was collected from the tribal people by using questionnaires and participatory method. The study led to scientific identification and documentation of 193 edible species among which fruit was the most used part (83 species) followed by leaves (78 species). In addition local beverages were also prepared from some of these plants e.g leaf petioles of *Caryota urens* and *Borassus flabellifer*; whereas some were directly sold in the market as leafy vegetables. The authors suggested inclusion of important wild food plants in agroforestry systems for preserving the traditional knowledge and for socio-economic development of the tribals.

Ray *et al.* (2020) have done an exploratory analysis of the WEPs consumed in India, examining their diversity, patterns of use, and relevance to building sustainable food systems. They assessed the diversity of WEPs being used in India and found documentation of 1403 species from 184 families. They also shortlisted 32 species as the most important plants on the basis of ethnobotanical indices and suggested their inclusion in National Food Policy for cultivation on priority basis. On the basis of their evaluation, they proposed the use of untapped nutritional potential of WEPs to combat the micronutrient deficiency.

Sreekumar *et al.* (2020) gave a review focused on the edible wild fruits of the Western Ghats region in India. They compiled use of 237 wild fruiting plant species from 136 genera belonging to 65 families used by tribal community for edible purposes. The edible fruit plants included 37 endemic and 11 red listed species. On the basis of their review, they suggested identification of threats to these plants and proper evaluation of their nutritional as well as anti-nutrient content.

Mishra *et al.* (2021) examined the contribution of WEPs in meeting the nutritional needs of indigenous people residing in the Achanakmaar-Amarkantak Biosphere Reserve of Central India. A total of 172 wild edibles including mushrooms were documented during this study and maximum utilization of wild plants was observed by the primitive Baiga community as compared with other ethnic groups of the region. The WEPs consumed in the region were used for supplementing the stable diets and were found to be rich in calcium, iron, vitamin B₁ and vitamin C. The researchers also observed exploitation of the poor communities by middlemen who procured wild plants for market, so they suggested development of proper mechanisms for marketing of wild foods for upliftment of marginalized groups.

Singh and Mathew (2021) carried out an ethno-botanical investigation of plants traditionally used by the Garo tribe of Meghalaya, India including spices, wild edible fruits and aquatic plants. They surveyed the west Garo hills for identification of plants used by the local tribal groups for their nutraceutical values. Traditional healthcare practitioners were also interviewed by them to know about the WEPs with medicinal value. They recorded use of 43 wild edible fruit tree species, 19 species used to obtain spices and 5 species of aquatic edible plants. They concluded that WEPs played vital role in nutrition of economically weak population of the region.

Sharma and Wagh (2024) conducted extensive field surveys in four north-eastern districts of Madhya Pradesh to study the cultural importance index (CI) and relative frequency of citation (RFC) for wild medicinal and edible plants of the area. They identified 85 plant species consumed in different ways with fruit being the most consumed part. The roots were found to be the most frequently used medicinal plant part whereas bark was found to be the second most used plant part for medicinal

purposes. These plants were also rich in essential elements like Ca, Fe, Na, K, Zn and vitamins B and C.

2.1.6.2 Ethnobotanical work done on WEPs of J&K:

The earliest reports of WEP use from the region were mostly based on general surveys that were conducted in the form of ethnobotanical explorations, but later the studies became more specific and were focused on a particular region or tribe. Koul *et al.* (1982) initiated the studies on WEPs of this region. They reported use of twenty lesser known wild plants used for consumption in the form of vegetables and beverages. Vir Jee *et al.* (1984) and Dar *et al.* (1984) also reported some WEPs while working on ethnobotany of Rajouri and Kashmir regions of J&K.

Kaul *et al.* (1987) conducted extensive ethnobotanical studies in North-West and trans Himalayas. They recorded use of some wild plants utilised traditionally as substitutes of tea from J&K state. Ethno-botanical explorations of J&K state by Srivastava (1988) led to documentation of 109 WEPs being used by Gujjar and Bakarwal tribes residing in the far flung regions of the state. Kaul *et al.* (1991) studied ethnobotany of Padari community of erstwhile District Doda and at present part of District Kishtwar. They recorded ethnobotanical data of 68 plant species out of which 38 were utilized as food.

Samant and Dhar (1997) prepared an inventory of WEPs of Indian Himalayas and studied the endemism, diversity and economic potential of WEPs. The data of edible species were analysed by them for diversity in different phytogeographical regions and they concluded that the highest diversity of WEPs occurs in the West Himalayan region.

Dhar and Dhar (2000) documented the wild edible herbs consumed in J&K state. They observed the need for cultivation of these plants being used as potherbs as they were mostly collected from the wild.

Rashid and Anand (2007) & Rashid *et al.* (2008) documented the use of some lesser known WEPs consumed by the Gujjar Tribe of District Rajouri, Jammu and Kashmir. They reported use of 57 plant species for consumption by Gujjar tribe of the study

area. Rosaceae followed by Polygonaceae were found to be the most dominant among 33 families of reported wild edible plant species. They also identified various factors responsible for the loss of biodiversity in the region.

Khan *et al.* (2009) studied the WEPs of Sewa catchment area of District Kathua, J&K in Northwest Himalayas. They carried out extensive field survey which led to identification of 97 species of WEPs consumed by the local people. Kumar and Hamal (2009) enumerated 50 species of wild edibles including 46 plant species and 4 fungi from Kishtwar high altitude national park in northwest Himalayas, Jammu and Kashmir (India). Out of 33 plant families utilized for edible purposes in the region, Rosaceae and Asteraceae members were the most used.

Dad and Khan (2011) studied the WEPs used by pastorals at high-altitude grasslands of Gurez Valley of Kashmir. They reported use of 26 plants from 21 genera and 14 families, by the three ethnic groups namely Gujjars, Bakarwals and Pahloos of these grasslands. Many of the uses were found to be common between these communities, though the local names of plants were not same.

Dangwal *et al.* (2014) explored the WEPs used by people belonging to Gujjar and Bakerwal tribes of District Rajouri in J&K. As a result of exhaustive field survey conducted between 2009 and 2011, they documented 58 species of WEPs from 50 genera of 39 families which were being consumed as fruits, vegetables, flavoring agents (spices), roots, raw tubers and seeds/grains. Rosaceae constituted the major family of WEPs used in the area. Mir (2014) conducted an ethnobotanical survey of edible plants used by the tribal people of Kupwara, J& K and documented the use of 31 species of wild edibles including 29 plants and 2 fungi. The WEP species belonged to 19 families with most of the plants from family Asteraceae.

Singh *et al* (2016) conducted ethno-botanical investigations on the diversity of WEPs and fungi in Bandipora district of Kashmir Himalaya, India. They surveyed the study area and collected data by interviewing the local informants during field trips. A total of 111 species of WEPs belonging to 87 genera from 43 families were recorded by them. Various ethno-botanical indices such as Use value (UV), Informant Consensus factor (Fic), Fidelity level (FL) were used to analyse the data. On the basis of high FL

and *Fic*, they suggested the potential of these plants for being developed as nutraceuticals.

Trak and Giri (2017) inventorised the plants used by tribal people residing in district Kishtwar, Jammu and Kashmir. They reported medicinal as well as edible uses of wild plants utilized by the Gujjar and Bakarwal tribes of this area.

Bhatia *et al.* (2018) have identified the traditionally used WEPs of district Udhampur, J&K, India. They documented 90 species of WEPs belonging to 78 genera and 45 families. They gathered field information and used ethnobotanical indices like informant consensus factor and cultural value index. There was homogeneity in the traditional knowledge of WEPs in the area. Devi (2018) enumerated some traditionally used WEPs of Bhalwal area of Jammu District. Pandita and Dutt (2018) studied WEPs used in important ethnomedicinal practices among rural people of Bhandarwah, Jammu and Kashmir.

Singh and Bedi (2018) for the first time investigated the use of WEPs in raw form by Sheena Tribe of Kashmir. They conducted field studies in the region inhabited by this tribe and documented the use of 42 species from 32 genera and 17 families, which were used in raw form for consumption. They suggested that proper harvesting practices and maintaining populations of these plants could be utilized for upliftment of these tribal people.

Fayaz *et al.* (2019) carried out an ethnobotanical survey of Daksum forest range of Anantnag District, Jammu and Kashmir. They documented the traditional uses of 108 plant species including 65 species used as fruits and vegetables. Asteraceae and Rosaceae were found to be the most utilized families in this region.

The traditional knowledge and cultural importance of WEPs in Kishtwar region of J&K in North-West Himalayas was done by Thakur and Dutt (2020). They conducted ethnobotanical surveys of the region from 2019 to 2020 and collected data by interviewing informants using standard questionnaires. They recorded use of 130 species of WEPs from 103 genera and 52 families. High Informant consensus factor

and cultural importance index were observed for most of these species showing homogeneity of ethnobotanical knowledge regarding edible plants in the region.

A comprehensive study on cultural significance of medicinal edible fruits in District Bandipora of North Kashmir was done by Mir *et al.* (2020). They interviewed 220 informants by using a questionnaire for collection of data. The data was analyzed by applying two ethnobotanical indices i.e. cultural importance index (CI) and factor informant consensus (F_iC). They observed that many endemic wild fruits that are utilized in the region are still not widely known.

Gairola *et al.* (2021) documented the WEPs of Paddar Valley of District Kishtwar of Jammu and Kashmir. They conducted interviews of the informants and recorded the use of 42 WEP species from 38 genera belonging to 26 families. The WEP species consumed in the area include 40 angiosperms, 1 gymnosperm and 1 fern. Rosaceae was found to be the most dominant among reported families in the region followed by the family Polygonaceae.

Mahmood and Farooq (2021) reported Medicinal Uses of 24 edible plant species belonging to 26 families, used as vegetables by nomadic community of Pir Panjal region of District Rajouri, Jammu & Kashmir

Mir and Sehgal (2021) explored the therapeutic applications of edible wild fruits in the Chenab Valley of Jammu, India. They documented 32 species of wild fruits, representing 28 genera and 20 families, which local communities use to treat a range of health conditions.

Pala *et al.* (2021) investigated the ethnobotanical utilization of forest plants in Sindh forest of Manasbal, Kashmir Himalaya. They reported use of 135 plant species for various purposes including 18 species used for vegetable and 14 species of fruit plants in the region. Manhas *et al.* (2022) inventorised the wild edible plants of Purmandal Block of District Samba which lies in the foothills of Shiwaliks. The data was collected and analysed using standard ethno-botanical methods. They recorded used of 58 plant species with *Mangifera indica* showing highest use-reports and cultural

importance index. Total twelve use-categories were considered by them which showed high informant consensus factor.

An extensive ethnobotanical work was conducted on less studied Gaddi and Sippi tribes inhabiting district Doda of Jammu and Kashmir, by Singh *et al.* (2023). They studied the diversity of wild edible fungi and plants used by this semi-nomadic tribe and documented a total of 77 species. Khan *et al.* (2024) studied cultural significance of wild food plants in District Ganderbal lying in Western Himalayas of Kashmir. They documented 55 wild food species including 5 fungi as a result of field surveys and interviews. They evaluated CFSI (Cultural food significance index) and JI (Jaccard index) to study the cultural importance of these plants in the local communities. They suggested need for further nutritional and pharmacological evaluation on these plants.

2.2 Studies on Nutritional content of WEPs

Disciglio *et al.* 2017 investigated 11 species of wild edible plants and three cultivated species widely consumed in Southern Italy for anti-oxidant activity, phenol content and mineral elements. The range of calcium content was found between 0.784 g/kg fresh weight for *Beta vulgaris* to 5.886 g/kg fresh weight for *Scolymus hispanicus*. In addition to calcium, *S. hispanicus* showed good magnesium and potassium content. *Diplotaxis tenuiflora* was found to have high content of sulphur and phosphorus. The qualitative parameters showed significant variation between wild plants and their cultivated counterparts e.g high antioxidant activity was found in wild *Cichorium intybus* and *Borago officinalis*. Among the analysed plants, *C. intybus* was found to have richest qualitative profile in terms of medicinal and nutritional properties.

Kibar and Kibar (2017) have evaluated the nutritional and seed properties of three wild edible plant species consumed as vegetable in the Middle Black Sea Region of Turkey. They collected these plants from five different locations of four provinces of the region. The nutritional analysis showed presence of important nutrients and minerals in these wild plants. The researchers concluded that these can be utilized as good and cost-effective sources of nutrients for common people.

Narzary and Basumatary (2017) have done experiments to determine the mineral composition of some WEPs consumed by Bodo tribe of Assam located in North-East India. The methodology included collection and identification of plants followed by sample preparation and analysis of metals. The plant samples were evaluated for the presence of macroelements such as Ca, Mg, K, Na, and also microelements such as Zn, Fe, Cu, Mn, Co, Cr, Se, Ni. The presence of toxic metals like Cd and As was also tested in the plants. It was found that the selected WEPs showed presence of various macro as well as microelements, but no toxic metals were found. Pinela *et al.* (2017) have reviewed the nutritional and toxicological characteristics of WEPs from north-east Portugal. They have highlighted the need for commercialization and conservation of WEPs as they are rich in nutrients and are used traditionally in rural areas. They have also proposed strategies like collaboration between different disciplines to generate relevant outputs and also ecologically sustainable development.

Sarikurkcü *et al.* (2017) worked out the anti-oxidant properties, enzyme inhibitory activities of selected wild edible vegetables of Turkey. Ethanol extracts of the aerial parts of 17 edible plants were used for analysis. The results showed high antioxidant activities in *Mentha piperata*, *Rumex acetosella* and *R. patientia*. Highest amount of phenolics, saponins and flavonols were found in *M. piperata* whereas highest flavonoid content was found in *Lepidium sativum* and *Opopanax hispidus*. A strong overall correlation emerged between the total phytochemical content of the plants and their antioxidant potential.

Ceccanti *et al.* (2018) have reviewed the phytochemical aspects and toxicity of some common WEPs of the Mediterranean region. These WEPs showed presence of beneficial phytochemicals but some had toxic components also. In addition they also compiled data about germination tests of selected species and concluded that some of the WEPs can be domesticated and developed as new crops. Seal *et al.* (2018) have done estimation of water-soluble vitamins in selected WEPs consumed by the tribal people of North-eastern Region in India. They used HPLC method for the rapid determination of water-soluble vitamins such as vitamin B-complex and ascorbic acid. The results showed presence of these water-soluble vitamins in WEPs.

Nutritional evaluation of edible tubers of some wild plants was done by Suwardi *et al.* (2018). The plant material was collected, and samples prepared were analyzed for presence of carbohydrates, proteins, fats and vitamin C. The results suggested use of the evaluated species as alternative food. Datta *et al.* (2019) worked out the nutritional composition, mineral content, antioxidant activity and quantitative estimation of water-soluble vitamins and phenolics in some WEPs having medicinal uses also. They estimated the proximate nutrient composition of carbohydrates, fats, proteins and minerals by using standard food analysis methods. The antioxidant content, vitamins and phenolics were analyzed by high-profile liquid chromatography method. The results suggested that these WEPs have potential to be utilized as nutraceuticals as they are a good source of natural antioxidant and vitamin B.

Mzoughi *et al.* (2019) studied the composition of nutrients, phytochemicals and biological activities of a wild edible plant i.e., Swiss chard. The results revealed the presence of carbohydrate as major macronutrient. In addition, the leaves of this plant were found to be rich in Fe, Ca and Mg. Significant antioxidant activity was also reported along with inhibitory effects on α -amylase and α -glucosidase activity indicating its hypoglycemic potential.

Petropoulos *et al.* (2019) evaluated nine Mediterranean wild edible species from the Asteraceae family under controlled commercial cultivation conditions, for content of bioactive compounds and antimicrobial activities. The investigation was carried over two growing seasons and the results showed high flavonoid content in most of the studied plants and antimicrobial activity was also reported. They concluded that the studied species had cultivation potential on commercial level and could be used in the food industry.

The nutritional profile, total phenolic levels, antioxidant capacity, and α -amylase inhibition of various fractions from selected wild edible plants have also been studied by Rana *et al.* (2019). They evaluated anti-diabetic WEPs for nutrients, minerals, flavonoid and phenolic content. They also assessed α -amylase inhibition activity of the plant samples collected from different locations. The results revealed that the investigated wild plants were source of high fiber and protein but low fat content and

could be used against obesity. These wild plants were rich in various minerals including Ca, Mg, Na, K, Fe, Cu and Zn. The amounts of minerals were similar or higher as compared to some of the commonly cultivated vegetables.

Shan *et al.* 2019 evaluated the antioxidant activity and polyphenolic content in twenty wild edible fruits used by Himalayan communities. The evaluation was carried out using standard protocols. The results revealed highest flavonols and phenolics in acetone extracts of *Rubus ellipticus* and *Prunus domestica* whereas maximum flavonoid content was observed in aqueous extract of *Rosa moschata*. High antioxidant activity was exhibited by extracts of *Duchesnea indica* and *Berberis lyceum* fruits. The research findings indicate that indigenous wild fruits traditionally consumed by Himalayan communities contain abundant bioactive compounds with promising therapeutic applications for chronic health conditions, particularly those related to oxidative stress and free radical damage.

Alam *et al.* (2020) did a comparative study on the nutritional make-up, polyphenolic composition, and the antidiabetic and antioxidant properties of several edible wild plant species from Bangladesh. They collected samples of five WEPs after confirming their identity and processed them for estimation of various components. The fat composition was estimated using petroleum ether solvent method, protein content was determined by Micro-Kjeldahl method, fibre content was estimated by gravimetric method and carbohydrate content was determined by difference. Moisture and ash contents were also calculated by weight difference method. The mineral profile was evaluated by atomic absorption spectrophotometry; potassium was estimated by flame spectrophotometry. Ascorbic acid evaluation was done by spectrophotometric method by using freshly processed plant samples. Analysis of phenolics, flavonoid content and evaluation of α -amylase inhibitory activity was also done by them. The results showed presence of low fat content, high protein and mineral content in the investigated plants. Inhibition of α -amylase was evident as well. The authors therefore suggested that broader cultivation and consumption of these species, alongside staple crops, could help better meet nutritional needs.

Nemzer *et al.* (2020) studied the nutritional and phytochemical composition of various plant parts from two wild and cultivated genotypes of purslane (*Portulaca oleracea* L.). The methodology used by them included UV–Vis spectrophotometry for phenolics and carotenoid content, ICP-MS for mineral content, HPLC for total amino-acids and vitamins, gas chromatography for fatty acids. They found almost similar content of omega-3 fatty acids in both whereas cultivated purslane showed higher amount of amino acids and vitamins. Wild purslane on the other hand showed two times greater content of some phytochemicals such as alkaloids, flavonoids, phenolic acids and betanins. On the basis of results they concluded that purslane has high nutraceutical potential and can be cultivated to derive benefits.

A comparative study on anti-oxidant activities of seven wild edible plants of Korea was done by Ji and Joo (2021), in which the sprouts of *Rosa multiflora* showed highest anti-oxidant activity. Kumar and Shiddamallayya (2021) analyzed the nutritional and anti-nutritional content of WEPs used in the Hassan district of Karnataka state in India. They surveyed the study area and identified the 12 most frequently used species of WEPs. The disease-free samples of edible plant parts were collected for nutritional analysis. Dry samples were used for nutritional component analysis whereas fresh samples were used for vitamin C analysis. AOAC methods were used for determining the nutritional components i.e., fats, protein, moisture, fibre and ash. They calculated the carbohydrate content by subtracting the value of other nutrients from 100. Vitamin C was estimated by using 2, 6-dichlorophenol indophenol reduction method. They also evaluated the mineral content in plant samples. The analysis of total phenolics and anti-nutrient contents like tannins and oxalates was also determined by them. Several samples exhibited appreciable levels of calcium, iron and protein. Their findings showed higher nutritional value of the studied WEPs as compared to some commonly consumed vegetables. Among the studied WEPs some were found to have very low levels of anti-nutrients whereas some showed their presence.

Lee *et al.* (2021) studied anti-obesity and anti-oxidant potential of some *Allium* spp used as wild edibles in Korea. Anti-adipogenic phenolics were found to be present in two species which can be beneficial against obesity. This study is quite significant as

obesity, at present, is a global challenge as it is major underlying cause of various diseases.

Moura *et al.* (2021) did an evaluation of multi-element profiles and bioactive phenolic content of ten unconventional edible plants from Brazil. They used optical emission spectroscopy method for determining the mineral composition of these plants and found presence of high levels of aluminium, iron, calcium, magnesium, sodium and phosphorus. Their results also showed presence of phenolic bio-actives and some flavonoids.

Some important medicinal plants from cold desert of Himalayas were evaluated by Radha *et al.* (2021) for phytochemicals, nutrient and mineral content. They collected 10 plant species, including *Betula utilis* which showed highest use value, from the high hills of district Kinnaur lying in Western Himalayan region. They used atomic absorption spectroscopy method for determining mineral content in leaves of these plants. The results showed presence of essential minerals like Ca, Na, K, Mg, Mn and phytochemicals like saponins, alkaloids, flavonoids. The results indicated that these plants have potential to be utilized for therapeutic purposes and for diet supplementation.

A study on anti-nutritional factors and anti-oxidant activity of seven commonly consumed wild edible plants of Ethiopia was done by Adamu *et al.* (2022). The parameters like total flavonoid content, phenolic content, DPPH and FRAP anti-oxidant assays, anti-nutrients like oxalates, phytates and tannins were evaluated using standard methods of food analysis. The results indicated highest anti-oxidant activity in leaves of *Rumex nervosus* and *Amaranthus hybridus*. The leaves of *A. hybridus* also showed highest flavonoid content among the evaluated samples. The anti-nutrient content was found to be low with values lying in safe limit. The results indicated that these plants can prove to be highly beneficial diet supplements.

Nyero *et al.* (2023) performed qualitative and quantitative assessment of phytochemicals in some wild edible plants used by rural people of northern Uganda. For analysing phytochemical content of the plant samples, they used petroleum ether and ethanol extracts whereas for studying the anti-oxidant activity of these plants

methanol extracts were prepared. The presence of free radical scavenging activity was observed in all the plants. DPPH activity showed significant positive correlation between total tannins and total phenolic content. Thus, it was concluded that consumption of these wild plants could be highly beneficial for human health as they are good source of anti-oxidants and phytochemicals which can provide protection against diseases related to oxidative stress.

The North-eastern region of India is one of the biodiversity hotspots and also home to many tribes which are dependent on natural resources in many ways. They utilise a wide number of locally growing wild edible species of plants as source of food. Talang *et al.* (2023) evaluated fourteen such species of wild plants for their nutrient composition including six species on which no such study had been conducted earlier. These plants were collected from some remote regions of Meghalaya and Nagaland states of north-east India. Samples were prepared and analyzed using standard methods of AOAC. *Herpetospermum operculatum* showed the highest protein content among evaluated plants, and also high content of iron and zinc. Based on the results of nutrient profiling, the authors identified some of the most nutritious wild vegetables. They suggested that measures for conservation of these species should be taken; efforts should be made for incorporation of these plants in cultivation to promote economy and well-being of native communities.

Thus, it is evident from the literature review that ethno-botanical studies of WEPs are crucial for preserving traditional knowledge and understanding the role these plants play in local communities. This knowledge is vital for maintaining cultural heritage and ensuring the continued use of these plants in traditional diets and practices. These studies are being conducted in diverse regions, including mountainous areas, tropical forests, and arid zones, highlighting the global importance of WEPs. Apart from surveys for identification and documentation of WEPs, other areas of this field are also being investigated like evaluation of the nutrients and other phytochemical constituents for understanding their potential health benefits, integration into modern diets or pharmaceutical applications. In recent years there has been further diversification of study areas related to WEPs such as focus on their conservation with emphasis on documenting threats to WEPs, such as climate change and over-

harvesting, etc. Many studies suggest integration of ethno-botanical research on WEPs with modern applications. The potential of these plants in pharmaceuticals and agriculture is being explored for sustainable development and economic benefits for local communities.

Table 2.1: Literature Review of Ethnobotanical Importance of the analysed Plants

Name of the Plant	Part Used	Ethno-botanical Importance	Reference
<i>Cichorium intybus</i> L.	Leaves, Roots, flowers	Leaves edible, used as diuretic, laxative, for improving appetite, treating migraine, improving liver and gall bladder function, poultice used in gout swelling, root used in throat infections and against bee sting, flowers used as tonic.	Bahmani <i>et al.</i> , 2015; Boghrati <i>et al.</i> , 2021; Janda <i>et al.</i> , 2021; Arihan, 2022; Banu, 2024; Sahar & Ali, 2024; Khan <i>et al.</i> , 2025.
<i>Diplazium esculentum</i> (Retz.) Sw.	Young fronds	Young fronds edible, used as vegetable, pickle. Traditionally used for treatment of Asthma, diarrhea, dysentery, headache, measles, fever, constipation, bone fracture, gland swellings, oligospermia	Semwal <i>et al.</i> , 2021; Ghabru <i>et al.</i> , 2022; Jupri <i>et al.</i> , 2022 Pohthmi & Sharma, 2023; Singh, 2025
<i>Eremurus himalaicus</i> Baker	Leaves	Leaves consumed as vegetable and also used as galactagogue. Traditionally used to treat jaundice, liver disorders, diabetes, acne, skin infections,	Mushtaq <i>et al.</i> , 2014; Amin and Bhat, 2015; Mushtaq <i>et al.</i> , 2016, 2017; Farhadi <i>et al.</i> , 2023;

		hyperlipidemia	Haq, 2024;
<i>Fagopyrum esculentum</i> Moench.	Leaves, Seeds	Leaves used as vegetable, seed for flour making, leaves and seeds used for animal feed. Traditionally used to treat anemia, constipation, wounds, ulcers, gum bleeding, diabetes, hypertension. Plant used in intercropping as weed suppressant	Debiage <i>et al.</i> , 2016; Nagar & Jain, 2016; Al-Snafi, 2017; Singh <i>et al.</i> , 2020; Singh and Verma, 2022; Virili <i>et al.</i> , 2024
<i>Malva neglecta</i> Wallr.	Leaves, Flower, Fruit, Root	Wound healing, maturation of abscess, for treating inflammation, bruises, insect bites, stomachache, diarrhea, asthma, gynaecological disorders, diabetes, throat infection cough, acne, burns, dermatitis. Leaves used as vegetable, flowers used for dye preparation	Batsatsashvili <i>et al.</i> , 2017; Al-Snafi, 2019; Saleem <i>et al.</i> , 2020; Jan <i>et al.</i> , 2021; Karakaya <i>et al.</i> , 2023
<i>Phytolacca acinosa</i> Roxb.	Leaves, Rhizome, fruit	Treatment body aches, eye infections, sores, edema, young leaves used as vegetable, red dye obtained from berries	Manzoor <i>et al.</i> , 2017; Jan <i>et al.</i> , 2021; Mir <i>et al.</i> , 2024; Magray <i>et al.</i> , 2025; Khalid <i>et al.</i> , 2025

<i>Taraxacum officinale</i> (L.) Weber ex F.H.Wigg.	Leaves, Roots, Flowers	Treatment of food-borne infections, liver disorders, gallstones, digestive issues, As diuretic and detoxifying agent. Leaves consumed as salad, vegetable, dried roots used for tea.	Sharifi <i>et al.</i> , 2018; Cavalloro <i>et al.</i> , 2022; Murtaza <i>et al.</i> , 2022; Gavrilovic <i>et al.</i> , 2024; Taha & Abdelwahab, 2024; Turkmen <i>et al.</i> , 2024; Wu <i>et al.</i> , 2024
<i>Urtica dioica</i> L.	Leaves	Leaves, tender shoots used as vegetable, tea, Sap used to treat eczema, crushed aerial parts applied to relieve joint pain. Also used against fever, cough, cold, cuts, wounds	Jan <i>et al.</i> , 2017; Devkota <i>et al.</i> , 2022; Janačković <i>et al.</i> , 2022; Alimoddin <i>et al.</i> , 2024; Jalali <i>et al.</i> , 2024; Ulcay, 2024.

Chapter 3

MATERIALS AND METHODS

The details of study area, the materials used and the methods followed in order to fulfil the research objectives are described below.

3.1 Study Area

The Union Territory of J&K, with an approximate area of 42,241 km², is divided into 20 districts, District Doda being one of them. The district is surrounded by district Kishtwar in the Northeast and in the West by district Ramban; which were earlier part of District Doda. It has district Anantnag lying in its North and district Udhampur in the Southwest. In the South it is surrounded by district Kathua and district Chamba of Himachal Pradesh (Singh *et al.*, 2023).

3.1.1 Topography

District Doda of J&K is a large district with geographical area of 2,625 km² with an average elevation of 1,107m above sea level (Hamid *et al.*, 2024). The mountainous district lies in the eastern portion of the Jammu division, situated between the outer and middle Himalayan ranges. Geographically, it extends from 32°53' to 34°21' N latitude and 75°1' to 76°47' E longitude, with a total forest cover of about 47% of the total area (FSI, 2021; Singh *et al.*, 2023).

3.1.2 Climatic Conditions

The district does not experience a uniform climate because of wide variation of elevation owing to its mountainous topography and rugged terrain. Along its altitudinal range, three major climatic zones occur i.e., sub-tropical, temperate, and alpine. These diverse environmental conditions support a broad spectrum of vegetation, making the region a rich abode of plant biodiversity. The district receives an average yearly rainfall of about 35.08 inches. Summer temperatures typically range from 26–29 °C, while winter temperatures drop to 2–15 °C. Higher altitude areas experience heavy snowfall in winter, and the mountain peaks lying in southwest of Bhaderwah valley remain snow-covered for much of the year. The region is also

traversed by the Chenab River, which serves as its principal drainage system (Dar *et al.*, 2018; FSI, 2023). District Doda comprises of four administrative sub-divisions i.e., Doda, Thathri, Bhaderwah and Bhalessa which are further divided in to eighteen tehsils.

3.1.3 Demographic Attributes

The total population of the district is 409,936 according to census 2011, comprising of different ethnic groups. The district has a population density of 79 persons per square kilometre, with a sex ratio of 922 women per 1,000 men and an overall literacy rate of 65.97%. The region has a Muslim majority; other main religion practised is Hinduism. The major languages spoken in the region are Kashmiri, Bhaderwahi and Sirazi. Kashmiri is the dominant language followed by Bhaderwahi which is a mix of Dogri–Kangri used by roughly 53,000 residents in Doda. The main tribes inhabiting this region are Gujjar, Bakerwal, Gaddi and Sippi. The district is mountainous and pre-dominantly rural with agricultural and pastoral economy. The region is quite rich in plant diversity. The rural population uses the locally available plant species in many ways including the medicinal and edible purposes. The climatic conditions, diverse flora, multi-cultural population and lack of urbanization in the area make it an important site for various ethnobotanical investigations including the proposed study.

3.1.4 Vegetation and forest types

District Doda supports a wide range of vegetation types due to its sharp altitudinal and climatic gradient. The region exhibits ecological diversity in the form of forest types ranging from sub-tropical dry evergreen scrubs of *Olea* with *Quercus*, *Ziziphus* and *Punica* on hot lower slopes (~800–1,200 m), temperate coniferous belts dominated by *Cedrus deodara* (deodar), *Pinus wallichiana* (pine), *Picea smithiana* (spruce) and *Abies pindrow* (fir) between 1,800–2,800 m, interspersed with oak forests (*Quercus dilatata*, *Q. leucotrichophora*, *Q. semecarpifolia*) often mixed with *Rhododendron* and *Taxus* (Arya *et al.*, 2014). Above ~3,000 m, the vegetation grades into sub-alpine scrub with *Betula utilis* and *Rhododendron campanulatum*, finally giving way to alpine juniper scrub (*Juniperus communis*, *J. recurva*) and herbaceous meadows

(>3,400 m) . This sequence of vegetation makes Doda a representative cross-section of Western Himalayan forest diversity.

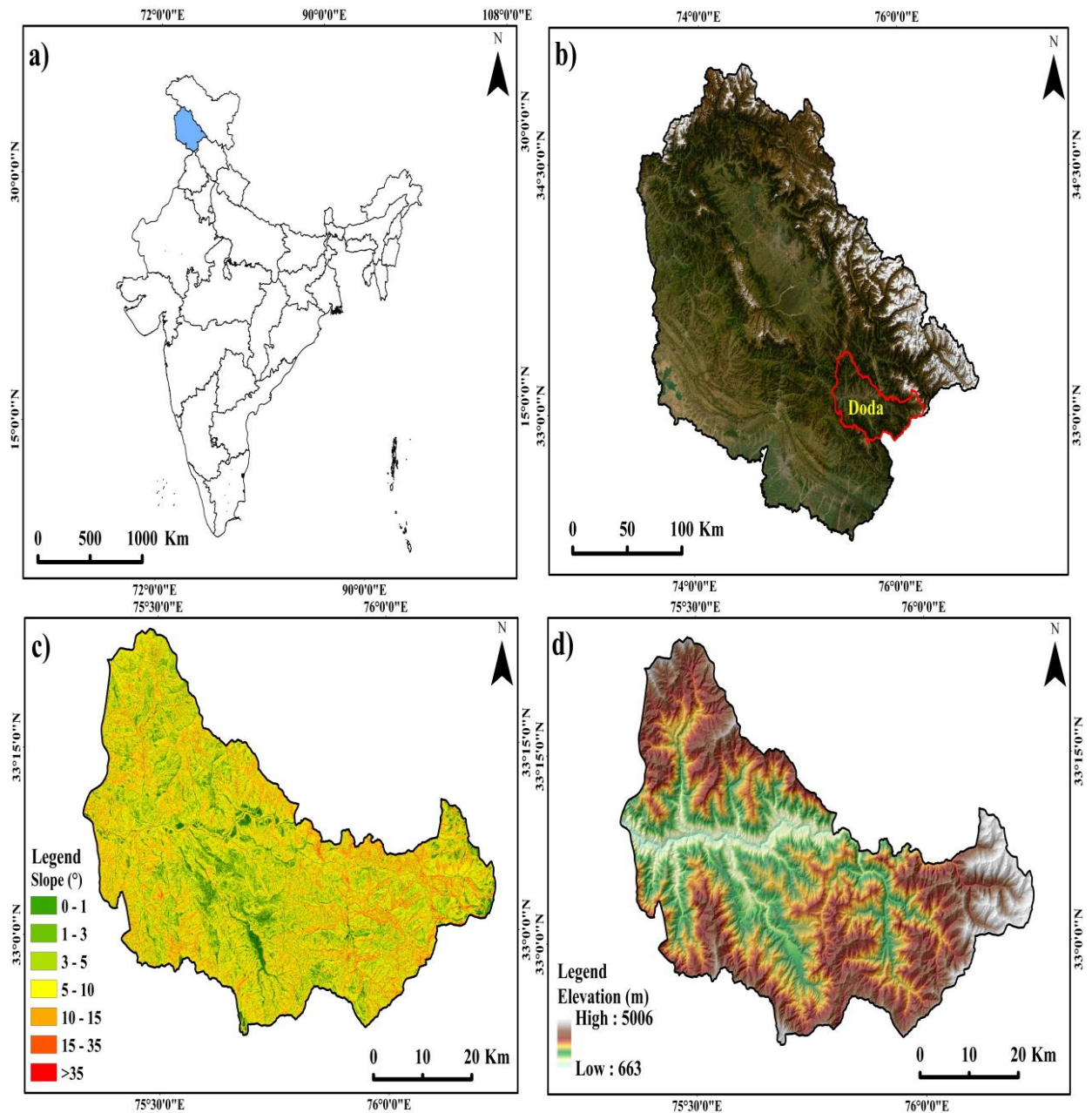


Fig 3.1: Map of (a) India (b) J&K showing District Doda (Study Area)

(c) Slope Map (d) Elevation Map

3.2 Field Survey

The ethnobotanical study of WEPs was carried out by using methods of Jain (2010) and Martin (2010). The field work was carried out at the selected sites for collection of relevant data following a stratified purposive sampling approach.

3.2.1 Selection of sites

The study area was surveyed for selection of suitable sites covering all areas of the district. The field-work was carried out in the sub-divisions of Bhaderwah, Doda, Thathri, Bhalessa which are located in different directions of the district having unique geographical attributes. The sites were selected to represent the major phytogeographical regions and socio-cultural variability of the district. The villages surveyed included Gandoh, Latizar, Shelhala, Tanta, Bhatyas and Kahara in Bhalessa region with average elevation of 1700-2500m. In Thathri region with altitude 1265 m, the villages Premnagar, Lopa and Tipri were surveyed. In Assar region of Doda having average elevation of 1100 m, the field study was carried out in Jathi, Mangota and Baggar villages. Other villages surveyed were Gundna, Khellani, Beoli, Kastigarh, Malwana villages of Doda (altitude 1107 m-2000m); whereas Nalthi , Bhalla, Padri, Gul-danda, Chattergala areas of Bhaderwah region (1600-2600 m average elevation) were also visited for field-work.

3.2.2 Collection of Data

Ethnobotanical information related to traditional nomenclature, collection practices, processing, and consumption of WEPs was obtained through direct interaction with local residents and knowledgeable informants. Data collection employed a mixed-method approach comprising semi-structured questionnaires, individual interviews, and focused group discussions to capture community perceptions and ethnobotanical knowledge. The inclusion of participants from different age ranges and genders was also ensured.

Questionnaire for Ethnobotanical Investigations on Wild Edible Plants (WEPs)	
Name of the informant: _____	
Age: _____	Gender: _____
Occupation: Farmer, Labourer, Local healer, Housewife, Govt job, other _____ (specify)	
Address/Place/Phone no. _____	

Local Name of the plant: _____	
Collected from : _____	
Flowering season : _____	
Life form : Herb/Shrub/Tree/Climber	
Part used : Leaf/Stem/Root/Fruit/Flower/Bud/Latex/Sap/Seed/Bark/Other _____	
Form used : Raw/Cooked/Dried/Boiled/Any other _____	
Consumed as : Chutney / Spice / Vegetable / Fruit / For therapeutic purpose / Drink or Juice / Tea/Other _____	
Uses :	As food: _____
	As medicine: _____
Side effects (If any) : Yes _____ (Specify)	
No	
Season of collection for consumption: _____	
Frequency of usage : Very Frequent / Frequent / Less frequent	
Taste / Preference : Highly preferred / Moderately preferred / Least preferred	

Fig 3.2: Sample Questionnaire for data collection.

3.2.3 Collection and Identification of Plant Specimens

The field trips were conducted in different seasons throughout the year. The plants were collected during their respective flowering seasons from ending March to Mid-October. The local names of the plants were documented along with their local uses, edible parts, mode of consumption, etc.

3.2.4 Herbarium Preparation

A Herbarium of the collected WEPs was prepared using standard botanical procedure. Identification was done from local flora and by consulting experts. The herbarium sheets of the collected plants were submitted in the Herbarium, University of Jammu where accession numbers were assigned to them.

3.2.5 Analysis of Data using Ethno-botanical Indices

The edible plant species identified as a result of the ethnobotanical survey were assessed to determine their respective importance for local people. This was done by using ethno-botanical indices like Use-value index (UVI), Factor Informant Consensus (FIC) and relative frequency of citation (RFC).

3.2.5.1 Use –Value Index (UVI)

The use-value (UV) index for each recorded species was computed using the following standard formula:

$$UVI = UR/N$$

UR = No. of use reports

N= Total no of informants

3.2.5.2 Factor Informant Consensus (F_iC)

$$F_i C = \frac{n_{ur} - n_t}{n_{ur} - 1}$$

n_{ur} : number of use reports for each plant.

n_t : number of species used for a particular purpose.

3.2.5.3 Relative Frequency of Citation (RFC):

To assess the local prominence of each taxon, the Relative Frequency of Citation (RFC) was calculated as follows:

$$RFCs = FCs/N = \sum_{i=1}^N UR_i$$

FC (Frequency of Citation) = No. of informants who mention use of the species

N = number of informants participating in the survey

UR=use Reports

i = informant

s = plant species

3.3 Analysis of Nutritional and Anti-nutritional Components

The plant material was collected, processed, and samples were prepared for analysis of various parameters following standardized laboratory procedures.

3.3.1 Plant materials and sample processing

The following eight plants were analysed for nutrient content, minerals, oxalates (anti-nutrient), phytochemicals (tannins, flavonoids), and anti-oxidant activity: *Taraxacum officinale*, *Phytolacca acinosa*, *Urtica dioica*, *Malva neglecta*, *Eremurus himalaicus*, *Diplazium esculentum*, *Fagopyrum esculentum*, *Cichorium intybus*.

The collected specimens were washed thoroughly under running tap water to eliminate surface contaminants adhering to the plant parts and finally washed with distilled water and blotted dry. They were then shade dried for 3 days followed by drying in oven at $50^{\circ} \pm 1^{\circ}\text{C}$ till constant weight was recorded. Thereafter the samples were grinded, finely powdered and stored in vacuum desiccator until analysis. Biochemical analysis was performed on dried powdered samples. The moisture content of samples of each species on fresh weight basis was also worked out. The major nutritional components analysed were carbohydrates, protein, lipids, crude fibre and ash content. To ensure analytical reliability, all assays were conducted in triplicate, and findings were expressed on dry weight (DW) basis.

3.3.2 Nutrient evaluation

The plant samples were evaluated for the presence of moisture, ash, fibre, carbohydrates, proteins and fat as per standard methods of Association for Official Agricultural Chemists (AOAC 2000, 2005, 2008).

3.3.2.1 Determination of moisture content

Moisture content determination of the freshly collected plant samples was done by weight difference method. 5 grams of each sample were weighed and allowed to dry overnight at room temperature. After that they were dried in oven at $55^{\circ}\text{C} \pm 1^{\circ}\text{C}$ till

constant weight was recorded. From the difference of fresh weight and dry weight moisture percentage was calculated as below.

The percentage of moisture for each sample was calculated by using the following formula.

$$\text{Moisture (\%)} = \frac{(W1 - W2) \times 100}{W1 - W}$$

$$W1 - W$$

W1 = Weight of the dish containing the sample before drying

W2 = Weight of the dish containing the sample after drying

W = Weight of the empty dish

3.3.2.2 Determination of Ash content

Ash Content Analysis for each plant sample was carried out as per the protocol outlined in AOAC (2000). 4 g of dried powdered sample was weighed in a silica crucible. The sample was then kept in a muffle furnace at 630°C for 3 hours. Percentage of ash was estimated as per the following formula:

$$\text{Total Ash \%} = \frac{M2 - M}{M1 - M} \times 100$$

$$M1 - M$$

M1 = Weight (in gm) of the dish with the sample before ashing

M2 = Weight (in gm) of the dish with the sample after ashing

M = Weight (in gm) of the empty crucible

3.3.2.3 Determination of Crude Fibre

Fibre estimation of plant samples was carried out by AOAC 978.10 gravimetric method (Thiex, 2009). A moisture- and fat-free subsample (1 g) was digested in 100 mL of 1.25% H₂SO₄ by gentle boiling for 30 minutes. The mixture was then filtered, and the residue was repeatedly washed with hot distilled water until free of acid. The acid-free residue was transferred back to the same flask, followed by the addition of

100 mL of 1.25% NaOH, and digested again for 30 minutes. After filtration, the residue was washed thoroughly with hot distilled water to remove any traces of alkali. The residue was then dried in a hot air oven at 100°C overnight and weighed. Subsequently, it was ignited in a muffle furnace at 500°C (±10°C) for 4 hours. The loss in weight after ignition represented the crude fibre content of the sample.

$$\text{Crude fibre \%} = \frac{\text{Weight of residue}}{\text{Weight of the sample}} \times 100$$

3.3.2.4 Determination of Crude Protein

Protein content was estimated by the Micro-Kjeldahl method (AOAC, 2000) using 5 g of each sample. In this procedure, the sample was subjected to wet combustion with concentrated sulfuric acid in the presence of a copper catalyst, facilitating the conversion of organic nitrogen to ammonia, which remained in solution as ammonium sulphate. The digested material was subsequently distilled with NaOH, and the liberated ammonia was quantified by titration against 0.1 N HCl. Protein content was then calculated from the total nitrogen obtained by using following formula:

$$\% \text{ Nitrogen} = \frac{(\text{Sample titre} - \text{Blank titre}) \times \text{N of HCl} \times \text{Volume of digest}}{\text{Weight of sample} \times \text{Aliquot of the digest}} \times 100$$

$$\text{Protein content} = \% \text{ Nitrogen} \times 6.25 \text{ (Where 6.25 is conversion factor)}$$

3.3.2.5 Determination of Total Carbohydrates

Total carbohydrate concentration was quantified using the phenol–sulfuric acid method. A series of glucose standards was prepared from a 1 mg/mL stock solution to obtain concentrations of 20, 40, 60, 80 and 100 µg/mL. Distilled water was used as the reagent blank. For the assay, 1 mL of each glucose standard was transferred into test tubes, followed by the addition of 1 mL of 5% phenol solution. After gentle mixing, 3.0 mL of concentrated sulfuric acid was added carefully. The reaction mixtures were allowed to stand at room temperature for 10 min, and the absorbance was measured at 490 nm against the reagent blank.

For sample analysis, 0.2 mL of plant extract was diluted with 0.8 mL of distilled water to obtain a final volume of 1 mL. The diluted sample was then treated with 1 mL of 5% phenol and 3.0 mL of concentrated sulfuric acid under the same conditions as the standards. A calibration curve was prepared by plotting glucose concentration ($\mu\text{g/mL}$) against absorbance at 490 nm. The carbohydrate concentration of the samples was determined from the glucose standard curve.

In addition, carbohydrate content was estimated by difference as part of proximate composition analysis (AOAC, 2008). The percentage of carbohydrate was calculated according to the following equation:

$$\text{Carbohydrate \%} = 100 - [\text{Moisture \%} + \text{Ash \%} + \text{Protein \%} + \text{Fat \%} + \text{Crude fibre \%}]$$

3.3.2.6 Determination of Total Lipid

Total lipid content was determined using Soxhlet extraction technique (AOAC, 2000). Approximately 1 g of dried plant material was placed in a thimble lined with cotton at the top and inserted into the extraction chamber. A pre-weighed round-bottom flask containing hexane was connected to the chamber, and the condenser was attached to complete the assembly. Continuous extraction was carried out for 5 hours at an appropriate temperature. After extraction, the excess solvent was recovered by gentle evaporation, and the flask was subsequently dried and reweighed. The increase in flask weight corresponded to the lipid content, which was calculated using the standard formula given below:

$$\% \text{ Fat Content} = \frac{\text{Final weight of the beaker} - \text{Empty weight of the beaker}}{\text{Sample weight}} \times 100$$

3.3.2.7 Determination of calorific value

Calorific values (energy values) of the samples expressed in terms of Kilocalories (Kcal)/100g were calculated by using the standard formula given below

$$\text{Energy, E} = [(9 \times \text{fat}) + (4 \times \text{carbohydrates}) + (4 \times \text{protein})] \text{ Kcal /100g}$$

3.3.3 Mineral estimation

The estimation of minerals was done by Energy-dispersive X-ray fluorescence (EDXRF) technique (Tezotto *et al.*, 2013; Ibrahim *et al.*, 2024).

3.3.3.1 EDXRF method

Energy Dispersive X-ray Fluorescence (EDXRF) was employed to determine the macro- and micro-nutrient profile of the sample. Three consecutive EDXRF spot runs were recorded, followed by a more comprehensive Fundamental Parameters (FP) quantification. This was done to confirm elemental reproducibility, identify dominant macro-elements, quantify essential micro-minerals, and evaluate potential nutritional relevance.

3.3.3.2 Equipment used

Elemental profiles were obtained using a benchtop EDXRF spectrometer (Thermo Fisher), equipped with an Ag-target X-ray tube and a Be detector window. The instrument operated at a maximum voltage of 50 kV, with a spectral resolution of 0.024 keV (2048 channels) and approximately 25% detector dead time.

3.3.3.3 Method

Approximately 1.00 g of powdered sample was placed in polypropylene XRF cuvettes and sealed with a 6 µm thick Mylar® film to hold the material in place, with no further chemical treatment or preparation. Measurements were performed under three experimental conditions in an air atmosphere at 15 kV and 10 µA, with a counting time of 30 s for each condition. For every sample, three independent replicates were analyzed, and three spectra were recorded per sample.

3.3.4 Oxalate estimation

The estimation of oxalate content was done by potassium permanganate titration method (Abdi *et al.*, 2022). The apparatus required for titration was burette, conical flask, funnel and filter paper. Thereagents used were 3N H₂SO₄ and 0.01 M KMnO₄.

3.3.4.1 Procedure

For oxalate estimation, 3 g of each plant sample was thoroughly mixed with 75 mL of 3 N H₂SO₄ and stirred on a magnetic stirrer for 1 h. The mixture was subsequently filtered through filter paper. A 25 mL aliquot of the filtrate was taken in a conical

flask and titrated against standardized 0.01 M KMnO_4 solution until a persistent pale pink colour appeared, indicating the endpoint. The volume of KMnO_4 consumed was recorded. Under the acidic titration conditions, 1 mL of 0.01 M KMnO_4 is equivalent to approximately 2.25 mg of anhydrous oxalic acid. The oxalate content was calculated by taking into consideration the volume of KMnO_4 consumed, total extraction volume, aliquot volume and weight of the plant sample used for extraction. The results were expressed as mg oxalate/g sample.

3.4 Phytochemical evaluation

The phytochemical profile of plant samples was studied by Fourier Transform Infrared Spectroscopy (FTIR) method. Estimation of tannins and flavonoids was done using UV spectrophotometry. Anti-oxidant activity of the plant samples was studied by 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay.

3.4.1 Preparation of Plant Extract

The extraction of plant phytochemicals was done using Soxhlet Method with methanol as solvent.

3.4.1.1 Materials and equipment used

Plant sample: 5 grams (dried and powdered), Solvent: Methanol (150 mL), Soxhlet extractor, Heating mantle, Round-bottom flask

3.4.1.2 Method

For extract preparation of each plant sample, weighed 5 grams of the dried, powdered plant sample. Placed the plant material in a thimble and inserted it into the Soxhlet extractor which was then attached to a round-bottom flask containing 150 mL of methanol. The Soxhlet extractor was connected to a condenser. Heated the flask on a heating mantle to allow methanol to boil and condense. The condensed methanol extracted phytochemicals from the plant material as it passed through the thimble. The process was continued for 8 hours, allowing multiple cycles of solvent extraction. After 8 hours, the heating was stopped and the system was allowed to cool. Collected

the methanol extract from the flask. Concentrated the methanol extract using a rotary evaporator to obtain the phytochemicals.

3.4.2 FTIR sample analysis

Fourier Transform Infrared Spectroscopy (FTIR) was employed to determine phytochemical profile of the plant samples (Sutariya, *et al.*, 2023). The equipment used for FTIR analysis was Perkin Elmer Spectra Range: 400-4000 cm^{-1} . A small drop of the sample was placed on a KBr window and covered with a second window, which was gently rotated about a quarter turn to obtain a uniform thin film. The paired plates were then mounted in the sample holder for spectral acquisition. In cases where the sample appeared overly concentrated, the plates were separated and one surface was cleaned before reassembling and re-running the scan. After each analysis, the KBr windows were thoroughly cleaned to avoid cross-contamination of the samples. The windows were first wiped with tissue, rinsed several times with methylene chloride followed by ethanol, and then polished using a KBr polishing kit. Gloves were worn throughout handling to prevent fingerprints or fogging. Major absorption peaks were subsequently marked in the chromatogram.

3.4.3 Tannin estimation

It was done by UV Spectrophotometry using Folin Ciocalteu (FC) method. The equipments used were volumetric flasks, Test tubes and UV Spectrophotometer. The reagents used were 35% Sodium Carbonate Na_2CO_3 , Folin Ciocalteu reagent, and Gallic acid as standard (Mohammed and Manan, 2015).

3.4.3.1 Procedure

Standard solutions of gallic acid at different concentrations were prepared. To each solution, 1 mL of 35% sodium carbonate was added, followed by 1 mL of Folin Ciocalteu reagent. At last 3 mL of distilled water was added and absorbance was noted at 725 nm. For plant samples 0.1 mL of plant extract was taken, the volume of which was made to 1 mL, and then addition of 1mL of sodium carbonate, 1mL of FC reagent and 3mL of distilled water was done and the absorbance was noted at 725 nm.

A standard curve of concentration of gallic acid versus absorbance at 725 nm was prepared and using this graph concentration of tannins in each sample was calculated.

3.4.4 Flavonoid Content

It was determined by UV Spectrophotometry (AOAC, 2005). The Equipment used included Volumetric flask, Test tubes, UV Spectrophotometer. The reagents used were 5% Sodium nitrite NaNO_2 , 10% Aluminium Chloride AlCl_3 , 1M NaOH and Quercetin.

3.4.4.1 Procedure

Standard solution of Quercetin of different concentrations (0.2 - 1.0) was prepared to which 4mL distilled water was added, followed by 0.3 mL of 5% NaNO_2 . Then 0.3 mL of 10% AlCl_3 was added and at last addition of 2mL of 1M NaOH was done and absorbance was noted at 510 nm. For plant samples 0.1 mL of plant extract was taken, the volume of which was made to 1mL, then 4mL of distilled water was added, then 0.3 mL of 5% NaNO_2 was added. Then 0.3 mL of 10% AlCl_3 was added and at last 2mL of 1M NaOH was added and absorbance was noted at 510 nm. A standard curve of concentration of quercetin versus absorbance at 510 nm was prepared and using this graph concentration of flavonoid in the sample was calculated.

3.5 Antioxidant Assay

The anti-oxidant activity of the plant samples was done by DPPH method (AOAC, 2000). The Equipments and reagents used included Volumetric flask, Test tubes, Cuvette and UV spectrophotometer, DPPH (2,2-diphenyl-1-picrylhydrazyl), Methanol and Ascorbic acid.

3.5.1 Procedure

A series of ascorbic acid standard solutions with concentrations ranging from 0.25 to 1.50 $\mu\text{g/mL}$ were prepared in methanol. An appropriate aliquot of each standard solution was mixed with freshly prepared DPPH methanolic solution and incubated in the dark at room temperature for 30 minutes. The absorbance was measured at 515 nm using methanol as the blank. For the plant samples, the methanolic extract was

reconstituted at 1 mg/mL, 5 μ L of plant extract was mixed with 3.995 mL of DPPH methanolic solution, giving a final reaction volume of 4.0 mL. The reaction mixtures were incubated in the dark at room temperature for 30 minutes, after which the absorbance was recorded at 515 nm. A DPPH control containing DPPH solution without plant extract was used as the control. The absorbance of the DPPH control was 0.977. The percentage of DPPH radical-scavenging activity was calculated using the formula:

$$\% \text{ DPPHscavenging} = \frac{A_B - A_A}{A_B} \times 100$$

where, A_B represents Absorbance of the control

A_A represents Absorbance of the sample

3.6 Statistical analysis

Data pertaining to nutritional and phytochemical parameters were subjected to one-way analysis of variance (ANOVA) using IBM SPSS Statistics (version 22.0; Armonk, NY, USA). Tukey's post hoc test was applied at $p = 0.05$ (or $p < 0.05$) to determine statistically significant differences among means. Pearson correlation between mineral content was done with Past 3 software (1.0.0.0).

Chapter-4

RESULTS

4.1 Ethno-botanical Investigation on WEPs

The ethno-botanical field survey led to the identification and documentation of 85 species of wild edible plants (WEPs) occurring in the study area, representing a rich and diverse repository of traditional plant-based food resources (Appendix –I). The local nomenclature and usage of these species was also recorded. These species are distributed across 73 genera reflecting a broad taxonomic spectrum of edible flora.

4.1.1 Family-Wise Distribution and Dominance

The documented species are distributed among 42 plant families, including 38 angiosperm families, 2 gymnosperms and two ferns. Out of these, Polygonaceae (11 species) and Rosaceae (10 species) are the most represented. The prominence of these families signifies their ecological adaptability and cultural preference. Species of *Polygonaceae* such as *Fagopyrum esculentum*, *Rumex nepalensis*, and *Oxyria digyna* are commonly harvested for their nutrient-rich leaves often consumed as seasonal greens. Similarly, the *Rosaceae* family represented by *Rubus*, *Rosa*, *Prunus*, and *Fragaria* species contributes primarily wild fruits that serve as valuable sources of vitamins, antioxidants, and dietary fiber.

Other families with notable edible representation include Amaranthaceae, Apiaceae, Fabaceae, Lamiaceae, Asteraceae, and Brassicaceae, each contributing several herbaceous taxa utilized primarily as leafy vegetables or condiments. The plant families alongwith the number of taxa utilized from each family are shown in figure 4.1.

4.1.2 Growth Habit and Life-Form Spectrum

The data indicate that a majority of the recorded WEPs are herbaceous accounting for approximately 71% of the total life-form spectrum (figure 4.2), followed by shrubs (14%) and trees (13%). Herbaceous species are mostly utilized as vegetables whereas tree species such as *Punica granatum*, *Pyrus pashia*, *Diospyros lotus*, and *Morus alba*

; shrubs like *Rubus niveus* and *Berberis lyceum* predominantly yield fruits, which are used in the local diet.

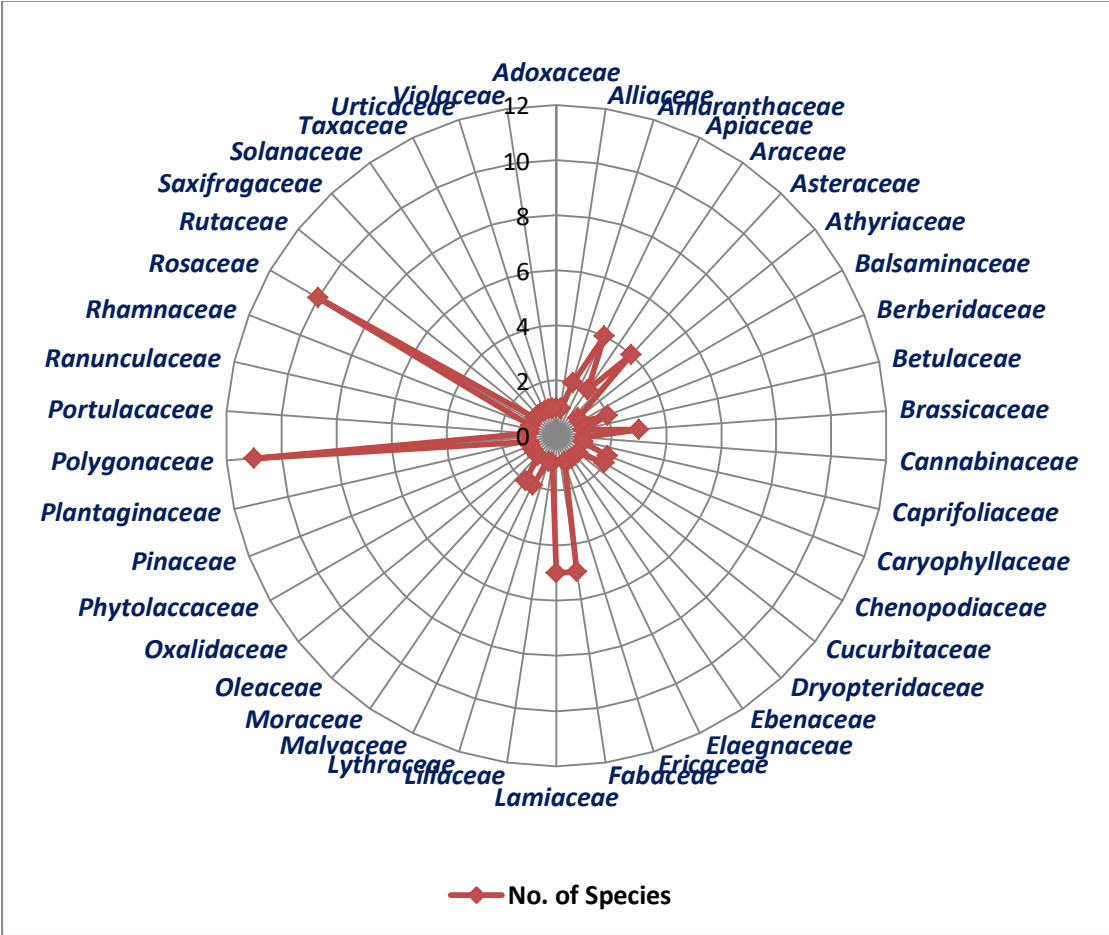


Figure 4.1: Families of Wild Edible Plant Species utilized in District Doda

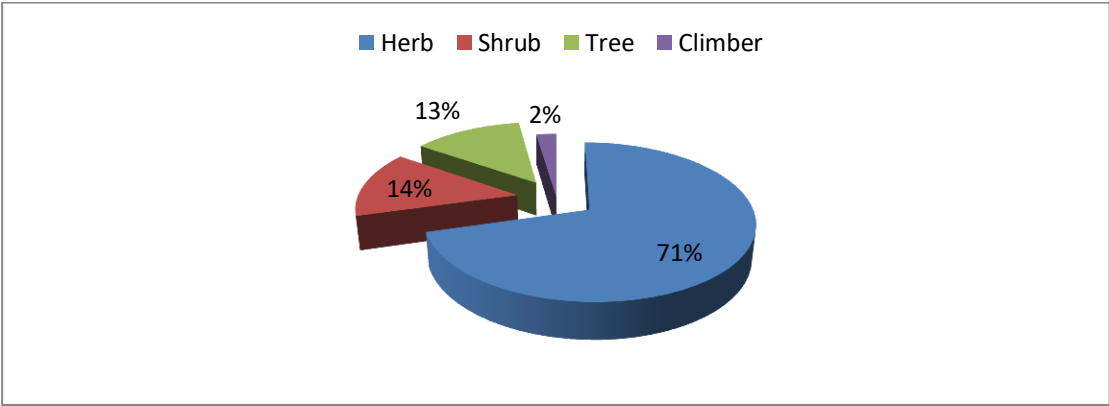


Figure 4.2: Percentage of different life-forms of Wild Edible Plants utilized in District Doda

4.1.3 Plant Parts Utilized

The analysis of plant parts used revealed that leaves constitute the most frequently consumed plant organ (48%), followed by fruits and seeds (figure 4.3). Notably, plant parts such as roots, bulbs, rhizomes, and corms (e.g., *Angelica glauca*, *Arisaema jacquemontii*) are also consumed, often for their aromatic or medicinal properties. Flowers (e.g., *Rhododendron arboreum*, *Prunella vulgaris*, *Rosa moschata*) and bark (*Taxus wallichiana*) represent more specialized uses. The multiplicity of plant parts used from certain taxa such as *Allium stracheyi* (leaves and bulb) and *Plantago lanceolata* (leaves and seeds) was also observed.

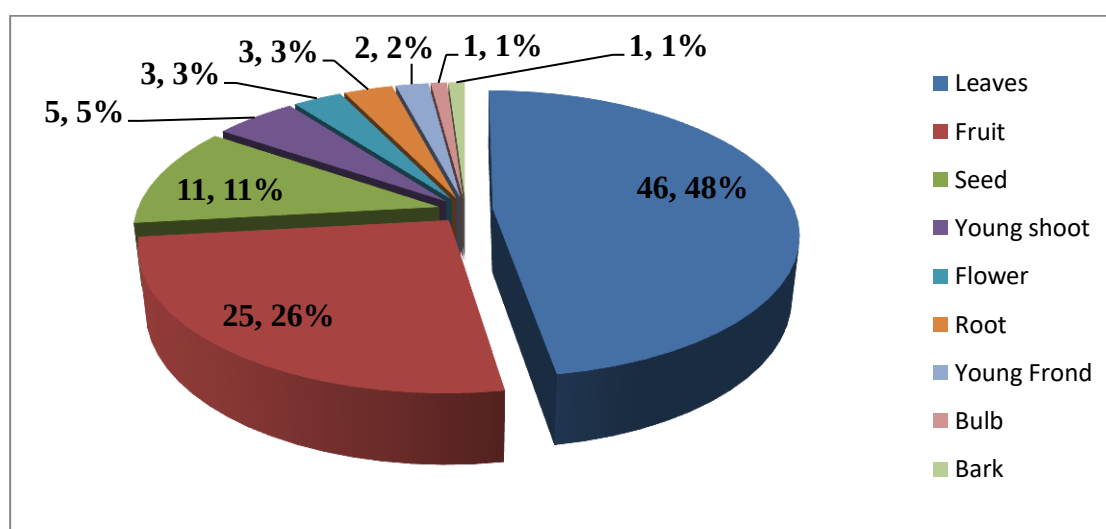


Figure: 4.3: Plant parts of Wild Edible Plants Consumed in District Doda

4.1.4 Ethno-Functional Use Categories

Based on traditional applications, the documented plants were classified into six primary ethno-functional categories (figure 4.4) i.e. vegetables, fruits, edible medicinals, spices, beverages and seeds. Vegetables represent the dominant category, comprising 37 leafy greens and tender shoots from families such as *Amaranthaceae*, *Brassicaceae* and *Polygonaceae*. Species like *Urtica dioica*, *Malva neglecta*, and *Chenopodium album* are frequently consumed as nutritious vegetables rich in minerals and vitamins. Fruits also form a major group represented by 25 species from *Rosaceae*, *Moraceae*, *Rhamnaceae*, *Elaeagnaceae* and other families. Wild fruits such as *Viburnum grandiflorum*, *Rubus niveus*, *Duchesnea indica*, and *Ziziphus mauritiana*

are locally popular for their palatable taste. Edible Medicinals include several taxa serving dual purposes of food and medicine, exemplifying the food–medicine continuum. *Taraxacum officinale* (medicinal leafy vegetable), *Angelica glauca* (digestive aid), *Viola canescens* (respiratory tonic), and *Cichorium intybus* (anti-diabetic leaves) are some of the taxa falling into this category. Spices and Condiments from plants like *Mentha longifolia*, *Thymus serpyllum*, and *Zanthoxylum armatum* are valued for their flavoring and carminative properties. Beverages prepared from flowers and leaves of species such as *Rhododendron arboreum* and *Bistorta amplexicaulis* include traditional infusions or teas. Seeds of some species like *Corylus jacquemontii* are consumed directly whereas seeds of *Fagopyrum esculentum* and *Fagopyrum tataricum* are consumed as flour.

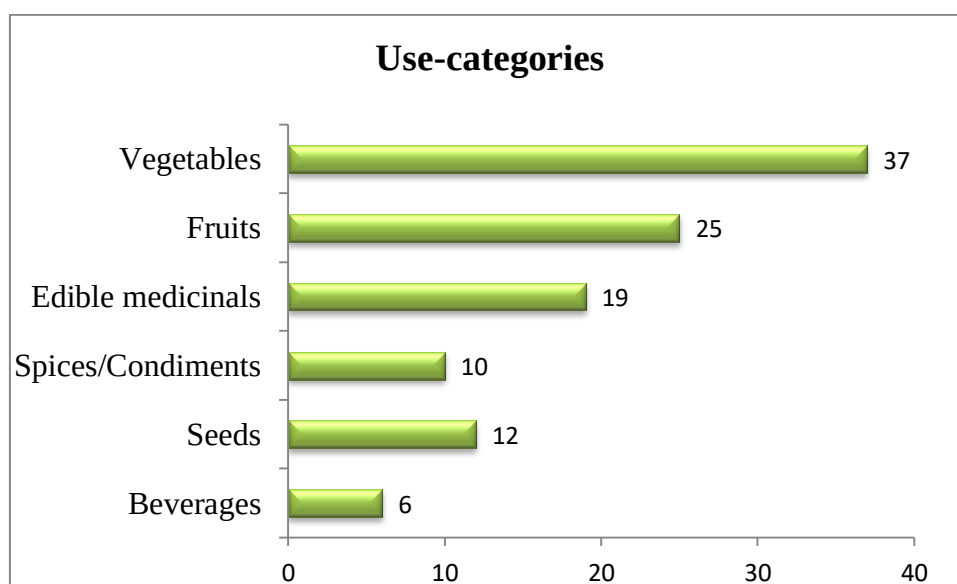


Figure 4.4: Use-categories of the studied Wild Edible Plants

4.1.5 Use-value index , Informant Consensus factor and Relative frequency of citation

The highest use-value index of 1.99 was found in *Taraxacum officinale* and lowest value was observed in *Arisaema jacquemontii* i.e., 0.52. All the use-categories showed significant values of informant consensus factor. The highest informant consensus factor was obtained for wild vegetables (0.98) followed by wild fruits (0.97) whereas seeds showed lowest value for the same (0.69). The edible medicinals, spices and beverages showed FiC values of 0.95, 0.78 and 0.72 respectively. The

values of relative frequency of citation were found in the range of 0.08 to 1. The maximum value of 1 was obtained for most of the fruits and many leafy vegetables indicating their significance (Appendix-1).

4.2 Nutrient Evaluation

Nutrient content was evaluated in eight important wild leafy vegetables i.e., *Taraxacum officinale*, *Phytolacca acinosa*, *Urtica dioica*, *Malva neglecta*, *Eremurus himalaicus*, *Diplazium esculentum*, *Fagopyrum esculentum*, and *Cichorium intybus* by using standard methods of AOAC. The plants were evaluated for moisture, ash, fibre, fat, protein and carbohydrate content.

4.2.1 Moisture and ash content

The moisture content of the evaluated plant species ranged between 92.53% for *E. himalaicus* to 78.27% for *P. acinosa* on fresh weight basis. Highest ash content was found in *M. neglecta* (19.4%), followed by *P. acinosa* (16.83%) whereas lowest ash content was found in *T. officinale* (9.60%).

Table 4.1: Content of moisture (%) and ash (%) in the plant samples

Samples	Moisture content	Ash content
<i>T. officinale</i>	85.10±0.30 ^d	9.60±0.10 ^h
<i>P. acinosa</i>	78.26±0.50 ^f	16.83±0.21 ^b
<i>U. dioica</i>	79.13±0.35 ^f	13.20±0.10 ^f
<i>M. neglecta</i>	82.16±0.31 ^c	19.46±0.31 ^a
<i>E. himalaicus</i>	92.53±0.45 ^a	14.33±0.21 ^d
<i>D. esculentum</i>	90.76±0.25 ^b	11.76±0.15 ^g
<i>F. esculentum</i>	81.50±0.50 ^e	13.60±0.20 ^e
<i>C. intybus</i>	87.33±1.12 ^c	16.10±0.10 ^c

Results are expressed as the mean ± SD (n=3). Values in the same column with different superscripts are significantly different (p<0.05).

4.2.2 Fibre content

Among the evaluated plant samples crude fibre content was found to be highest in *Diplazium esculentum* (34.70%), followed by *Cichorium intybus* (26.50%) and *Malva neglecta* (23.80%). Lowest fibre content was found in *Phytolacca acinosa* sample (9.80%).

Table 4.2: Content of crude fiber (%) in the plant samples

Samples	Crude fiber
<i>T. officinale</i>	12.30±0.30 ^e
<i>P. acinosa</i>	9.80±0.30 ^g
<i>U. dioica</i>	10.80±0.10 ^f
<i>M. neglecta</i>	23.80±0.90 ^c
<i>E. himalaicus</i>	11.70±0.20 ^e
<i>D. esculentum</i>	34.70±0.50 ^a
<i>F. esculentum</i>	16.40±0.50 ^d
<i>C. intybus</i>	26.53±0.95 ^b

Results are expressed as the mean ± SD (n=3). Values in the same column with different superscripts are significantly different (p<0.05).

4.2.3 Protein content

The percentage of protein content was found to be highest in *C. intybus* (12.5%) followed by *D. esculentum* (10.27%) and *F. esculentum* (9.16%). Lowest protein percentage was observed in *T. officinale* (3.50%).

Table 4.3: Crude protein (%) in the evaluated plant samples

Samples	Crude protein
<i>T. officinale</i>	3.50±0.19 ^g
<i>P. acinosa</i>	4.07±0.05 ^f
<i>U. dioica</i>	4.33±0.07 ^f
<i>M. neglecta</i>	6.94±0.48 ^d
<i>E. himalaicus</i>	5.00±0.01 ^e
<i>D. esculentum</i>	10.27±0.48 ^b
<i>F. esculentum</i>	9.16±0.01 ^c
<i>C. intybus</i>	12.50±0.83 ^a

Results are expressed as the mean ± SD (n=3). Values in the same column with different superscripts are significantly different (p<0.05).

4.2.4 Total carbohydrate content

The quantitative estimation of total carbohydrate content was done by using glucose solution as standard. Calibration curve was plotted by taking absorbance on Y-axis and concentration on X-axis (Figure 4.5). Highest carbohydrate concentration was found in *Diplazium esculentum* followed by *Taraxacum officinale*; whereas *Phytolacca acinosa* sample showed presence of lowest concentration of carbohydrate among the evaluated samples.

Table 4.4: Concentration of standard for carbohydrate estimation

S. No.	Concentration (ug/ml)	O.D at 490 nm
Blank	0	0
T1	20	0.254
T2	40	0.542
T3	60	0.761
T4	80	0.962
T5	100	1.124

Figure 4.5: Glucose standard graph for carbohydrate estimation

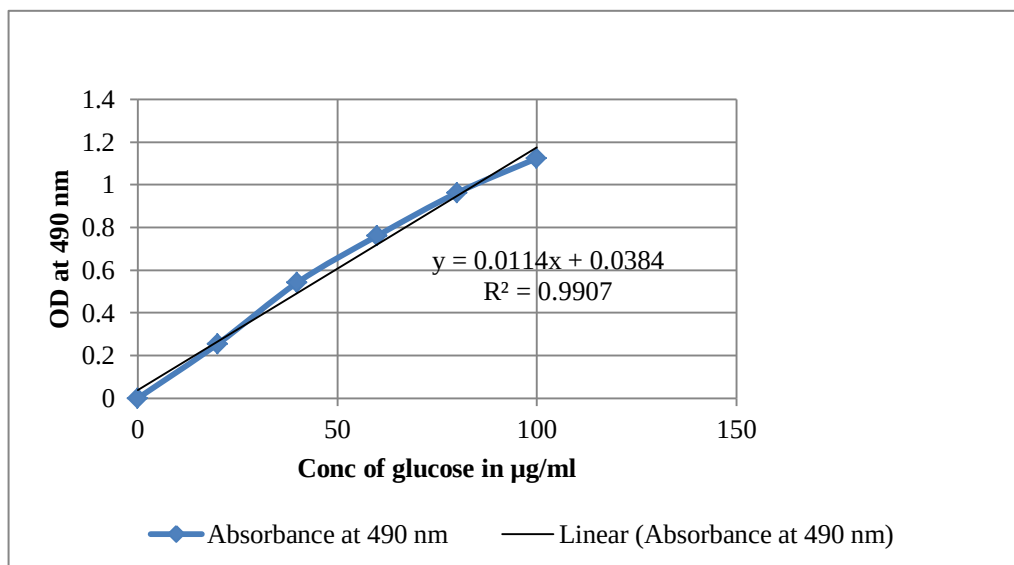


Table 4.5: Total carbohydrate concentration in plant samples.

S. No.	Samples	O.D at 490 nm	Conc. as glucose equivalent (µg/ml)
1	<i>Taraxacum officinale</i>	0.872	365.6±0.09 ^b
2	<i>Phytolacca acinosa</i>	0.449	180±0.18 ^h
3	<i>Urtica dioica</i>	0.762	317.3±0.18 ^d
4	<i>Malva neglecta</i>	0.569	232.7±0.09 ^g
5	<i>Eremurus himalaicus</i>	0.622	255.9±0.18 ^f
6	<i>Diplazium esculentum</i>	0.991	417.8±0.09 ^a
7	<i>Fagopyrum esculentum</i>	0.802	334.9±0.26 ^c
8	<i>Cichorium intybus</i>	0.720	298.9±1.44 ^e

Results are expressed as the mean ± SD (n=3). Values in the same column with different superscripts are significantly different (p<0.05).

4.2.5 Fat content

Fagopyrum esculentum sample showed highest percentage of fat (11.40%) followed by *Malva neglecta* (8.50%) and *Cichorium intybus* (5.20%). *Eremurus himalaicus* sample showed presence of only 1.30% of fat.

Table 4.6: Content of fat (%) in the plant samples

Samples	Fat content
<i>T. officinale</i>	4.60±0.10 ^c
<i>P. acinosa</i>	2.30±0.20 ^d
<i>U. dioica</i>	2.60±0.10 ^d
<i>M. neglecta</i>	8.50±0.20 ^b
<i>E. himalaicus</i>	1.30±0.10 ^e
<i>D. esculentum</i>	2.40±0.20 ^d
<i>F. esculentum</i>	11.40±0.20 ^a
<i>C. intybus</i>	5.20±0.10 ^c

Results are expressed as the mean ± SD (n=3). Values in the same column with different superscripts are significantly different (p<0.05).

Table 4.7: Proximate composition (g/100 g dry weight), moisture content (% fresh weight) and calorific value of the evaluated plant samples

Name of the Plant	Moisture Content (± SEM)	Crude Protein (± SEM)	Fat Content (± SEM)	Total Carbohydrates (± SEM)	Ash (± SEM)	Crude Fibre (± SEM)	Energy (Kcal/100gm)
<i>T. officinale</i>	85.10±0.17	3.5±0.1	4.60±0.05	70±0.05	9.60±0.05	12.30±0.17	335.4
<i>P. acinosa</i>	78.27±0.29	4.07±0.02	2.30±0.11	67.03±0.1	16.83±0.12	9.80±0.17	305.1
<i>U. dioica</i>	79.13±0.2	4.33±0.04	2.60±0.05	69.07±0.1	13.20±0.057	10.80±0.05	317
<i>M. neglecta</i>	82.16±0.17	6.94±0.27	8.50±0.11	41.36±0.05	19.46±0.176	23.80±0.51	269.7
<i>E. himalaicus</i>	92.53±0.26	5.00±0	1.30±0.06	67.7±0.1	14.33±0.12	11.70±0.11	302.5
<i>D. esculentum</i>	90.77±0.14	10.28±0.27	2.40±0.12	40.92±0.05	11.76±0.088	34.70±0.28	226.4
<i>F. esculentum</i>	81.50±0.28	9.17±0.001	11.40±0.1	49.43±0.15	13.60±0.115	16.40±0.28	337
<i>C. intybus</i>	87.33±0.64	12.5±0.4	5.20±0.05	39.7±1.5	16.10±0.057	26.50±0.54	255.6

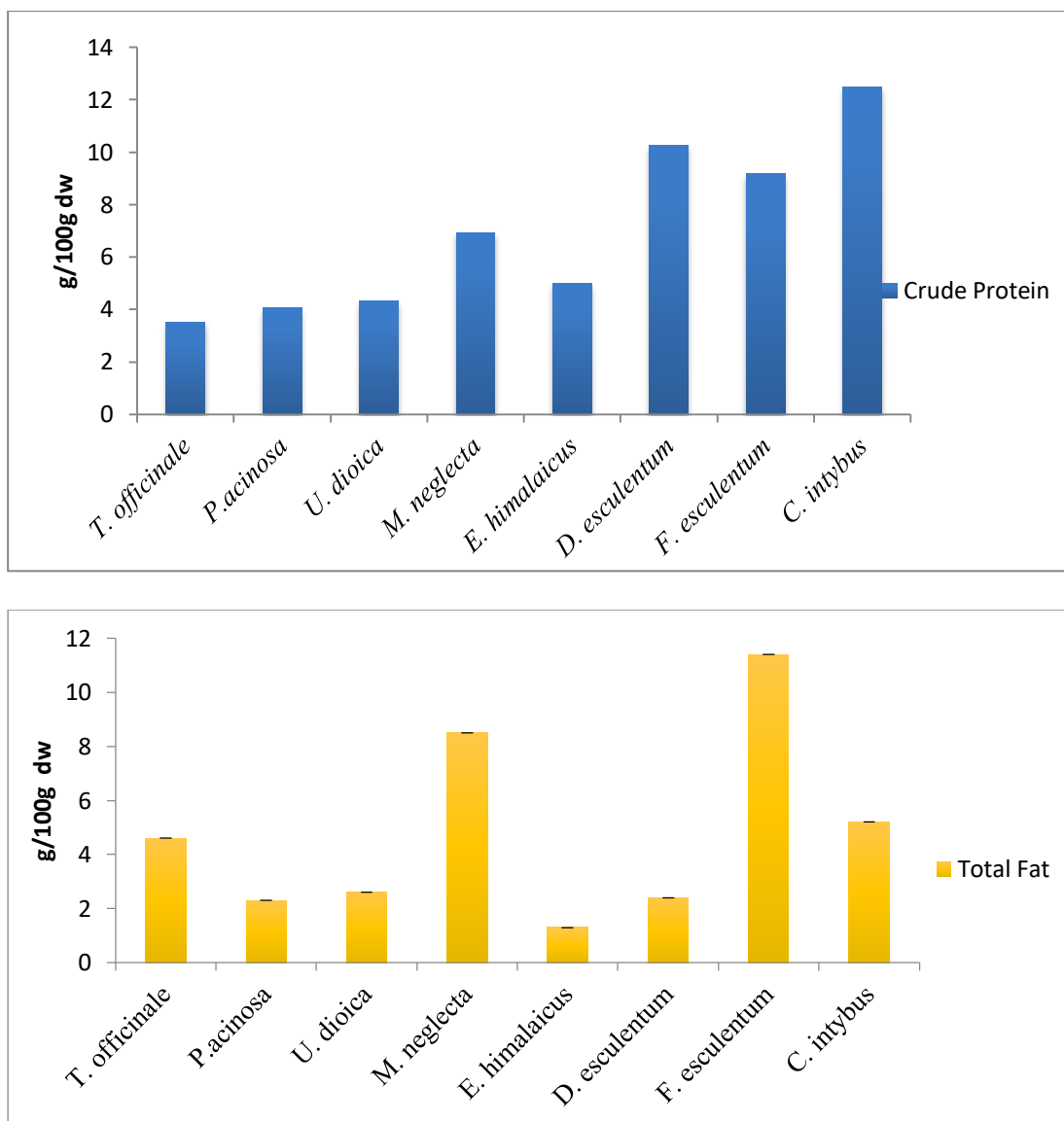


Figure 4.6: Total protein and fat content in the evaluated plant samples

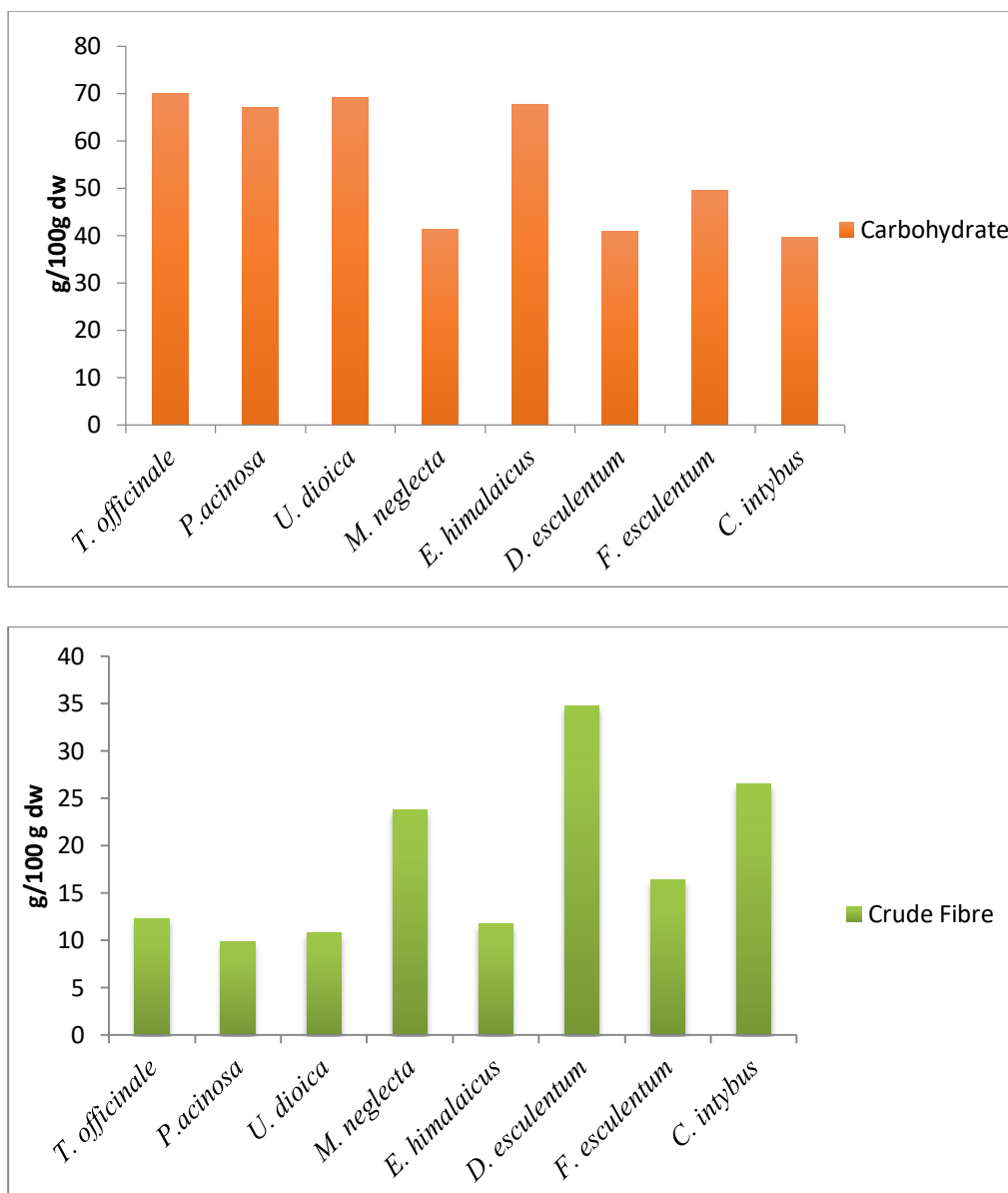


Figure 4.7: Total carbohydrate and fibre content in the evaluated plant samples

4.3: Elemental Analysis

The elemental composition of the plant samples was thoroughly examined using X-ray fluorescence spectroscopy. The analysis revealed the presence of a diverse array of essential minerals, including calcium, magnesium, potassium, and iron; which are vital for various physiological processes and their dietary intake is beneficial to human health. For analysing the composition of elements in the plant samples, triplicates were performed. The evaluated plant samples showed distinct elemental profiles.

4.3.1. *Taraxacum officinale*

The major essential elements found to be present with consistency across the three runs in *Taraxacum* were potassium, calcium, iron and magnesium. Besides, phosphorus and zinc were also observed. The content of potassium was found to be highest at 3.75%. The percentage of calcium, magnesium and iron was 0.95%, 0.55% and 0.05% respectively.

4.3.2 *Phytolacca acinosa*

P. acinosa sample showed strong presence of essential elements such as potassium, calcium magnesium, phosphorus and iron in all the runs. Zinc, copper and manganese were also consistent. The highest values were obtained for potassium (5.86%), followed by calcium (0.90%) and magnesium (0.80%)

4.3.3 *Urtica dioica*

The sample was characterized by the consistent presence of calcium (4.02%), potassium (2.59%), magnesium (0.75%), sulphur (0.56%) and phosphorus (0.45%). Small amounts of zinc, copper, manganese and selenium were also observed.

4.3.4 *Malva neglecta*

It showed major presence of potassium (2.57%) followed by calcium (1.96%) and silicon (1.58%). Besides it also showed presence of sulphur, magnesium, phosphorus and iron.

4.3.5 *Eremurus himalaicus*

The main minerals present in *E. himalaicus* sample were potassium (4.68%), calcium (0.85%), chloride (0.47%), magnesium (0.43%), phosphorus (0.43%), sulphur (0.29%), silicon (0.16%) and iron (0.02%).

4.3.6 *Diplazium esculentum*

The sample showed presence of potassium (5.29%) , phosphorus (0.72%), magnesium (0.57%), sulphur (0.36%), calcium (0.27%), silicon (0.23%), chloride (0.10%) and iron (0.02%).

4.3.7 *Fagopyrum esculentum*

The mineral composition evaluation of *F. esculentum* leaf sample revealed presence of potassium (2.57%), calcium (1.54%), magnesium (0.95%), silicon (0.59%), phosphorus (0.40%), chloride (0.32%), sulphur (0.29%), and iron (0.08%)

4.3.8 *Cichorium intybus*

The leaf samples were found to possess highest percentage of potassium (4.89%), followed by calcium (1.58%), chloride (1.12%) , sulphur (0.65%), phosphorus (0.59%), magnesium (0.54%), silicon (0.332%), iron (0.045%) and manganese (0.005%) .

Table 4.8: *Taraxacum officinale* leaf sample XRF elemental identification (1st run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	58.754	49.850
	8	O	Oxygen	38.955	44.032
	11	Na	Sodium	0.062	0.100
	12	Mg	Magnesium	0.175	0.301
	15	P	Phosphorus	0.183	0.401
	19	K	Potassium	1.525	4.213
	20	Ca	Calcium	0.248	0.702
	26	Fe	Iron	0.076	0.301
	30	Zn	Zinc	0.022	0.100

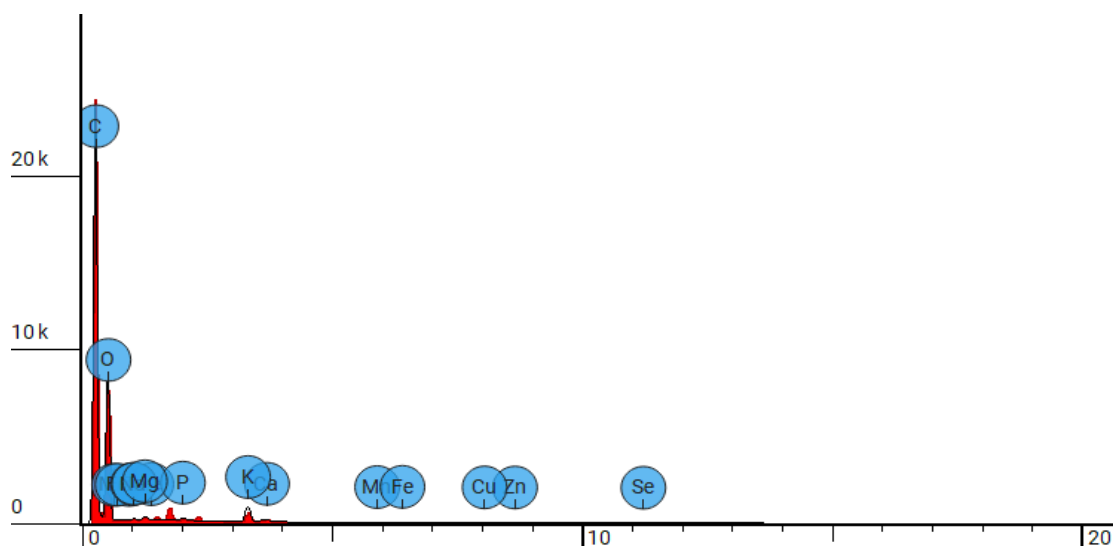


Figure 4.8: *Taraxacum officinale* graph of elements represented by peaks (1st Run)

Table 4.9: *Taraxacum officinale* leaf sample XRF elemental identification (2nd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	55.795	45.281
	8	O	Oxygen	40.581	43.876
	12	Mg	Magnesium	0.183	0.301
	15	P	Phosphorus	0.336	0.703
	19	K	Potassium	2.166	5.723
	20	Ca	Calcium	0.445	1.205
	26	Fe	Iron	0.106	0.402

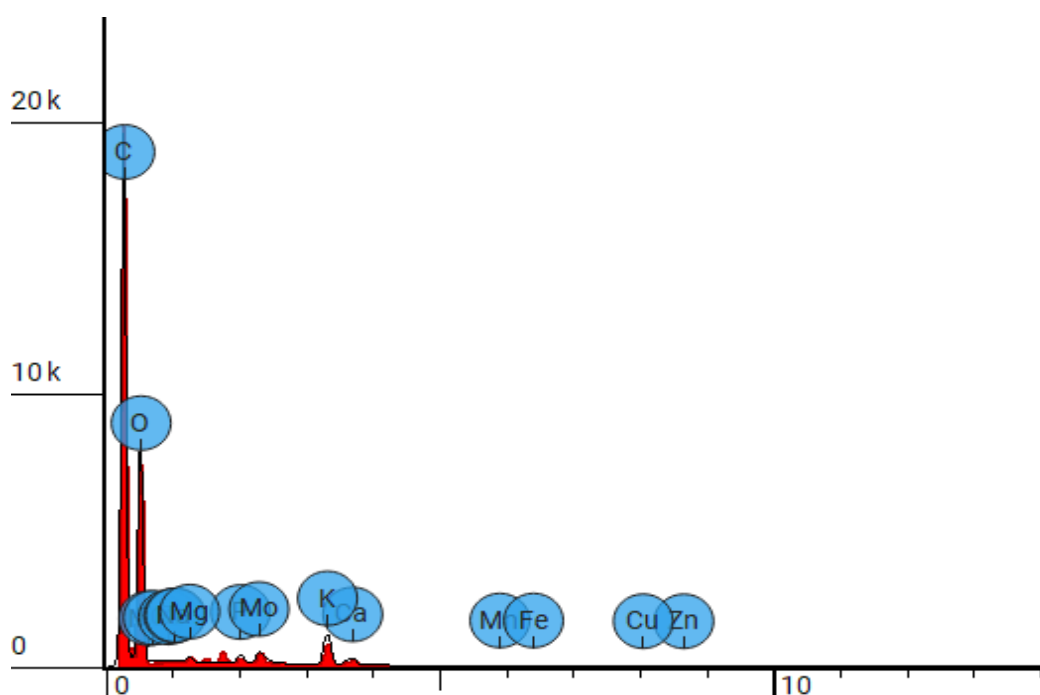


Figure 4.9: *Taraxacum officinale* graph of elements represented by peaks (2nd Run)

Table 4.10: *Taraxacum officinale* leaf sample XRF elemental identification (3rd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	54.841	45.528
	8	O	Oxygen	42.164	46.633
	11	Na	Sodium	0.063	0.101
	12	Mg	Magnesium	0.299	0.503
	19	K	Potassium	2.120	5.729
	20	Ca	Calcium	0.435	1.206
	26	Fe	Iron	0.078	0.302

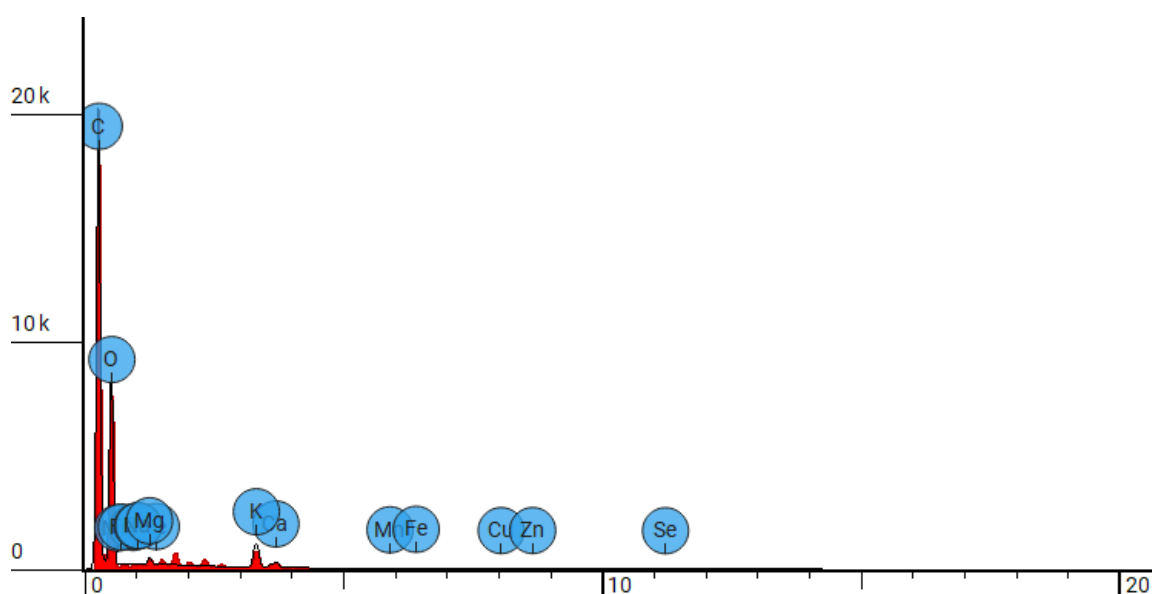


Figure 4.10: *Taraxacum officinale* graph of elements represented by peaks (3rd Run)

Table 4.11: Essential Element content of *Taraxacum officinale* (FP method)

S.No.	Element	Result (%)	Stat. Err.	LLD	LLQ
1.	K	3.75	0.0267	0.0094	0.0281
2.	S	1.42	0.0028	0.0008	0.0024
3.	Ca	0.949	0.0112	0.124	0.371
4.	Mg	0.552	0.0243	0.550	1.67
5.	P	0.472	0.0021	0.011	0.032
6.	Si	0.462	0.0037	0.026	0.077
7.	Fe	0.0500	0.0006	0.003	0.008
8.	Mn	0.0061	0.0003	0.005	0.014
9.	Zn	0.0040	<0.0001	<0.0001	0.0002
10.	Cu	0.0009	<0.0001	<0.0001	0.0003

Table 4.12: *Phytolacca acinosa* leaf sample XRF elemental identification (1st run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	48.300	38.038
	8	O	Oxygen	46.464	48.749
	12	Mg	Magnesium	0.251	0.400
	15	P	Phosphorus	0.246	0.501
	19	K	Potassium	3.943	10.110
	20	Ca	Calcium	0.686	1.802
	26	Fe	Iron	0.109	0.400

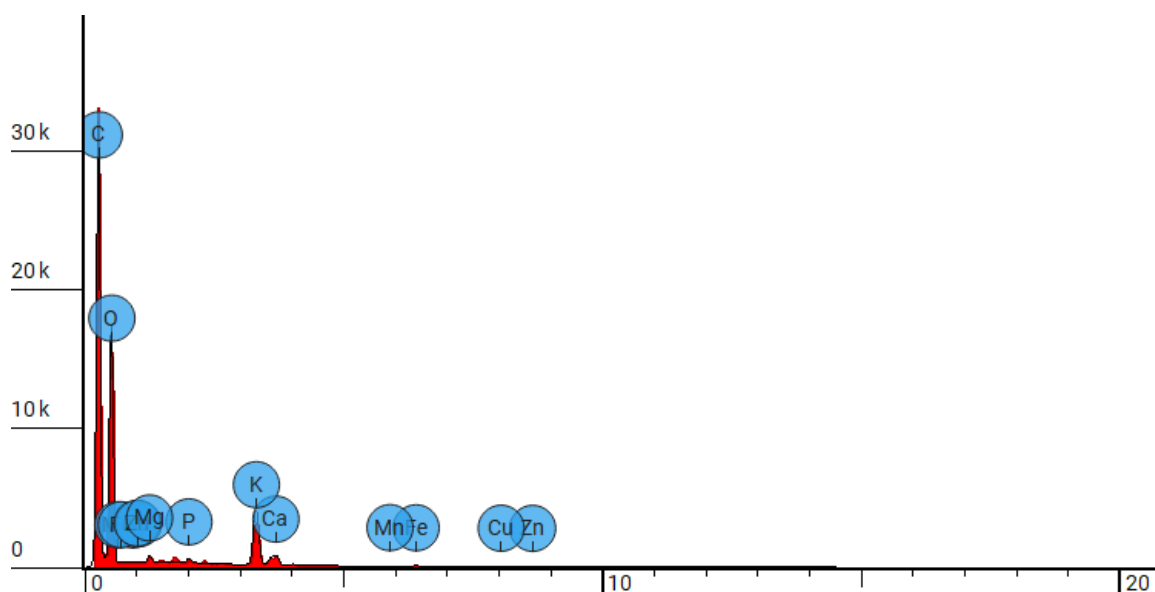


Figure 4.11: *Phytolacca acinosa* graph of elements represented by peaks (1st Run)

Table 4.13: *Phytolacca acinosa* leaf sample XRF elemental identification (2nd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	37.725	27.000
	7	N	Nitrogen	6.707	5.600
	8	O	Oxygen	45.307	43.200
	12	Mg	Magnesium	0.414	0.600
	15	P	Phosphorus	0.325	0.600
	19	K	Potassium	8.498	19.800
	20	Ca	Calcium	0.712	1.700
	26	Fe	Iron	0.120	0.400

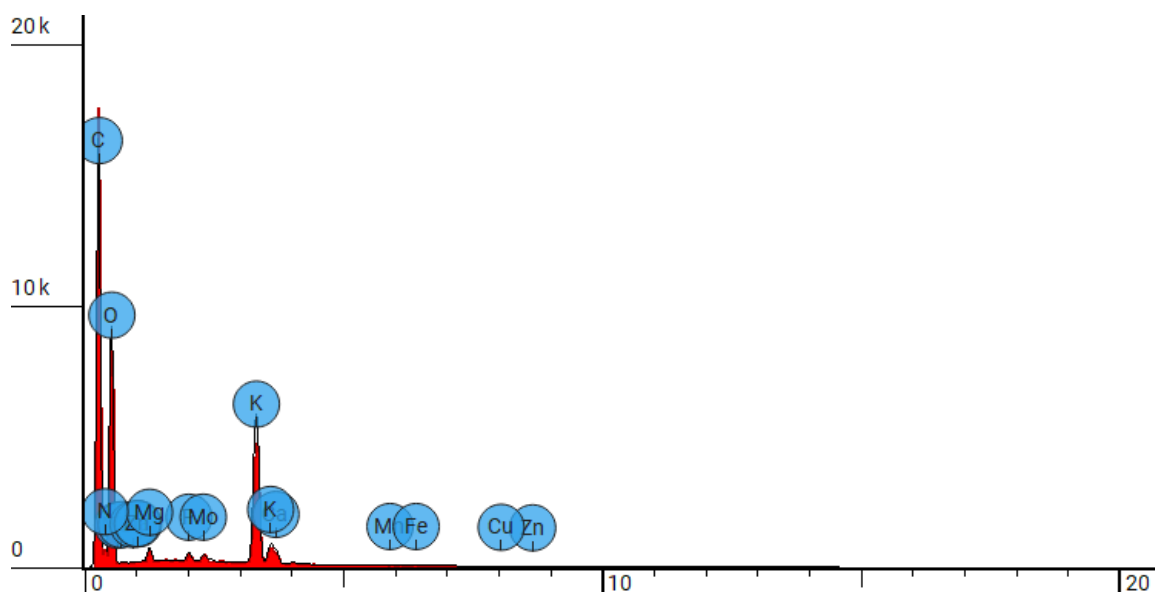


Figure 4.12: *Phytolacca acinosa* graph of elements represented by peaks (2nd Run)

Table 4.14: *Phytolacca acinosa* leaf sample XRF elemental identification (3rd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	39.511	29.116
	7	N	Nitrogen	4.672	4.016
	8	O	Oxygen	47.453	46.586
	12	Mg	Magnesium	0.538	0.803
	15	P	Phosphorus	0.264	0.502
	19	K	Potassium	6.277	15.060
	20	Ca	Calcium	0.980	2.410
	26	Fe	Iron	0.117	0.402

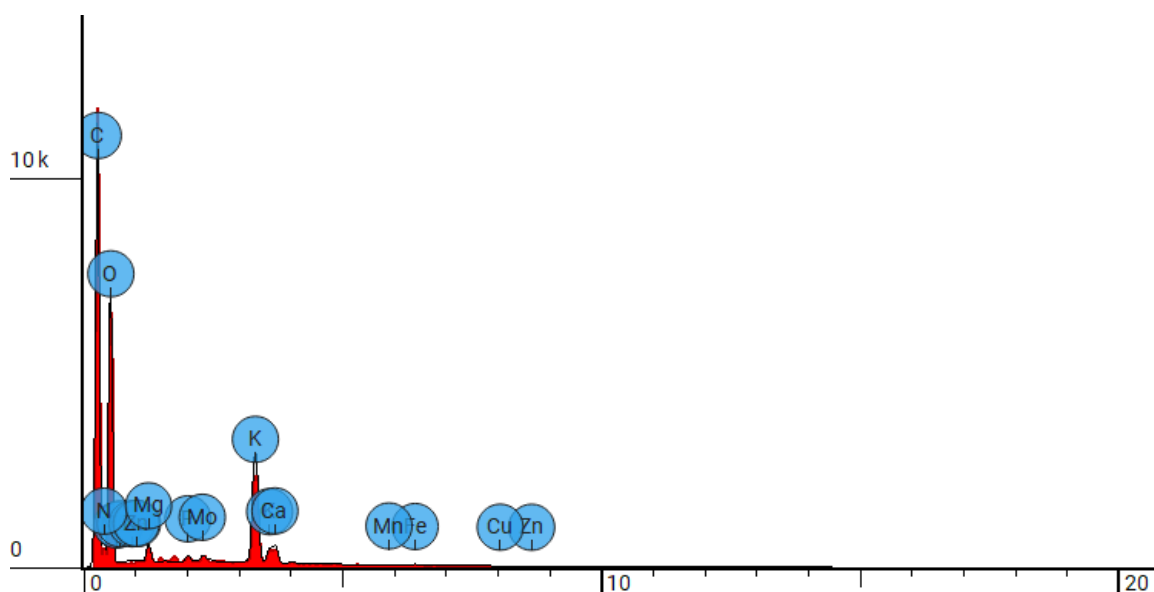


Figure 4.13: *Phytolacca acinosa* graph of elements represented by peaks (3rd Run)

Table 4.15: Essential Element content of *Phytolacca acinosa* sample (FP method)

S.No.	Element	Percentage	Stat. Err.	LLD	LLQ
1.	K	5.86	0.0321	0.071	0.212
2.	Ca	0.902	0.0115	0.156	0.469
3.	Mg	0.802	0.0277	0.597	1.79
4.	S	0.445	0.0016	0.009	0.026
5.	Si	0.326	0.0032	0.026	0.077
6.	P	0.297	0.0017	0.011	0.032
7.	Fe	0.0436	0.0003	0.004	0.012
8.	Mn	0.0090	0.0003	0.004	0.012
9.	Cu	0.0032	<0.0001	<0.0001	0.0003
10.	Zn	0.0029	0.0001	0.0001	0.0002

Table 4.16: *Urtica dioica* XRF elemental identification (1st run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	50.412	41.767
	7	N	Nitrogen	5.402	5.221
	8	O	Oxygen	41.388	45.683
	12	Mg	Magnesium	0.180	0.301
	15	P	Phosphorus	0.282	0.602
	19	K	Potassium	1.377	3.715
	20	Ca	Calcium	0.908	2.510
	26	Fe	Iron	0.052	0.201

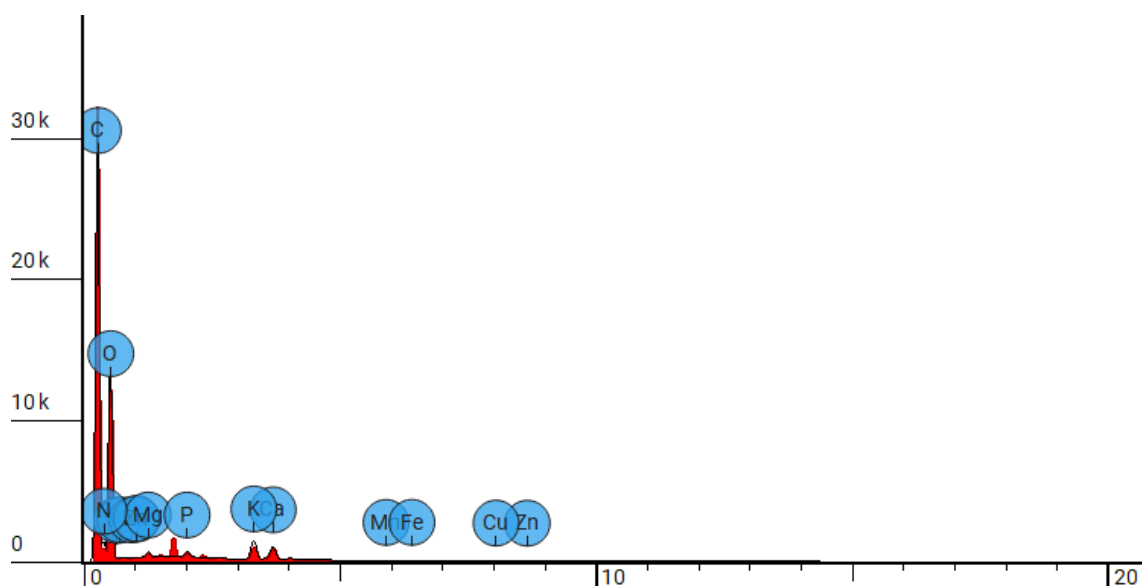


Figure 4.14: *Urtica dioica* graph of elements represented by peaks (1st Run)

Table 4.17: *Urtica dioica* XRF elemental identification (2nd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	53.000	43.430
	8	O	Oxygen	43.550	47.543
	12	Mg	Magnesium	0.302	0.502
	15	P	Phosphorus	0.190	0.401
	19	K	Potassium	1.391	3.711
	20	Ca	Calcium	1.504	4.112
	26	Fe	Iron	0.026	0.100

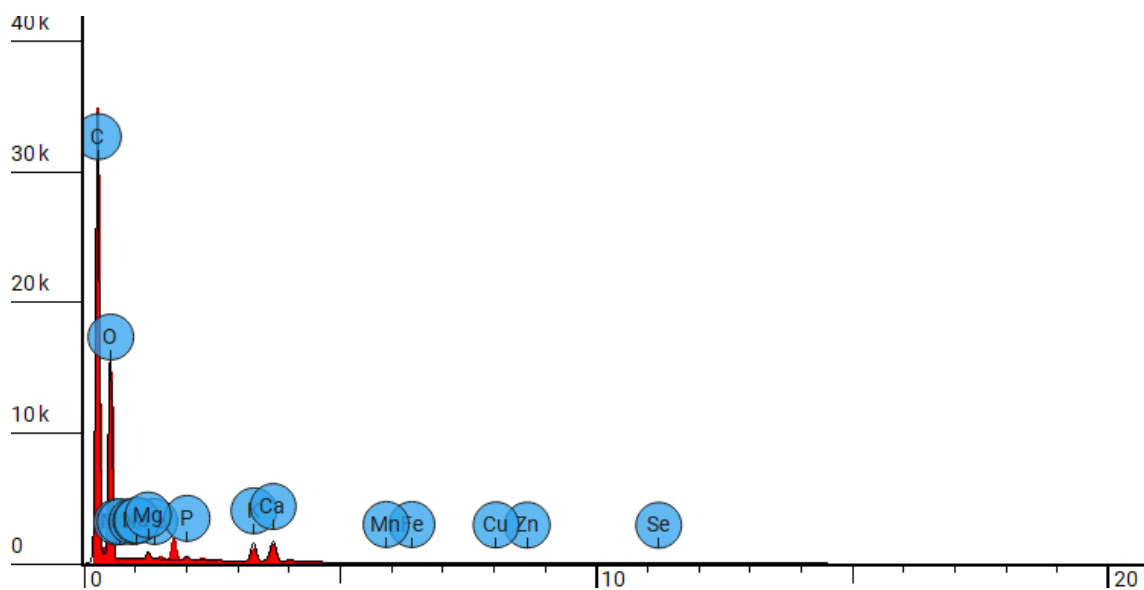


Figure 4.15: *Urtica dioica* graph of elements represented by peaks (2nd Run)

Table 4.18: *Urtica dioica* XRF elemental identification (3rd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	53.732	43.544
	8	O	Oxygen	42.743	46.146
	12	Mg	Magnesium	0.183	0.300
	15	P	Phosphorus	0.239	0.501
	19	K	Potassium	1.707	4.505
	20	Ca	Calcium	0.888	2.402
	26	Fe	Iron	0.080	0.300

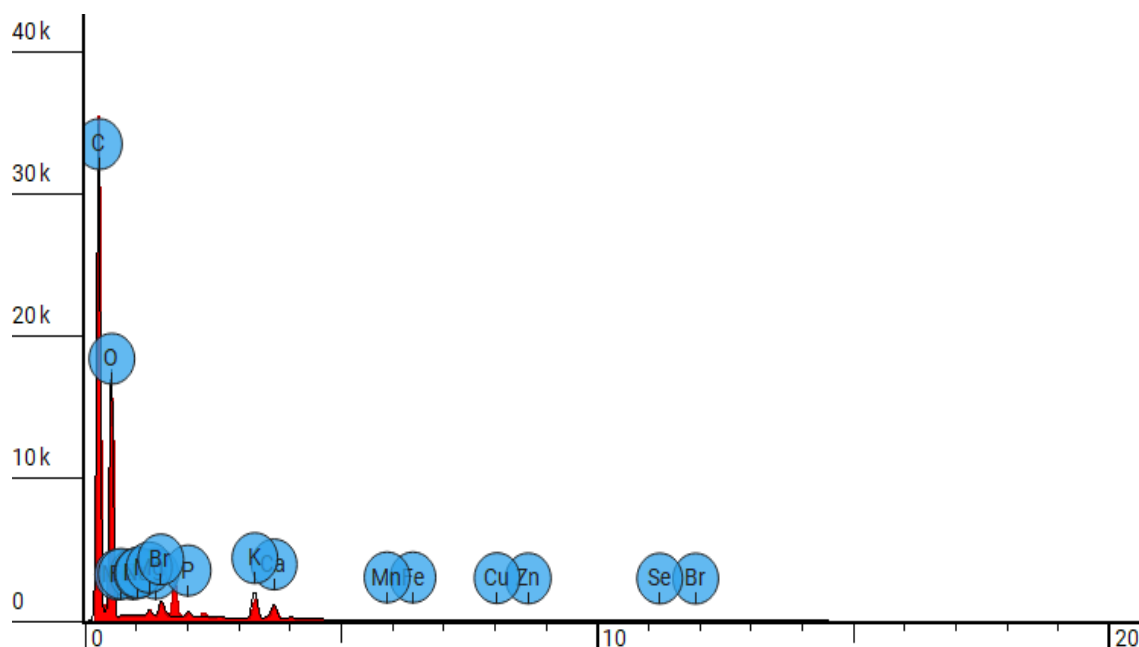


Figure 4.16: *Urtica dioica* graph of elements represented by peaks (3rd Run)

Table 4.19: Essential Element content of *Urtica dioica* (FP method)

S.No.	Element	Percentage	Stat. Err.	LLD	LLQ
1.	Ca	4.02	0.0216	0.0103	0.0309
2.	K	2.59	0.0226	0.0094	0.0283
3.	Si	1.53	0.0267	0.025	0.075
4.	Mg	0.751	0.0263	0.0563	0.169
5.	S	0.569	0.0018	0.0009	0.0026
6.	P	0.451	0.0022	0.0018	0.0054
7.	Fe	0.0625	0.0007	0.0003	0.0010
8.	Mn	0.0073	0.0004	0.0006	0.0017
9.	Zn	0.0048	<0.0001	<0.0001	0.0002
10.	Cu	0.0015	<0.0001	0.0001	0.0003

Table 4.20: *Malva neglecta* XRF elemental identification (1st run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	54.539	45.519
	8	O	Oxygen	43.021	47.835
	11	Na	Sodium	0.063	0.101
	12	Mg	Magnesium	0.179	0.302
	19	K	Potassium	1.557	4.230
	20	Ca	Calcium	0.542	1.511
	26	Fe	Iron	0.026	0.101

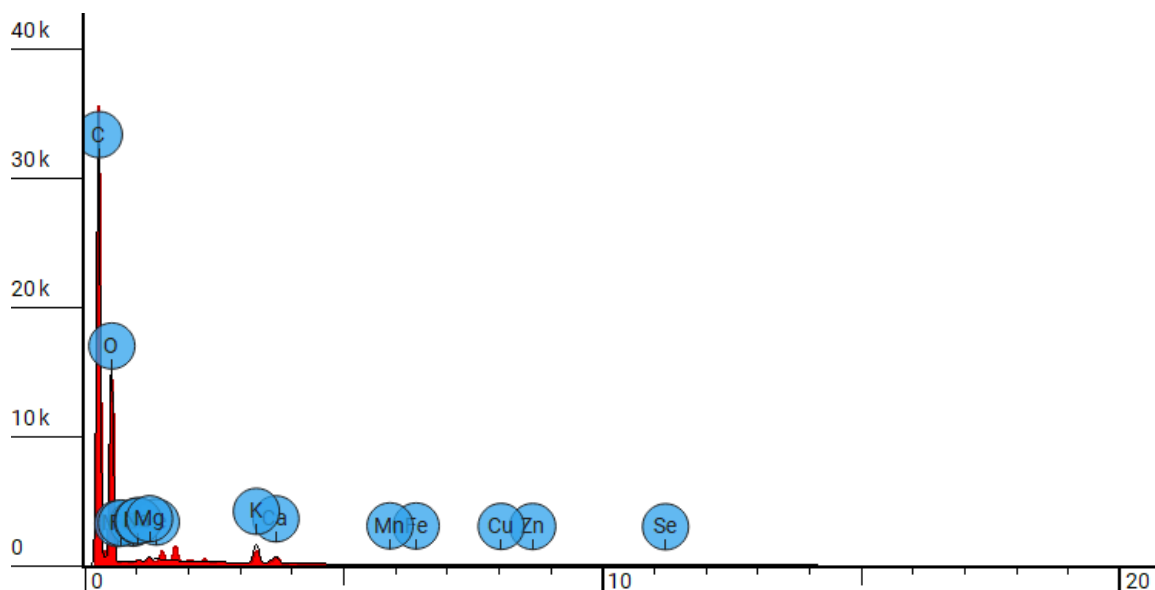


Figure 4.17: *Malva neglecta* graph of elements represented by peaks (1st Run)

Table 4.21: *Malva neglecta* XRF elemental identification (2nd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc
	6	C	Carbon	53.025	43.544
	8	O	Oxygen	43.736	47.848
	11	Na	Sodium	0.127	0.200
	12	Mg	Magnesium	0.120	0.200
	15	P	Phosphorus	0.189	0.400
	19	K	Potassium	1.573	4.204
	20	Ca	Calcium	1.096	3.003
	26	Fe	Iron	0.079	0.300

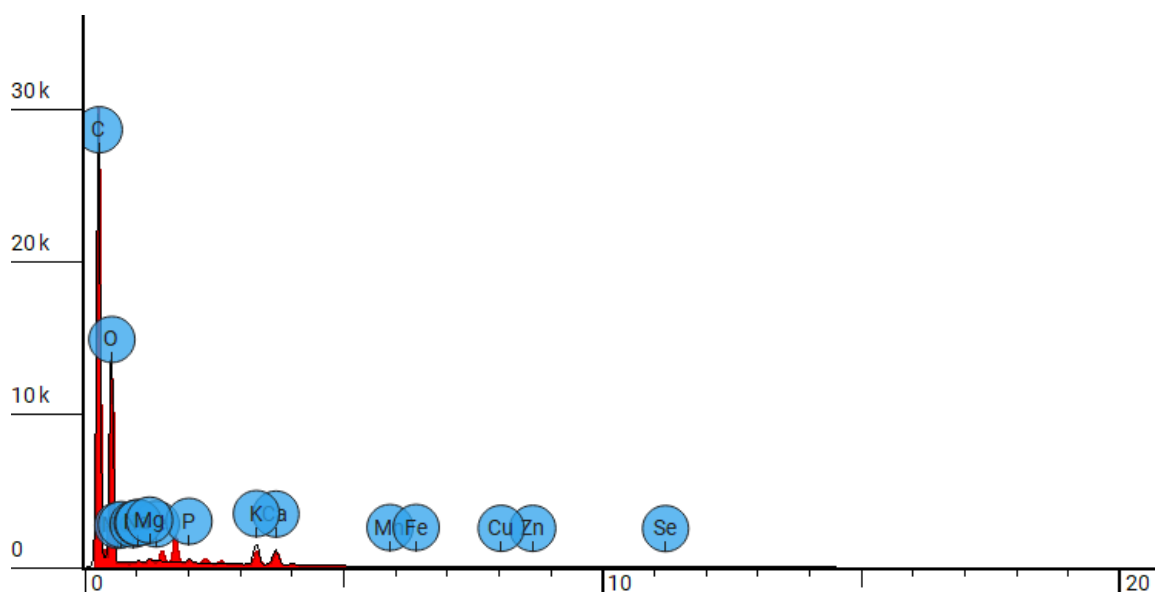


Figure 4.18: *Malva neglecta* graph of elements represented by peaks (2nd Run)

Table 4.22: *Malva neglecta* XRF elemental identification (3rd run)

	Element number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	56.780	47.247
	8	O	Oxygen	40.092	44.444
	11	Na	Sodium	0.063	0.100
	12	Mg	Magnesium	0.178	0.300
	15	P	Phosphorus	0.187	0.400
	16	S	Sulfur	0.225	0.501
	19	K	Potassium	1.478	4.004
	20	Ca	Calcium	0.865	2.402
	26	Fe	Iron	0.078	0.300

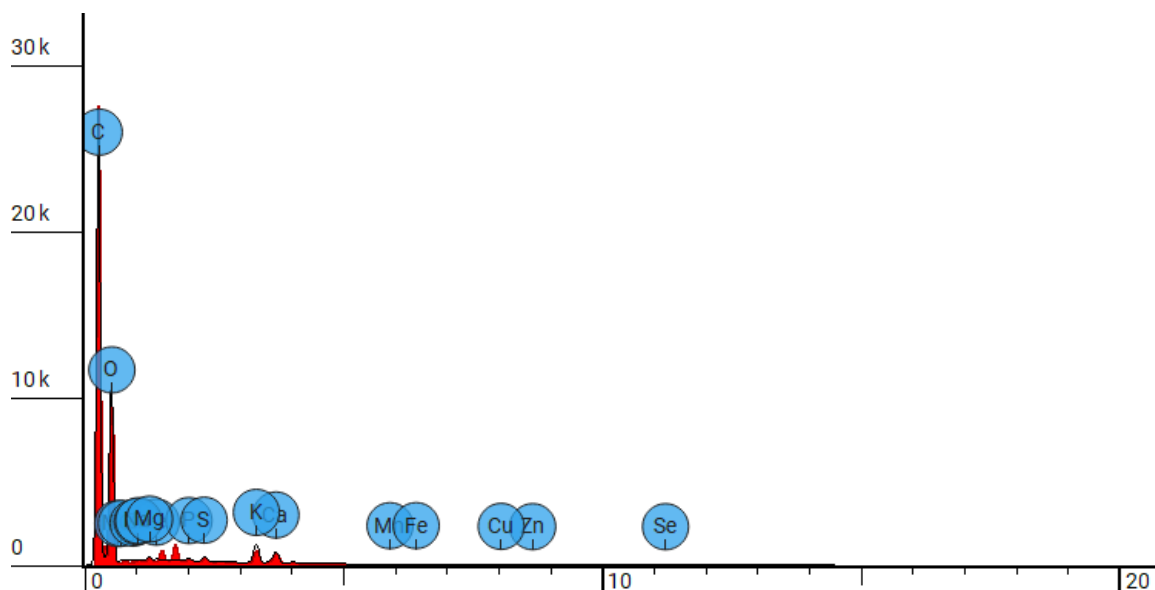


Figure 4.19: *Malva neglecta* graph of elements represented by peaks (3rd Run)

Table 4.23: Essential Element content of *Malva neglecta* (FP method)

S. No.	Element	Percentage	Stat. Err.	LLD	LLQ
1.	K	2.57	0.0219	0.092	0.276
2.	Ca	1.96	0.0147	0.272	0.816
3.	Si	1.58	0.0066	0.024	0.072
4.	S	0.646	0.0019	0.008	0.025
5.	Mg	0.531	0.0234	0.520	1.62
6.	P	0.416	0.0020	0.015	0.044
7.	Fe	0.219	0.0012	0.002	0.007
8.	Mn	0.0088	0.0003	0.004	0.012
9.	Zn	0.0073	<0.0001	<0.0001	0.0001
10.	Cu	0.0011	<0.0001	<0.0001	0.0002

Table 4.24: *Eremurus himalaicus* XRF elemental identification (1st run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	57.401	48.500
	8	O	Oxygen	40.333	45.400
	12	Mg	Magnesium	0.058	0.100
	15	P	Phosphorus	0.138	0.300
	19	K	Potassium	1.963	5.400
	20	Ca	Calcium	0.106	0.300

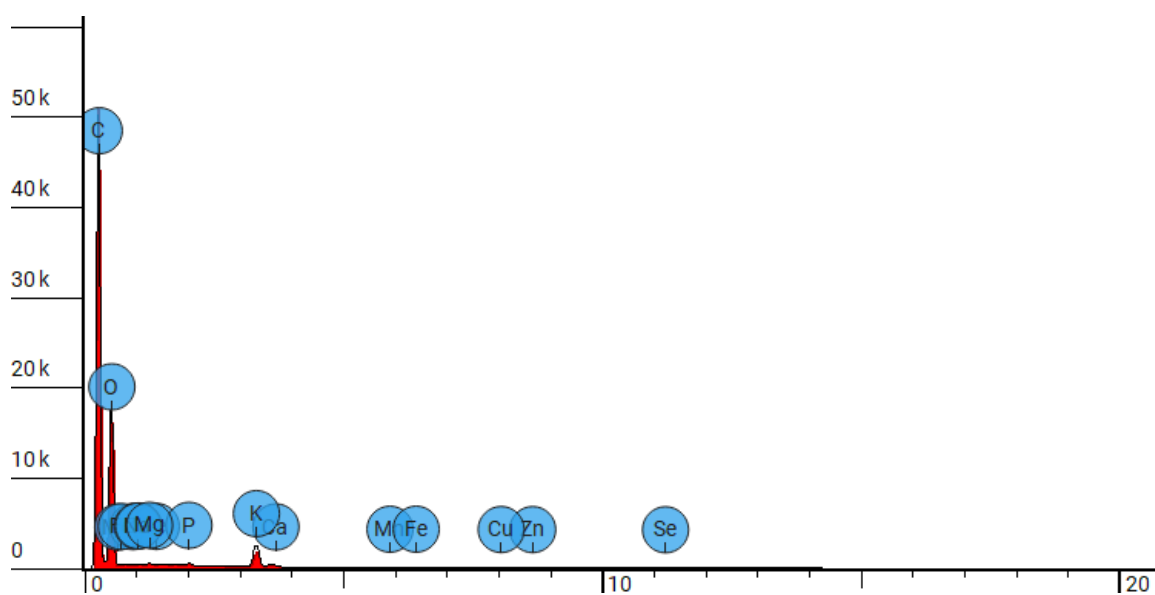


Figure 4.20 : *Eremurus himalaicus* graph of elements represented by peaks (1st Run)

Table 4.25: *Eremurus himalaicus* XRF elemental identification (2nd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	58.158	48.996
	8	O	Oxygen	39.182	43.976
	12	Mg	Magnesium	0.059	0.100
	14	Si	Silicon	0.255	0.502
	15	P	Phosphorus	0.092	0.201
	19	K	Potassium	2.050	5.622
	20	Ca	Calcium	0.179	0.502
	26	Fe	Iron	0.026	0.100

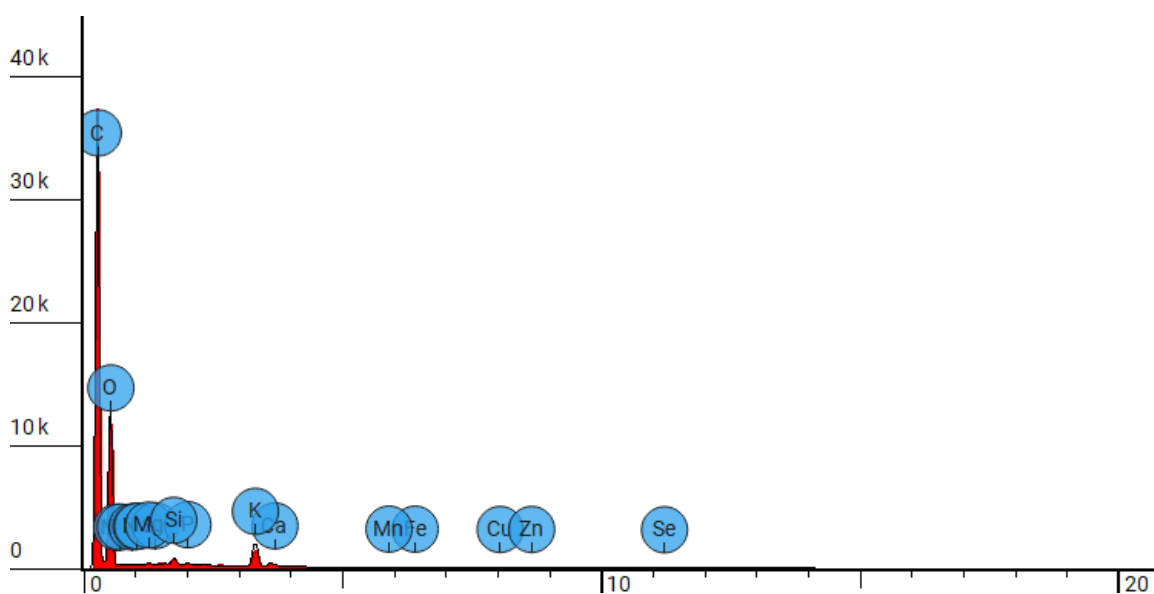


Figure 4.21: *Eremurus himalaicus* graph of elements represented by peaks (2nd Run)

Table 4.26: *Eremurus himalaicus* XRF elemental identification (3rd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	48.846	38.539
	8	O	Oxygen	45.903	48.248
	12	Mg	Magnesium	0.125	0.200
	15	P	Phosphorus	0.344	0.701
	19	K	Potassium	4.326	11.111
	20	Ca	Calcium	0.456	1.201

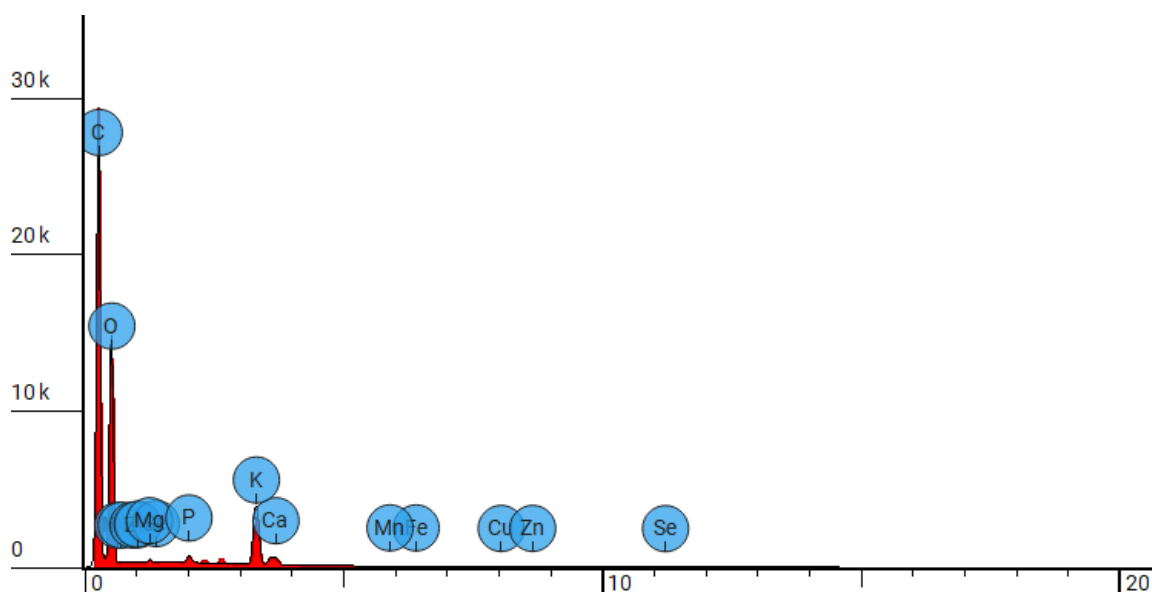


Figure 4.22: *Eremurus himalaicus* graph of elements represented by peaks (3rd Run)

Table 4.27: Essential Element content of *Eremurus himalaicus* (FP method)

S.No.	Element	Percentage	Stat. Err.	LLD	LLQ
1.	K	4.68	0.0281	0.055	0.166
2.	Ca	0.852	0.0103	0.126	0.379
3.	Mg	0.438	0.0246	0.397	1.79
4.	P	0.430	0.0020	0.011	0.032
5.	S	0.295	0.0013	0.009	0.026
6.	Si	0.161	0.0022	0.026	0.077
7.	Fe	0.0240	0.0004	0.002	0.005
8.	Mn	0.0032	0.0002	0.003	0.009
9.	Zn	0.0019	<0.0001	<0.0001	0.0001
10.	Cu	0.0010	<0.0001	<0.0001	0.0002

Table 4.28: *Diplazium esculentum* XRF elemental identification (1st run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	47.975	38.038
	8	O	Oxygen	47.194	49.850
	12	Mg	Magnesium	0.187	0.300
	15	P	Phosphorus	0.489	1.001
	19	K	Potassium	3.994	10.310
	20	Ca	Calcium	0.113	0.300
	26	Fe	Iron	0.027	0.100

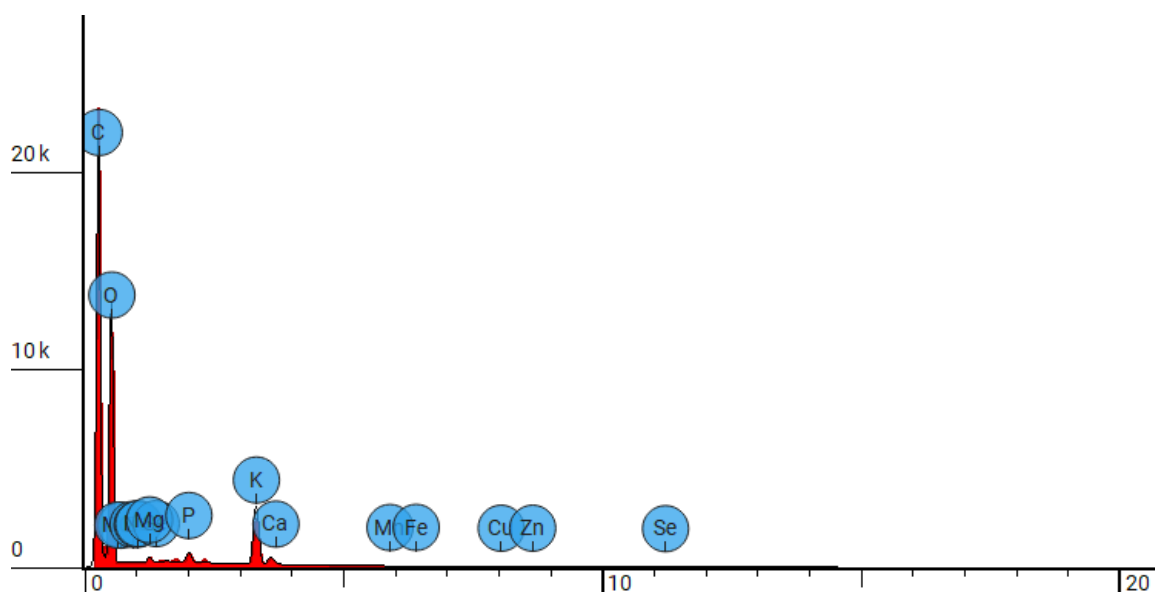


Figure 4.23: *Diplazium esculentum* graph of elements represented by peaks (1st Run)

Table 4.29: *Diplazium esculentum* XRF elemental identification (2nd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	48.360	38.338
	8	O	Oxygen	46.726	49.349
	12	Mg	Magnesium	0.187	0.300
	15	P	Phosphorus	0.538	1.101
	19	K	Potassium	3.956	10.210
	20	Ca	Calcium	0.151	0.400
	26	Fe	Iron	0.081	0.300

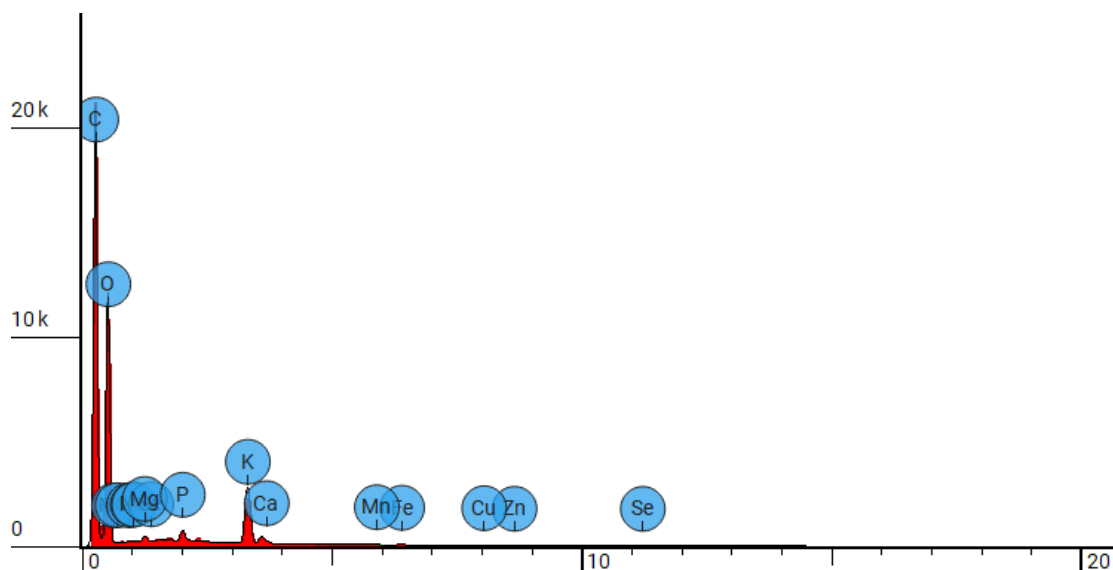


Figure 4.24: *Diplazium esculentum* graph of elements represented by peaks (2nd Run)

Table 4.30: *Diplazium esculentum* XRF elemental identification (3rd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	44.385	35.365
	7	N	Nitrogen	4.837	4.496
	8	O	Oxygen	46.492	49.351
	12	Mg	Magnesium	0.186	0.300
	15	P	Phosphorus	0.437	0.899
	19	K	Potassium	3.505	9.091
	20	Ca	Calcium	0.113	0.300
	26	Fe	Iron	0.027	0.100

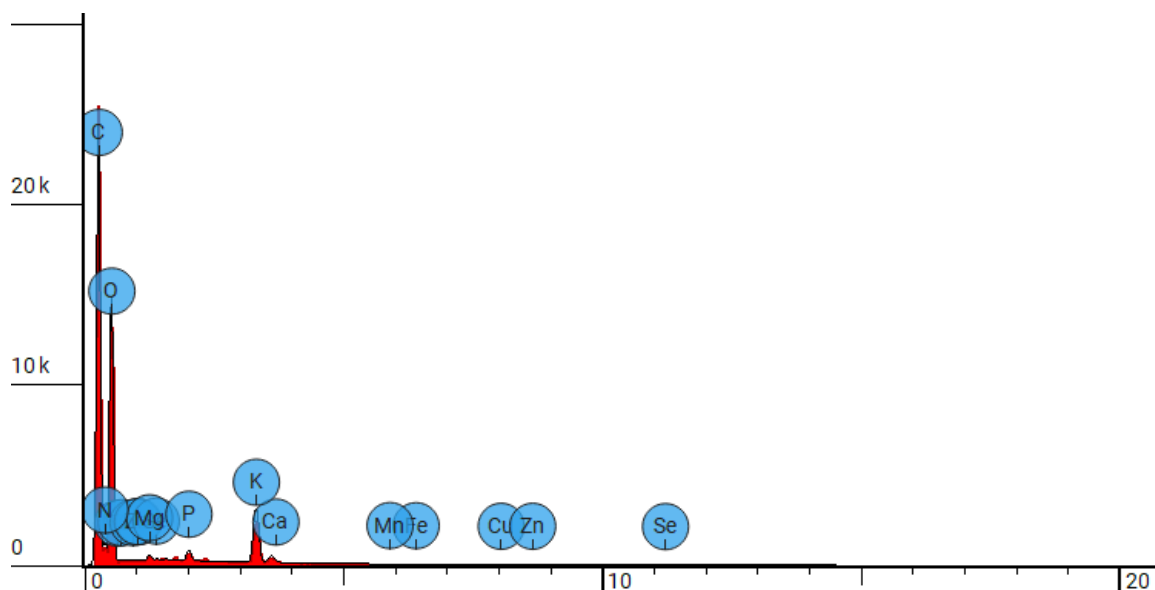


Figure 4.25: *Diplazium esculentum* graph of elements represented by peaks (3rd Run)

Table 4.31: Essential Element content of *D. esculentum* (FP method)

S.No.	Element	Percentage	Stat. Err.	LLD	LLQ
1.	K	5.29	0.0319	0.0103	0.0310
2.	P	0.720	0.0025	0.010	0.030
3.	Mg	0.565	0.0248	0.0574	0.172
4.	S	0.359	0.0014	0.016	0.0480
5.	Ca	0.268	0.0079	0.160	0.480
6.	Si	0.229	0.0026	0.025	0.074
7.	Fe	0.0193	<0.0001	<0.0001	0.0002
8.	Zn	0.0048	<0.0001	0.0001	0.0002
9.	Cu	0.0024	<0.0001	0.0001	0.0003
10.	Mn	0.0022	0.0002	0.0005	0.0016

Table 4.32: *Fagopyrum esculentum* XRF elemental identification (1st run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	47.061	37.613
	8	O	Oxygen	48.702	51.856
	12	Mg	Magnesium	0.682	1.103
	15	P	Phosphorus	0.292	0.602
	19	K	Potassium	2.583	6.720
	20	Ca	Calcium	0.489	1.304
	26	Fe	Iron	0.135	0.502

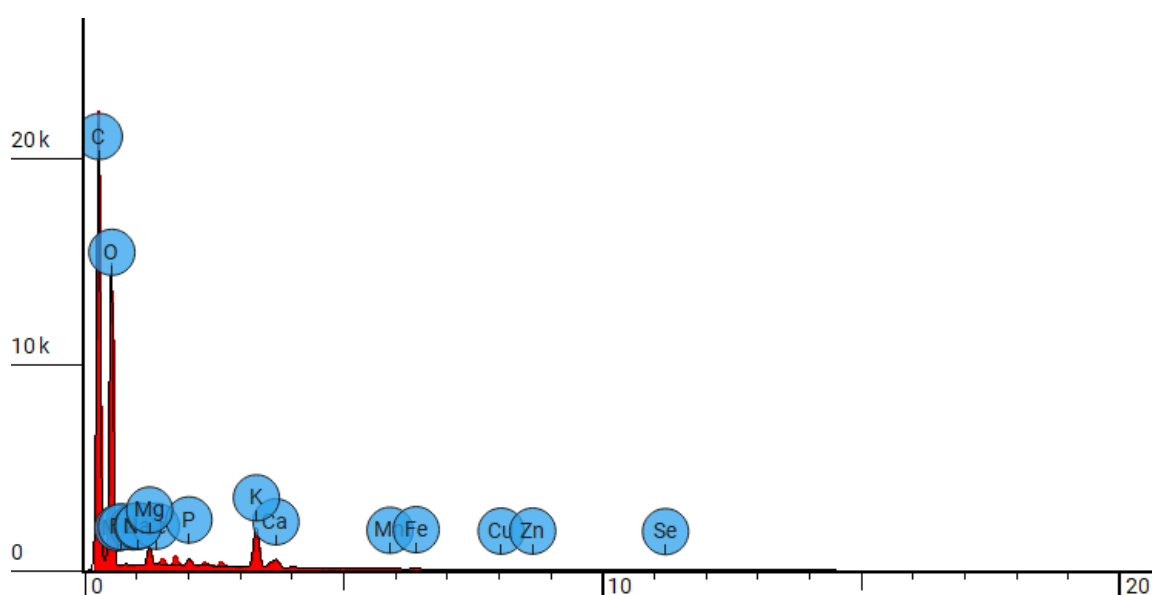


Figure 4.26: *Fagopyrum esculentum* graph of elements represented by peaks (1st Run)

Table 4.33: *Fagopyrum esculentum* XRF elemental identification (2nd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	51.572	42.281
	8	O	Oxygen	45.086	49.243
	12	Mg	Magnesium	0.486	0.807
	15	P	Phosphorus	0.239	0.505
	19	K	Potassium	2.079	5.550
	20	Ca	Calcium	0.406	1.110
	26	Fe	Iron	0.132	0.505

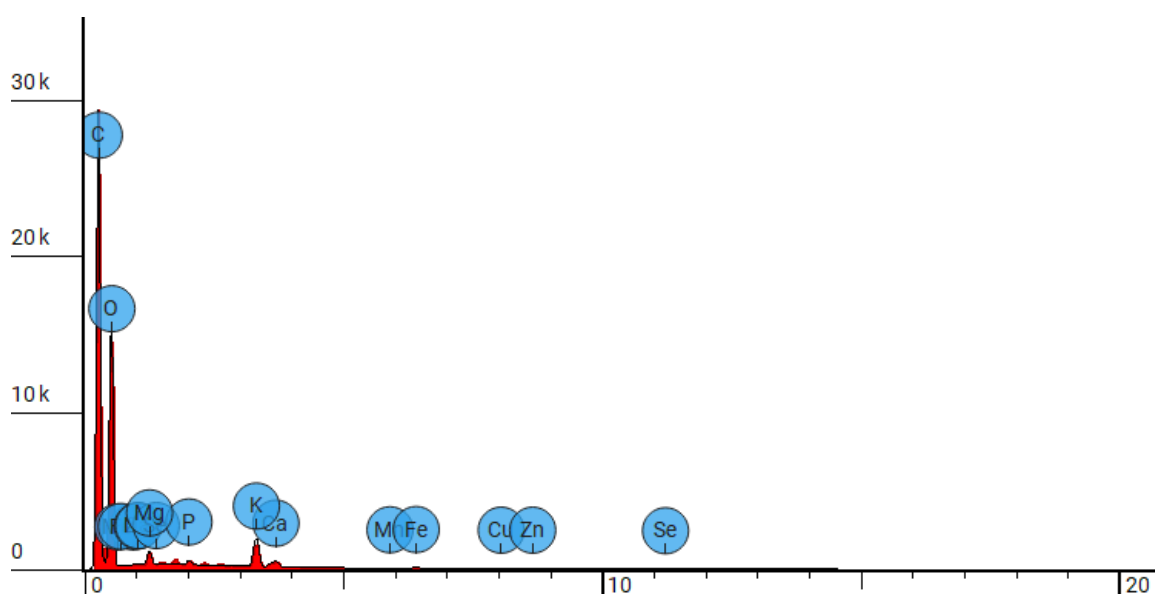


Figure 4.27: *Fagopyrum esculentum* graph of elements represented by peaks (2nd Run)

Table 4.34: *Fagopyrum esculentum* XRF elemental identification (3rd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	49.937	40.565
	8	O	Oxygen	46.342	50.151
	12	Mg	Magnesium	0.613	1.009
	15	P	Phosphorus	0.289	0.605
	19	K	Potassium	2.137	5.651
	20	Ca	Calcium	0.521	1.413
	26	Fe	Iron	0.160	0.605

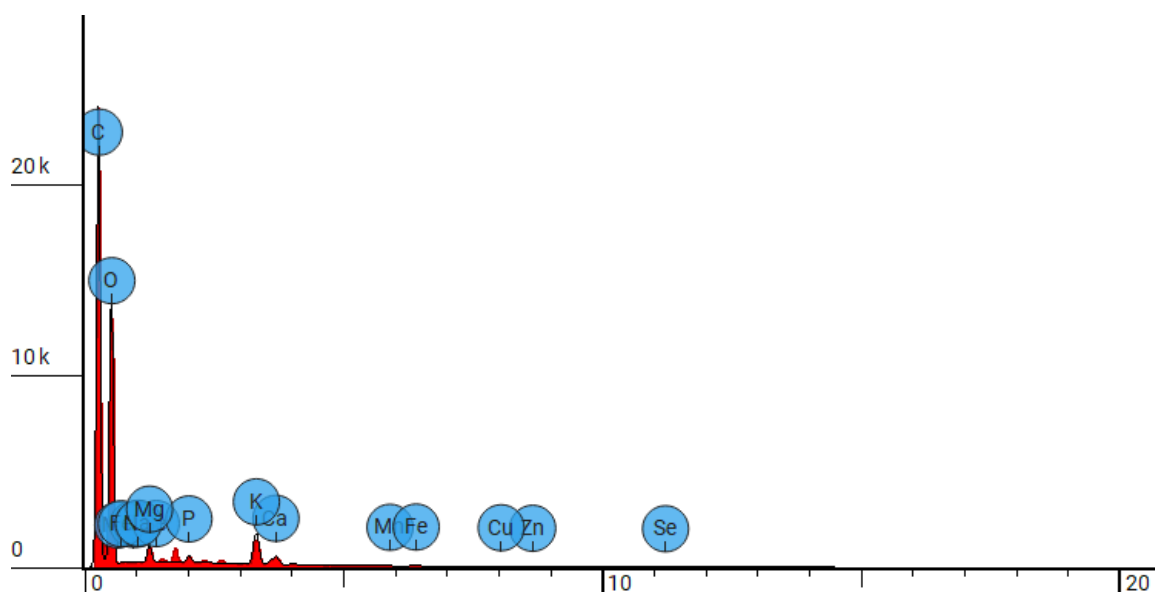


Figure 4.28: *Fagopyrum esculentum* graph of elements represented by peaks (3rd Run)

Table 4.35: Essential Element content of *Fagopyrum esculentum* (FP method)

S. No.	Element	Percentage	Stat. Err.	LLD	LLQ
1.	K	2.57	0.0217	0.0076	0.0229
2.	Ca	1.54	0.0130	0.093	0.278
3.	Mg	0.948	0.0261	0.936	1.61
4.	Si	0.592	0.0039	0.023	0.070
5.	P	0.402	0.0018	0.013	0.038
6.	S	0.288	0.0012	0.008	0.024
7.	Fe	0.0830	0.0007	0.002	0.007
8.	Mn	0.0067	0.0003	0.004	0.012
9.	Zn	0.0019	<0.0001	<0.0001	0.0001
10.	Cu	0.0011	<0.0001	<0.0001	0.0002

Table 4.36: *Cichorium intybus* XRF elemental identification (1st run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	49.995	39.439
	8	O	Oxygen	44.576	46.847
	11	Na	Sodium	0.199	0.300
	12	Mg	Magnesium	0.125	0.200
	15	P	Phosphorus	0.344	0.701
	19	K	Potassium	3.625	9.309
	20	Ca	Calcium	0.989	2.603
	26	Fe	Iron	0.109	0.400

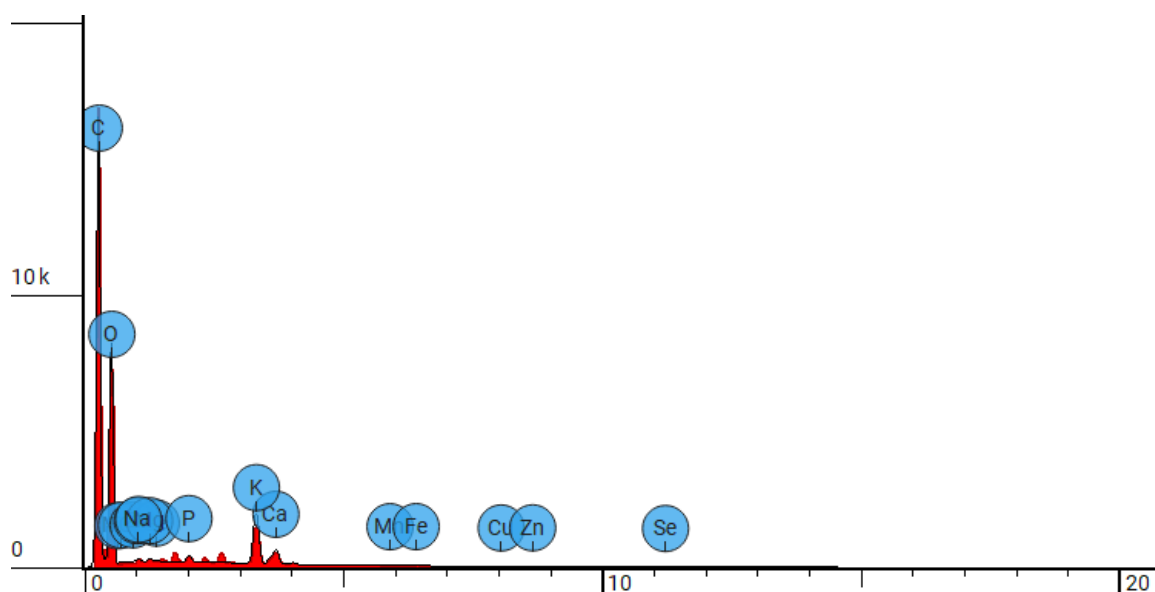


Figure 4.29: *Cichorium intybus* graph of elements represented by peaks (1st Run)

Table 4.37: *Cichorium intybus* XRF elemental identification (2nd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	56.838	47.437
	8	O	Oxygen	40.133	44.623
	11	Na	Sodium	0.126	0.201
	12	Mg	Magnesium	0.119	0.201
	15	P	Phosphorus	0.187	0.402
	19	K	Potassium	2.145	5.829
	20	Ca	Calcium	0.433	1.206

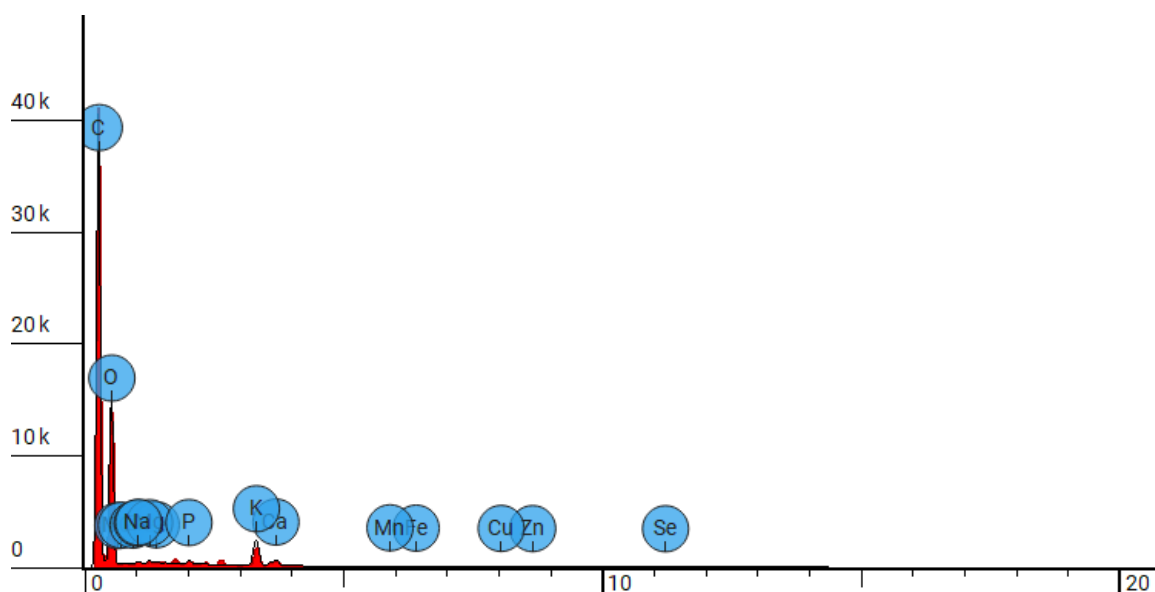


Figure 4.30: *Cichorium intybus* graph of elements represented by peaks (2nd Run)

Table 4.38: *Cichorium intybus* XRF elemental identification (3rd run)

	Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
	6	C	Carbon	49.819	39.740
	8	O	Oxygen	45.308	48.148
	11	Na	Sodium	0.262	0.400
	12	Mg	Magnesium	0.186	0.300
	15	P	Phosphorus	0.341	0.701
	19	K	Potassium	3.353	8.709
	20	Ca	Calcium	0.677	1.802
	26	Fe	Iron	0.054	0.200

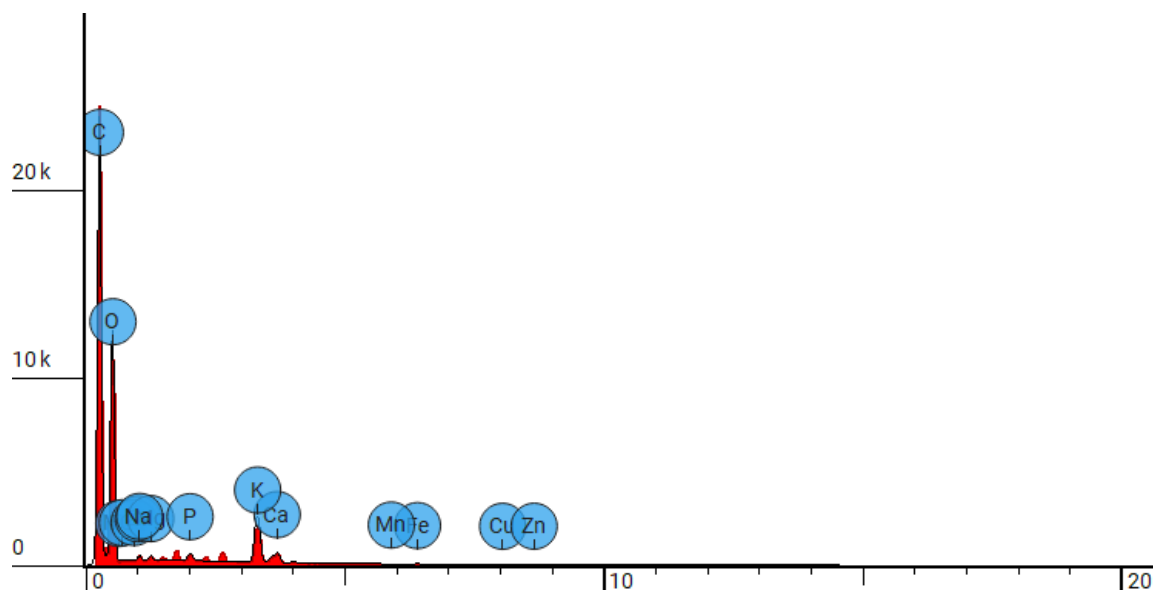


Figure 4.31: *Cichorium intybus* graph of elements represented by peaks (3rd Run)

Table 4.39: Essential element content of *Cichorium intybus* (FP method)

S. No.	Element	Percentage	Stat. Err.	LLD	LLQ
1.	K	4.89	0.0303	0.0078	0.0235
2.	Ca	1.58	0.0145	0.0141	0.0422
3.	S	0.653	0.0021	0.0010	0.0029
4.	P	0.593	0.0026	0.0012	0.0037
5.	Mg	0.536	0.0273	0.0639	0.192
6.	Si	0.332	0.0035	0.0030	0.0091
7.	Fe	0.0447	0.0006	0.0003	0.0008
8.	Mn	0.0052	0.0003	0.0004	0.0013
9.	Zn	0.0028	0.0001	0.0001	0.0002
10.	Cu	0.0015	0.0001	0.0001	0.0003

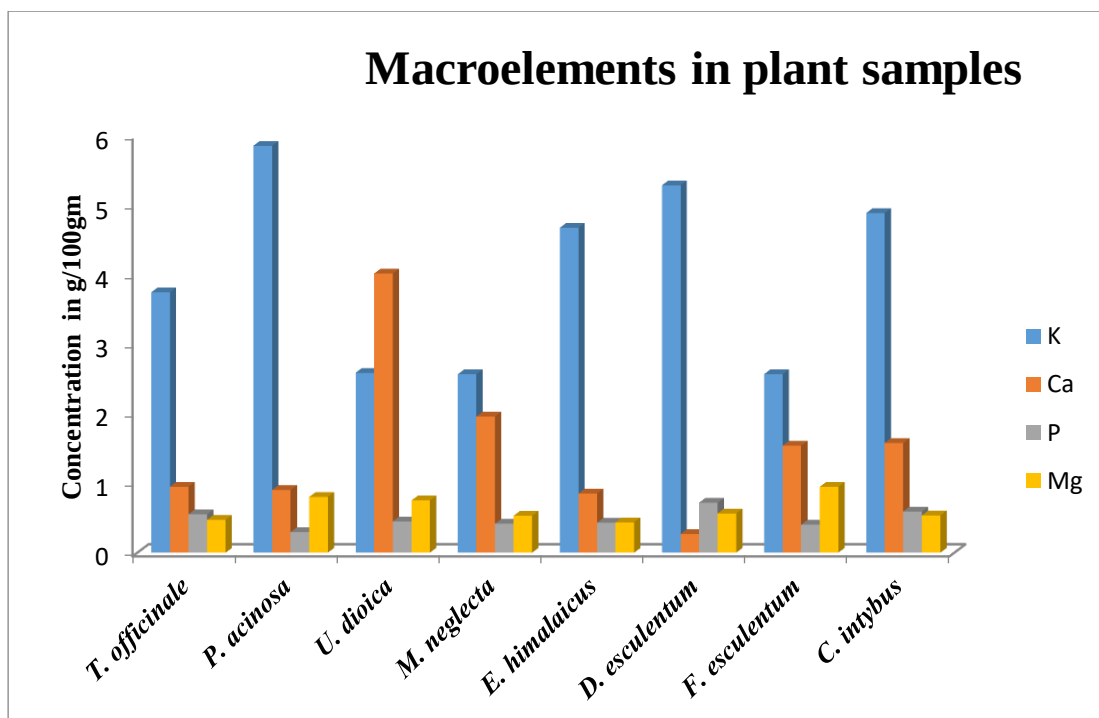


Figure 4.32: Concentration of some important macroelements in the analysed plant samples.

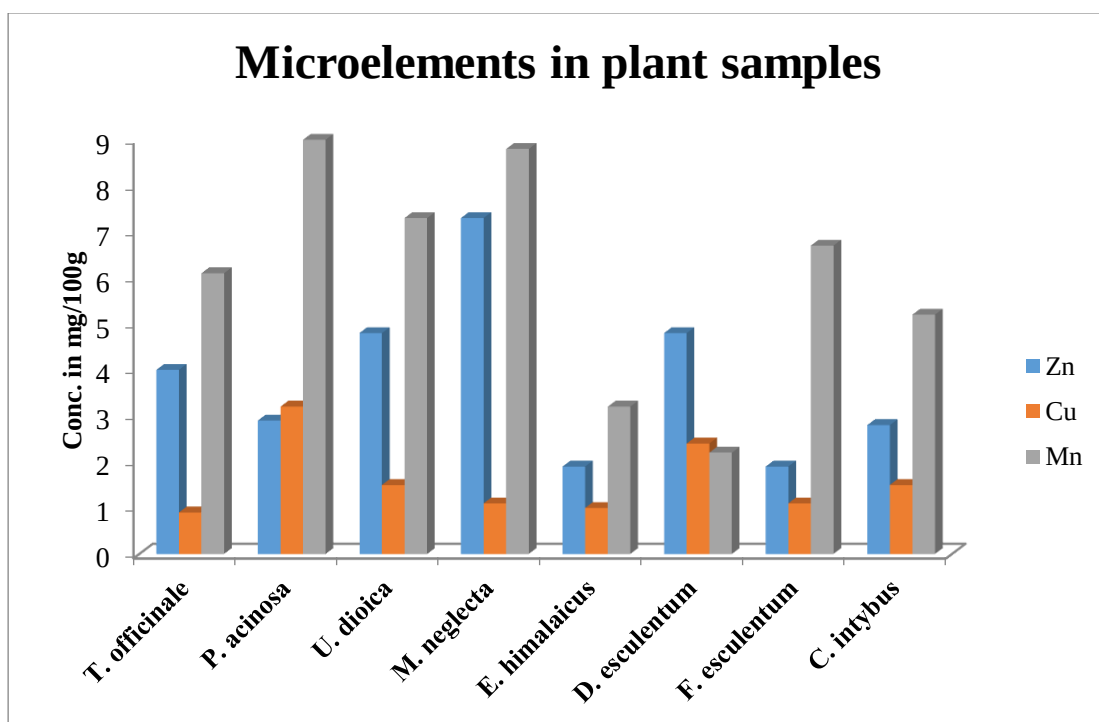


Figure 4.33: Concentration of some important micro-elements in the analysed plant samples.

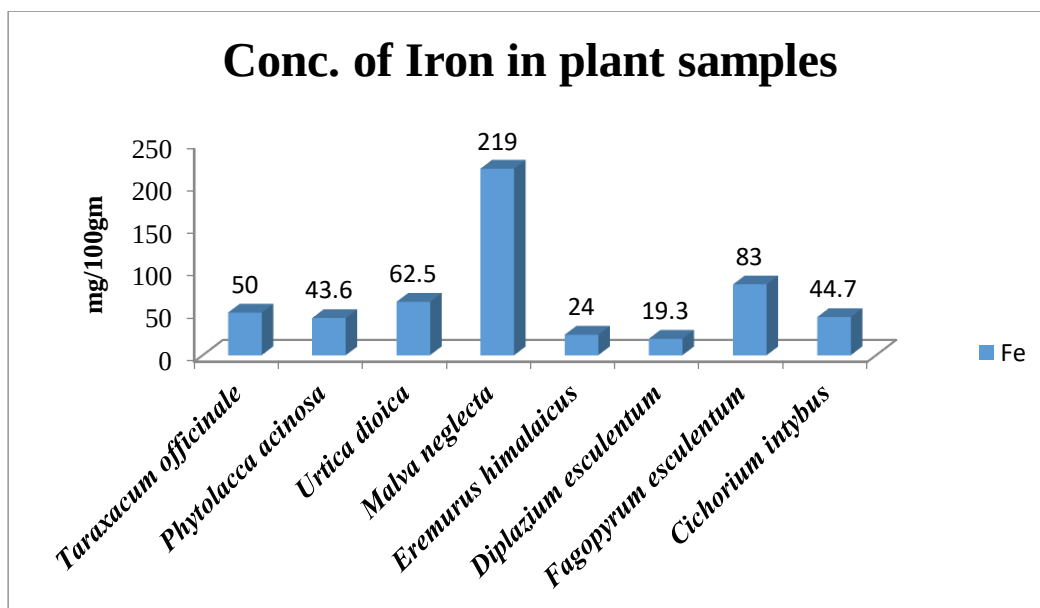


Figure 4.34: Concentration of iron in the analysed plant samples.

4.3.9 Statistical Analysis:

Pearson correlation between various elements present in the plant samples is shown in figure. 4.35. The size of the circles is proportional to the absolute value of correlation coefficients, while their colour signifies the value in positive or negative correlation region as represented in the right bar of varying colour intensities from intense blue to intense red, ranging from +1 to -1, correspondingly.

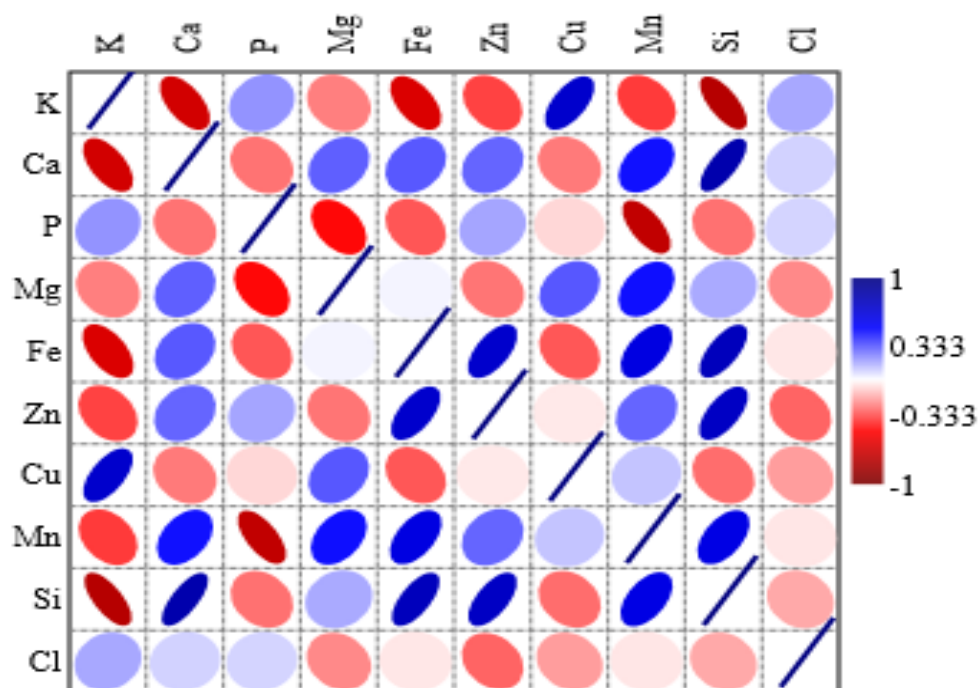


Figure 4.35: Pearson correlation between various mineral elements present in the plant samples.

4.4 Oxalate Content

Highest oxalate content among the evaluated plant samples was found to be present in *T. officinale* (15.75 mg/g), *F. esculentum* (15.75 mg/g) and *P. acinosa* (15.07 mg/g). The concentration of oxalate in all the samples is given in table 4.40. *D. esculentum* sample was found to have lowest oxalate content (4.27 mg/g).

Table 4.40: Concentration of oxalate in the evaluated plant samples

S. No.	Samples	Vol. of KMnO ₄ used in titration(mL)	Concentration of Oxalate (mg/g) $\pm$ SD
1	<i>Taraxacum officinale</i>	7	15.75 $\pm$ 0.45 ^a
2	<i>Phytolacca acinosa</i>	6.7	15.07 $\pm$ 0.23 ^a
3	<i>Urtica dioica</i>	2.9	6.52 $\pm$ 0.39 ^c
4	<i>Malva neglecta</i>	3.1	6.97 $\pm$ 0.23 ^c
5	<i>Eremurus himalaicus</i>	4.5	10.12 $\pm$ 0.45 ^b
6	<i>Diplazium esculentum</i>	1.9	4.27 $\pm$ 0.23 ^d
7	<i>Fagopyrum esculentum</i>	7	15.75 $\pm$ 0.45 ^a
8	<i>Cichorium intybus</i>	3	6.75 $\pm$ 0.23 ^c

Results are expressed as the mean $\pm$ SD (n=3). Values in the same column with different superscripts are significantly different (p<0.05).

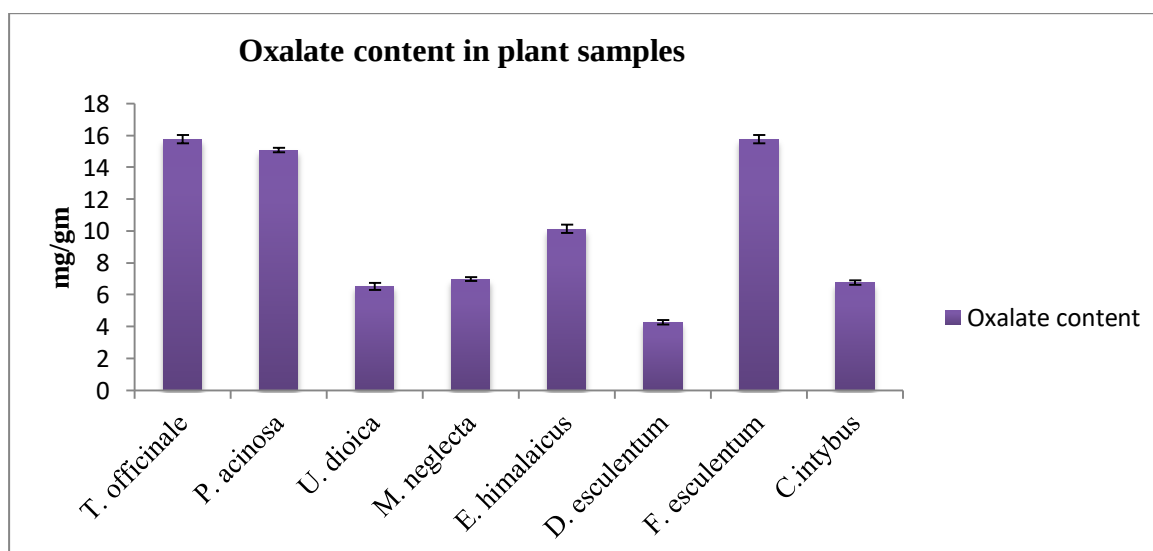


Figure 4.36: Concentration of oxalate in the evaluated plant samples

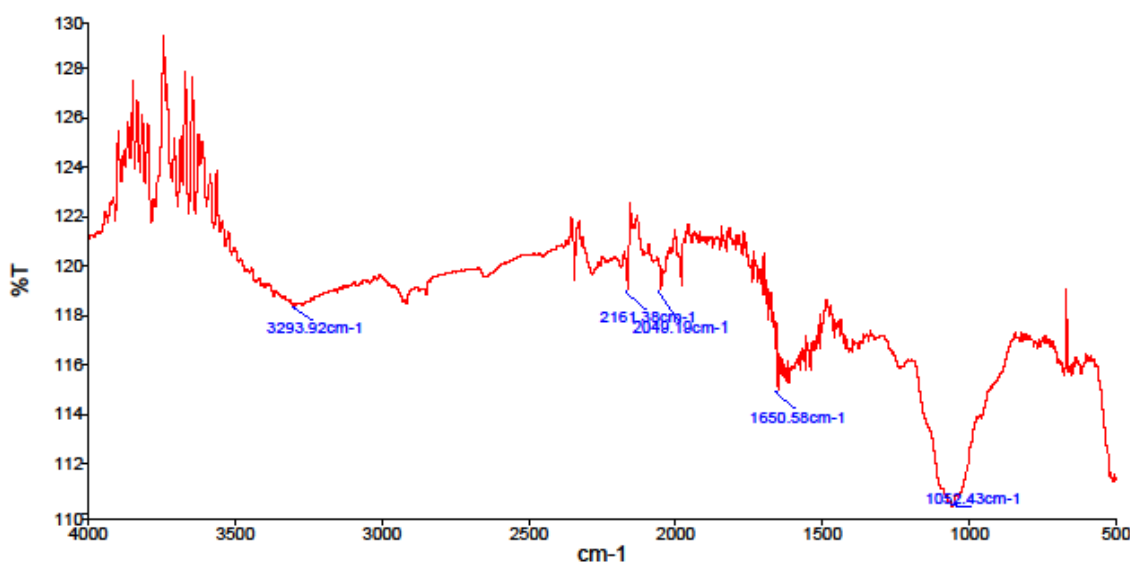
4.5 Phytochemistry

FTIR spectroscopy was employed to characterize the chemical constituents present in the plant samples. Tannin and flavonoid contents were evaluated which act as dietary anti-oxidants. Anti-oxidant activity of the plant samples was also determined. The results are discussed below.

4.5.1 FTIR Analysis

4.5.1.1 *Taraxacum officinale*

The intense and broad peaks in the $3700\text{--}3200\text{ cm}^{-1}$ region confirm the abundance of hydroxyl (-OH) group containing phytochemicals, primarily flavonoids, inulin, and polyphenols. The sample showed pronounced C=O and C=C stretching peaks ($1737\text{--}1650\text{ cm}^{-1}$), indicating significant levels of phenolic acids and sesquiterpene lactones, key players in the anti-inflammatory and hepato-protective properties. The moderate C-H stretches at 2917 cm^{-1} suggest the presence of terpenoids or fatty acids. The peak at 1052 cm^{-1} is a strong marker of carbohydrates, consistent with inulin, a key prebiotic fibre in dandelion. The low-wavenumber peaks confirm aromatic ring structures, typical of phenolic compounds.



(a)

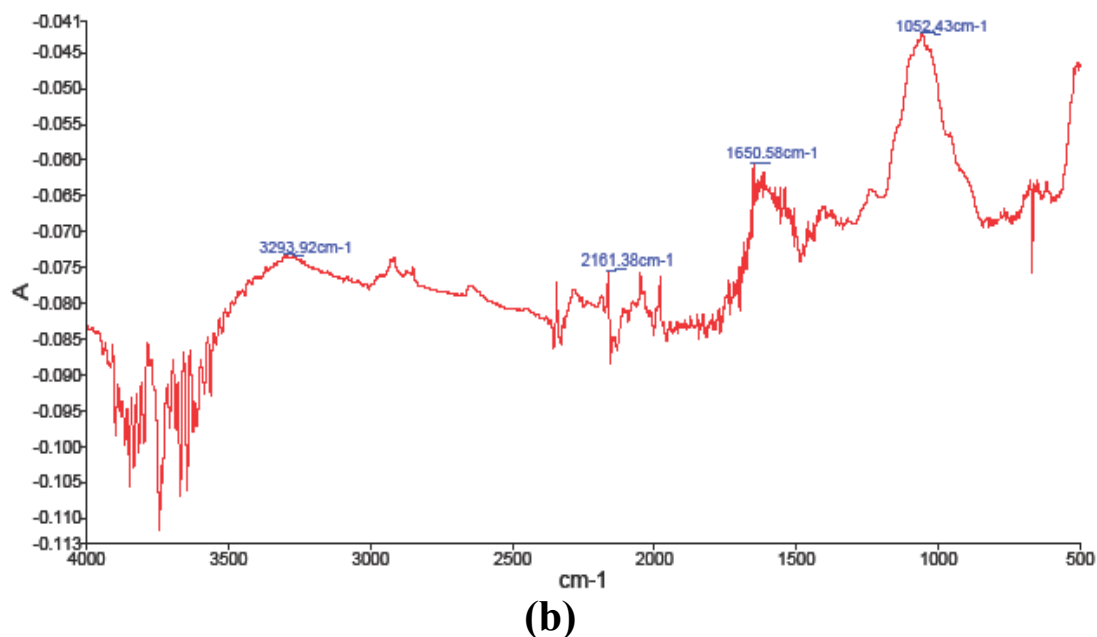
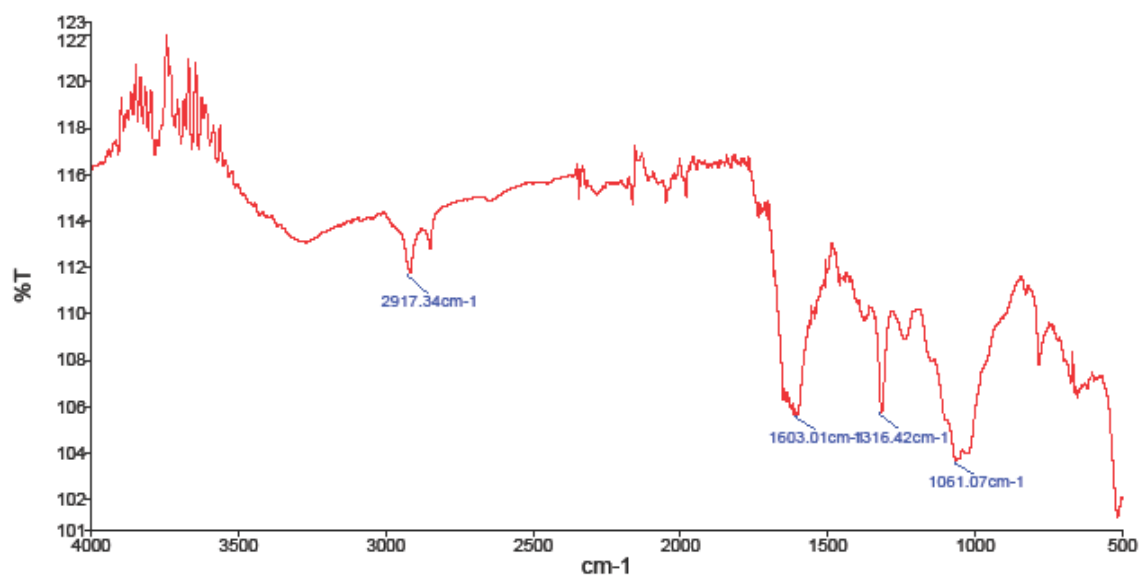


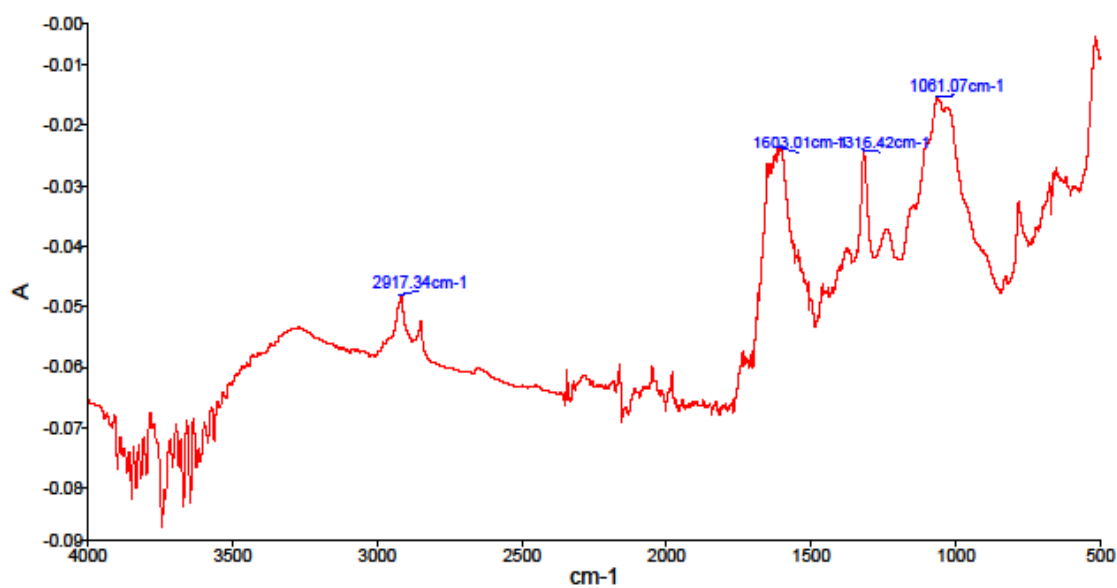
Figure 4.37: Graph showing (a) Transmittance, T and (b) Absorbance, A of *T. officinale* sample

4.5.1.2 *Phytolacca acinosa*

Strong O–H stretching region ($3890\text{--}3574\text{ cm}^{-1}$) suggests a high presence of phenolic compounds, flavonoids, and sugar-rich molecules like saponins. The C–H stretch at 2917 cm^{-1} is distinct, indicating a moderate concentration of aliphatic chains, typically found in triterpenoids or lipids. The C=C/C=O region around 1603 cm^{-1} shows moderate intensity, indicative of aromatic phenolics and possibly lignans. Peaks at 1316 and 1239 cm^{-1} support the presence of alkaloids and glycosidic linkages, both key to the plant's medicinal activity. The low-wavenumber signals ($\sim 650\text{--}780\text{ cm}^{-1}$) correspond to aromatic substitutions, further affirming the polyphenolic profile.



(a)



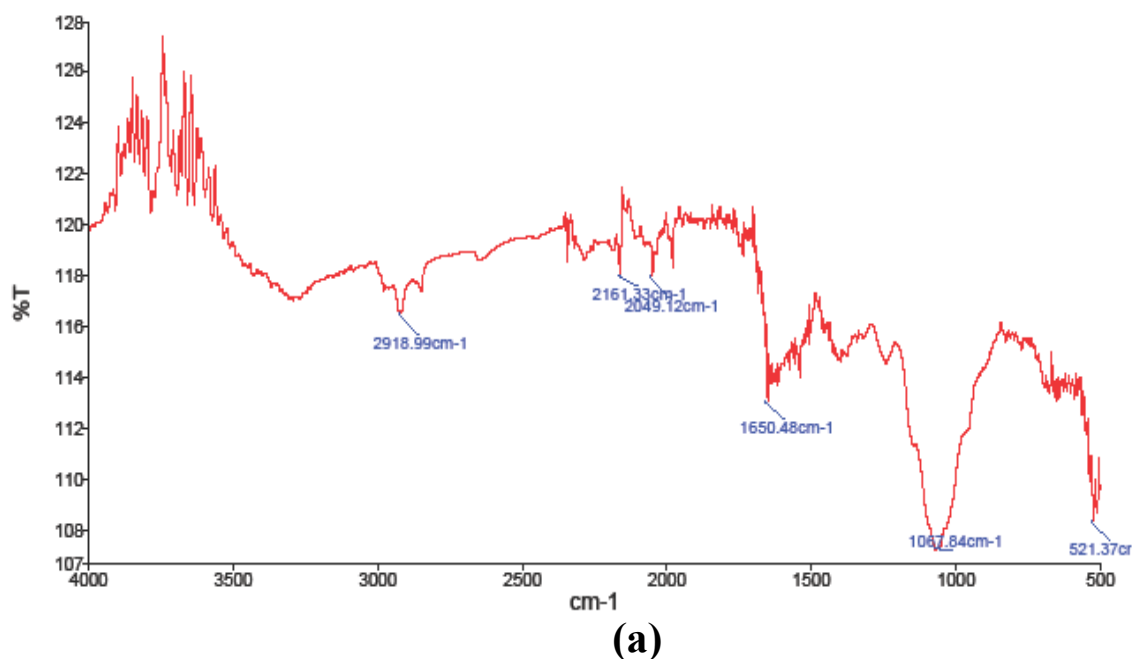
(b)

Figure 4.38: Graph showing (a) Transmittance, T and (b) Absorbance, A of *P. acinosa* sample

4.5.1.3 *Urtica dioica*

The relative Functional Group Abundance (Semi-Quantitative) in *Urtica dioica* leaf sample showed presence of approximately 30% Hydroxyl (-OH) / N-H ($3890\text{--}3574\text{ cm}^{-1}$) and 25% glycosidic /carbohydrate C-O bonds. Both carbonyl (C=O) region and aromatic rings (C=C, CH bending) were found to be 15% each. In addition aliphatic / methyl groups (10%) and minor skeletal vibrations ($<5\%$) were observed.

Strong O-H/N-H and carbohydrate C-O signals indicate a hydrophilic matrix dominated by polysaccharides/oligosaccharides (e.g., starches, pectins, glycosides) and abundant hydrogen-bonded hydroxyls typical of sugars and phenolic OH groups. The C=O band ($1737\text{--}1698\text{ cm}^{-1}$) is consistent with esters/carboxyls (pectic acids or phenolic esters). Aromatic features point to phenolics/flavonoids/tannins. Modest aliphatic bands imply a low lipid content. Overall the sample showed primarily carbohydrates and phenolic secondary metabolites with minor lipophilic material.



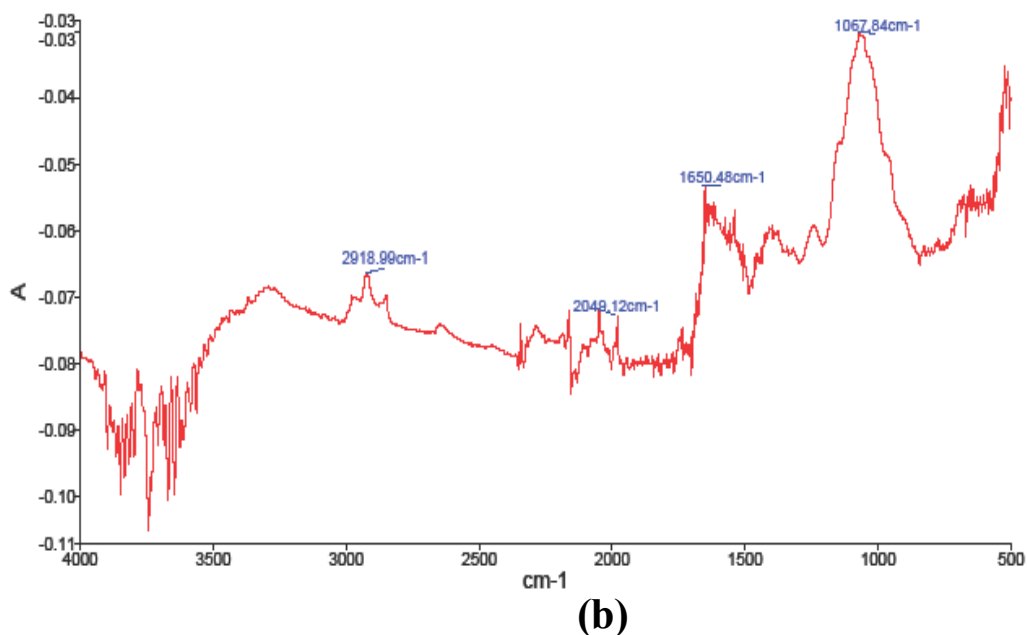


Figure 4.39: Graph showing (a) Transmittance, T and (b) Absorbance, A of *U. dioica* sample

4.5.1.4 *Malva neglecta*

Among the observed functional group, O–H / N–H ($3700\text{--}3200\text{ cm}^{-1}$) were found to be high around 30-35% followed by 25% glycosidic bands ($1239\text{--}1066\text{ cm}^{-1}$). Very strong O–H/N–H and glycosidic bands indicate high polysaccharide or glycoside content. The prominent 1638 cm^{-1} band suggests conjugated C=O and/or C=C consistent with conjugated phenolics or flavonoids. Signals in the $1543\text{--}1398\text{ cm}^{-1}$ range support presence of amides, proteinaceous material or carboxylates (proteins, pectins). Moderate C–H indicates some aliphatic components (lipids/waxes). The sample overall showed mucilaginous polysaccharides plus phenolics and protein/pectin content.

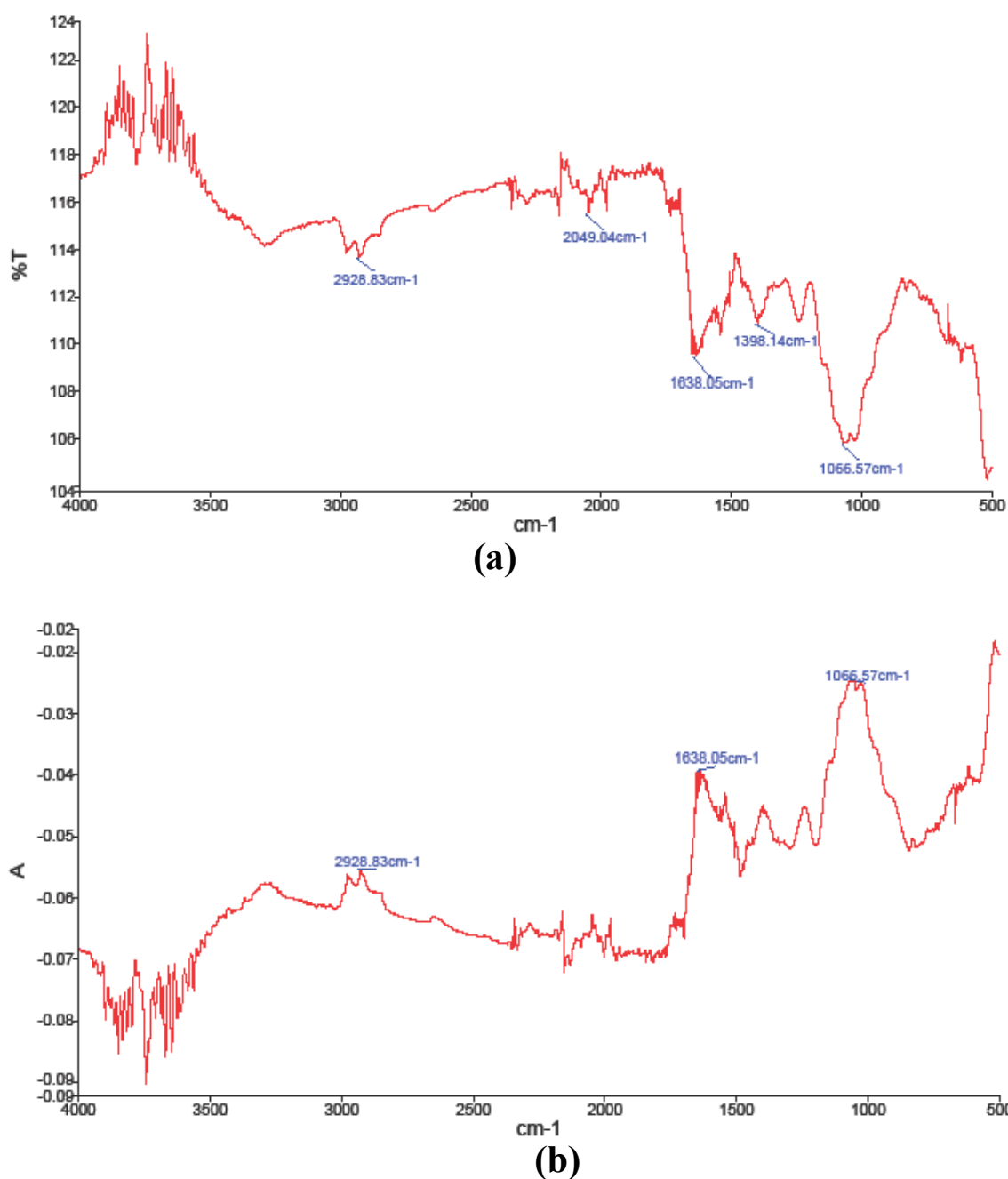
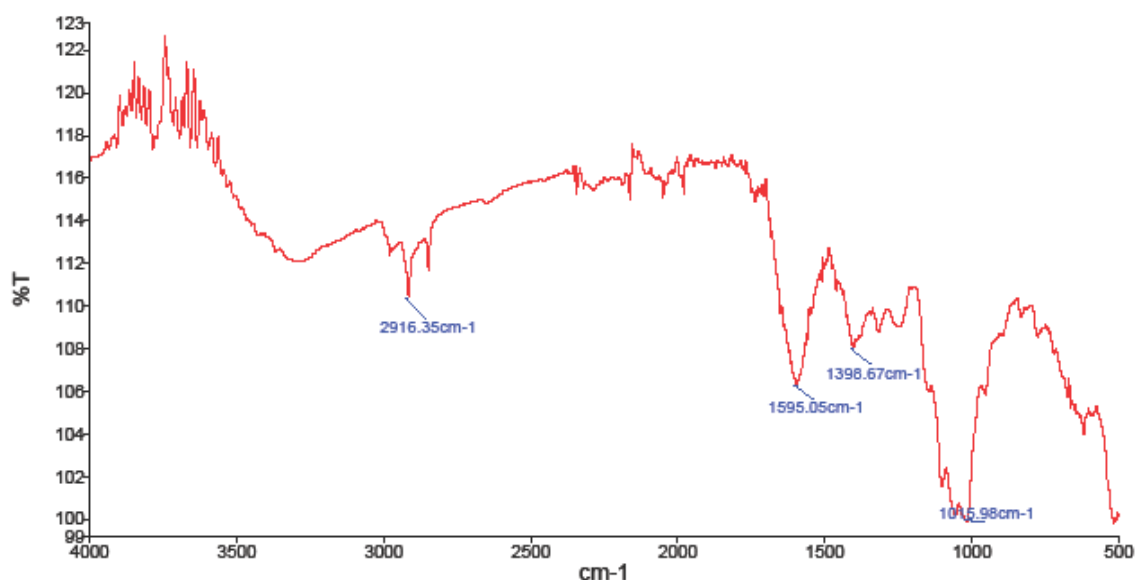


Figure 4.40: Graph showing (a) Transmittance, T and (b) Absorbance, A of *M. neglecta* sample

4.5.1.5 *Eremurus himalaicus*

In this plant sample dominant hydroxyl/amino (approximately 30%) and C–O/C–N bands (around 25%) point to a mix of polysaccharides and nitrogen-containing compounds (e.g., amino acids, small peptides, glycoproteins). Aromatic C=C

indicates phenolic or flavonoid content. The stronger aliphatic contribution relative to other samples suggests a slightly higher lipid or aliphatic secondary-metabolite fraction. Trace triple-bond signals could indicate low-abundance specialized metabolites (alkynes or nitriles), but these require confirmatory analysis (GC–MS/LC–MS). The sample shows carbohydrate-rich material with proteinaceous and aromatic secondary-metabolite content and small amounts of unusual conjugated species.



(a)

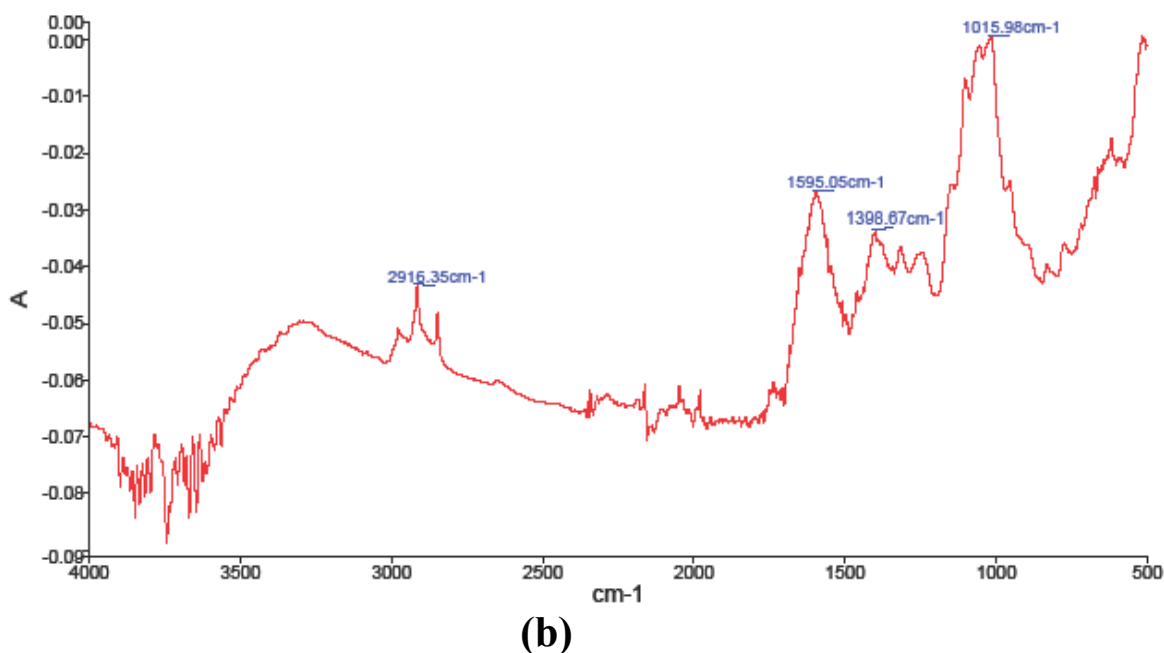


Figure 4.41: Graph showing (a) Transmittance, T and (b) Absorbance, A of *E. himalaicus* sample

4.5.1.6 *Diplazium esculentum*

This plant sample was characterized by dominant polysaccharides and a notable phenolic fraction. The profile closely resembles *Urtica* showing abundant hydrogen-bonded OH/NH (30%) and high carbohydrate/glycoside content possibly sugars, inulin-like/fructan or pectin components (25%). Carbonyl band intensity (15%) suggests esters, carboxylic acids, or conjugated carbonyls (pectins, phenolic esters). Aromatic signals (15%) indicate phenolic compounds/flavonoids. Aliphatic bands (10%) suggest low but present lipid content.

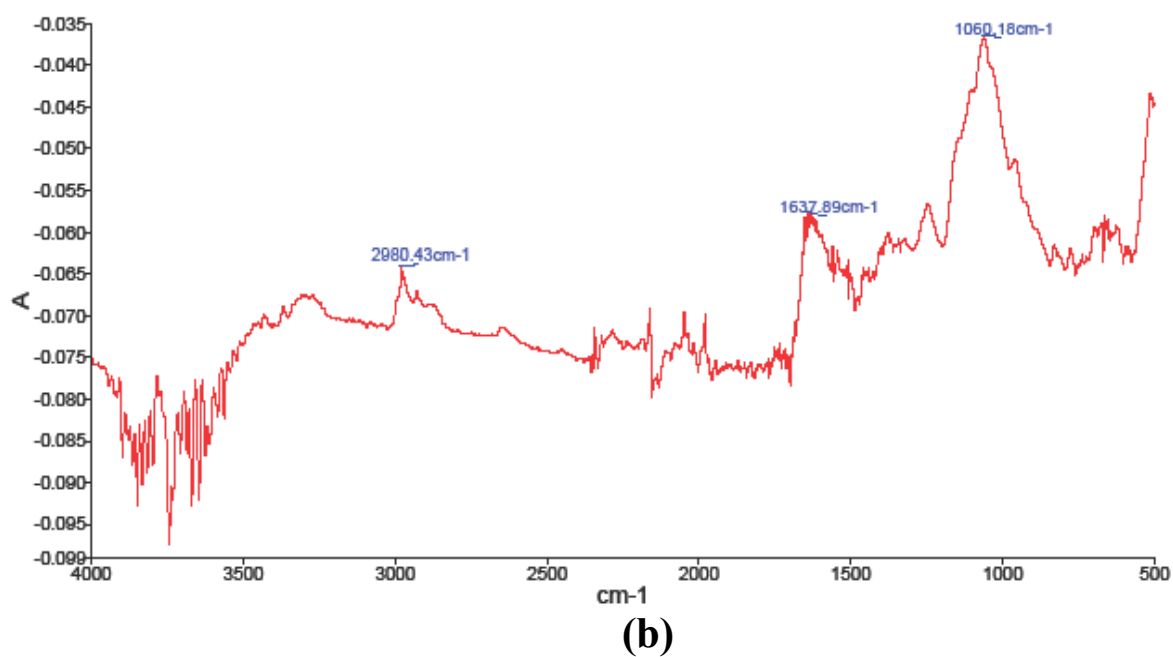
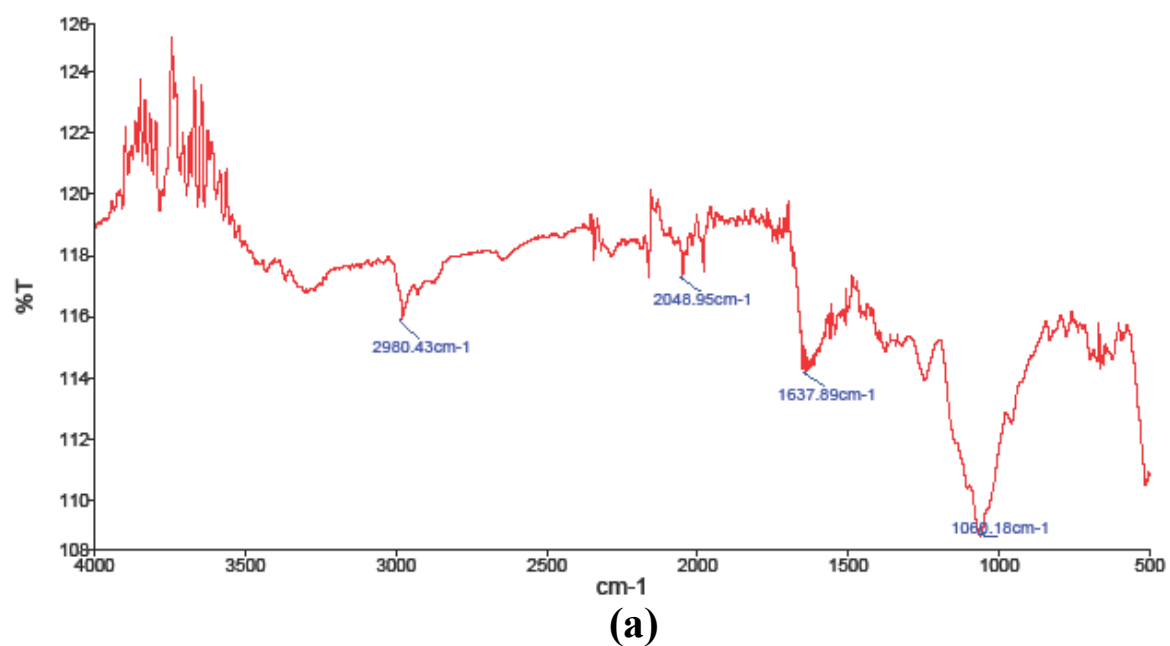
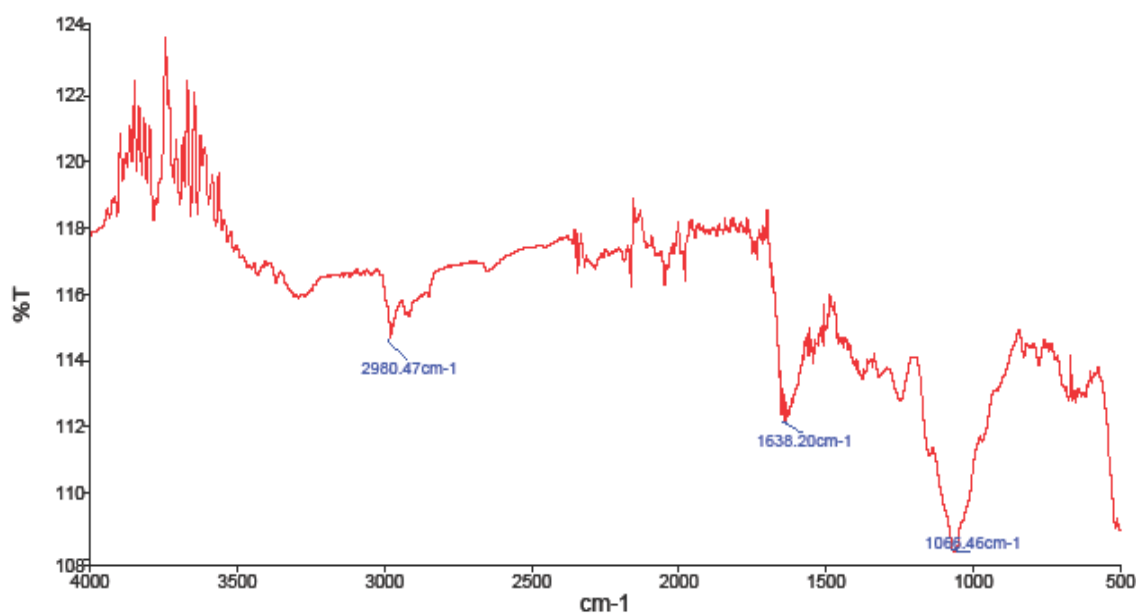


Figure 4.42: Graph showing (a) Transmittance, T and (b) Absorbance, A of *D. esculentum* sample

4.5.1.7 *Fagopyrum esculentum*

The relative functional group abundance showed presence of around 30% hydroxyl and N–H groups, 25% glycosidic / carbohydrate C–O groups, 15% carbonyl (C=O) groups and aromatic rings. The sample shows strong polysaccharide signature (starch/oligosaccharides) and clear aromatic bands matching phenolic/flavonoid compounds. Carbonyl bands support presence of phenolic esters, organic acids or carbohydrate-bound carbonyls. Modest aliphatic groups indicate limited lipid content. In general, the sample showed carbohydrate-dominant matrix with significant flavonoid/phenolic presence.



(a)

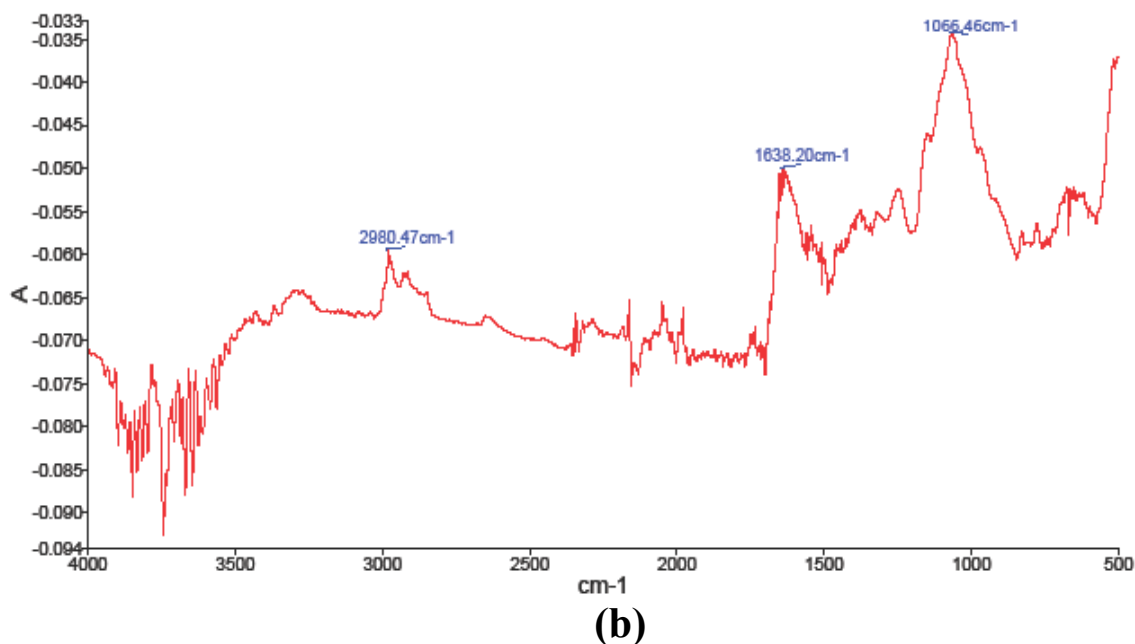


Figure 4.43: Graph showing (a) Transmittance, T and (b) Absorbance, A of *F. esculentum* sample

4.5.1.8 *Cichorium intybus*

The relative functional group abundance of the sample showed around 30–35% OH / N–H (3293 cm^{-1}) groups, 25% carbohydrate-related C–O bonds ($1247, 1016\text{ cm}^{-1}$), 15% carbonyl bonds (1732 cm^{-1}), 15% aromatic rings ($1609, 825, 616\text{ cm}^{-1}$) and 10% aliphatic groups ($2980, 1379\text{ cm}^{-1}$). The sample overall exhibited presence of inulin-type carbohydrates and phenolic acids/esters. Well-defined O–H and carbohydrate bands align with inulin/fructan-rich profile typical of the $1016\text{--}1247\text{ cm}^{-1}$ glycosidic bands strongly support fructan/polysaccharide abundance. The 1732 cm^{-1} carbonyl peak suggests esterified carboxyls or phenolic esters. Distinct aromatic ring bands indicate polyphenols such as chlorogenic acid or other caffeic acid derivatives. Moderate aliphatic signals show low lipid content.

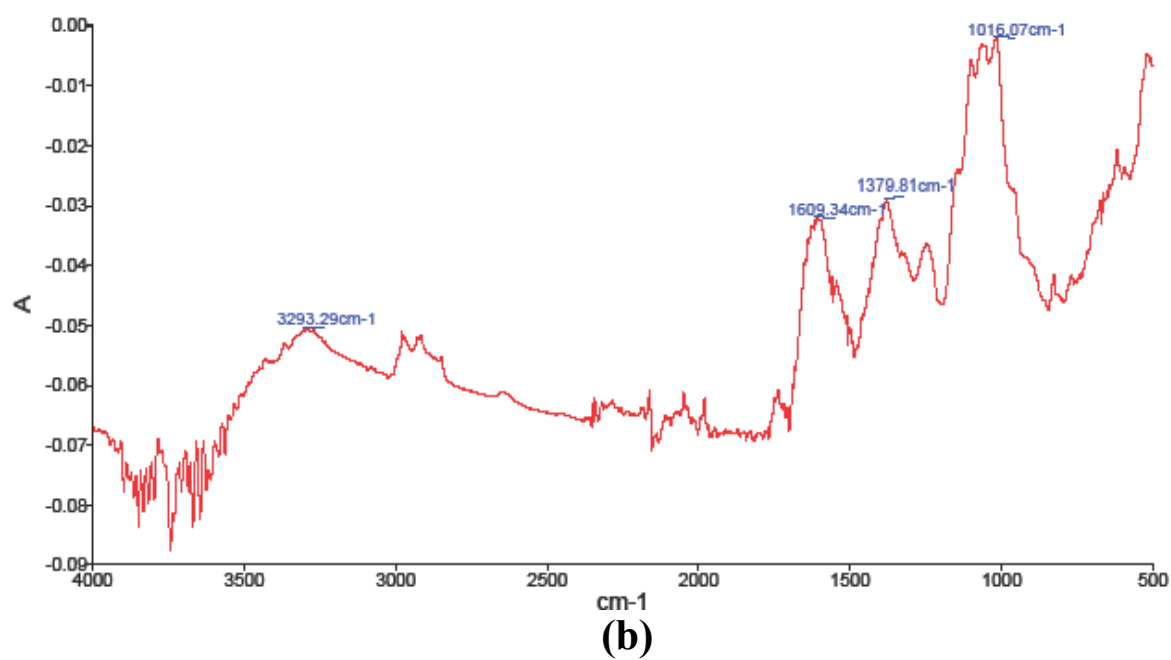
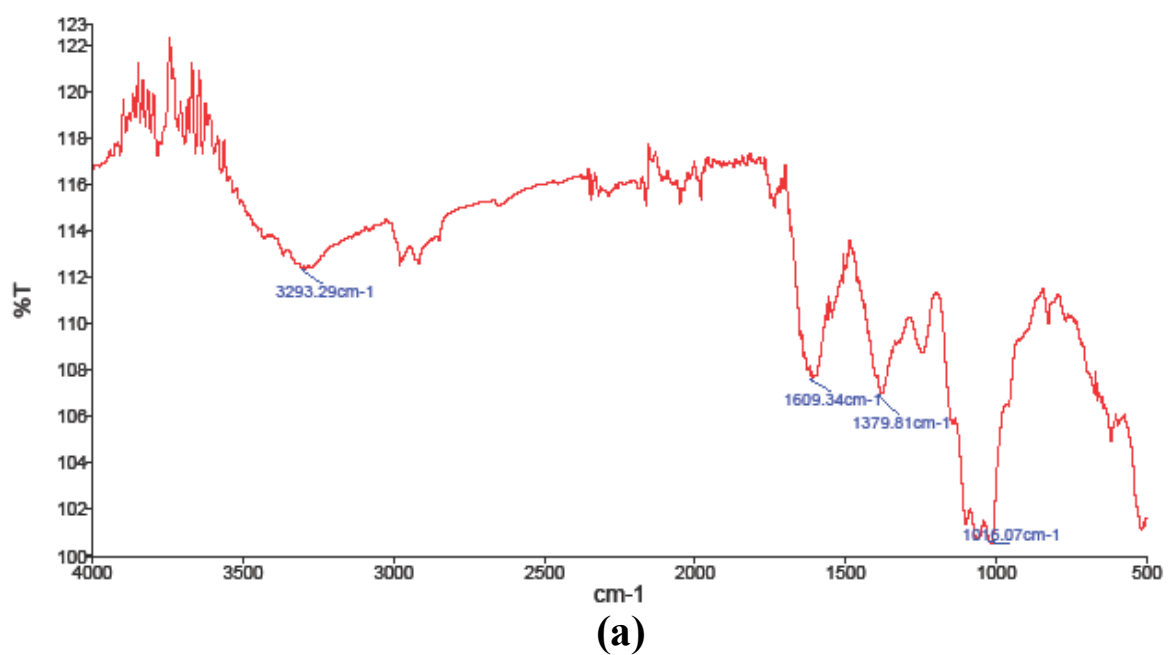


Figure 4.44: Graph showing (a) Transmittance, T and (b) Absorbance, A of *C. intybus* sample

4.5.2. Tannin content

The tannin content was calculated from the calibration curve shown in figure 4.45 and was expressed as gallic acid equivalent (GAE) in mg/g (Table 4.41). The highest tannin content was observed in *F. esculentum* (65.9 GAE mg/g) and lowest was found in *M. neglecta* (20.04 GAE mg/g). *T. officinale*, *D. esculentum* and *C. intybus* showed comparable tannin content i.e. 63.17 GAE mg/g, 63.0 GAE mg/g and 62.52 GAE mg/g respectively.

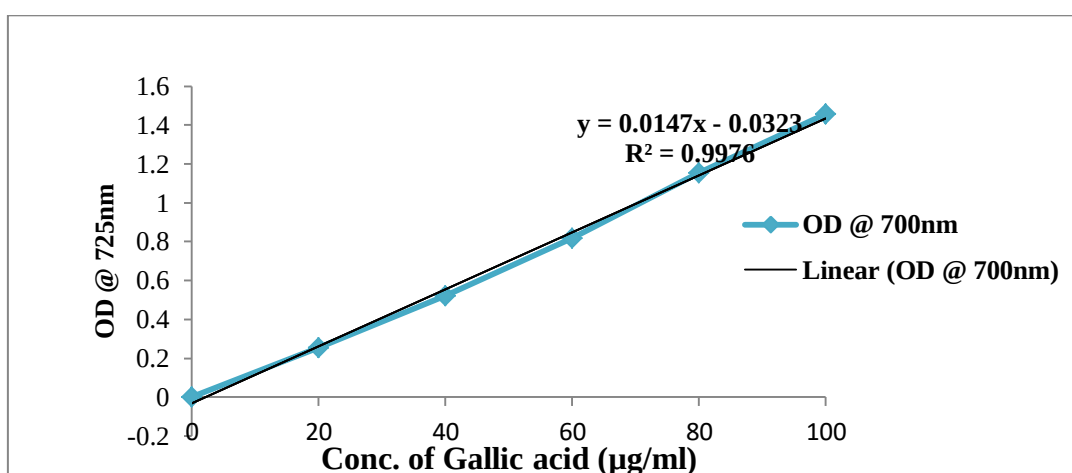


Figure 4.45: Standard Curve for estimation of tannin content in plant samples

Table 4.41: Standardisation of gallic acid for estimation of tannin content

S. No.	Vol. of Std. GA	Vol. of distilled water	Vol. of 35% Na ₂ CO ₃	Vol. of 0.5M FC reagent	OD @ 725nm
1	0	1	1	1	0.00
2	0.2	0.8	1	1	0.256
3	0.4	0.6	1	1	0.523
4	0.6	0.4	1	1	0.818
5	0.8	0.2	1	1	1.154
6	1.0	0	1	1	1.456

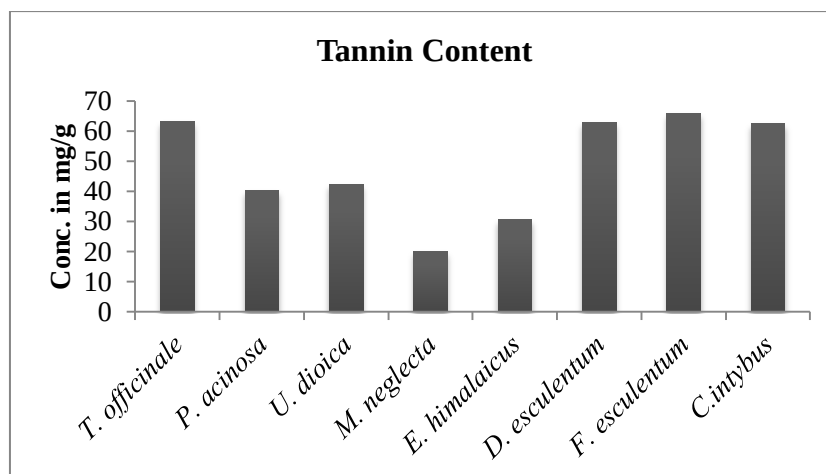


Figure 4.46: Total tannin content (GAE) in plant samples

4.5.3 Flavonoid content

Total flavonoid content in the plant samples was calculated by using quercetin as standard (figure 4.47) and was expressed as quercetin equivalent (QE) in mg/g (Table 4.43). The highest value was found in *P. acinosa* (2.052 QE mg/g) followed by *U. dioica* (2.002 QE mg/g). The lowest content of total flavonoids was observed in *E. himalaicus*.

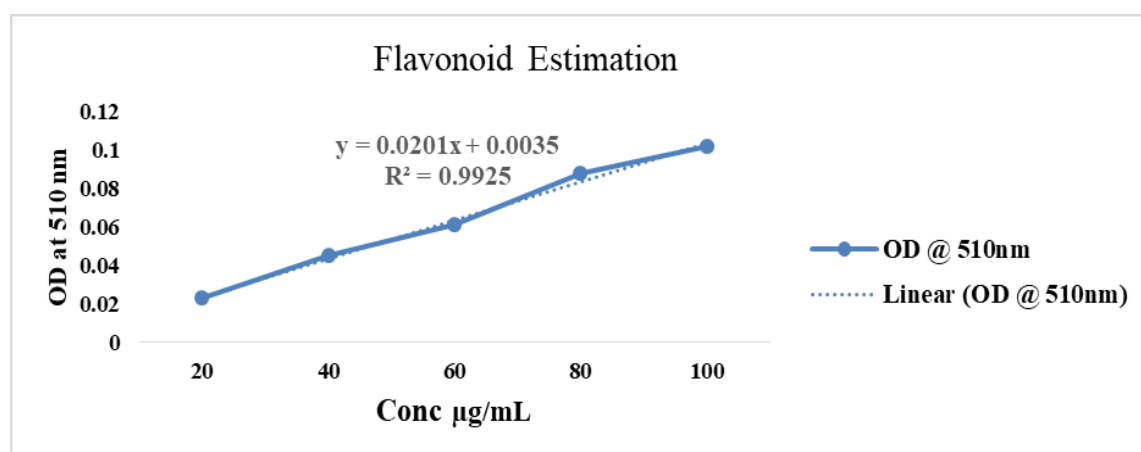


Figure 4.47: Standard curve for estimation of flavonoid content in plant samples

Table 4.42: Standardization of quercetin for estimation of Flavonoid content

S.No.	Vol. of Stnd. Quercetin (mL)	Vol. of distilled water (mL)	Vol. of 5% NaNO ₂ (mL)	Vol. of 10% AlCl ₃ (mL)	Vol of 1M NaOH (mL)	OD @ 510nm
1	0	1	0.3	0.3	2	0.000
2	0.2	0.8	0.3	0.3	2	0.023
3	0.4	0.6	0.3	0.3	2	0.045
4	0.6	0.4	0.3	0.3	2	0.061
5	0.8	0.2	0.3	0.3	2	0.088
6	1.0	0	0.3	0.3	2	0.102

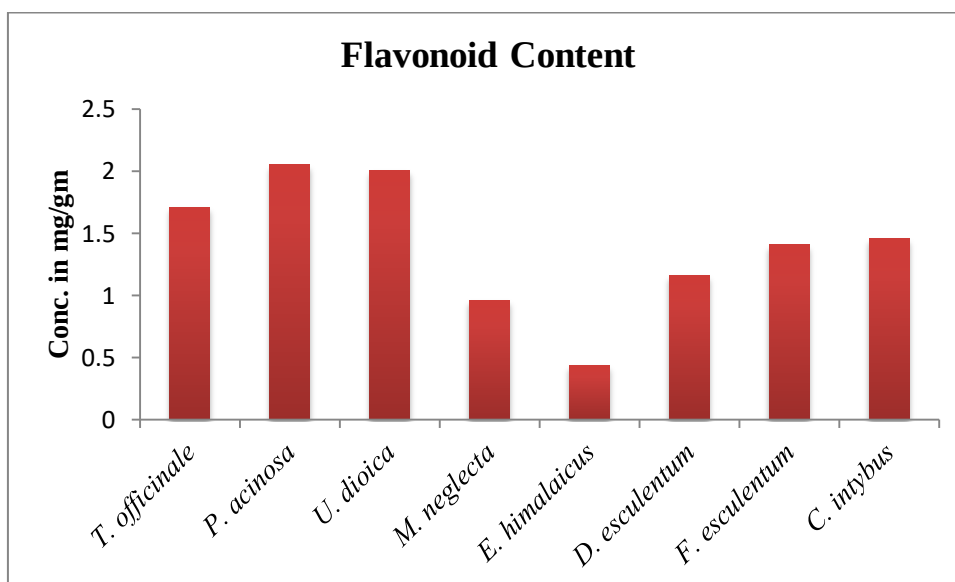


Figure 4.48: Total flavonoid content (QE) in plant samples

Table 4.43: Concentration of Total tannins and flavonoids in plant samples

Plant Sample	Conc. Of Tannins as GAE ($\mu\text{g/ml}$)	Conc. Of Tannins as GAE (mg/g)	Conc. of flavonoid as QE ($\mu\text{g/mL}$)	Conc. of flavonoid as QE (mg/g)
<i>Taraxacum officinale</i>	1263.46 $\pm$ 0.68 ^b	63.17	34.07 $\pm$ 0.50 ^b	1.70
<i>Phytolacca acinosa</i>	803.60 $\pm$ 0.68 ^c	40.18	41.04 $\pm$ 0.50 ^a	2.05
<i>Urtica dioica</i>	849.86 $\pm$ 1.36 ^d	42.49	40.04 $\pm$ 0.50 ^a	2.00
<i>Malva neglecta</i>	400.88 $\pm$ 1.36 ^g	20.04	19.15 $\pm$ 0.50 ^c	0.96
<i>Eremurus himalaicus</i>	616.53 $\pm$ 2.04 ^f	30.83	8.70 $\pm$ 0.50 ^f	0.44
<i>Diplazium esculentum</i>	1260.06 $\pm$ 0.01 ^b	63.00	23.13 $\pm$ 2.49 ^d	1.16
<i>Fagopyrum esculentum</i>	1319.25 $\pm$ 0.68 ^a	65.96	28.10 $\pm$ 2.49 ^c	1.41
<i>Cichorium intybus</i>	1250.54 $\pm$ 2.04 ^c	62.53	29.10 $\pm$ 0.50 ^c	1.46

Results are expressed as the mean $\pm$ SD (n=3). Values in the same column with different superscripts are significantly different ($p < 0.05$).

4.5.4. Anti-Oxidant Activity

The anti-oxidant activity of plant samples was determined by DPPH assay. The results revealed that the plant extracts exhibited varying levels of radical scavenging activity.

The highest activity was shown by *E. himalaicus* (74.92%), indicating strong antioxidant potential, followed by *F. esculentum* (56.60%) showing moderate antioxidant capacity. The lowest value was shown by *P. acinosa* (32.13%) suggesting weaker antioxidant properties compared to the other samples. The remaining samples demonstrated DPPH activities ranging between 34.6% and 42.63%.

Table 4.44: Antioxidant activity assay, calibration of standard

Vol. of Standard sol.(mL)	Vol. of methanol (mL)	Vol. of methanolic DPPH (mL)	Incubation in the dark for 30 minutes	OD @ 515 nm
0.25	1.25	3		0.152
0.50	1.00	3		0.119
0.75	0.75	3		0.097
1.00	0.50	3		0.082
1.25	0.25	3		0.048
1.50	0	3		0.022

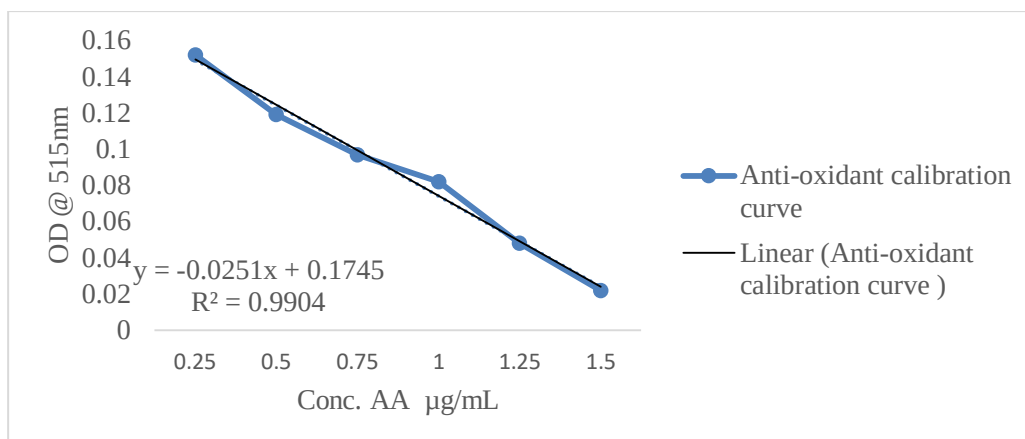


Figure 4.49: Anti-oxidant standard response curve

Table 4.45: Antioxidant (%DPPH) activity of plant samples

S.No.	Plant Sample	OD @ 515 nm	%DPPH (activity)
1.	<i>T. officinale</i>	0.560	42.68±1.02 ^c
2.	<i>P. acinosa</i>	0.663	32.13±1.94 ^f
3.	<i>U. dioica</i>	0.637	34.80±0.10 ^c
4.	<i>M. neglecta</i>	0.638	34.69±0.92 ^c
5.	<i>E. himalaicus</i>	0.245	74.92±0.10 ^a
6.	<i>D. esculentum</i>	0.579	40.73±0.82 ^d
7.	<i>F. esculentum</i>	0.424	56.60±0.10 ^b
8.	<i>C. intybus</i>	0.588	39.81±0.10 ^d

Results are expressed as the mean ± SD (n=3). Values in the same column with different superscripts are significantly different (p<0.05).

Chapter 5

Discussion

Plants produce a vast array of compounds, broadly categorized as primary and secondary metabolites. Primary metabolites are essential for basic plant survival and include carbohydrates, lipids, proteins, and vitamins (Simsek & Whitney, 2024). They are also vital for human beings, providing energy, building blocks, and essential nutrients. Secondary Metabolites are not directly involved in plant growth and development but play crucial roles in defence against pathogens or predators, protection against abiotic stress, attracting pollinators or dispersal agents, and other ecological interactions (Simsek & Whitney, 2024). Many of these metabolites have significant impacts on human health and may act as antimicrobial, anticancer, and anti-inflammatory agents (Wijesekara & Xu, 2023). The present study offers a comprehensive evaluation of wild edible plants traditionally consumed in District Doda integrating ethnobotanical documentation with detailed analyses of eight selected species for their nutritional composition, mineral profiles, anti-nutritional factors, phytochemical constituents, and antioxidant potential.

5.1 Ethno-botanical Investigation:

The study recorded 85 Wild Edible Plant (WEP) species belonging to 73 genera and 42 families in the study area, reflecting the floristic richness and robust traditional ecological knowledge (TEK) typical of Himalayan ecosystems (Thapliyal *et al.*, 2024). The flora is dominated by angiosperms (38 families), complemented by select gymnosperms and pteridophytes underscoring the ecological breadth of edible taxa accessible to local communities. Family-level patterns revealed that Polygonaceae (11 spp.) and Rosaceae (10 spp.) jointly contribute nearly one-quarter of all documented WEPs, owing to their ecological abundance, nutritional versatility, and deep cultural embedding in local food habits on similar patterns observed across the Western Himalayan regions (Khan *et al.*, 2024). Other important contributors such as Fabaceae, Asteraceae, Lamiaceae, Apiaceae, Amaranthaceae, Brassicaceae, and Chenopodiaceae expand the functional spectrum of WEPs by providing leafy vegetables, spices, condiments, and nutrient-dense seeds. The flora is overwhelmingly

herbaceous (74%), with fewer shrubs (11%) and trees (14%), reflecting a subsistence strategy centered on fast-regenerating, easily harvestable resources commonly found in field margins, forest edges, and meadows. Leaves (47%) constitute the most consumed plant part, underscoring the nutritional importance of leafy greens rich in minerals and vitamins, followed by fruits (29%), seeds (9%), roots and rhizomes (7%) mirroring ethnobotanical patterns reported from other mountainous regions (Rana *et al.*, 2019). Ethno-functional classification further shows that vegetables (42.4%) form the largest use-category, followed by fruits (29.4%), edible medicinals (10.6%), spices (7.1%), beverages (4.7%), and seeds (5.8%), illustrating a well-developed food–medicine continuum characteristic of Himalayan ethno-gastronomy (Haq *et al.*, 2022). Quantitative ethnobotanical indices further highlight the cultural importance of key species: *Taraxacum officinale* exhibited the highest use-value (UV = 1.99), while *Arisaema jacquemontii* showed the lowest (UV = 0.52), and informant consensus factor (FiC) values were strongest for wild vegetables (0.98) and wild fruits (0.97), consistent with patterns reported from other Himalayan regions (Aryal *et al.*, 2018; Dangwal and Lal, 2024). The relative frequency of citation (RFC) ranged from 0.08–1.00, with many fruits and leafy vegetables scoring the maximum value, indicating their broad recognition and frequent use. Collectively, the findings highlight an adaptive, ecologically sustainable, and culturally embedded ethnobotanical knowledge system, although certain high-value medicinal edibles such as *Angelica glauca* and *Ajuga parviflora* may remain vulnerable to overharvesting. As modernization and shifting food habits increasingly erode traditional foraging practices, the documentation and promotion of WEPs gain critical importance for safeguarding biocultural heritage, enhancing nutritional resilience, and identifying conservation strategies in fragile landscapes.

5.2 Nutrient Composition

The proximate composition analysis of the selected wild edible plants revealed significant interspecific variations in their nutritional profiles, reflecting differences in their physiology, ecological adaptations, and potential dietary contributions. Moisture content ranged from 78.27% in *Phytolacca acinosa* to 92.53% in *Eremurus himalaicus*, indicating that most of these species are moisture-rich and may be consumed as hydrating foods. The observed moisture values are consistent with previous reports on leafy greens, which generally contain 80–92% water (USDA, 2019; Singh *et al.*, 2001). But higher moisture levels, while contributing to palatability and freshness, can also limit shelf life due to susceptibility to microbial spoilage (Kaur & Kapoor, 2021).

Crude protein content varied markedly among the species, with *Cichorium intybus* (12.5%) and *Diplazium esculentum* (10.28%) showing the highest concentrations, followed by *Fagopyrum esculentum* (9.17%). These levels are nutritionally significant, as they exceed the protein content of many conventional vegetables (FAO, 2021; Singh *et al.*, 2001). The relatively high protein in *C. intybus* and *D. esculentum* suggests their potential role as alternative plant-based protein sources particularly in rural diets. *C. intybus* is traditionally used as a liver tonic and digestive enhancer (Street *et al.*, 2013), and its high protein and fibre contents align with its therapeutic role in improving metabolism. Similarly, *D. esculentum* is valued as a nutritious vegetable and source of dietary fibre for maintaining digestive health (Yumkham *et al.*, 2016).

Fat content was generally low across the samples, characteristic of green vegetables, with values ranging from 1.3% in *E. himalaicus* to 11.4% in *F. esculentum*. Although total lipid levels are modest, the presence of essential fatty acids in leafy greens has been reported (Simopoulos, 2004), and species such as *F. esculentum* (buckwheat) may contribute beneficially to dietary lipid intake. Carbohydrate levels varied significantly, with proximate values ranging from 39.7% to 70%. These findings highlight their potential as important energy sources, corroborated by the calculated calorific values lying in the range of 255.6 kcal/100g to 337 kcal/100g. *F. esculentum*

followed by *T. officinale* showed the highest calorific values. *T. officinale*, though not a staple food, has long been consumed as a tonic for liver and kidney health (Martínez *et al.*, 2015), and its moderate energy coupled with medicinal properties supports its role as a functional food.

Ash content, representing the mineral fraction, was highest in *Malva neglecta* (19.4%) and *P. acinosa* (16.8%), indicating their richness in inorganic nutrients such as calcium, iron, and potassium. Similar observations have been made for wild greens, where high ash values correlate with their ethnomedicinal use in treating mineral-deficiency disorders (Odhav *et al.*, 2007). *M. neglecta* (mallow) has been traditionally used as an anti-inflammatory and emollient plant (Agelet & Vallès, 2003), and its high mineral and fibre content reinforce its use as a dietary and therapeutic herb. *P. acinosa*, though toxic in high doses, has ethnobotanical significance in some Himalayan communities for its purgative and medicinal properties (Negi *et al.*, 2010).

Crude fibre content showed striking differences, with values ranging from 9.8% in *P. acinosa* to 34.7% in *D. esculentum*. Fibre is crucial for gastrointestinal health, prevention of metabolic disorders, and satiety regulation (Slavin, 2005). The exceptionally high fibre in *D. esculentum* suggests its importance as a functional food for populations at risk of lifestyle-related diseases. Similarly, *C. intybus* and *M. neglecta* also exhibited high fibre levels, consistent with their traditional use in digestive and detoxification remedies. *Urtica dioica*, which showed moderate fibre and protein values, is a well-documented medicinal food used for anemia, allergies, and joint health due to its high mineral and phytochemical content (Chrubasik *et al.*, 2007). *E. himalaicus*, besides being used as vegetable has medicinal ethnobotanical applications also. It is used in traditional Himalayan medicine for its antioxidant and adaptogenic properties (Kala, 2005).

5.3 Mineral Profile

The elemental analysis of the selected edible wild plants using Energy Dispersive X-ray Fluorescence (EDXRF) revealed considerable variation in both macro- and microelements, reflecting their differential mineral-accumulating capacities. The

analysis revealed presence of nutritionally significant quantities of essential macro-elements such as Ca, Mg, K, P, and microelements such as Fe, Zn, Cu, Mn, Si, in the evaluated plant samples. These elements play important roles in plant metabolism, enzyme activity, and antioxidant defence mechanisms. These minerals are essential for plant growth, energy production, and stress response, which can also directly impact the antioxidant properties. For instance, potassium is crucial for regulating osmotic balance and enzyme function, chlorine plays a role in maintaining membrane stability and ion homeostasis, manganese is a cofactor for numerous enzymes involved in oxidative metabolism, while calcium and magnesium are involved in chlorophyll synthesis and photosynthesis, contributing to the overall antioxidant capacity (Alemu *et al.*, 2024). These elements contribute to the structural integrity of the plant, as well as the regulation of various biochemical pathways. The presence of these elements can influence the overall antioxidant and bioactive potential of the extract. Some of them are essential cofactors for antioxidant enzymes, such as superoxide dismutase and catalase. They can also enhance the free radical scavenging and reactive oxygen species quenching abilities of the plant extracts. Besides, these elements have an important role in human nutrition. They are vital for human health, supporting enzyme activity, bone health, and antioxidant defence mechanisms, among other functions. The variations in the elemental profiles observed across the eight evaluated plant samples suggest that these plants can be an important dietary source of essential elements for human beings. The antioxidant and bioactive properties of the extracts may also be influenced by the presence and relative abundance of these essential minerals. Further investigations are warranted to elucidate the specific mechanisms by which the elemental composition of the extracts can modulate their antioxidant and pharmacological activities.

5.2.1 Macro-elements

Potassium (K) was found in relatively high concentrations, ranging from 2.57–5.86 g/100 g DW. *P. acinosa* (5.86 g/100 g) and *D. esculentum* (5.29 g/100 g) emerged as the richest sources. Potassium is crucial for maintaining electrolyte balance, neuromuscular function, and regulation of blood pressure (He & MacGregor, 2008). A diet rich in potassium from plant sources is associated with reduced risk of

hypertension and stroke. The values observed are comparable to or higher than commonly consumed leafy greens, underscoring the potential of these plants as functional foods (Natesh *et al.*, 2017).

Calcium and magnesium essential for bone health, muscle contraction, and enzymatic regulation (Weaver & Plawecki, 1994), showed notable differences across the studied plants. Calcium (Ca) displayed significant variability, with *U. dioica* recording the highest concentration (4.02 g/100 g), followed by *M. neglecta* (1.96 g/100 g) and *C. intybus* (1.58 g/100 g). Calcium is the principal mineral for bone and dental health, while also contributing to muscle contraction, blood clotting, and enzyme activation (Bronner, 1994). The exceptionally high Ca level in *U. dioica* suggests its potential role as a plant-based alternative in addressing health issues related to calcium deficiency.

Magnesium (Mg) was highest in *F. esculentum* (0.95 g/100 g), followed by *P. acinosa* (0.80 g/100 g). Magnesium plays a vital role in numerous enzymatic reactions, including protein synthesis, nerve function, and glucose metabolism (Rosanoff *et al.*, 2012). Diets high in Mg are inversely associated with type 2 diabetes and cardiovascular diseases.

Phosphorus (P) ranged between 0.29 g/100 g in *P. acinosa* to 0.72 g/100 g in *D. esculentum*. Phosphorus is essential for energy metabolism, nucleic acid synthesis, and bone mineralization (Achikanu *et al.*, 2021). While all samples provided moderate levels of phosphorus, *D. esculentum* stands out as a comparatively richer source.

5.2.2 Micro-elements:

Iron (Fe) content ranged widely, from 19.3 mg/100 g in *D. esculentum* to 219 mg/100 g in *M. neglecta*. Iron is indispensable for oxygen transport via hemoglobin, myoglobin and cellular respiration (Beard, 2001). The extraordinarily high Fe level in *M. neglecta* suggests its importance in combating iron-deficiency anemia, especially in regions with limited access to animal-derived iron sources. However, bioavailability, influenced by antinutrients like oxalates and phytates, must be considered.

Zinc (Zn) content was found to be highest in *M. neglecta* (7.3 mg/100 g), followed by *U. dioica* and *D. esculentum* (4.8 mg/100 g each). Zinc supports immune function, growth, wound healing, and reproductive health (Prasad, 2013). Plant-derived Zn often shows lower bioavailability due to some anti-nutrients, yet the high concentrations observed suggest these plants could significantly contribute to dietary zinc intake (Janet, 2003).

Copper (Cu) levels ranged from 0.9 mg/100 g in *T. officinale* to 3.2 mg/100 g in *P. acinosa*. Copper is essential for iron metabolism, connective tissue synthesis, and antioxidant defense (Turnlund, 1998). The high Cu content in *P. acinosa* indicates its role in preventing copper deficiency-related conditions such as anemia and connective tissue disorders.

Manganese (Mn) content was highest in *P. acinosa* (9 mg/100 g) and *M. neglecta* (8.8 mg/100 g). Manganese acts as a cofactor for enzymes involved in bone development, carbohydrate metabolism, and antioxidant defense (Gyamfi *et al.*, 2023). The high Mn concentrations highlight these plants as valuable sources for supporting metabolic and skeletal health. The diversity in mineral composition underscores the importance of dietary diversification, as no single plant provides all essential nutrients in optimal amounts. Furthermore, the findings validate the ethnomedicinal uses of these species, many of which are traditionally consumed as wild vegetables and herbal remedies.

5.4 Oxalate Content as anti-nutrient

Oxalates have been referred to as anti-nutrients in human nutrition as they interfere with absorption of vital mineral nutrients and also have harmful effect on health (Natesh *et al.*, 2017). They are known to strongly chelate divalent cations such as Ca^{2+} and Mg^{2+} , forming insoluble salts (Avila-Nava *et al.*, 2021). While excessive intake is associated with calcium oxalate kidney stone formation (Mitchell *et al.*, 2019), moderate levels do not pose major risks. (Ghanati *et al.*, 2024). Proteins are essential macronutrients for growth, repair, and enzymatic processes. However, antinutritional factors like tannins and oxalates can reduce protein bioavailability by forming complexes with amino acid residues or by binding essential cofactors such as calcium, magnesium, and iron required for protein metabolism. Tannins cause precipitation of

proteins by forming complexes via hydrogen and covalent bonding, thereby making them unavailable for absorption (Natesh *et al.*, 2017). Although oxalates primarily inhibit mineral absorption, their indirect effect on protein utilization is significant; low bioavailability of iron and zinc, for instance, impairs protein synthesis and hemoglobin formation.

Among the evaluated plants, *U. dioica* contained only 6.525 mg /100 g oxalates, far lower than *T. officinale* and *F. esculentum* (both 15.75 mg/100 g). This indicates that the high calcium in *U. dioica* is likely more bioavailable than in oxalate-rich plants. Similarly, the magnesium in *F. esculentum* may not be fully absorbed due to its high oxalate load, suggesting limited efficiency as a magnesium source unless processed before consumption. Iron is abundant in *M. neglecta* (219 mg/100 g DW), *F. esculentum* (83 mg), and *U. dioica* (62.5 mg). Iron deficiency anemia remains a major global nutritional concern, and plant-based iron sources are often limited by inhibitors such as oxalates and phytates (Gupta *et al.*, 2005). *M. neglecta* having extraordinary iron levels, has relatively modest oxalate content (6.975 mg/100 g), making it a particularly potent dietary iron source compared to *F. esculentum* (83 mg Fe with 15.75 mg oxalates). This balance highlights *M. neglecta* as a nutritionally favorable candidate for addressing iron deficiency, especially in vegetarian diets. By contrast, the high oxalate of *F. esculentum* may substantially reduce its iron bioavailability despite high concentration. Potassium, a key regulator of blood pressure and neuromuscular function (He & MacGregor, 2008), was most abundant in *P. acinosa* (5.86 g/100 g) and *D. esculentum* (5.29 g/100 g). Both species exhibited moderate oxalate levels (15.075 mg and 4.275 mg, respectively). In this context, *D. esculentum* is particularly valuable: its high potassium content coincides with the lowest oxalate level among all species, suggesting high bioavailability. Similarly, phosphorus, essential for ATP production and bone mineralization, was best represented in *D. esculentum* (0.72 g/100 g) and *C. intybus* (0.593 g/100 g), both with relatively low oxalate levels (4.275–6.75 mg), supporting favorable nutritional contributions. But overall the oxalate levels in the studied plants were found to be relatively modest as compared to some commonly used leafy greens (Radek and Savage, 2008). Moreover, traditional processing methods such as blanching, fermentation, and cooking further

reduce soluble oxalates, enhancing mineral bioavailability (Siener *et al.*, 2006). Thus, incorporating these edible wild greens into diets could alleviate micronutrient deficiencies in vulnerable populations, particularly iron and calcium deficiencies, provided preparation methods mitigate oxalate effects.

5.5 FTIR Analysis

The FTIR analyses of the eight plant samples revealed a phytochemical spectrum dominated by hydroxyl, carbonyl, glycosidic, and aromatic functional groups, consistent with the presence of polyphenols, flavonoids, polysaccharides, and terpenoids. Such compounds are central to their documented ethnomedicinal value, with antioxidant, hepatoprotective, anti-inflammatory, anti-microbial and immune-modulating properties (Khalid *et al.*, 2025; Murali *et al.*, 2021; Schütz *et al.*, 2006). All plant samples exhibited strong and broad absorptions between 3890–3574 cm^{-1} , indicative of O–H stretching vibrations. This is characteristic of phenolic and flavonoid derivatives, which play a crucial role in free radical scavenging and oxidative stress regulation (Chen *et al.*, 2022; Oliveira *et al.*, 2016). The intensity of this region was particularly high in *Taraxacum officinale*, *Phytolacca acinosa*, and *Urtica dioica*, highlighting their dense polyphenolic profile.

The 1737–1698 cm^{-1} region, representing C=O stretching, was pronounced in *T. officinale* and *C. intybus*. These peaks suggest high levels of phenolic acids and sesquiterpene lactones, secondary metabolites associated with anti-microbial, anti-diabetic, anti-carcinogenic, anti-inflammatory and hepatoprotective activities (Johnson *et al.*, 2020; Chaturvedi and Dwivedi, 2016 ; Devi and Battu, 2019). Additionally, aromatic C=C stretching vibrations between 1650–1600 cm^{-1} were evident across *M. neglecta*, *U. dioica*, and *F. esculentum*, pointing to lignan and flavonoid structures that reinforce their α -glucosidase inhibitory activities, antioxidant and protective effects (Oluwole *et al.*, 2022; Lei *et al.*, 2022).

Distinct carbohydrate signals were noted in the 1200–1000 cm^{-1} region across *T. officinale*, *D. esculentum*, *F. esculentum*, and *C. intybus*. The diagnostic band at $\sim 1050 \text{ cm}^{-1}$ in *T. officinale* corresponds to inulin, a well-known fructan prebiotic that enhances gut health (Patriche *et al.*, 2017; Pourfarzad *et al.*, 2015). Buckwheat (*F.*

esculentum) demonstrated similar glycosidic (peaks, consistent with rutin and other flavonoid glycosides with anti-oxidative, anti-carcinogenic, cardioprotective and anti-inflammatory potential (Bohlouli *et al.*, 2021; Kokalj *et al.*, 2017). Moderate absorptions at 2917–2980 cm^{-1} across *P. acinosa*, *M. neglecta*, and *E. himalaicus* indicate C–H stretching, a hallmark of aliphatic chains, terpenoids, and fatty acids. These components are often linked to anti-oxidant, antimicrobial and membrane-modulating properties (Hoshino, 2024; Grassman *et al.*, 2002). Amide I and II bands (~ 1650 and 1537 cm^{-1}) were observed in *U. dioica* and *M. neglecta*, denoting proteins, peptides, or nitrogenous alkaloids. In *U. dioica*, this reflects its dual role as both a medicinal and nutritional plant, commonly used in hematinic preparations due to its protein and mineral content (Chrubasik *et al.*, 2007).

Although all the analysed species share a strong polyphenolic foundation, distinct phytochemical fingerprints also emerged. *T. officinale* and *C. intybus* are rich in inulin like polysaccharides and phenolic acids, *P. acinosa* is dominated by saponins and alkaloids, *U. dioica* shows significant proteinaceous signatures, while *M. neglecta* is characterized by mucilaginous glycosides. *E. himalaicus* and *D. esculentum* emphasize polyphenolic–glycosidic complexes, whereas *F. esculentum* is defined by rutin-linked glycosides. These variations provide a scientific rationale for their complementary therapeutic uses, validating traditional ethnopharmacological practices.

5.6 Phytochemical Analysis: Tannins and Flavonoids

The phytochemical analysis was also done to determine the presence of tannins and flavonoids in the plant extracts. Tannins are a class of polyphenolic compounds that are widely distributed in plants and have been found to possess a variety of pharmacological properties (He, 2022). These molecules are useful for cross-linking with proteins and other macromolecules (He, 2022). They are also known for their astringent properties, and they are found in various plant products including tea, coffee, wine, fruits, and legumes (Chung *et al.*, 1998). Regarding their effects on human health, these phytochemicals have antioxidant properties helping to mitigate oxidative stress (Sharma *et al.*, 2019). They exert antimicrobial effects as they may inhibit the growth of undesirable bacteria and protect against microbial infections

(Chung *et al.*, 1998). They may also serve as natural regulators of the microbial population in various habitats, including the human gastrointestinal tract (Chung *et al.*, 1998). Many other physiological effects are also attributed to tannins. Some studies suggest tannins can accelerate blood clotting, reduce blood pressure, and modulate immune responses (Chung *et al.*, 1998). From a nutritional standpoint, foods rich in tannins have traditionally been considered to have lower nutritional value due to their ability to impede food consumption and digestion (Chung *et al.*, 1998). They can diminish nutrient bioavailability in the gut (Sharma *et al.*, 2019). But side-effects are usually caused by ingesting high amount i.e approximately between 0.6g to 1g of tannic acid daily (Chung *et al.*, 1998; Abdi *et al.*, 2022).

5.6.1 Tannins

The varying levels of tannins observed across the analyzed plant samples suggest differences in the phytochemical profiles of these plants. Tannin levels revealed wider variability, ranging from 20.04 mg/g in *M. neglecta* to 65.96 mg/g in *F. esculentum*. The highest tannin levels i.e., more than 60 mg/g, were found in *F. esculentum*, *T. officinale*, *C. intybus*, and *D. esculentum*, consistent with their phenolic richness and reported health-promoting effects, including hepatoprotection and metabolic regulation (Ivanov, 2014; Jasim., 2018; Bonafaccia *et al.*, 2003). By contrast, the low tannin content of *M. neglecta* aligns with its traditional use as a demulcent, where mucilage rather than astringent polyphenols dominate (Conforti *et al.*, 2008).

Samples with higher tannin concentrations, such as *F. esculentum* with 65.96 mg/g, may have increased capacity for protein cross-linking and other biochemical activities associated with tannins. Conversely, samples with lower tannin levels, like *M. neglecta* at 20.04 mg/g, may exhibit reduced tannin-related functionality. These differences in tannin content could influence the overall biological and pharmacological properties of the plant extracts, warranting further investigation into the potential impacts on their biochemical activities.

5.6.2 Flavonoids

The analysis further identified the presence of flavonoids in the extracts. Flavonoids are a group of plant secondary metabolites that have been extensively studied for their

antioxidant, anti-inflammatory, and antimicrobial activities (Michalaki & Grintzalis, 2023). They comprise a vast family of polyphenolic compounds, naturally present in a variety of plant sources. These bioactive phytochemicals have garnered significant attention for their diverse health-promoting properties (Belkaid *et al.*, 2006). Notably, flavonoids are renowned for their potent antioxidant and anti-inflammatory activities, which are crucial for mitigating oxidative stress and inflammation. Epidemiological evidence further suggests that regular consumption of polyphenol-rich foods and beverages may help prevent various degenerative diseases (Belkaid *et al.*, 2006). Among the numerous flavonoid subclasses, cyanidins have been of particular nutritional interest, demonstrating promising effects in the treatment of various health conditions (Galvano *et al.*, 2004). Importantly, since flavonoids cannot be synthesized by the humans, maintaining an adequate dietary supply through the consumption of plant-based foods is considered advantageous for optimal health (Hässig *et al.*, 1999).

The plant extracts were tested for the presence of flavonoids, and it was found that the samples varied considerably in their flavonoid content. Flavonoid levels ranged from 0.43 mg/g in *E. himalaicus* to 2.05 mg/g in *P. acinosa*. The samples *P. acinosa* and *U. dioica* had the highest flavonoid concentrations, therefore may exhibit enhanced antioxidant, anti-inflammatory, and antimicrobial activities due to the biological properties associated with flavonoids (Khalid *et al.*, 2025; Chrubasik *et al.*, 2007). In contrast, *E. himalaicus* had the lowest flavonoid content, which could result in reduced flavonoid-related functionality in this extract suggesting that other phytochemical groups (e.g., polyphenolic acids) may contribute more substantially to its bioactivity as it showed highest anti-oxidant capacity also. The differences in flavonoid levels across the eight plant extracts suggest that the plants have distinct phytochemical profiles, which could influence their overall biological and pharmacological properties.

5.7 Antioxidant activity

The antioxidant capacity of the plant extracts was evaluated using the DPPH radical scavenging assay. This assay was employed to measure the ability of the extracts to quench free radicals (Asomadu *et al.*, 2024). Along with various factors, the antioxidant activity can be attributed to the presence of phenolic compounds such as

tannins and flavonoids, that were identified in the phytochemical analysis (Michalaki & Grintzalis, 2023; Mithraja *et al.*, 2012). Radical scavenging activity showed striking differences across species, with *E. himalaicus* (74.92%) and *F. esculentum* (56.60%) displaying the strongest antioxidant potential, while *P. acinosa* (32.14%) showed the weakest response. The varying levels of activity across the samples suggest differences in their antioxidant compositions, which could be explored further for potential applications.

The relationship between phytochemical levels and antioxidant activity was not strictly linear. While tannin and flavonoid-rich plants like *F. esculentum* displayed high radical scavenging potential, other species such as *P. acinosa* and *U. dioica* showed relatively lower activity despite moderate flavonoid levels. Interestingly, *E. himalaicus* exhibited high antioxidant activity despite having the lowest flavonoid content, suggesting that non-flavonoid phenolics or other molecules may play a significant role in its antioxidant mechanisms (Prior *et al.*, 2005, Seabra *et al.*, 2006). This indicates that antioxidant efficacy may also be influenced by the quality and structure of phenolics rather than just total concentration (Rice-Evans *et al.*, 1997). Moreover, synergistic interactions between tannins, flavonoids, and other polyphenols likely determine the net antioxidant response.

5.8 Implications and Relevance

The present research holds significance not only at the local level, but also in the broader global context. Widespread inadequacies of minerals such as iron, zinc, and calcium continue to drive ‘hidden hunger’ worldwide, undermining child and maternal health and slowing progress towards SDG-2 targets on ending all forms of malnutrition (FAO, 2024). Recent estimates suggest that large shares of the global population consume insufficient amounts of multiple essential micronutrients, reinforcing the need for food-based solutions. Micronutrient deficiencies particularly of iron, zinc, and calcium remain a major public health concern in developing regions, where nearly one-third of the global population is affected (WHO, 2021). These deficiencies contribute to impaired vision, weakened skeletal development, cognitive retardation, anaemia, stillbirths, and heavy strain on already overburdened healthcare

systems. Strengthening food quality rather than quantity is therefore an urgent nutritional priority.

This study on WEPs directly addresses the nutrition pillar of SDG 2 by diversifying diets with nutrient-dense species adapted to local agroecologies (Passarelli, 2024). Food-based approaches are central to durable gains because they improve diet quality, not just calorie supply. In this context, WEPs provide naturally occurring packages of minerals and bioactives that can be mainstreamed through community diets and local value chains (Bechoff, 2023). Scientific reviews emphasize the application of complementary strategies such as biofortification, supplementation, dietary diversification, and nutrition education where locally available plant foods can fill critical intake gaps. Dehydration exerts minimal impact on the proximate and mineral composition of green leafy vegetables, making dehydrated wild food plants a concentrated natural reservoir of essential micronutrients suitable for incorporation into diverse food products (Gupta *et al.*, 2013). Value addition of traditional foods with dehydrated wild edible plants particularly leafy greens offers a practical food-based strategy to alleviate micronutrient malnutrition alongside existing approaches such as supplementation, food fortification, improved crop management, nutritional education, and dietary diversification (Kumar *et al.*, 2023).

The results of this study align with the growing research evidence which shows that many WEPs deliver meaningful fractions of recommended intakes for minerals and other protective compounds, offering a culturally acceptable, low-cost route to boost diet quality. Because they are adapted to local conditions, WEPs can be resilient to climate variability and require minimal external inputs. Structured valorization, processing, packaging, and inclusion in familiar foods can help translate this nutritional potential into regular consumption (Clemente-Villalba *et al.*, 2023).

Beyond nutrition, WEPs can catalyze local rural economies. Non-timber forest products (NTFPs) including WEPs can contribute a substantial share of household cash income, buffer lean seasons, and provide women-led microenterprise opportunities through harvesting, drying, and simple value addition. These pathways align closely with SDG-2 targets on sustainable and resilient food systems; and also with SDG-8 by fostering decent work through the formalization of WEP value chains.

Therefore, the wild edible plants examined in this study, many of which grow abundantly and remain underutilized, present affordable and sustainable dietary sources of vital minerals. Their wider dietary adoption may help reduce hidden hunger while providing additional bioactive health benefits and creating livelihood opportunities for rural households through harvesting, processing, and local market integration. However, further studies on bioavailability and detailed anti-nutrient profiling are required before comprehensive dietary recommendations can be established.

Moreover, research on WEPs is fundamental not only for documenting and validating ethnobotanical knowledge but also for understanding ecosystem processes and developing sustainable conservation strategies. Ecological investigations enable the identification of vulnerable populations, assessment of regeneration potential, and formulation of sustainable harvesting protocols that balance human use with long-term ecosystem health. Furthermore, WEP research contributes to climate change adaptation by identifying resilient species capable of thriving under harsh environmental conditions such as drought, low soil fertility, and extreme temperatures. These species represent valuable genetic resources for future crop improvement and ecological restoration programmes. Conserving their genetic diversity enhances ecosystem adaptability while supporting global food security under changing climatic conditions related to the achievement of several sustainable development goals, particularly those related to food security (SDG 2), terrestrial ecosystems (SDG 15), and climate action (SDG 13). Therefore, integrating ecological assessments with ethnobotanical, nutritional, and conservation studies offers a comprehensive framework for protecting these valuable plant resources and maintaining ecosystem resilience in the face of global environmental change.

Chapter 6

Summary and Conclusion

The present investigation included an ethnobotanical survey on wild edible plants District Doda of J&K as a result of which such plant species were collected, identified and related traditional knowledge was recorded. This ethnobotanical assessment documented 85 wild edible plant species distributed across 42 families, with Polygonaceae and Rosaceae as the leading contributors. The edible flora is dominated by herbs (74%), reflecting sustainable foraging practices focused on easily regenerating species. Leaves (48%) and fruits (29%) are the major edible parts, and vegetables (42%) form the largest use-category. The study revealed rich traditional knowledge in the study area involving nutritionally and medicinally significant species.

In addition, an integrated assessment of the proximate composition, mineral profile, oxalate content, functional group chemistry, and phytochemical-antioxidant potential of eight wild edible plant species collected from the study area was carried out. These species, which were analyzed to elucidate their nutritional and functional significance included *Taraxacum officinale*, *Phytolacca acinosa*, *Urtica dioica*, *Malva neglecta*, *Eremurus himalaicus*, *Diplazium esculentum*, *Fagopyrum esculentum*, and *Cichorium intybus*. All of them are traditionally consumed as green leafy vegetables having additional health benefits.

Proximate analysis revealed considerable interspecific variability among the evaluated plants. Moisture content ranged from 78.27% (*P. acinosa*) to 92.53% (*E. himalaicus*), while *C. intybus* and *D. esculentum* exhibited the highest protein contents (12.5% and 10.28%, respectively). *F. esculentum* recorded maximum fat (11.4%) and energy (337 kcal/100 g DW), indicating its potential as an energy-dense food source. *T. officinale* was carbohydrate-rich (70%), whereas *M. neglecta* exhibited exceptional ash (19.4%) and crude fibre (23.8%) contents, reflecting high mineral and roughage potential.

EDXRF-based mineral analysis demonstrated potassium as the most abundant macroelement (2.57–5.86 g/100 g), followed by calcium, phosphorus, and

magnesium. *M. neglecta* was particularly rich in iron (219 mg/100 g) and zinc (7.3 mg/100 g), while *U. dioica* exhibited the highest calcium content (4.02 g/100 g). Oxalate concentrations ranged between 4.275 mg/100 g (*D. esculentum*) and 15.75 mg/100 g (*T. officinale*), inversely correlating with protein and mineral bioavailability. Low-oxalate species such as *M. neglecta*, *U. dioica*, and *D. esculentum* demonstrated superior nutritional accessibility.

FTIR spectroscopic analysis confirmed the predominance of hydroxyl and amino functional groups (30–35%), carbohydrate-associated C–O linkages (20–25%), and moderate carbonyl and aromatic absorptions (~15%), signifying polysaccharides, polyphenols, glycosides, and proteinaceous constituents. Species-specific bands validated the presence of bioactive compounds such as flavonoids, phenolic esters, mucilages, and inulin-type fructans.

Phytochemical quantification revealed marked interspecific variation in tannin (20.04–65.96 mg/g) and flavonoid (0.435–2.052 mg/g) contents. *F. esculentum*, *T. officinale*, and *C. intybus* exhibited the highest tannin levels, while *P. acinosa* and *U. dioica* contained the most flavonoids. Antioxidant activity, expressed as radical scavenging activity (RSA), ranged from 32.13% (*P. acinosa*) to 74.92% (*E. himalaicus*), showing a strong positive correlation with phenolic content in most of the evaluated species.

Collectively, the findings highlight the biochemical richness, nutritional diversity, and antioxidant potential of these Himalayan wild edibles. Their inclusion in modern diets and nutraceutical formulations could improve nutritional security, mitigate micronutrient deficiencies, and promote the conservation of ethnobotanical knowledge.

6.1 Key Findings

Nutrients:

1. *T. officinale* has high carbohydrate content whereas *F. esculentum* has highest fat content of 11% and highest calorific value of 337 kcal/100 g on dry weight basis.
2. *C. intybus* and *D. esculentum* have good protein content, so may serve as supplementary protein sources.
3. *M. neglecta*, *U. dioica*, and *D. esculentum* are fibre and mineral-rich species, thus holding promise for improving digestive health and combating micronutrient deficiencies.

Minerals:

1. *U. dioica* stands out as a calcium-rich leafy vegetable.
2. *M. neglecta* is exceptionally high in iron and zinc, suggesting strong potential against micronutrient malnutrition.
3. *P. acinosa* provides high potassium, copper, and manganese, supporting cardiovascular and metabolic health.
4. *F. esculentum* excels in magnesium, relevant for preventing metabolic disorders.
5. *D. esculentum* is a good source of potassium and phosphorus.
6. *T. officinale* is having high levels of zinc and potassium.

Oxalate content and Mineral-oxalate balance:

1. *D. esculentum* has lowest amount of oxalates whereas highest content is present in *F. esculentum* and *T. officinale*.
2. *M. neglecta*, *U. dioica*, and *D. esculentum* have high mineral and low oxalate content which can be considered nutritionally desirable.
3. High mineral and high oxalate contents are present in *F. esculentum* and *T. officinale* which may lead to reduced bioavailability.

4. *P. acinosa*, *E. himalaicus* and *C. intybus* have moderate content of minerals and oxalates.

FTIR analysis:

1. All evaluated plants have a baseline spectrum of phenolics and glycosides with clear phytochemical distinctions also.
2. *T. officinale* and *C. intybus* share a strong inulin-like glycoside signature, aligning with their known prebiotic and hepatoprotective effects.
3. *P. acinosa* shows strong evidence of saponins and alkaloids, consistent with its cytotoxic and immune-modulating traditional uses.
4. *U. dioica* has high carbohydrate and proteinaceous content, reflecting both its nutritional and medicinal utility.
5. *M. neglecta* reflects dominance of mucilaginous glycosides and flavonoid derivatives, validating its demulcent and anti-inflammatory applications.
6. *E. himalaicus* and *D. esculentum* spectra emphasize polyphenols and glycosides, aligning with antioxidant-rich ethnomedicinal profiles.
7. *F. esculentum* presents rutin-linked glycosidic peaks, reinforcing its role as a nutraceutical food source.

Tannins, Flavonoids and anti-oxidant activity:

1. *F. esculentum* has highest tannin content and *M. neglecta* has lowest content of tannins.
2. High-tannin species such as *F. esculentum* (65.96 mg/g), *T. officinale* (63.17 mg/g), *C. intybus* (62.53 mg/g), and *D. esculentum* (63.00 mg/g) exhibit nearly three-fold higher tannin levels compared to low-tannin species *M. neglecta* (20.04 mg/g).
3. Moderate tannin levels are present in *U. dioica* (42.49 mg/g), *P. acinosa* (40.18 mg/g), and *E. himalaicus* (30.82 mg/g).
4. *P. acinosa* and *Urtica dioica* have the highest flavonoid concentrations.
5. Lowest flavonoid levels around 0.43 mg/g are present in *E. himalaicus*.
6. Radical scavenging activity shows striking differences across species with

P. acinosa having the weakest radical scavenging activity of 32.14%.

7. *E. himalaicus* (74.92%) and *F. esculentum* (56.60%) have highest radical scavenging activity, thus showing the strongest antioxidant potential.

6.2 Conclusion

The ethnobotanical findings demonstrate that the study region possesses a remarkably rich and culturally embedded diversity of Wild Edible Plants, reflecting both ecological abundance and sophisticated traditional ecological knowledge. The investigation also highlights a strong food–medicine continuum and cultural dependence on wild flora as dietary supplements and medicinal resources. The dominance of herbaceous greens and wild fruits underscores their continued importance in providing essential micronutrients, bioactive compounds, and seasonal dietary diversity.

The comprehensive evaluation of eight of these wild edible plants demonstrates their multidimensional nutritional and therapeutic potential. The integration of proximate, mineral, FTIR, and phytochemical analyses confirms that these taxa are reservoirs of essential nutrients, bioactive metabolites, and antioxidant compounds.

Some wild plant species such as *M. neglecta*, *U. dioica*, and *D. esculentum* emerge as nutritionally superior, owing to their rich mineral composition, high protein content, and low oxalate interference, making them ideal candidates for dietary inclusion. On the other hand, species like *F. esculentum* and *T. officinale*, though high in energy and phenolics, require processing interventions to minimize oxalate content and enhance nutrient absorption.

FTIR analysis validated the biochemical complexity of these species, underscoring their richness in polysaccharides, glycosides, flavonoids, and phenolic esters that underpin their ethnomedicinal applications. The strong correlation between phenolic concentration and antioxidant activity in species such as *F. esculentum*, *T. officinale*, *C. intybus* and *D. esculentum* further confirms their potential as natural sources of antioxidants for functional foods and nutraceuticals. This integrated analysis highlights that while tannins and flavonoids are key contributors to antioxidant

activity, they cannot fully explain the variation across species. Plants like *E. himalaicus* suggest the presence of alternative antioxidant systems, while *F. esculentum* demonstrates the classic polyphenol-driven antioxidant model. These results not only bridge the indigenous knowledge with modern nutritional science, but also validate the ethnomedicinal uses of the studied taxa, providing a robust baseline for advanced phytochemical investigations and bioactivity-guided isolation of ethnobotanically important plants. This can facilitate the translation of traditional knowledge into evidence-based pharmacological applications.

Another promising direction involves integrating WEPs into biodiversity conservation and sustainable livelihood programmes. Conservation of wild genetic resources through community-based management, in situ conservation, and sustainable harvesting will help preserve traditional ecological knowledge while enhancing rural income through value-added products and local food enterprises. Ethnobotanical knowledge coupled with scientific validation can transform neglected species into economically valuable crops without compromising ecosystem integrity.

The overall findings advocate for the valorization, domestication, and conservation of the underutilized Himalayan wild edibles. Promoting their use could diversify food sources, enhance micronutrient intake, and contribute to sustainable livelihood practices in mountain communities. Moreover, the research results can also be applied in product formulations as dehydrated wild vegetables are a concentrated natural source of micronutrients. They can be utilized for development of nutraceuticals, various value added products and also as food fortification agents. Future research should also prioritize bio-availability studies, clinical validation of health benefits, toxicological assessment, post-harvest processing, cultivation protocols, consumer acceptance, and commercialization strategies. These investigations will accelerate the transition of WEPs from traditionally consumed forest resources to climate-smart crops contributing to resilient food systems. The work undertaken provides an excellent baseline for such translational research and positions these underutilized species as promising candidates for future nutritional interventions, sustainable agricultural development and enhancing rural economy.

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Appendix-1: List of Wild Edible Plants of District Doda, J&K, their local names, uses, use-value index (UV), relative frequency of citation (RFC) and accession number.

S.No	Botanical Name	Family	Life Form	Common Name	Local Name	Part Used/Uses	UV	RFC	Herbarium Accession No.
1.	<i>Ajuga parviflora</i> Benth.	Lamiaceae	Herb	Bugleweed	Butein	Leaves, roots, young shoot- Crushed plant parts mixed with water taken as blood purifier	0.53	0.5	HBJ16973
2.	<i>Allium stracheyi</i> Baker	Amaryllidaceae	Herb	Jamboo	Kahyur	Leaves, Bulb- Leaves as vegetable/ Bulb as flavouring agent	0.55	0.5	HBJU16956
3.	<i>Amaranthus spinosus</i> L.	Amaranthaceae	Herb	Prickly Amaranth	Wan leesa	Leaves- Leaves cooked as vegetable	0.91	0.8	HBJU18364
4.	<i>Amaranthus viridis</i> L.	Amaranthaceae	Herb	Wild amaranth	Jangli Wasta hakh	Leaves- cooked as vegetable	0.91	0.8	HBJU18363
5.	<i>Anethum graveolens</i> L.	Apiaceae	Herb	Indian Dill	Sowa	Leaves, seeds- Spice/Condiment	0.79	0.7	HBJU16957

6.	<i>Angelica glauca</i> Edgew.	Apiaceae	Herb	Angelica	Chorai	Rhizome Spice/Condiment/Medicinal	0.53	0.5	HBJU16958
7.	<i>Arisaema jacquemontii</i> Blume	Araceae	Herb	Jacquemont's cobra lily	Sarf Goggal	Corm- boiled, peeled and cooked in oil and spices	0.52	0.5	HBJU16959
8.	<i>Arisaema propinquum</i> Schott	Araceae	Herb	Wallach's cobra lily	Jangli aloo	Corm- Corms pickled/cooked	0.52	0.5	HBJU16960
9.	<i>Berberis aristata</i> DC	Berberidaceae	Shrub	Tree turmeric	Kaw-dach	Fruits-eaten raw	0.62	0.8	HBJU17792
10.	<i>Berberis lycium</i> Royle	Berberidaceae	Shrub	Indian Barberry	Khumlai	Fruit Raw fruits eaten	0.77	0.8	HBJ16964
11.	<i>Berginia ciliata</i> (Haw.) Sternb.	Saxifragaceae	Herb	Winter Begonia	Zakhme hayat	Leaves -Leaves eaten for medicinal purpose, used for kidney ailments	0.69	0.6	HBJU16999
12.	<i>Bistorta amplexicaulis</i> (D.Don)Greene	Polygonaceae	Herb	Red Bistort	Chai mool, chai-patter	Root, leaves -used to prepare tea	0.94	0.8	HBJ16986
13.	<i>Blitum virgatum</i> L.	Amaranthaceae	Herb	Strawberry blite	Fruits	Fruit- Raw fruits eaten, leaves occasionally added to vegetables.	0.71	0.05	HBJU17794

14.	<i>Cannabis sativa</i> L.	Cannabaceae	Herb	Indian Hemp	Bhaeng	Leaves- Leaves used for fritters.	0.62	0.3	HBJU18367
15.	<i>Capsella bursa-pastoris</i> (L.) Medik	Brassicaceae	Herb	Shepherd's purse	Panja	Leaves - used as potherb	0.67	0.5	HBJU16615
16.	<i>Chaerophyllum reflexum</i> Lindl.	Apiaceae	Herb	Kashmir Chervil	Dodij	Leaves, tender shoot- Cooked as vegetable	0.72	0.6	HBJU16626
17.	<i>Chenopodium murale</i> (L.) S. Fuentes, Uotila & Borsch	Amaranthaceae	Herb	Nettle-leaved goosefoot	Wanleesa	Leaves - Cooked as vegetable	0.69	0.4	HBJU18378
18.	<i>Chenopodium album</i> L.	Chenopodiaceae	Herb	White Goosefoot	Kon	Leaves, seeds- Leaves cooked as vegetable, seeds used to make porridge	0.70	0.6	HBJU16625
19.	<i>Cichorium intybus</i> L.	Asteraceae	Herb	Common chicory	Kasni Hand	Leaves- Cooked as vegetable, useful for diabetics, taken for digestive and liver issues ; to reduce inflammation	1.31	1.0	HBJU16962

20.	<i>Corylus jacquemontii</i> Decne.	Betulaceae	Tree	Indian Hazel Nut	Wurien	Seed Kernel- eaten raw, pressed to extract oil	0.88	0.6	HBJU17793
21.	<i>Crataegus songarica</i> K.Koch	Rosaceae	Shrub	Hawthorn	Ringa	Fruit -Fruit eaten raw	0.90	0.8	HBJU16993
22.	<i>Descurainia sophia</i> (L.)Webb ex Prantl.	Brassicaceae	Herb	Flix weed	Lasji Beoul	Seeds - mixed with water consumed as laxative	0.78	0.6	HBJU18376
23.	<i>Diospyros lotus</i> L.	Ebenaceae	Tree	Date-plum	Amlok	Fruit- Raw fruit eaten in fresh or dried form	1.21	1.0	HBJU18368
24.	<i>Diplazium esculentum</i> (Retz.)Sw	Aspleniaceae	Herb	Fiddlehead fern	Daed, Kasrod	Young frond -cooked as vegetable, often cooked with milk/curd, taken for improving bowel health.	1.0	1.0	HBJ16963
25.	<i>Dipsacus inermis</i> Wall.	Caprifoliaceae	Herb	Himalayan teasel	Wopal Hakh	Leaves - cooked as vegetable	0.81	0.8	HBJ16966
26.	<i>Dryopteris ramosa</i> (C. Hope) C. Chr.	Polypodiaceae	Herb	Kunji	Waeni	Young frond -cooked as vegetable	0.79	0.7	HBJU17795

27.	<i>Elaeagnus umbellata</i> Thunb.	Elaeagnaceae	Shrub	Autumn olive	Guwaein	Fruit-eaten raw	0.91	0.9	HBJU16969
28.	<i>Eremurus himalaicus</i> Baker	Asphodelaceae	Herb	Himalayan fox tail lily	Kohl	Leaves-cooked as palatable vegetable, used as galactagogue	0.92	0.8	HBJU18377
29.	<i>Fagopyrum cymosum</i> (Trevir.) Meisn	Polygonaceae	Herb	Tall Buckwheat	Drow, fafru	Leaves- mixed/cooked with other leafy vegetables	0.82	0.7	HBJU16983
30.	<i>Fagopyrum esculentum</i> Moench	Polygonaceae	Herb	Common Buckwheat	Drow	Leaves mixed/cooked with other leafy vegetables for digestive issues, seeds consumed as flour	0.82	0.7	HBJ16982
31.	<i>Fagopyrum tataricum</i> (L.) Gaertn	Polygonaceae	Herb	Green Buckwheat	Chsokdrow, Fafru	Leaves- mixed/cooked with other leafy vegetables	0.82	0.7	HBJU16620
32.	<i>Ficus palmata</i> Forssk.	Moraceae	Tree	Wild fig	Faeg	Fruit-eaten raw, eaten to treat constipation., anaemia. Latex used for curdling milk.	1.2	1.0	HBJ16978
33.	<i>Fragaria vesca</i> L.	Rosaceae	Herb	Wild strawberry	Chanch	Fruit-eaten raw	1.0	1.0	HBJU16997

34.	<i>Impatiens glandulifera</i> Royle	Balsaminaceae	Herb	Himalayan Balsam	Gulmaenz	Young leaves, flowers edible	0.58	0.4	HBJU17791
35.	<i>Jurinea heteromalla</i> (D.Don) N.Garcia	Asteraceae	Herb	Kaliziri	Shamtu	Seeds consumed as carminative	0.56	0.4	HBJU16961
36.	<i>Koenigia polystachya</i> (Wall. Ex Meisn.) T.M.Schust.& Reveal	Polygonaceae	Herb	Himalayan knotweed	Amthila	Leaves-eaten cooked or raw, used for flavoring	0.66	0.5	HBJU16984
37.	<i>Lactuca perennis</i> L.	Asteraceae	Herb	Mountain Lettuce	Chsaire Dodij	Leaves, tender shoot cooked as vegetable	0.78	0.6	HBJU18366
38.	<i>Lathyrus aphaca</i> L.	Fabaceae	Herb	Yellow Pea	Burzul, jangli matar	Seeds consumed, leaves mixed with other vegetables	0.81	0.8	HBJU18382
39.	<i>Malva neglecta</i> Wallr.	Malvaceae	Herb	Common Mallow	Sochal	Leaves –cooked as vegetable, given for constipation and digestive issues, used as demulcent	1.21	1.0	HBJU16617

40.	<i>Malva parviflora</i> L.	Malvaceae	Herb	Cheeseweed	Wan Soechal	Leaves- cooked as vegetable, Fruit edible	1.12	1.0	HBJU18371
41.	<i>Medicago sativa</i> L.	Fabaceae	Herb	Lucerne	Watchch	Leaves mixed with other leafy vegetables	0.86	0.8	HBJU18381
42.	<i>Melilotus indicus</i> (L.) All.	Fabaceae	Herb	Yellow sweet clover	Jangli methi	Leaves mixed with other leafy vegetables.	0.83	0.8	HBJU18369
43.	<i>Mentha aquatic</i> L.	Lamiaceae	Herb	Marsh mint	Veina, Wan fatina	Leaves used for flavoring	1.12	0.9	HBJU18383
44.	<i>Mentha longifolia</i> (L.) L.	Lamiaceae	Herb	Wild mint	Jangli pudina	Leaves used for flavoring	1.12	1.0	HBJ16972
45.	<i>Morus alba</i> L.	Moraceae	Tree	White mulberry	Tael, Tuel	Fruit consumed	1.10	1.0	HBJU16977
46.	<i>Nasturtium officinale</i> W.T.Aiton	Brassicaceae	Herb	Watercress	Choo	Leaves, tender shoot cooked as vegetable	0.94	0.8	HBJ16965
47.	<i>Olea europea</i> L.	Oleaceae	Shrub	Common Olive	Kahu kul	Fruit eaten, used for obtaining oil	0.82	0.8	HBJU18372

48.	<i>Oxalis corniculata</i> L.	Oxalidaceae	Herb	Yellow Woodsorrel	Chsokaember, Ambli	Leaves used in chutneys.	0.92	0.5	HBJU16618
49.	<i>Oxyria digyna</i> (L.) Hill	Polygonaceae	Herb	Mountain sorrel	Chukru	Leaves used in flavoring or cooked with other vegetables	0.88	0.6	HBJ16980
50.	<i>Persicaria hydropiper</i> (L.) Delarbre	Polygonaceae	Herb	Water pepper	Chsukri	Leaves-added to vegetables during cooking.	0.76	0.7	HBJ16987
51.	<i>Phytolacca acinosa</i> Roxb.	Phytolaccaceae	Herb	Indian pokeweed	Ashrail, Asral	Young leaves mixed with others, cooked as vegetable, given for immunity.	0.98	0.8	HBJ16979
52.	<i>Pinus roxburgii</i> Sarg.	Pinaceae	Tree	Chir Pine	Yaedi Kuj	Seeds-eaten raw	0.61	0.6	HBJU18373
53.	<i>Plantago lanceolata</i> L.	Plantaginaceae	Herb	Ribwort Plantain	Gul	Leaves- mixed, cooked with other vegetables. Seeds used for treating constipation.	0.72	0.6	HBJU18374
54.	<i>Polygonum aviculare</i> L.	Polygonaceae	Herb	Prostrate Knotweed	Bhid Drob	Leaves-cooked as vegetable with mixed green leaves.	0.78	0.6	HBJU18379

55.	<i>Portulaca oleracea</i> L.	Portulacaceae	Herb	Common purslane	Nunnar	Leaves- cooked alone or mixed with other leafy vegetables.	1.12	1.0	HBJ16988
56.	<i>Potentilla indica</i> (Andrews) Th.Wolf	Rosaceae	Herb	Mock strawberry	Sarf chaench	Fruit-eaten raw	1.0	1.0	HBJU16998
57.	<i>Prinsepia utilis</i> Royle	Rosaceae	Shrub	Himalayan cherry	Jeentay	Fruit-seed used to obtain oil	0.76	0.7	HBJU16995
58.	<i>Prunella vulgaris</i> L.	Lamiaceae	Herb	Self-heal	Kal Wyoth	Flower, leaves-dried and used for medicinal tea	0.86	0.8	HBJ16975
59.	<i>Prunus armeniaca</i> L.	Rosaceae	Tree	Wild Apricot	Chsaer	Fruit-eaten raw, seed kernel pressed to obtain edible oil	1.21	1.0	HBJU16992
60.	<i>Punica granatum</i> L.	Lythraceae	Tree	Wild pomegranate	Daen	Fruit-seeds eaten raw, used for chutneys.	1.32	1.0	HBJU16976
61.	<i>Pyrus pashia</i> Buch.-Ham. ex D.Don	Rosaceae	Tree	Wild Himalayan pear	Tanji	Fruit-eaten raw	1.0	1.0	HBJU16994

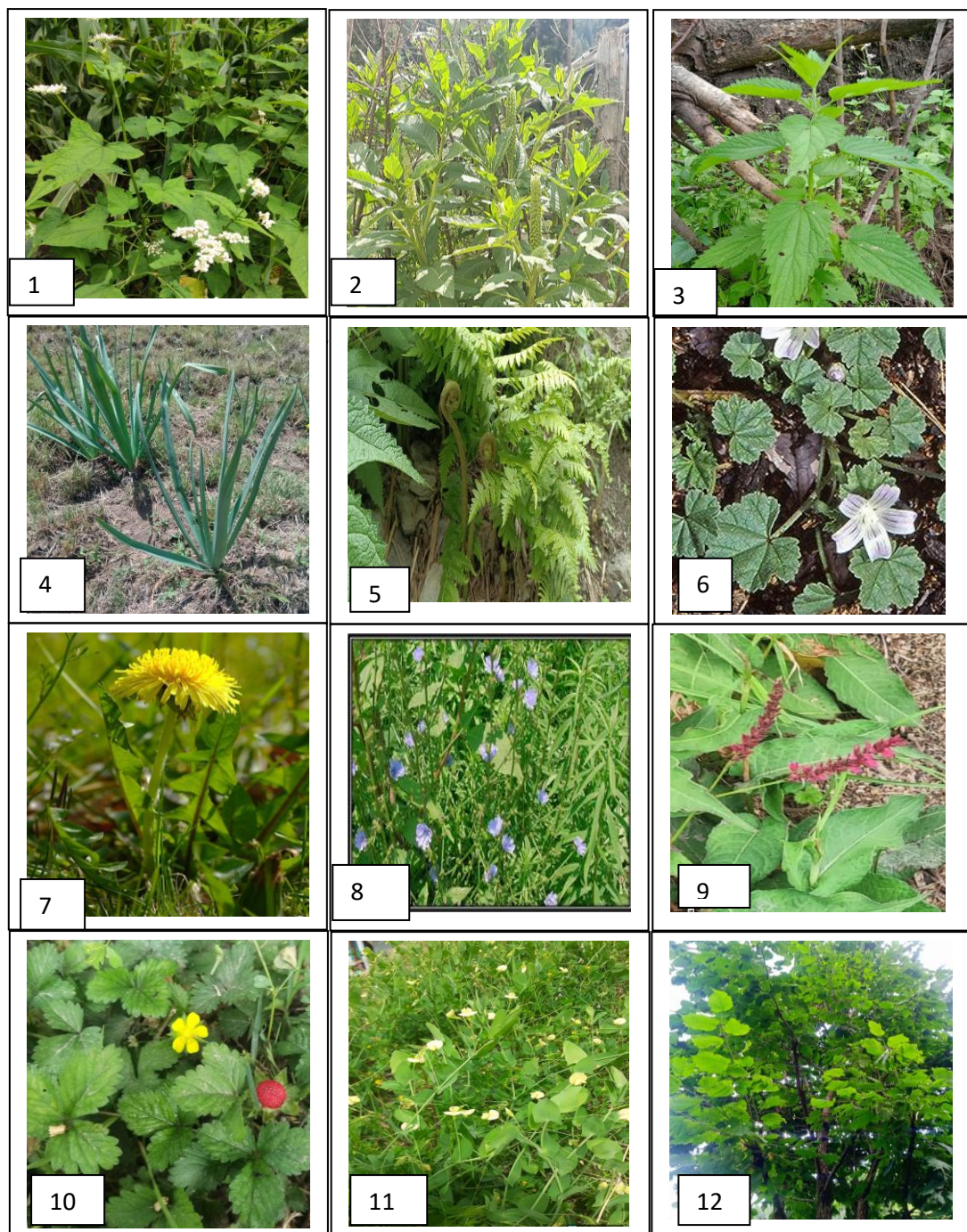
62.	<i>Ranunculus muricatus</i> L.	Ranunculaceae	Herb	Spiny fruit Buttercup	Changeer	Leaves-occasionally mixed ,cooked with leafy vegetables	0.53	0.02	HBJU18380
63.	<i>Rhododendron arboretum</i> Sm	Ericaceae	Shrub	Tree Rhododendron	Burshoo	Flower-used to prepare tea and cooling sherbet drink,	0.88	0.7	HBJU16970
64.	<i>Rosa macrophylla</i> Lindl.	Rosaceae	Shrub	Himalayan rose	Bangulab	Fruit-eaten raw	0.86	0.7	HBJU16990
65.	<i>Rosa moschata</i> Herrm.	Rosaceae	Liana	Musk rose	Jangli golab	Fruit eaten raw, Flower used for flavoring	0.84	0.7	HBJU16991
66.	<i>Rubus ellipticus</i> Sm.	Rosaceae	Climbing Shrub	Yellow Himalayan raspberry	Chanch	Fruit-eaten raw	1.0	1.0	HBJU16996
67.	<i>Rubus niveus</i> Thunb.	Rosaceae	Shrub	Hill Raspberry	Kraed Chaench	Fruit-eaten raw	1.0	1.0	HBJU16621
68.	<i>Rumex dentatus</i> L.	Polygonaceae	Herb	Aegean dock	Jangli palak	Leaves-cooked as vegetable	0.84	0.8	HBJU16985

69.	<i>Rumex hastatus</i> D.Don	Polygonaceae	Small Shrub	Arrowleaf dock	Halbaloo,	Leaves-cooked as vegetable	0.82	0.8	HBJ16981
70.	<i>Rumex nepalensis</i> Spreng.	Polygonaceae	Herb	Nepal Dock	Hubul	Leaves -cooked as vegetable	0.80	0.8	HBJU16619
71.	<i>Scandix pecten- veneris</i> L.	Apiaceae	Herb	Shepherd's needle	Wan Dainwal	Leaves- used as condiment	0.78	0.7	HBJU18365
72.	<i>Silene vulgaris</i> (Moench) Garcke	Caryophyllaceae	Herb	Bladder Campion	Wotta Karam	Leaves/young shoots - cooked as palatable vegetable	0.88	0.8	HBJU16616
73.	<i>Solanum nigrum</i> L.	Solanaceae	Herb	Black Nightshade	Kambai	Fruit- ripe fruit eaten for stomachache, leaves-mixed, cooked with leafy vegetables, given to jaundice patients.	0.96	0.9	HBJU16624
74.	<i>Solena heterophylla</i> Lour.	Cucurbitaceae	Climber	Himalayan creeping cucumber	Wan Laer	Fruit eaten as salad	0.78	0.7	HBJ16968
75.	<i>Stellaria media</i> (L.) Vill.	Caryophyllaceae	Herb	Chickweed	Koku	Leaves, tender shoot-cooked as vegetable	0.98	0.9	HBJ16967

76.	<i>Taraxacum officinale</i> (L.) Weber	Asteraceae	Herb	Common Dandelion	Handh	Leaves, Young shoot-blanchd and cooked as vegetable, consumed for anti-inflammatory effect, given to women after childbirth	1.99	1	HBJU16614
77.	<i>Taxus wallichiana</i> Zucc.	Taxaceae	Tree	Himalayan Yew	Kovud	Bark-decoction used as medicinal tea.	0.92	0.8	HBJU16623
78.	<i>Thymus serpyllum</i> L.	Lamiaceae	Herb	Wild thyme	Jangli ajwain	Leaves-used as condiment, given to treat stomachache	0.82	0.8	HBJ16974
79.	<i>Urtica dioica</i> L.	Urticaceae	Herb	Stinging nettle	Soie, Shaddar	Leaves-tender leaves cooked as vegetable, soup given to fever patients	1.12	0.9	HBJU17000
80.	<i>Viburnum grandiflorum</i> Wall ex DC	Viburnaceae	Shrub	Himalayan viburnum	Kul Maench	Fruit-ripe berries eaten.	1	1	HBJU16955
81.	<i>Vicia hirsuta</i> (L.) Gray	Fabaceae	Climbing Herb	Lentil	Jangli mosur	Seeds – unripe seeds eaten raw	0.81	0.6	HBJU18370

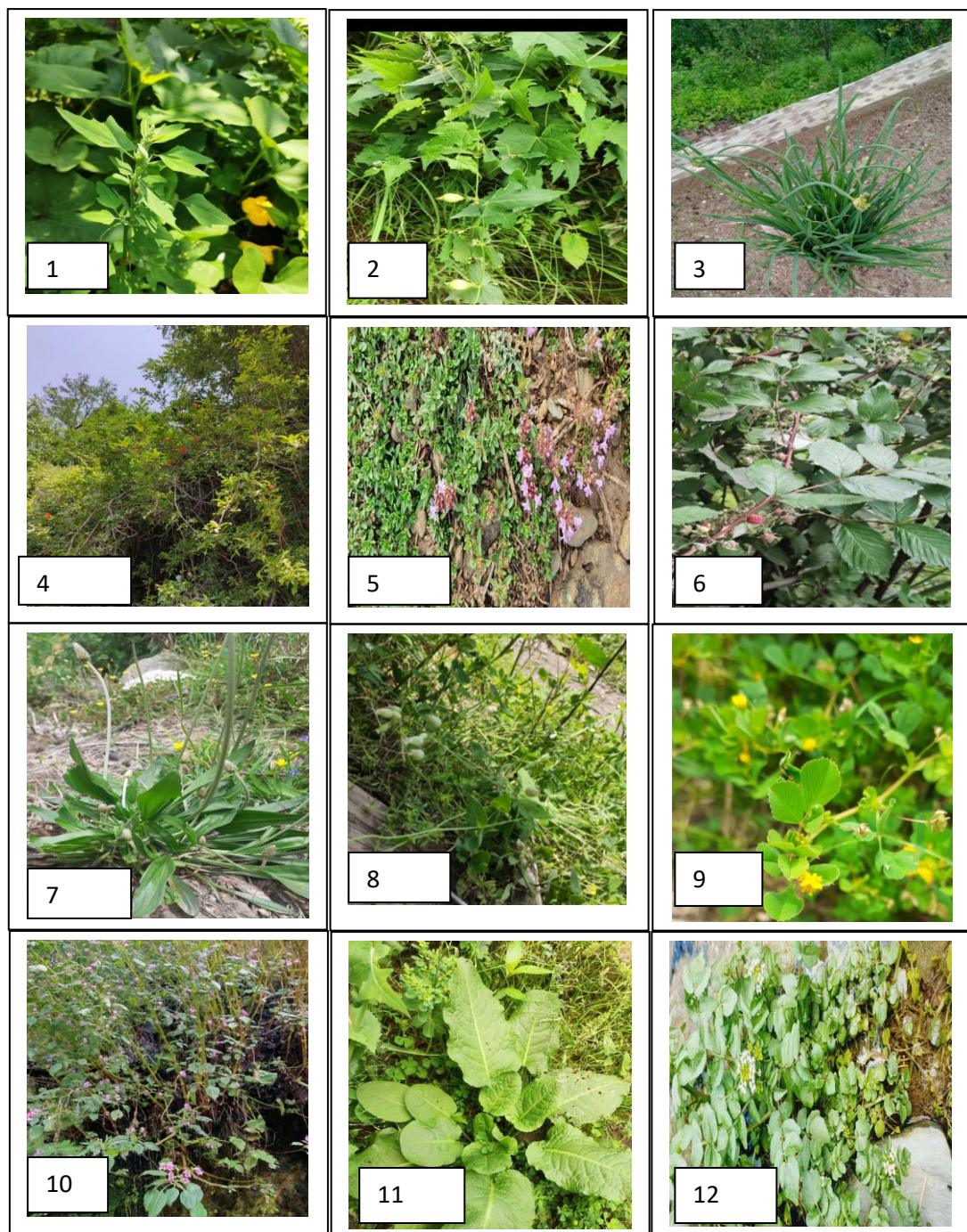
82.	<i>Vicia sativa</i> L.	Fabaceae	Climbing Herb	Garden vetch	Jangli matar	Fruit, seeds-eaten raw	0.81	0.7	HBJ16971
83.	<i>Viola canescens</i> Wall.	Violaceae	Herb	Sweet Violet	Banafsha	Leaves, Whole plant-decoction prepared with water used as herbal tea for cold,cough.	0.84	0.8	HBJU18375
84.	<i>Zanthoxylum armatum</i> (Thunb.) Druce	Rutaceae	Tree	Winged prickly ash	Tumru	Seeds-used as condiment,flavouring agent	0.62	0.4	HBJU17001
85.	<i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	Tree	Indian jujube	Baer	Fruit-consumed when ripe.	1.0	1.0	HBJ16989

Appendix-II : Photographs of some Wild Edible Plants Collected from the study area



Plates: 1. *Fagopyrum esculentum* 2. *Phytolacca acinosa* 3. *Urtica dioica* 4. *Eremurus himalaicus* 5. *Diplazium esculentum* 6. *Malva neglecta* 7. *Taraxacum officinale* 8. *Cichorium intybus* 9. *Bistorta amplexicaulis* 10. *Potentilla indica* 11. *Lathyrus aphaca* 12. *Corylus jaquemontii*

Appendix-II : Photographs of some Wild Edible Plants Collected from the study area



Plates: 1. *Chenopodium album* 2. *Solena heterophylla* 3. *Allium stracheyi* 4. *Punica granatum* 5. *Thymus serpyllum* 6. *Rubus niveus* 7. *Plantago lanceolata* 8. *Silene vulgaris* 9. *Medicago sativa* 10. *Impatiens glandulifera* 11. *Rumex nepalensis* 12. *Nasturtium officinale*

APPENDIX-III

List of Publications

1. "Assessment of potentially toxic elements in some wild edible plants of district Doda, Jammu and Kashmir, India." *Journal of Geochemical Exploration* 267 (2024): 107604. Sania Hamid, Devendra Kumar Pandey, and Deepika Singh

List of Papers Presented in Conferences

1. Paper presented in International Conference on Sustainability: Life on Earth 2021 (ICS-LOE2021) organized by Department of Botany and Zoology, School of Bio-engineering and Biosciences at Lovely Professional University, Punjab held on 17-18 December 2021.
2. Paper presented in 5th International Conference on Advances in Agriculture Technology and Allied Sciences on June 4-5, 2022.
3. Paper presented in Two Day International Conference on 'Ethnobiology: Present and Future perspectives' held at Government Degree College Billawar on 25-26 November, 2022.