

Nutritional Potential and Traditional Uses of High Altitude Wild Edible Plants in Eastern Himalayas, India

Hui Tag, Jambey Tsering, Pallabi Kalita Hui, Baikuntha Jyoti Gogoi, Vijay Veer

Abstract—The food security issues and its relevance in High Mountain regions of the world have been often neglected. Wild edible plants have been playing a major role in livelihood security among the tribal Communities of East Himalayan Region of the world since time immemorial. The Eastern Himalayan Region of India is one of the mega diverse regions of world and rated as top 12th Global Biodiversity Hotspots by IUCN and recognized as one of the 200 significant eco-regions of the Globe. The region supports one of the world's richest alpine floras and about one-third of them are endemic to the region. There are at least 7,500 flowering plants, 700 orchids, 58 bamboo species, 64 citrus species, 28 conifers, 500 mosses, 700 ferns and 728 lichens. The region is the home of more than three hundred different ethnic communities having diverse knowledge on traditional uses of flora and fauna as food, medicine and beverages. Monpa, Memba and Khamba are among the local communities residing in high altitude region of Eastern Himalaya with rich traditional knowledge related to utilization of wild edible plants. The Monpas, Memba and Khamba are the followers Mahayana sect of Himalayan Buddhism and they are mostly agrarian by primary occupation and also heavily relying on wild edible plants for their livelihood security during famine since millennia. In the present study, we have reported traditional uses of 40 wild edible plant species and out of which 6 species were analyzed at biochemical level for nutrients contents and free radical scavenging activities. The results have shown significant free radical scavenging (antioxidant) activity and nutritional potential of the selected 6 wild edible plants used by the local communities of Eastern Himalayan Region of India.

Keywords—East Himalaya, Local community, Wild edible plants, Nutrition, Food security.

I. INTRODUCTION

THE recent UN reports suggests that nearly 900 million people of the world still face hunger, while the malnourished population is estimated to be about two billion [1], [2]. It further suggests that malnutrition is a health threat especially affecting poor women and children [3]. Although nutrition and food security issues have been debated well before and a consensus opinion has been built across the globe among the scientists at UN forum but the food security issues and its specific relevance in high mountain regions have not been debated well [4]. In high altitude region of the world,

apart from few land races of local crop cultivars, wild edible plants are still playing a major role in supporting livelihood and food security of the local communities in developing countries like Africa and Asia [5]. In the recent decades, wild edible and medicinal plants used by ethnic communities of the developing nations have attracted the attention of many scientists across the globe as comparative studies of those traditionally used food and medicinal plants have lead to the discovery of many significant health benefit compounds including antioxidants and nutraceutical agent. It has been predicted that successful domestication of such potential wild edible plants could uplift the economic condition of poor farmers in rural localities [6].

A recent review by some international NGOs has revealed that the East Himalayan region is home to 144 species of economical significant food and medicinal plants and animal species which includes 36 species of globally significant plants, 45 species of mammals, 50 species of birds, 16 species of reptiles, 12 species of amphibians, 2 species of invertebrates which are mainly found endemic in the Eastern Himalayan Region of India [7].

The East Himalaya supports one of the world's richest alpine floras and about one-third of them are endemic to the region [8]. There are at least 7,500 flowering plants, 700 orchids, 58 bamboo species, 64 citrus species, 28 conifers, 500 mosses, 700 ferns, and 728 lichens. According to the World Wide Fund for Nature (WWF) & ICIMOD [9], the temperate broadleaved forests in the region are among the most species rich temperate forests in the world. Nearly 50% of the total flowering plants recorded in India are from the North Eastern region of India including Arunachal Himalaya. Further, the East Himalaya Region of the world has been rated as the 'cradle of flowering plants.' [10]. The region is also well known for its botanically curious and rare species such as *Magnolia*, *Coptis teeta* and *Sapria himalayana* discovered in Arunachal Himalayan Region of India. There are about 700 species of orchids in the North Eastern region of India alone. Of these, 545 species belonging to 122 genera are restricted to Arunachal Pradesh [11]. The genus *Rhododendron* of the *Ericaceae* family is remarkable group of showy plants with nearly 98% of them being confined to the East Himalaya and a substantial number of species being endemic to Arunachal Pradesh, Manipur, Sikkim and Mizoram [12].

The region is exceptionally rich in local culture, traditional knowledge and biodiversity. Some of the wild edible and medicinal plants found in the region are, *Centella asiatica*,

Hui Tag (Corresponding Author), Jambey Tsering, and Pallabi Kalita Hui are with the Pharmacognosy & Nutritional Biochemistry Research Laboratory, Centre of Biodiversity, Department of Botany, Rajiv Gandhi University, Rono Hills, Doimukh, Itanagar -791112, Arunachal Pradesh, India (Mobile number: +91 9436224195; e-mail: huitag2008rgu@gmail.com)

Baikuntha Jyoti Gogoi and Vijay Veer are with the Division of Phytochemistry, Defence Research Laboratory, Tezpur, Assam, India.

Diplazium esculentum, *Elaeagnus umbellata*, *Fragaria vesca*, *Houttuynia cordata*, *Litsea cubeba*, *Mentha arvensis*, *Panax bipinnatifidus*, *Phyllanthus emblica*, *Piper longum*, *Plantago major*, *Potentilla peduncularis*, *Psidium guajava*, *Pyrus pashia*, *Rhododendron arboreum*, *Ribes orientale*, *Rubus ellipticus*, *Urtica dioica*, *Zanthoxylum armatum* and *Zanthoxylum rhetsa* [13]. Interestingly, the North East India and Arunachal Himalayan Region have been identified as Indian centre for origin of cultivated crops and wild land races [14].

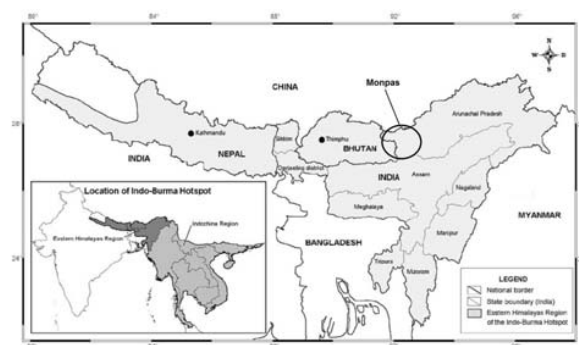


Fig. 1 Eastern Himalayan Region of India

Although the region is rich in both cultivated and wild edible plant resources, no systematic attempt has been made so far to document those high altitude wild plant species for further value addition research. The local communities residing in the high altitude region of East Himalayas are mostly dependent on upland agriculture with single cropping season. Winter receives heavy snowfall in those middle and high altitude region which restricts agricultural practices and other human activities. Due to topographic disadvantage and inclement weather pattern, agricultural productivity is low, resulting in large food deficits [15]. It further suggests that wild edible plants supplements not only the food quantity and diversity but also contributes to the essential nutrients required by human and provides economic benefits for poor farmers [16], [17]. Wild food and medicinal plants can play a prominent role in rescuing lives during the time of famine and war as those happened in Himalayan region of India during brief Indo-China border conflict in 1962 and 1965-1966 [18]. Domestication of nutrient rich plants and their commercialization can largely improve the poor economic condition and food insecurity of the rural people [19], [20]. Therefore, the present study is sought to appraise ethnobotanical uses and diversity of wild edible plants used by the local communities namely Monpa, Memba and Khamba residing in high altitude regions of East Himalaya and to validate its nutraceutical and marketing potential of selected unexplored wild edible plants which could possibly be used for ensuring future regional and global food security for people residing in high altitude region of the Himalayan and elsewhere temperate and alpine zone of the world.

II. STUDY AREA

Monpas in India are the local communities found in Tawang and West Kameng Districts of Arunachal Pradesh (East Himalaya). Almost 60% of high mountain ranges of Arunachal Pradesh are concentrated in Tawang and West Kameng Sector. Present study site is located between 26° 55' to 27° 52' N latitudes and between 91° 32' to 92° 55' to E longitudes (Fig. 1) covering total geographical area of 9,507 km² with elevations ranging from 200 meter in the foot hills region. Altitudinal gradient and slope increases gradually upto about 7,750m and the mountain ranges extending towards northern side. The entire region is steep mountainous terrain bounded by two international borders, China (Tibet) in the north and Bhutan in the west. Monpas, Memba and Khamba are mostly agrarian in nature and their source of living depends on some staple crops nurtured in upland agricultural field including Finger millet, Maize, Potato, Barley, Rice, Chili, etc. and domesticated animals like Yak, Sheep, Cow and Horse. The *Brokpa*, subtribe of Monpa lives in high altitude grassland and they are professional in Yak rearing and herding.

III. MATERIALS AND METHODS

A. Ethnobotanical Study

Quantitative ethnobotanical field methods suggested by Martin [21] and Begosi [22] were followed to assess the diversity and use of ethnobotanical resources and traditional knowledge status of local community. We have interviewed 140 informants with direct field exploration from 66 study sites (villages) mostly located in temperate and sub-alpine regions of West Kameng, Tawang and West Siang Districts of Arunachal Pradesh, India. The plant parts used, mode of consumption and vernacular names and associated local beliefs if any were recorded. The plant were identified and authenticated by Botanical Survey of India, Arunachal Regional Centre, Itanagar. Voucher specimen of each species were collected and deposited at Plant Systematic and Pharmacognosy Research Laboratory, Department of Botany, Rajiv Gandhi University, Doimukh, Arunachal Pradesh.

B. Plant sample for Nutraceutical Analysis

Based on ethnobotanical survey report gathered from 66 villages including both rural and sub-urban areas, only six plants with highest use value index (UVI) among total wild edible plants collected were considered for nutraceutical analysis. The plant sample were dried in shade and pulverized into small pieces.

C. Proximate Nutrient Analysis

All analyses were performed at dry matter basis (DM). Moisture content (MC), ash value (AV) and crude fat (CFT) were estimated following the procedure of Association of Official Analytical Chemistry [23]. Crude Fiber (CF) was determined by using Fibertech Hot Extraction Unit [24]. The crude protein (CP) was determined using micro Kjeldahl-titration method by multiplying the factor 6.25 with nitrogen

evaluated by the methods of Association of Official Analytical Chemistry [25].

The NFE and carbohydrate content were calculated as the weight difference (in %) using moisture content, ash value, crude fiber, crude fat, and crude protein [26]. Determination of α -tocopherol and carotene content of the plants materials were first includes the extraction of total lipid material from dried plant powder [27]. This was followed by extraction and estimation of α -tocopherol and carotene levels by the procedure of Rosenberg [28] using spectrophotometer.

D. Mineral Analysis

The method of Association of Official Analytical Chemistry [29] was followed for determination of mineral contents. Briefly, 0.2 gram of each samples were wet digested and Flame photometer was used for determination of Sodium (Na), Potassium (K) and Calcium (Ca) using standard reference. For determination of Nitrogen (N) and Phosphorus (P), 0.2g of sample was digested in 4.4ml digestion mixture at 120°C for 5 hours until the solution becomes colorless and any remaining solid white. The solution was filtered into a 100ml standard flask and made up to the mark with deionised water. From this solution N was determined using Kjeldahl apparatus and P by spectrophotometer at wavelength 880nm.

E. Preparation of Crude Extract

50g sample were mixed with 100ml methanol and kept for 1 day. The mixture was filtered through Whatman paper No.41. The residue was re-extracted twice with increasing time. The total filtrate was concentrated under vacuum rotary evaporator at 50°C and stored at -4°C until use.

F. Determination of Total Phenolic Content (TPC) and Antioxidant Property

TPC of plant extract was determined by the Folin-Ciocalteu's method with reduced volumes as described by Gogoi and his colleague [30]. The absorbance was measured at 765nm and the result was expressed as mg Gallic acid equivalent/gram dry extract weight (mg GAE/g extract). Antioxidant property of extract was determined by DPPH assay according to the method developed by Brand-Williams and his colleague [31] and Gogoi and his colleague recently [30]. Ascorbic acid and trolox were used as standards. The absorbance was measured at 517nm and IC₅₀ value (50 % inhibition concentration) was determined by plotting non-linear regression curve.

IV. RESULTS

A. Ethnobotanical Findings

The local residents residing in the high altitude region of Arunachal Himalayan have good knowledge on utilization of wild edible plants but most of this knowledge is concentrated only to yak herders, forest dwellers and people with low economic income. In the present study, only 06 species were found to be frequently used out of 40 species of wild edible identified to be used by local communities as alternative and supplementary food resources.

B. Nutritional Analysis of Ethnobotanical Significant Plants

In the present studies, the six plants with high Use Value Index (UVI) were selected for nutraceutical analysis viz. *Diplazium esculentum* (shoot), *Elaeagnus umbellata* (fruit), *Maianthemum purpureum* (shoot), *Oenanthe javanica* (shoot), *Panax bipinnatifidus* (tuber) and *Pyrus pashia* (leaves). The plants were collected from high altitude alpine and temperate regions where people are largely relying on wild foods and tubers. Shoots of *D. esculentum*, *M. purpureum* and *O. javanica* are consumed by the local tribal communities as green vegetables in both rural and urban areas. These plants were found to be distributed abundantly in the present study sites ranging from foothill region to 3700m altitude throughout temperate and sub-alpine forest, wasteland, agricultural land, streamside, marshy area and along roadside. The local tribal residents usually collect these leafy vegetables in large quantity, sundried and preserved for winter food security. The fruit of *E. umbellata* is eaten raw and also used for preparation of local fruit wine. Children are fond of fruit as the taste and flavor are sweet and stimulant. Some of these edible fruits have been frequently used for the treatment of diarrhea. These medicinal and food plants are widely distributed near sandy beds of rivers and streams at an altitude of 2000-3100m. The other two plants (*P. bipinnatifidus* and *P. pashia*) are mostly found in temperate broad leaved forest. The tuberous root, leaf and stem of *P. bipinnatifidus* are used in various traditional medicines and also consumed in raw form as health rejuvenating agent. Ripen fruits of *P. pashia* are eaten raw, tender leaves and twigs are used as fodder and fuel wood by the local residents.

C. Proximate Nutrient Contents

The proximate nutrient content of 6 species is presented in Table I. The nutrient content in all the species analyzed were in detected in significant quantity. The moisture content in six shade dried wild edible plants part ranged from (13-26)% and the ash content varied from (4-18)%. Significant quantity of crude protein content was detected in *M. purpureum*, *O. javanica* and *D. esculentum*. Crude fat content was determined to be 4-5% in *E. umbellata* and the three leafy vegetables, while it was 1-2 % in *P. bipinnatifidus* and *P. pashia*. Crude fibre was found maximum in *E. umbellata* (21.80%) and *P. pashia* (21.22%). It was found lowest in *P. bipinnatifidus* (3.99%). The carbohydrate content in three leafy vegetables i.e. *M. purpureum*, *O. javanica* and *D. esculentum* was estimated lower than the carbohydrate content of *E. umbellata*, *P. bipinnatifidus* and *P. pashia*, whose carbohydrate content was estimated more than 60% of the dry weight. Highest gross energy value was found in *E. umbellata* (3722.67 kcal/100g) followed by *P. pashia*, *M. purpureum*, *O. javanica*, *D. esculentum* and *P. bipinnatifidus*. The P/E value was found maximum in *M. purpureum*, *O. javanica* and *D. esculentum* and lowest in *P. pashia*.

D. Mineral and Vitamin Contents

Among the various micronutrients, potassium was present in highest quantity followed by calcium, sodium and

phosphorus (Table II). Potassium content varied from 0.29% (*E. umbellata*) to 1.75% (*P. bipinnatifidus*). Potassium content was also higher in *O. javanica* and *D. esculentum*. Calcium and sodium content was detected to be highest in *O. javanica* followed by *D. esculentum*, *M. purpureum* and *E. umbellata*. Phosphorus was found highest in *P. pashia*. A significant

amount of α -tocopherol was found in all the analyzed plant samples (18.45-55.02 mg/100g) except in *P. bipinnatifidus* which have such elements in traces amount (2.59 mg/100g). Both the vitamins analyzed (α -tocopherol and Carotenoid) were estimated highest in *P. pashia* leaves.

TABLE I
NUTRIENT CONTENTS OF SELECTED PLANTS

Component	<i>D. esculentum</i>	<i>E. umbellata</i>	<i>M. purpureum</i>	<i>O. javanica</i>	<i>P. bipinnatifidus</i>	<i>P. pashia</i>
Moisture (dry sample) %	21.69±1.22 b	13.99±0.27 d	12.93±1.74 d	13.73±0.20 d	24.95±0.61 c	26.33±0.39 a
Ash %	17.61±0.64 a	4.07±0.11 d	11.92±1.08 b	17.37±0.73 a	5.32±0.40 c	4.40±0.19 c,d
Crude Protein %	17.42±0.19 c	15.13±0.25 d	27.17±0.14 a	22.46±0.07 b	2.13±0.22 e	1.79±0.07 f
Crude Fat %	5.64±2.16 b	4.36±0.56 b	5.54±0.47 a	3.85±0.14 b	1.95±0.54 c	0.89±0.07 d
Crude Fibre %	12.69±1.39 b	21.80±0.71 a	10.16±0.67 c	7.58±0.27 d	3.99±0.09 e	21.22±1.18 a
Total Carbohydrate %	37.65±1.82 b	62.45±0.28 a	42.45±3.07 d	42.58±0.99 c	65.64±0.46 a	66.61±0.42 a
Gross energy (kcal/100g)	3416.93±35.62 b	3722.67±43.93 a	3375.87±48.37 c	3309.33±14.97 c	2887.53±38.54 d	2814.13±23.05 b
P/E (mg protein/kcal)	5.10±0.10 c	4.07±0.05 d	8.06±0.16 a	6.79±0.04 b	0.74±0.08 e	0.64±0.02 f

Values represent mean \pm SD of 3 replicates. Means sharing the same letter are not significantly different ($P=0.05$) using Duncan's multiple range test.

TABLE II
MINERAL AND VITAMIN CONTENTS OF SELECTED PLANTS

Component	<i>D. esculentum</i>	<i>E. umbellata</i>	<i>M. purpureum</i>	<i>O. javanica</i>	<i>P. bipinnatifidus</i>	<i>P. pashia</i>
Na %	0.36±0.01 d	0.47±0.02 c	0.53±0.03 b	0.65±0.01 a	0.13±0.03 e	0.09±0.00 e
K %	1.12±0.02 c	0.29±0.02 f	0.73±0.01 e	1.29±0.01 b	1.75±0.06 a	0.80±0.01 d
Ca %	1.29±0.01 b	0.81±0.05 d	1.09±0.03 c	1.44±0.02 a	0.75±0.11 d	0.65±0.04 e
P %	0.08±0.00 b c	0.10±0.00 a,b,c	0.07±0.01 c	0.06±0.00 c	0.10±0.04 a,b	0.13±0.01 a
α -tocopherol (mg/L)	18.45±0.07 e	19.51±0.56 d	25.56±0.31 c	29.12±0.96 b	2.59±0.28 f	55.02±0.35 a
Carotenoid (mg/L)	0.002±0.0002 c	0.003±0.0002 b	0.002±0.0002 c	0.003±0.0003 a	0.003±0.0003 c	0.083±0.0009 b

Values represent mean \pm SD of 3 replicates. Means sharing the same letter are not significantly different ($P=0.05$) using Duncan's multiple range test.

E. Extract yield, TPC and Antioxidant activity

Yield of extract was found highest in *P. bipinnatifidus* (43.79%) and *P. pashia* (18.48%) as given in Table III. TPC was detected highest in *P. pashia* leaf extract (356.47mg/g GAE or 35.6%), followed by shoot extract of *O. javanica* (36.42mg/g GAE) and *M. purpureum* (19.82mg/g GAE). TPC in other three samples was very low. As antioxidant and free radical scavenging potential of a plant is largely contributed by the presence of phenolic compounds, and in the present studies, *P. pashia* leaf extract which had the highest phenolic content showed maximum scavenging activity among the six plants extract (Fig. 2). The IC₅₀ value of *P. pashia* i.e. concentration of extract required to inhibit DPPH free radical by 50% was estimated at 28.97 μ g/ml. The IC₅₀ values of standards trolox and ascorbic acid were determined as 4.43 μ g/ml and 8.71 μ g/ml respectively (Table III). *O. javanica* also showed potent free radical scavenging activity with IC₅₀ value of 94.00 μ g/ml. The other plant samples had little to low antioxidant properties.

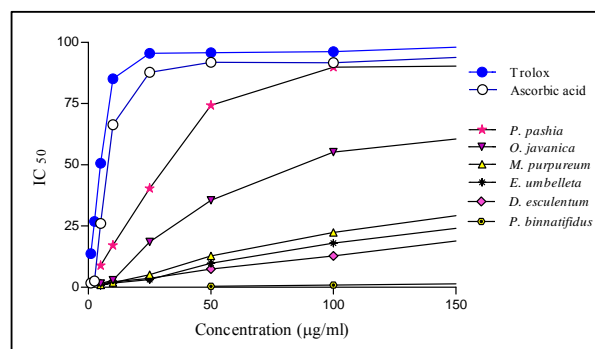


Fig. 2 DPPH free radical scavenging activity of standard and selected plants

TABLE III
EXTRACT YIELD, TOTAL PHENOLIC CONTENT AND INHIBITION CONCENTRATION OF STANDARDS AND SELECTED PLANTS

Standard/sample	Yield of extract (%)	TPC (mg/g; GAE/extract)	Inhibition concentration IC ₅₀ (μ g/ml)
Trolox	-	-	4.43±0.28 d
Ascorbic acid	-	-	8.71±0.26 d
<i>D. esculentum</i>	5.47	6.97±1.31 d	370.13±9.44 b
<i>E. umbellata</i>	3.78	7.67±0.77 d	346.13±13.55 b,c
<i>M. purpureum</i>	7.55	19.82±1.42 c	234.07±8.47 b,c,d
<i>O. javanica</i>	6.80	36.42±1.86 b	94.00±2.10 b,c,d
<i>P. bipinnatifidus</i>	43.79	0.32±0.34 e	3564.67±493.29 a
<i>P. pashia</i>	18.48	356.47±3.01 a	28.97±0.90 c,d

Values represent means \pm SD of 3 replicates. Means sharing the same letter are not significantly different ($P=0.05$) using Duncan's multiple range test

V. DISCUSSION

The local tribal communities residing in the Arunachal Himalaya are well versed in traditional knowledge and utilization of their native flora and fauna. They used a variety of both plant and animal parts in their traditional local recipe as well as for the treatment of various diseases [32]. With the limitation of cultivable agricultural land and single cropping season, people have made good use of wild edible plants as a source of food security since time immemorial [33]. Wild edible plants offer variety in family diet and contribute to house hold food security among the tribal communities of East Himalayan region of India [34]. In the present study, a diverse wild edible plants was found to be used by the local tribal communities residing in high mountain regions of Eastern Himalaya. A total of 40 wild edible plants were identified but the more species could be identified in course of further field research. Most of the plant parts are consumed in raw form and doesn't require sophisticated processing system and number of species used in such local herbal recipes is substantial [19], [35]. With advancing modern knowledge system and innovative agricultural technology, tribal communities of East Himalaya have started cultivating a number of both native and exotic cash crop species of high trade and commercial value [36], [37]. Even though, the local residents collect a good number of wild plants mostly green leaves and fruits from their community forest land for local consumption and to mitigate nutritional deficiency by supplementing leafy vegetable of high antioxidant and nutritional potential. Due to easy accessibility and availability of wild edible plants, market potential within the region had not boost till date as people directly collect plants from the wild. However, awareness campaign on commercial significance of such valuable botanical resources may lead to change in the current demand and supply trends of wild edible plants in the local and regional market. As for example *P. bipinnatifidus* was found to have increasing its use value in the last few decades due to its recognition as medicinal plants. Earlier, the people had little knowledge about the medicinal value of this plant as only some traditional medicine man use the tuber in the preparation of some decoction for the treatment of a variety of diseases, but now the plant is widely cultivated in home gardens. The tuber is largely used as food additives in a variety of item including local wine, vegetables, tea and herbal medicine decoction which had increased its demand in unorganized market sector within the region itself. Another plant with high use value index is the leaves of *P. pashia*. The dried leaves are used as coloring agent for preparation of butter tea among local *Monpa* tribes which is still quite popular in both rural and urban areas. Literature survey confirms that *P. pashia* is an important ethnobotanical plants but consumption of its leaves as beverage (tea) was unique to *Monpa* community [38]. Antioxidant potential detected in present studies on *P. pashia* fruits has further open up scope for wider applications.

In the present investigation, nutraceutical value of six wild edible plants which shows highest UVI are presented. High crude protein content was determined in leafy vegetables

which were more as compared to those reported by various authors from other Himalayan region [39], [40]. The crude fat and crude fibre content were determined higher as compared to other commercial fruits investigated by earlier workers [35]. The macro-elements were also comparable to other wild edible plants reported by the previous workers which is within the tolerable limit [35], [41]. A good quantity of α -tocopherol was also detected in the all aerial parts of the plants and it was found lower in tuber of *P. bipinnatifidus* which is an underground part.

Phenolic compound have been found in all six species, whereas such compounds were found responsible for antioxidant activity [42]-[44]. Phenolic compound determined as gallic acid equivalent was detected to be very high in *P. pashia* and *O. javanica*. These two species also showed potent free radical scavenging activity, which indicates positive correlation between total phenolic compound and antioxidant activity. This high value of nutrient contents and high UVI directly indicates that the wild edible plants have been preferred as major source of nutrients supplement for maintaining proper health among the rural residents.

The present study provides firsthand information to both scientific community, defence personnel posted in high altitude region of the world, and local tribal communities of the Eastern Himalayan region. The nutrient rich plants can be recommended for commercialization which may boost up local economy of the tribal community and would ensure health and food security in middle and high altitude residents where transportation and communication system has been remain as a challenging factor which acts impediment to developmental process in the region.

VI. CONCLUSION

Wild edible plants used by the local communities - *Monpas*, *Memba*, and *Khamba* residing in the East Himalayan region are remarkable. The present study has documented 40 wild edible plants which are primarily consumed in raw form and doesn't require sophisticated processing. A variety of traditional recipes prepared out these wild edible are found to be nutritious and anti-oxidant potential. These plants are would sufficiently support the local population during the time of war and famine. Most of the edible plant parts are available only during spring and summer season. However, local communities have rich traditional knowledge related to wise use of wild edible plants to ensure food security through traditional drying and storage methods. Biochemical analysis of some frequently harvested plant parts shows that wild edible plant are good source of natural protein, fibre, carbohydrates, minerals and vitamins which are essential for balancing dietary deficiency. Shoots of *O. javanica* and leaves of *P. pashia* were found to have potential antioxidant properties. These two plants are widely distributed along temperate regions due to numerous and small seed size. Artificial propagation system may be promoted for production of raw material in commercial scale which may ultimately improve the rural livelihood of the tribal population.

ACKNOWLEDGMENT

This study is a part of the project funded by the Defence Research Laboratory (DRL), Tezpur under Defence Research and Development Organization (DRDO), Ministry of Defence, Government of India. We are grateful to the respondents and local facilitators for their active participation in this study and sharing their valuable traditional knowledge. We are also thankful to UGC, New Delhi, Government of India for partial funding support through Centre with Potential for Excellence in Biodiversity Project and Vice Chancellor, Rajiv Gandhi University, Doimukh, Itanagar, India, and Scientist i/c, G. B. Pant Institute of Himalayan Environment and Development (GBPIHED), Vivek Vihar, Itanagar, India, for providing logistic and laboratory facilities.

REFERENCES

- [1] FAO, WFP, & IFAD, *The State of Food Insecurity in the World 2012. Economic Growth is Necessary but Not Sufficient to Accelerate Reduction of Hunger and Malnutrition*, Rome, 2012. pp. 3-35.
- [2] FAO, *The State of Food and Agriculture, Food Systems for Better Nutrition*, Rome, 2013, pp. 5-67.
- [3] FAO, *Gender and Nutrition*, <http://www.fao.org/docrep/012/al184e/al184e00.pdf>, 2010, pp-3-96. Accessed 28 January 2013.
- [4] J. Dame & M. Nusser, "Food Security in High Mountain Regions: Agricultural Production and the Impact of Food Subsidies in Ladakh, Northern India," *Food Security*, Vol. 3, 2011, pp. 179-194.
- [5] A. Afolayan, & F. Jimoh, "Nutritional Quality of Some Wild Leafy Vegetables in South Africa," *International Journal of Food Science and Nutrition*, 60(5), 2009, pp. 424-431.
- [6] Z. Bharucha & J. Pretty, "The Roles and Values of Wild Foods in Agricultural Systems," *Philosophical Transactions of the Royal Society B- Biological Sciences*, Vol. 365, (2010), pp. 2913-2926.
- [7] CEPF, *Ecosystem Profile: Indo-Burman Hotspot, Eastern Himalayan Region*. US-Asian Programme/ CEPF, WWF- Kathmandu, 2005.
- [8] U. Dhar, Conservation Implications of Plant Endemism in High-Altitude Himalaya. *Current Science*, Vol. 82, 2002, pp. 141-148.
- [9] WWF & ICIMOD, *Ecoregion-Based Conservation in the Eastern Himalaya: Identifying Important Areas for Biodiversity Conservation*. Kathmandu: WWF-Nepal, 2001.
- [10] A. Takhtajan, *Flowering Plants: Origin and Dispersal*. Edinburgh: Oliver & Boyd, London, 1969.
- [11] H. J. Chowdhery, *Orchid flora of Arunachal Pradesh*. Bishen Singh and Mahendra Pal Singh, Dehradun (India), 1998. pp. 8-40.
- [12] U.C.Pradhan & S.T. Lachungpa, *Sikkim Himalayan Rhododendrons*. Kalimpong (West Bengal), India, 1990, pp. 8-78.
- [13] H. Tag & J. Tsering, *Ethnobotanical Study and Nutritional Analysis on Middle and High Altitude Wild Edible Flora of West Kameng and Tawang Sector of Arunachal Pradesh for Defence Food Security*. Technical Report, DRL, Defence Research Laboratory, Defence R&D Organization, Ministry of Defence, Post Bag No.2, Tezpur-Assam-784001 (India), 2012, pp-3-98.
- [14] N.I. Vavilov, *Studies in the Origin of Cultivated Plants*. Institute of Applied Botany and Plant Breeding, Leningrad, 1926, pp. 20-150.
- [15] H. Tag, G. Murtem, A.K. Das, & Ranjay K. Singh, "Diversity and Distribution of Ethnomedicinal Plants Used by Adi Tribe of East Siang District of Arunachal Pradesh, India," *Pleione*, vol. 2(1), 2008, pp. 123-136.
- [16] A. Aberoumand & S.S. Deokule, "Determination of Elements Profile of Some Wild Edible Plants," *Food Analytical Methods*, Vol. 2(2), 2009, pp. 116-119.
- [17] FAO, *Use and Potential of Wild Plants in Farm Households*. FAO Rome, Italy, 1999.
- [18] M.T. Fentahun & H. Hager, "Exploiting Locally Available Resources for Food and Nutritional Security Enhancement: Wild Fruits Diversity, Potential and State of Exploitation in the Amhara Region of Ethiopia," *Food Security*, Vol. 1(2), 2009, pp. 207-219.
- [19] A.K. Mahapatra, & P.C. Panda, "Wild Edible Fruit Diversity and Its Significance in the Livelihood of Indigenous Tribals: Evidence from Eastern India," *Food Security*, Vol. 4(2), 2012, pp. 219-234.
- [20] M. Sundriyal & R.C. Sundriyal, "Wild Edible Plants of the Sikkim Himalaya: Values of Selected Species," *Economic Botany*, Vol. 58(2), 2004, pp. 286-299.
- [21] M.J. Martin, *Ethnobotany: A Methods Manual*. People and Plants Conservation Series, Earthscan, UK and USA, 2004.
- [22] A. Begossi, "Use of Ecological Methods in Ethnobotany: Diversity Indices," *Economic Botany*, Vol. 50(3), 1996, pp. 280-289.
- [23] AOAC, *Official Methods of Analysis*, 17th Ed., AOAC International Gaithersburg, Md., 2000.
- [24] Tecator, *Determination of Crude Fibre in Some Feed and Food Samples Using the Fibertec System and the Weende Method*, Application Note, AN 01/78-91, Tecator Ltd, Hoganes, Sweden, 1991.
- [25] AOAC, *Official Methods of Analysis*, 17th Eds., AOAC International Gaithersburg, Md., 2002.
- [26] B. Singh & N.P. Todaria, "Nutrients Composition Changes in Leaves of *Quercus semecarpifolia* at Different Seasons and Altitudes," *Annals of Forest Research*, Vol. 55(2), 2012, pp. 189-196.
- [27] J. Folch, M. Lees & G.H.S. Stanley, "A Simple Method for the Isolation and Purification of Total Lipids from Animal Tissues," *Journal of Biological Chemistry*, Vol. 266(1), 1957, pp. 497-509.
- [28] H.R. Rosenberg, H. R. *Chemistry and Physiology of the Vitamins*. Interscience Publisher, New York, 1992..
- [29] AOAC, "Official Methods of Analysis," 15th Ed., AOAC" Washington DC, USA, 1990.
- [30] B.J. Gogoi, J. Tsering, H. Tag & V. Veer, "Antioxidant Potential of *Garcinia* Species from Sonitpur District, Assam, North East India," *International Journal of Pharmaceutical Sciences and Research*, Vol. 3(9), 2012, pp. 3472-3475.
- [31] W. Brand-Williams, M.E. Cuvelier, & C. Berset, "Use of a Free Radical Method to Evaluate Antioxidant Activity," *LWT- Food Science and Technology*, Vol. 28(1), 1995, pp. 25-30.
- [32] T.K Hazarika, Lalramchuana & B.P. Nautiyal, "Studies on Wild Edible Fruits of Mizoram, India Used as Ethno-Medicine," *Genetic Resources and Crop Evolution*, Vol. 59, 2012, pp. 1767-1776.
- [33] M. Sundriyal, R.C. Sundriyal, E. Sharma, & A.N. Purohit "Wild Edibles and Other Useful Plants from the Sikkim Himalaya, India," *Oecologia Montana*, Vol. 7, 1998, pp. 43-54.
- [34] Y.J. Yumnam, S.I. Bhuyan, M.L. Khan & O.P. Tripathi, "Agro-Diversity of East Siang-Arunachal Pradesh, Eastern Himalaya," *Asian Journal of Agricultural Sciences*, Vol. 3(4), 2011, pp. 317-326.
- [35] M. Sundriyal & R.C. Sundriyal, "Wild Edible Plants of Sikkim Himalaya: Nutritive Values of Selected Species," *Economic Botany*, Vol. 55(3), 2001, pp. 377-390.
- [36] M. Sankaran, J. Prakash, N.P. Singh & A. Suklabaidya, "Wild Edible Fruits of Tripura," *Natural Product Radiance*, Vol. 5(4), 2006, pp. 302-305.
- [37] P.C. Tiwari, & B. Joshi, "Natural and Socio-Economic Factors Affecting Food Security in the Himalayas," *Food Security*, Vol. 4(2), 2012, pp. 195-207.
- [38] J. Tsering, B.J. Gogoi & H. Tag, "Ethnobotany and Phytochemical Analysis of *Pyrus pashia* Leaves," *International Journal of Pharmaceutical Sciences and Research*, Vol. 3(8), 2012, pp. 2721-2725.
- [39] R. K. Maikhuri, "Nutritional Value of Some Lesser- Known Wild Food Plants and Their Role in Tribal Nutrition: A Case Study in North East India," *Tropical Science*, Vol. 31(4), 2009, pp. 397-405.
- [40] S. Mann, D. Gupta, & R.K. Gupta, "Evaluation of Nutritional and Antioxidant Potential of Indian Buckwheat Grains," *International Journal of Traditional Knowledge*, Vol. 11(1), 2012, pp. 40-44.
- [41] T. Seal, "Determination of Nutritive Value, Mineral Contents and Antioxidant Activity of Some Wild Edible Plants from Meghalaya State, India". *Asian Journal of Applied Sciences*, 4(3), 2011, pp. 238-246.
- [42] A.G. Ayoola, S.S. Ipav, M.O. Sofidiya, A.A. Adepoju-Bello, A. B. Coker, & T.O. Odugbemi, "Phytochemical Screening and Free Radical Scavenging Activities of the Fruits and Leaves of *Allanblackia floribunda* Oliv (Guttiferae)," *International Journal of Health Research*, Vol. 1(2), 2008, pp-87-93.
- [43] R.A. Chavez-Santoscoy, J.A. Gutierrez-Urbe & S.O. Serna-Saldivar, "Phenolic Composition, Antioxidant Capacity and *in vitro* Cancer Cell Cytotoxicity of Nine Prickly pear (*Opuntia* spp.) Juice," *Plant Foods for Human Nutrition*, vol. 64(2), 2009, pp. 146-152.
- [44] I. Egea, P. Sanchez-Bel, F. Romojaro, & M.T. Pretel, "Six Edible Wild Fruits as Potential Antioxidant Additives or Nutritional Supplements," *Plant Foods for Human Nutrition*, Vol. 65(2), 2010, pp. 121-129.