# DIVERSITY AND PHYTOCHEMICAL STUDY OF SOME WILD EDIBLE VEGETABLES IN AIZAWL DISTRICT OF MIZORAM

**A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY**

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**Submitted**
**In partial fulfilment of the requirement of the Degree of Doctor of Philosophy in Botany of Mizoram University, Aizawl.**

# CERTIFICATE

This is to certify that Ms. **Rosie Lalmuanpuii** has submitted the thesis entitled “**Diversity and Phytochemical Study of Some Wild Edible Vegetables in Aizawl District of Mizoram**” under my supervision, for the requirement of the award of the Degree of Doctor of Philosophy in the Department of Botany, Mizoram University, Aizawl. The work is authentic, content of the thesis is the original work of the Research Scholar, and the nature and the presentation of the work are the first of its kind in Mizoram.

It is further certified that no portion(s) or part(s) of the content of the thesis has been submitted for any degree in Mizoram University or any other University or Institute.

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# DECLARATION

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November, 2020

I **Rosie Lalmuanpuii**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to do the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/ Institute.

This is being submitted to the Mizoram University for the degree of Doctor of Philosophy in Botany.

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# LIST OF ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| **WEVs** | Wild edible vegetables |
| **%** | Percentage |
| **<** | Less than |
| **>** | Greater than |
| **±** | Plus or minus |
| **≤** | Less than or equal to |
| **µg/ml** | Microgram per millilitre |
| **µl** | Microlitre |
| **1-D** | Simpson's index of dominance |
| **A.A** | Ascorbic acid |
| **A/F** | Abundance to frequency ratio |
| **ABTS** | 2,2'-azinobis, 3-ethylbenzothiazoline-6- sulfonic acid |
| **ANOVA** | Analysis of variance |
| **AOAC** | Association of Official Analytical Chemistry |
| **BSI** | Botanical survey of India |
| **CBH** | Circumference at Breast Height |
| **Conc.$HNO_3$** | Concentrated nitric acid |
| **$CuSO_4$** | Copper sulphate |
| **DMR** | Direct matrix ranking |
| **DMSO** | Dimethyl sulfoxide |
| **DPPH** | 2,2'-diphenyl-2-picrylhydrazyl |
| **DW** | Dry Weight |
| **e.g.** | Exempli gratia: For example |
| **et al.,** | "et alia": and others |
| **etc.** | Et cetera: and other things |
| **FAO** | Food and Agricultural Organisation |
| **$F_{ic}$** | Informant consensus factor |
| **Fl** | Fidelity level |
| **ft** | Feet |
| **g** | Gram |
| **h** | Hour |

| | |
|---|---|
| **H'** | Shannon Diversity Index |
| **$H_20$** | Water |
| **$H_2O_2$** | Hydrogen peroxide |
| **$H_2SO_4$** | Sulphuric acid |
| **$ha^{-1}$** | Per Hectare |
| **HCl** | Hydrochloric acid |
| **hrs** | Hours |
| **i.e.** | id est: that is |
| **IUCN** | International Union for Conservation of Nature |
| **IVI** | Important Value Index |
| **Kcal/100g** | Kilocalorie per 100 Gram |
| **$km^2$** | Square Kilometres |
| **kms** | Kilometres |
| **m** | Metre |
| **mg** | Milligram |
| **mg GAE/g** | milligram Gallic acid equivalent per Gram |
| **mg QE/g** | milligram Quercetin equivalent per Gram |
| **mg/100g** | Milligram per hundred Gram |
| **mg/g** | Milligram per Gram |
| **mg/kg** | Milligram per Kilogram |
| **mg/ml** | Milligram per Millilitre |
| **ml** | Millilitre |
| **mM** | Milli Molar |
| **mm** | Millimetre |
| **MP-AES** | Microwave Plasma Atomic Emission Spectroscopy |
| **MTCC** | Microbial Type Culture Collection |
| **N** | Normality |
| **$Na_2CO_3$** | Sodium carbonate |
| **NaOH** | Sodium hydroxide |
| **nm** | Nanometre |
| **O.D** | Optical Density |
| **$^oC$** | Degree Celsius |
| **PAST** | Paleontological Statistics Software Package for Education and |

| | |
|---|---|
| | Data Analysis |
| **Pet. ether** | Petroleum ether |
| **Ppt** | Precipitate |
| **R** | Correlation Coefficient |
| **$R^2$** | Coefficient of Determination |
| **ROS** | Reactive Oxygen Species |
| **rpm** | Revolution per minute |
| **SD** | Standard Deviation |
| **SE** | Standard Error |
| **SEM** | Standard Error Mean |
| **TFC** | Total Flavonoid Content |
| **TPC** | Total Phenolic Content |
| **UV-Vis** | Ultraviolet visible |
| **W/V** | Weight by Volume |
| **W/W** | Weight by Weight |
| **WHO** | World Health Organisation |
| **wt** | Weight |

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# CHAPTER I

# 1. Introduction

## 1.1 General introduction on wild edible vegetables

Wild edible vegetables (WEVs) refer to edible species that are not cultivated nor domesticated but harvested from the wild natural habitats and used as food for human consumption (Heywood, 2011; Seal, 2012). Food and Agriculture Organization (FAO) of the United Nations defines WEVs as “plants that grow spontaneously in self-maintaining populations in natural or semi-natural ecosystems and can exist independently of direct human action” (Heywood, 1999). In this regard, all plants that are gathered (not cultivated) are considered wild; including species harvested in agricultural areas as well as forest land (Termote, 2011).

The mode of consumption of WEVs differs among different ethnic communities worldwide, they can be consumed whole plants or in parts either raw or cooked as part of a salad or can be used as the main dish. WEVs play an important role in the livelihood of humankind; they provide a valuable food source among the indigenous people and one of the primary sources of income for the rural communities globally (Uprety et al., 2012). In many developing countries, WEV plays a significant role in safeguarding food security and improve nutrition in their diets (Ghorbani et al., 2012), moreover, they offer opportunities to the communities to cope with food scarcity (Ruffo et al., 2002). This is also known as ecosystem-based adaptation (EbA) (Perez et al., 2010). The usage of WEVs is generally reported as particularly important during the period of food shortage as they enhance livelihood, survival strategies, and support household economies (Ladio, 2001; Maroyi, 2011).

WEVs are the precious gift of nature upon which most of the ethnic communities strongly depend for their daily requirements, they not only provide food but also makes a significant contribution to meet the nutrient requirements of human throughout the year (Ogle et al., 2003; Reyes-Garcia et al., 2005). They are the crucial contributors of essential nutrients, minerals, and vitamins for the ethnic people (Ogle and Grivetti, 1985) thereby reducing the vulnerability of local people to food insecurity, famine, or conflict (Balemie and Kebebew, 2006). Sometimes the nutritional contents of WEVs are superior to the domesticated varieties (Msuya et al., 2010). They are also recognized for their characteristic colour, flavour, and therapeutic value which can be used to prevent nutrient deficiency and degenerative diseases (Gupta and Prakash, 2009).). Besides, they constitute the potential birthplace of species for domestication and provide valuable genetic traits for new crop production through breeding and selection (Pandey et al., 2008).

WEVs have been used by human beings since time immemorial as food, medicine, fodder, and many other purposes, their use has been reported from many parts of the world (Pieroni et al., 2007). Nearly 75,000 species of wild plants are believed to be edible (King, 1994). Despite the primary practice of agricultural systems on conventional crop plants, the traditional consumption of WEVs has never been disappeared (Balemae and Kebebew, 2006). Indeed, FAO in its state of food insecurity in the world report estimated that around one billion people use WEVs in their diet (FAO, 2009) but, many valuable food resources still need to be explored and documented (Mohan Ram, 2000).

WEVs are generally gathered from different habitats like the forest, cultivated lands, and even anthropogenically disturbed areas such as roadsides and wastelands by different traditions throughout the world. A large number of ethnic people and local populace residing in many developing countries draw a significant part of their subsistence and livelihood from wild plants (Schippmann et al., 2002). Besides these, they hold an important position in the traditional, cultural, religious and health sectors of rural and ethnic life of Indian (Shad et al., 2013).

With the increase in global populations, food, and nutritional insecurity increased from 777 million in 2015 to 815 million in 2016 (FAO, 2017). These statistics underline the fact that food scarcity is one of the most pressing problems faced by humans worldwide (Jman Redzic, 2006). This food scarcity is caused by intermittent rainfall patterns that caused the failure of crop production (IPC, 2017) poverty and landlessness (Harris and Mohammed, 2003). These factors are still at play in most of the world which could be worsened by the effect of climate change being experienced. In view of the fact that, WEVs promote household food security and also make a source of income for the rural people (Garrity, 2004).

WEVs also play a significant role as medicine for human since it can be easily accessed throughout the year (Ogle et al., 2003). It has been reported that WEVs are the source of ‘nutraceuticals’ which implies both nutritional and pharmaceutical potential (Heinrich et al., 2005). They are relatively low in calories, cholesterol-free having unique taste and flavour. They also provide non-nutritive bioactive compounds such as pigments, gums, resins which can benefit humans in many aspects. Besides, they also have antibacterial, hepatoprotective, anti-carcinogenic, etc. that can also be exploited in the pharmaceutical industry (Vincentea et al., 2014). Consequently, the WHO recommended a daily intake of at least 400 g of fruits and vegetables per person to protect against diet-related diseases (WHO, 2003).

Traditional knowledge of WEVs is transmitted from generation to generation through either oral or folksong without any written record; such practices are still prevalent among rural and tribal communities in many different parts of the world (Mishra et al., 2008). As a result, local knowledge is a key element in different ethnobotanical research to explore various aspects. For instance, differences in social status can affect insight access to knowledge and reliability attached to what someone knows (Martin, 1995). Generally, ethnobotanical knowledge and practices by any culture may vary by geographical origin, ethnicity, religion, occupation, social status, age, and gender, etc. (Martin, 1995). However, the ethnobotanical knowledge of wild edible vegetables in many parts of the world is being lost due to change in lifestyle, change in the occupational pattern of household members, and decline of the member of villages’ elders (FAO, 1995). So, there is an urgent need for awareness of the considerable practical and developing the social value of traditional knowledge regarding the ethnomedicinal properties that can be identified, documented, and digitalized.

# CHAPTER II

## 2. Review of literature

### 2.1 Diversity and Ethnobotanical survey of WEVs

Ethnobotanical knowledge is the result of successful experimentation with plants since ancient times which gives us food and medicines and is regarded as the interrelationship between man and his environment (Trivedi and Sharma, 2011). It is further defined as how they manage, classify, and use plants surrounding their environment by the local people (Martin, 1995). The term 'ethnobotany' was first used in the last 19th century by J.W Harsh Berger in 1895 (Cotton, 1996). Ethnobotany in recent years becomes valuable in health care development and in the field of certain conservation programs. It plays a significant role in the exploration and preservation of traditional knowledge (Kunwar and Bussmann, 2008). Traditional people worldwide are bestowed with a good knowledge of forest-based resources on which they search for food, shelter, medicines, fodder, agricultural tools, and other multipurpose resources (Martin, 1995).

Ethnobotanical studies have become a fast-growing multidisciplinary subject worldwide in various fields of research such as Botany, Anthropology, Linguistics, Agriculture, Archeology, and Economics (Martin, 1995). It mainly involves the study of indigenous knowledge about plant and interaction with culture and tradition; to find out how local people used forest resources to overcome their basic needs and further incorporation of plant resources into their culture and religion (Ballick and cox, 1996). Certain inquiry techniques have been described that normally depends on the objectives for ethnobotanical studies. It includes participant observation, direct field observations, group discussion, questionnaires, and market survey (Martin, 1995; Alexiades, 1996). Moreover, research on ethnobotanical information can also be achieved by the collection and investigations on their local songs, oral knowledge transmission, local names, and folk dances (Zemede, 1997).

Several studies have been found that highlight the importance of WEVs as food among the indigenous people worldwide (Dénes et al. 2012; Sujarwo et al. 2014). Some reports showed the impact of socio-cultural and environmental factors on wild food consumption (Powell et al., 2013; Shumsky et al., 2014). However, due to changes in modern lifestyles, and close association with the western lifestyles, the traditional knowledge regarding the use of WEVs has vanished in several places (Termote et al., 2011) that was recognized as one of the factors responsible for the negative impact on biodiversity conservation (Keller et al., 2005). Therefore, it is very urgent to assess and document traditional knowledge of WEVs to conserve biodiversity (Shrestha and Dhillion, 2006). There are several studies of WEVs that highlighted not only the importance of the conservation of traditional knowledge but also their contribution to meeting the needs of essential nutrients (Lulekal et al., 2013). However, the contribution of WEVs to the food system depends not only on the frequency of exploitation and the number of people using them but also to the agreement among the users (Powel et al., 2014). To get the reliable value of the particular plant species, quantitative ethnobotanical indices, based on informant consensus was used to know the agreement among the users (Heinrich et al. 1998). To validate these aspects, a quantitative ethnobotanical survey of WEVs has been reported from Harnai of Balochistan province-Pakistan (Tareen et al., 2016), Uganda (Ojelel et al., 2019), and Bandipora District of Kashmir Himalaya, India (Singh et al., 2016).

Wild edible plants have been reported as important supplementary foods in different parts of the world, especially in the period of seasonal food shortage (Balemie and Kebebew, 2006). In Northern Nigeria, leafy vegetables and other bush foods are collected as daily supplements of relishes and soups (Satheesh, 2015). Over the past few decades, several researcher group globally highlighted the consumption and gathering of WEVs that include Italy (Vitalini et al., 2013), Turkey (Ertug, 2000), and Switzerland (Abbet et al., 2014). Maji and Sikdar documented 115 WEVs from the Midnapore district of West Bengal (Maji and Sikdar, 1982), 108 wild edible plants at different altitudes of Uttar Pradesh (Joshi and Tewari, 2000). Many of the WEVs are reported to have more than one use category; that is used for construction, medicine, fuelwood, agricultural tools, etc. (Balemie and Kebebew, 2006; Ju et al., 2013).

According to previous literature, approximately 800 WEVs occurred in India (Singh and Arora, 1978). The indigenous people depend on agriculture and collection of wild vegetables from forest to meet their various necessities (Samant and Dhar, 1977). The Northeastern states of India are rich in biodiversity, survey and documentation of WEVs in different parts of the region have been conducted by various scientists that include native food plants of the Northeastern tribals (Arora, 1981), wild edible plants of Arunachal Pradesh (Murtem, 2000), ethnobiological notes on the Khasi and Garo tribes (Kayang, 2014), wild vegetables of Sikkim (Sundriyal and Sundriyal, 2004) and in Anglong District, Assam (Kar and Borthakur, 2008).

**2.2 The role of WEVs as household food security**

Forest are the principal components of the terrestrial ecosystems, providing a wide range of socio-economic benefits (Boyd et al., 2013) and are highly valuable to the world food security by supplying food to over 300 million people worldwide annually (Cheng et al., 2017). As mentioned above, WEVs is considered a dietary supplement among the local people in most of the developing countries, especially during the period of food famine (Bell, 1995). The occurrence of famines in Sudan during 1973/1984 - 1985 (Bell, 1995), Bihar (1965-1966) in India, and Bangladesh (1974-1975) for instance exposed the critical role played by the WEVs (FAO, 1999). Furthermore, it plays a significant role in food security during the period of food shortage, hence wild plants serve as a "buffer food" (Edward, 1992), reducing the chance of getting food insecurity for the local communities (Misra et al., 2008). The role of WEVs, in food security, had also been highlighted by different researchers (Edwards, 1992; Abbink, 1993; Bell; 1995). In these aspects, the Bankariya ethnic group of Nepal consumes and depends only on WEVs to survive since these ethnic groups do not practice either crop production or animal husbandry (Uprety, 2005). With the emergence of drought in 1966-1969 in Southern Ethiopia where complete crop failures occurred, the people of Konso in these regions consumed WEVs to survive and manage their diets (Guinand and Dechassa, 2000). About 73.33% of the WEVs were considered as famine food in Ethiopia, while 26.67% were consumed as food in their regular diet (Amente, 2017). It has also been reported that WEVs help to prevent starvations during the period of drought season and social unrest (Cunningham, 2001; Neudeck et al., 2012).

The importance of WEVs extended its potential in the life of many indigenous farming and hunter-gatherer communities (Turner et al., 2011). They are well-founded as an alternative source of food for the poor people especially prone to drought and famines which explained the importance of WEVs for survival (Erskine et al., 2015). WEVs are largely exploited in the Philippines (Chua-Barcelo, 2014), often underwent natural disasters such as drought and typhoons resulting in the severe food crisis which in turn affects the indigenous poor people when the food stocks are declined (Rovillos et al., 2009). During this period of food insufficiency, the indigenous people overcome the food crisis by hunting and gathering of wild food resources (Carino, 2012). Though, there has been a gradual increase in the occasional shifting of agriculture, wage labour and cash economies, hunting, and gathering of wild food resources is still in practice among the Ati Negrito in central Philippines ( Stewart, 1992).

### 2.3 WEVs as a source of medicine

WEVs have been in use since time immemorial, for the treatment of various diseases. In this aspect, Tareen et al. (2016) identified 59 WEVs from the Harnai Balochistan district, Pakistan, that serve important purposes in the treatment of various ailments. Moreover, 14 WEVs consumed in South Africa have been reported to have ethnomedicinal values (Mokgany and Tshisikhawe, 2019). WEVs have been reported for its use in the treatment of more than 52 diseases including diabetes, rheumatism, dysentery, dyspepsia, gastritis, constipation, urinary problem, etc. (Naik et al., 2018). Shin et al. (2018) also reported consumption of 18 WEVs as medicinal food from Southern Shan State, Myanmar. More than 400 ethnomedicinal plants are known to occur in the state of Mizoram (Lalramnghinglova, 2003).

### 2.4 The marketing potential of WEVs

WEVs offers a variety for marketing value, providing cash income, and socio-economic development of poor populace worldwide (Berry, 1967). Availability, prices, and market channels are crucial information for assessing the importance of WEVs at local and regional levels (Hegde et al, 1996). Moreover, they have become a commercial crop in many developing countries (Youkai et al., 2004) with ever-increasing marketing potential. WEVs that have been exploited as food sold in the local market has been investigated by many researchers in different parts of the world, including the market of Haflong (Medhi and Borthakur, 2012); Karbi Anglong (Kar and Borthakur, 2007); Assam (Borthakur 1996), Lall market of Gangtok (Hajra and Chakraborty 1981), Sikkim Himalaya (Sundriyal and Sundriyal, 2004), Mahur market of Dima Hasao district, Assam (Medhi and Borthakur,2013), and Xishuangbanna, Southwest market of China (You-Kai et al., 2004).

In Mizoram, a quantitative ethnobotanical survey of WEVs has not been given attention. Documentation of wild edible resources has been conducted in certain areas of Mizoram that include 59 species of edible flowers (Khomdram et al., 2019), wild fruit plants (Lalramnghinglova, 2001; Hazarika and Nautiyal., 2012), cultivated vegetables (Singh et al., 2013). However, there has not been researching carried out based on quantitative ethnobotanical approaches in Aizawl district, Mizoram. Therefore, the present study was designed to quantitatively determine the ethnobotanical indices of WEVs in Aizawl district, Mizoram associated with the traditional knowledge employed by the local people in traditional medicines. Documentation is indeed very important because wild species are fast diminishing in the region due to various anthropogenic activities. So, the research for studying its diversity and documentation will help in the conservation and will bring economic benefits, creating identities in regional food culture.

## 2.5 Traditional food recipe

A diverse range of food habits have been found worldwide that differs from different ethnic groups, a unique traditional food processing techniques practiced by the ethnic communities of Mizoram people have been discussed (Lalthanpuii et al., 2015). Among the most popular ones is the production of fermented food and beverages which have been traditionally inherited, that also constitute an essential component of the daily diet of the Mizo people (Thanzami and Lalhlenmawia, 2020). Moreover, the traditional food processing and fermented alcoholic beverages were reported by certain research group worldwide; fermented and ripened fish products in the North European countries (Skara et al., 2015), naturally fermented ethnic soybean foods of India (Tamang, 2015), traditional recipe of district Kangra of Himachal Pradesh, India (Kapoor et al., 2010).

Northeast India also has certain reports that include traditional food product of Manipur including food items such as *Iromba, Champhut, Kangshoi, Hawaijar, Soibum, Ngari,* and *Paknam* (Devi and Kumar, 2012; Jeyaram et al., 2009), traditional recipe of Tripura (Deb et al., 2013), non-fermented food of Sikkim (Tamang and Thapa, 2014), traditional food processing techniques of the Mizo people of Mizoram (Lalthanpuii et al., 2015), traditional process foods of the ethnic tribes of western hills of Manipur (Singh et al., 2018), and alcoholic beverage of different tribal groups (Singh and Singh, 2006). However, to the best of our knowledge, the cuisine exploration for the selected traditional WEVs has never been reported so far, therefore, the present study will give the first report from Mizoram which can also be useful for future references.

### 2.6 Floristic composition and phytosociology of WEVs

Overutilization of forest resources in India as well as in many other countries is shrinking at an alarming rate due to an increase in the human population which gradually led to habitat loss, causing the greatest threats to biodiversity (Wong, 2012). Hence, conservation of forest ecosystems is of prime fundamental importance for sustainable development. Among different forest types, the tropical forest has a great potential to contribute to mitigating climate change through conserving carbon pool in above ground and biomass in soil (Dar and Sundarapandian, 2015). To more extend, tropical forest comprises one of the most important ecosystems on earth due to their biological diversity, species richness, ecosystems services, influence on weather patterns and preservation of natural habitat for flora and fauna (Armenteras et al., 2009).

Forest is the important component of the vegetation that reflects the effects of the entire environment (Billings, 1952); it needs regular monitoring for maintaining ecosystem stability and species diversity (Naidu and Kumar, 2016). The study of floristic compositions is useful in identifying the status of the plants which enable them to be exploited through systematic and scientific approaches (Qureshi et al., 2011). The diversity of it primarily depends on several environmental factors such as climate, habitats, and altitudinal gradients (Saima et al., 2009). Therefore understanding the significance, several research groups have been investigated, documented, and reported in different parts of the world (Mehmood et al., 2015; Ali et al., 2016; Cao and Zhang, 1997).

Phytosociological analysis of the plant community is foremost for the ecological study of vegetation to understand the function of any community (Warger and Morrel, 1978). India is having rich biodiversity comprising 47513 species of flora and 18117 flowering plants (Arisdason and Lakshminarasimhan, 2016). Analysis of vegetation and Phyto-diversity of three dry deciduous forests of Doon Valley, India revealed that species richness and diversity increased with a decrease in tree density and basal area (Mandal and Joshi, 2014). Vegetation analysis from the evergreen forest of Kalakad- Mundanthurai Tiger Reserve, India recorded 173 woody species from 58 families (Ganesh et al., 1996). Analysis of species composition of tropical wet evergreen forest in and around Namdapha National park, Northeast India revealed the presence of 94 tree species, 25 shrubs species, and 61 herbs species which further showed the decline of vegetation with increasing disturbance (Nath et al., 2005). Moreover, Phyto-diversity analysis of the tropical rain forest of North Andaman Island, India has been reported by Bheemalingappa et al. (2018) which further observed that high diversity of the semi-evergreen forest, added to the biological richness of North Andaman Island. There are certain reports on the Tree species composition study India that include tropical forest in Eastern Ghats of Andra Pradesh (Naidu and Kumar, 2016), tropical forest of Garo hills (Kumar et al., 2006), two forest types of Nagaland (Mishra and Das,2019), traditional agroforestry system and natural forest of Barak valley, (Nandy and Das, 2013), the tropical semi-evergreen forest of Lunglei district, (Lalfakawma et al., 2009) and plant diversity in the indigenous home garden in Eastern Himalayan region of Mizoram (Barbhuiya et al., 2016). Herb and shrub species diversity studies have also been conducted from Lower Dachigam National park, Kashmir Himalaya, (Shameem et al., 2010; Yaqoob et al., 2014).

Literature surveys indicated that floristic composition and phytosociological studies of WEVs in Mizoram has not been investigated. Therefore, the present study focuses on the phytosociological attributes of WEVs along with their biodiversity conservation that may contribute valuable baseline data for documentation and management of native flora of the tropical forest ecosystem. This quantitative assessment will also be helpful for the detection of ecologically important species of WEVs.

### 2.7 Phenology of WEVs

Phenology is the study of recurring biological events in plants and animals, associated with biotic and abiotic factors (Kikim and Yadava, 2001). Several biologists have begun to work out the influence of phenological events in plant reproductive success (Okullo et al., 2004). The pattern of phenology has a direct impact on biodiversity and productivity of forest ecosystems (Rodriquez et al., 2014); often used for the characterization of vegetation and natural forest regeneration potential (Upadhyay and Mishra, 2010). Moreover, phenological observations are important mechanisms to uphold the species co-existence among different plant communities (Rathcke and Lacey 1985; Richardson et al., 2013). The study of phenology not only provides information about the vegetative and reproductive phase (flowering and fruiting behaviors), that corresponds to changes in the climatic condition of a particular area but also determines the degree of reproductive synchrony with other plant species (Zhang et al., 2007).

In the tropical forest ecosystem, a phenological pattern is mainly determined by seasonal changes in the duration of leafing, flowering, and fruiting of the plant species (Van Schaik et al., 1993). Floral formations mostly occur during the late dry season and the beginning of the rainy season when dry pollen is more mobile and less likely to encounter moisture thereby producing fruit during the rainy (Hamann, 2004). In the case of deciduous plants, leaf fall is quite common pronounced by the dry season, seasonal leaf flushing emerges with the onset of the wet season (Frankie et al., 1974), flowering and fruiting mostly occur during the leafless period (Hladik, 1978). This physiological mechanism is important to maintain shoot turgidity (Singh and Kushwaha, 2006) and optimizing photosynthetic gain in tropical forests (Kikim and Yadava, 2001). Several works on the phenology of tropical deciduous tree have been reported from different parts of the world; Mexican tropical Lower Montane Forest (Williams-Linera, 1997), tropical deciduous forest in India (Singh and Kushwaha, 2005), Mexico (Bullock and Solis Magallanes, 1990), Harvard Forest in Petersham (Klosterman and Richardson, 2017).

In the past few decades, phenological observations have to gain much attention since many living organisms are changing their life cycles due to ongoing climate changes (Menzel et al., 2006). Plant phenology has been recognized as an indicator of climatic changes and global change by the European Environmental Agency and the Intergovernmental Panel on Climate Change (IPCC, 2007)(Solomon, 2007). Previous observations have shown that the increased air temperature has an impact on phenological events (Menzel et al., 2006; CaraDonna et al., 2014). Leafing and flowering phenology are also sensitive to several abiotic factors such as precipitation, temperature, light, and relative humidity (Borchert, 1998; Van Schaik et al., 1993). The most favourable time for vegetative and reproductive events are determined by abiotic and biotic factor and more extend to a factor related to seed germination, seed dispersal, completion, herbivore and pollinators ( Petanidou et al., 1995; Johnson, 1993). The correlations of temperature with various phenological events have been studied by different workers previously (Juknys et al., 2012; Mendes et al., 2017; Khan et al., 2018) in this regard.

Several kinds of literature concerning phenology have been available from different parts of the world including; Tropical savanna and semi-deciduous forest of Venezuelan Ilanos, South America (Monasterio and Sarmiento, 1976), dry tropical forest in NE Spain (Pilar and Gabriel, 1998), Tropical rain forest in Malaya (Medway, 1972), Panama (De Steven et al., 1987), Brazil (Garcia et al.,2017), Western Himalayan flora of Muzaffarabad district, Pakistan (Khan et al.,2018), and Mexico (Nunez-Cruz et al., 2018). Phenological observations from the different forest of India has also been reported; the deciduous forest of Bandipur in Peninsular India (Prasad and Hegde, 1986), the tropical moist forest of Western Ghats in Karnataka (Bhat and Murali, 2001), Northwestern Punjab, India (Kaur et al., 2013), and Indian dry tropical forest (Kushwaha et al., 2011). Some studies have been conducted from tropical and subtropical forests in Northeast India (Shukla and Ramakrishnan, 1982; Sulistyawati et al. 2012; Devi and Garkoti 2013) in this regard. However, the study of phenology in plants has not given much attention in Mizoram, few works of literature are available in these aspects including floral phenology and pollen production of *Tectona grandis* from Mizoram, (Khandhuri, (2012) phenological patterns of E*rythrina variegata* and E*rythrina subumbrans* in tropical forests of Mizoram (Vanlalremkimi et al., 2016). Considering the scarcity of literature and the importance of phenological observations, the present work was carried to investigate the phenological events of some WEVs from Aizawl district, Mizoram to understand the response of plant species to climatic factors and periodicity of seasons of the district Aizawl, Mizoram.

### 2.8 Nutritional potential and mineral content of WEVs

In the past few decades, interest has focussed on WEVs for their medicinal and nutritional value to broaden the diversity of people's diets (Afolayan and Jimoh, 2009). In most developing countries, rural or tribal people harvested a large number of WEVs due to taste habits or food shortage to meet their basic needs (Mahapatra et al., 2012). Nowadays, the food situation becomes a major problem due to the shortage of land for cultivation, and the high prices of stable food. This has led to high emergence of malnutrition. Many people depend on starch-based foods for the supply of both energy and protein. This accounts in part for protein deficiency which prevails among the tribal populace as recognized by the Food and Agricultural Organization (Akubugwo et al., 2007). It has also been reported the conventional crop plant with high chemical inputs such as fertilizer, plant growth hormones and pesticides, etc. has lost their natural taste, appearance, and nutritional values (Sekeroglu et al., 2006). However, WEVs has now become a commercial crop with increasing marketing values due to their high nutritional importance and lack of residues from pesticides or fertilizers (Weng et al., 2001)**.**

Essential biochemicals in human diet such as protein, carbohydrates, and lipids can be obtained from WEVs (Datta et al., 2019). They not only provide essential biochemical and energy requirements but also render vitamins and minerals which are of prime importance for maintaining the physiological function of the body (Datta et al., 2019). Moreover mineral plays a crucial role in the regulation of metabolic activity in the human body (Gopalan et al., 2004). The concentration of these nutrients (Carbohydrates, proteins, fats, vitamins, and minerals) identified food quality (Seal, 2011). It has been reported that the content of antioxidant in large concentration by various crude extract of fruits, vegetables, herbs, cereals, and other plant materials improve the nutritional quality of food value (Seal, 2011). These nutritional qualities of WEVs are sometimes superior to the domesticated plants (Ebert, 2014; Khan et al., 2013). In these aspects, the superiority of wild edible plants over conventional crop plants has been reported from Sikkim Himalaya (Sundriyal and Sundriyal, 2004; Seal and Chaudhuri, 2016).

More recently, several works are focussed on nutritional, mineral, and heavy metal contents of WEVs consumed by various communities globally; Assam (Narzary et al., 2015), Arunachal Pradesh (Seal et al., 2017b), Kolkata (Datta et al., 2019), Meghalaya (Seal, 2011; Seal and Chaudhuri, 2016), South Africa (Odhav et al., 2007) and Sikkim (Sundriyal and Sundriyal, 2004), Jharkhan (Sinha, 2018). Micro and macro elements are responsible for maintaining the physiological and biological functions of the human body. Calcium provided important functions to build strong and healthy bones which might be beneficial for the normal functioning of the cardiac muscles (Seal and Chaudhuri, 2015, Indrayan et al., 2005). As calcium alone does not maintain human health, magnesium and potassium play an important role to assist calcium in maintaining human health. Thus, these three nutrients work together thereby maintaining the healthy nervous system (Devi et al., 2014). Magnesium helps to prevent muscle degeneration, growth retardation, impaired spermatogenesis, bleeding disorder (Chaturvedi et al., 2004). Manganese also contributed to the essential elements which function as co-factors for enzymes like arginase and glycosyltransferase. It plays a significant role in the formation of haemoglobin and activated some other enzymes like phosphoenolpyruvate carboxykinase and glutamine synthetase (Indrayan et al., 2005). The daily requirement for a healthy person reached 4.50mg (Sekeroglu et al., 2006).

### 2.8 Phytochemical and antioxidant activities of WEVs

Various secondary metabolites like alkaloid, saponin, tannin, phenolic compounds are important traditional herbal preparations that were used for the treatment of various ailments (Okoegwale and Omefezi, 2001). The phenolic compound had been reported as important secondary metabolites known to possess redox potential which makes them act as an antioxidant (Soobrattee et al., 2005), exhibiting a wide range of medicinal values such as anti-cancer, anti-diabetic and anti-inflammatory (Nagavani et al., 2010) Their free radical scavenging ability was due to the presence of hydroxyl group in them (Hatano et al., 1989). Flavonoid was also reported for their antioxidant activity which can scavenge free radical in the body and thus helps to protect the body against cancer and other diseases like arthritis, Type II diabetes mellitus, anti-inflammatory, antiallergenic, antiviral and vasodilating actions (Lee and Shibumoto, 2002; Parajuli et al., 2012; Pereira et al., 2009). Setchell and Cassidy (1999) reported that terpenoid, which has an antihepatotoxic property and thus help to prevent liver damage and also had antimicrobial and antiseptic properties.Tannin and saponin were also reported as active ingredients for pharmacological action in plants and vegetables (Hamzah et al., 2014). Saponin was reported to be cough suppressants and administered for haemolytic activity (Okwu, 2005) and tannin was also well known for its antioxidant, anti-inflammatory, diuretic, and antimicrobial properties (Okwu, 2004).

WEVs are a good source of antioxidant since most of them have a significant ethnomedicinal value, and are reported to play an important role in the treatment of several illnesses all over the world (Fouche et al., 2015). Several works are focussed on the antioxidant activity of WEVs globally; Zainol et al., 2013; Aryal et al., 2019; Fitriansyah et al.,2017; Mann et al., 2012. Free radicals such as reactive oxygen species (ROS) and reactive nitrogen species (RNS) are generated abundantly in the human body during normal cellular metabolism (Halliwell and Gutteridge, 2007). It plays a key role in the pathogenesis of many physiological conditions such as aging, cellular injury, cancer, neurodegenerative, cardiovascular, and renal disorder (Madamanchi et al., 2005; Szabo et al., 2010). Epidemiological studies have reported evidence in support of the role of ROS in the etiology of cancer (Ray et al., 2000). They are also formed by some external influence like pollution, drug, smoke, ionizing radical, stresses, synthetic pesticides, food, and spicy food, which are responsible for producing ROS that inhibit the formation of protein, depleting antioxidant in the immune system (Agrawal et al., 2011). The overproduction of reactive oxygen species causes tissue injury and oxidative damage to nucleic acid and proteins (Middleton et al., 2000). There are many endogenous antioxidant enzymes (such as catalase, superoxide dismutase, glutathione peroxidase/ reductase) capable of scavenging free radical which results in maintaining cellular functions (Kurutas, 2015). Endogenous antioxidants are synthesized within the living organisms and repair free radical damage internally by initiating cell regeneration (Bouayed and Bohn, 2010). However, under increased oxidative stress, this endogenous antioxidant may not be enough to maintain optimal cellular function. In this case, a dietary antioxidant may be crucial to maintain cellular metabolism

(Rahman, 2007). As a result of this interest has been a focus on the search of exogenous antioxidants (Vitamin C, E, B-carotene) from natural sources since they are less expensive, readily available and believed to have lesser side effects as compared to their synthetic counterparts (Tadhani et al., 2007). Vitamin C or ascorbic acid is one of the most powerful antioxidants, capable of scavenging ROS such as superoxide anion radical ($O_2^-$), hydroxyl radical ($OH^-$), non-free radicals species ($H_2O_2$), and singlet oxygen $(O_2)^2$ (Loganayaki et al., 2010). Therefore, the recommended dietary allowance of vitamin C is 75 mg/day and 90 mg/day for adult women and men respectively, and 45 mg/day for the children of 9–12 years old (Food and Nutrition Board, 2005). It can also synthesize tocopherol (Vitamin E) and also acts as cofactors for many enzymes such as hydroxylases (Loganayaki et al., 2010).

### 2.9 Antimicrobial activity of WEVs

Exploration of different sources in the search for antimicrobial compounds is of prime importance with the emergence of multidrug-resistant pathogens as mentioned in the introduction. In this regard, several research groups were working with diverse ranges of organisms from unicellular to multicellular that include WEVs of ethno-medicinal importance. Xia et al. (2011) investigated the antibacterial activities of six *Sonchus* wild vegetables (*S. oleraceus* ., *S. arvensis* ., *S. asper* ., *S. uliginosus* ., *S. brachyotus* and *S. lingianus* ) in China. The results revealed broad-spectrum antibacterial activities against *Escherichia coli*, *Salmonella enteric*, *Vibrio parahaemolyticus* and *Staphylococcus aureus*. 26 species of WEVs from China, Japan, Thailand, and Yemen were reported for its antimicrobial activity against *Bacillus cereus*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella infantis*.

The antimicrobial activity of the crude extract of several edible vegetables from Odisha, India were evaluated and showed broad-spectrum activity against the eight tested food-borne pathogens (Panda et al., 2011). The methanolic extract of *Ceropegia thwaitesii* an endemic species obtained from the Western Ghats of India was also identified as potent antimicrobial agents (Muthukrishnan et al., 2018).

Based on the literature survey, the selected wild edible vegetable of the specified site has not been explored for its antimicrobial potential. Therefore the present study aims to investigate the *in-vitro* antimicrobial potential of selected WEVs. This will further help in the management of plant and animal pathogens by formulation development of the potential plants (Mohana at al., 2008).

Since, WEVs have been reported as important supplementary foods in different parts of the world, especially in the period of seasonal food shortage, documentation is indeed very important. Besides this, it contains many essential bio-chemicals and offers potential sources of natural antioxidant compounds. Due to the dramatic loss of traditional knowledge of WEVs resulted in largely ignored in land use planning and implementation and biodiversity conservation, it is necessary to document and investigate the importance of WEVs. Prior to this present investigation, no comprehensive work has been carried out on studies of WEVs in Aizawl district, Mizoram. Accordingly, the present study entitled "**Diversity and Phytochemical Study of Some Wild Edible Vegetables in Aizawl District of Mizoram**" was designed with the following objectives:

1. Diversity, identification and ethnic study of wild edible species.
2. Phenological study of different wild vegetables.
3. Phytochemical analysis and anti-oxidant activity of important wild edible vegetables.

## Chapter III

## 3. Diversity, ethnobotanical study, and exploration of traditional recipes of WEVs among two ethnic groups of Aizawl district, Mizoram

### 3.1. Introduction

Ethnobotanical assessment of WEVs is a key for understanding indigenous knowledge systems. In many developing countries, the importance of WEVs has been recognized to maintain a balance between population growth and agricultural productivity (Vishwakarma and Dubey, 2011). The consumption of WEVs is still a common practice among rural communities. According to the Food and Agricultural Organization (FAO, 2009), there are around 30,000 species of plants that are edible globally, out of these, 7000 species are used as human food.

India is the second-largest population in the world, where 75% is living in rural areas. These rural communities largely depend on the wild food resource to meet their basic needs especially during the period of a food crisis, besides food supplements (Rashid, 2008). There are about 800 species of WEVs consumed by the tribal inhabitant within India (Singh and Arora, 1978). The plant parts and mode of consumption varied according to the species (Nath, 2015). Therefore, many tribal populations living in rural areas can overcome nutritional requirements through unconventional means (Singh and Arora, 1978). It also provides supplemental income opportunities to the rural household by selling WEVs in their local market (Moreno-Black and Price, 1993). There is a gradual increase in the demand for WEVs due to their organic nature and to the more extent of their high nutritive values (Guan et al. 2000; Youkai et al., 2004). Availability, market channels, and price information are crucial for accessing the importance of WEVs at local and national levels (Hedge et al., 1996) to complete the valuation of forest and forest products (Cunningham and Mbenkum 1993).

Ethnobotanical surveys provide information about the traditional uses of indigenous plants (Verpoorte et al., 2005), and as mentioned earlier WEVs have a great inspiration on humans as a source of medicine even before civilization. The strong correlation between the health and nutrition of WEVs is increasingly recognized as these plants offer traditional medicines (Saqib et al., 2011). The matter of opinion about wild food as medicine came into existence in Chinese medical theories and Chinese food therapy (Chen, 2000). Due to the shortage of medics, medicinal plants were used by certain people for various ailments because of fewer side effects and can be easily obtained from nature. They are an important source of active compounds and are used in the form of herbal medicines (Bussmann and Sharon, 2006). These plants contain high amount of nutraceutical value and are being widely used for the treatment and prevention of various diseases like cancer, ulcer, inflammation, snakebite, asthma, diabetes, and cardiovascular disease (Hussain et al., 2009; Abbet et al., 2014). Traditional plant-based knowledge is very helpful in discovering and developing a new drug and food resources (Heinrich and Gibbons, 2001). The majority of plant-based chemical compound which provide important components of medicines in the global market comes from medicinal plants through isolation of the active compound (Alamgir, 2017). In developing countries, more than 4.5 billion people rely on medicinal plants as part of their primary health care (Mussarat et al., 2014), and 25% of prescription drugs are derived from phytochemicals (Rai et al., 2004). The medicinal properties of WEVs vary from antioxidant, antimicrobial, and antipyretic that depend on the phytochemical constituents (Adesokan et al., 2008). Therefore, such plants should be examined for their properties, safety, and effectiveness in a systematic manner (Nascimento et al., 2000).

A total of 450 tribal communities are living in India, out of which 50% of the ethnic communities inhabiting in Northeast India (Sajem and Gosai, 2006). Since the agricultural product does not meet the requirements of the tribal people, the diversity of WEVs offers a new variety in the daily life requirement which contributed to household food security. Mizoram, a Northeast part of India has been largely reported for its rich natural bio-resources considered as Indo-Burma biodiversity hotpots by the International conservation (Zothanpuia et al., 2018). The ethnic tribal inhabitants of Mizoram have been living in the forest ecosystem enjoying their socio-cultural pattern, tradition, and typical food habits. A strong based of traditional knowledge is passed from one generation to the others through verbal means which is based on their needs, character, observation, trial and error, and long experience

(Kar et al., 2013). There are 94.7 % of the tribal people living in Mizoram and traditional knowledge provides them food, healthcare system, and shelter (Kar et al., 2013). There are 7 major tribes of Mizo living within Aizawl districts such as Hmar, Paihte, Pawi, Ralte, Lai, Mara, and Lusei (Liangkhaia, 1976). Among these, three major tribal groups such as Paihte, Hmar, and Lusei resides within Aizawl district.

Rice is the staple food of tribal groups of Mizoram. It is taken along with vegetables, salads, and meats. Vegetables are less imported from outside districts where forest-based WEVs are the main source of vegetables, especially among Hmar and Paihte tribes. Shifting cultivation is the main characteristic of traditional agriculture in Mizoram which is still in practice in highland to date, supporting the livelihood of the state by providing conventional food (Sati and Rinawma, 2014). However, conventional crops do not meet the requirements of the people; traditional recipes obtained from WEVs are still trending among local people in times that are generally collected on a seasonal based. Traditional Mizo foods are mainly prepared in boiled form, smoked and fermented formed, and spices are rarely used compared to other Indian cuisines (Kar et al., 2013). The typical Mizo popular dish includes 'Bai' (usually prepared from a combination of vegetables with fermented pork) and 'Tlak/Mung' (Simply boiled). Generally, the use of cooking oil in food preparations was never known to the ethnic group in the olden days. However, with the emergence of Christianity by the British missionary in the 1890s in Mizoram, the method of food preparation improved tremendously (Lalthanpuii et al., 2015). A method of food processing technique has also differed among ethnic groups (Phukan et al, 2006).

Tropical forest covers 52% of the total forest worldwide constituting the most important forest in terms of biodiversity (Djuikouo et al., 2010). The various species composition, community structure, and function serve vital ecological characteristics of the forest environment (Bisht and Bhat, 2013) which show variations in response to environmental and anthropogenic variables (Shaheen et al., 2008). Plants that grow together have a mutual relationship among them and with their environment (Mishra et al., 1997). The quantitative analysis of vegetation is called phytosociology (Braun- Blanquet, 1932) and it aims to describes vegetation, explain or predicts its pattern, and classify it in a meaningful manner (Odum, 1971). Tropical forest biomes provide many vital functions such as prevention of soil erosion, regulating air quality, maintaining soil fertility, seed dispersal, nutrient cycling, water purification, cultural diversity, ecotourism, and carbon sequestration (Armenteras et al., 2009). However, habitat loss, fragmentation, overexploitation, pollution, invasion of alien species, and climatic changes are the main factor causing threats to ecosystems and biodiversity which disrupt the community structure (IUCN, 2003).

In Northeast India, shifting cultivation is popular among the tribal community to earn their living, having adverse ecological effects (Devi and Yadava, 2006). Besides, major anthropogenic activities such as extracting timber, overgrazing, agriculture expansion, overexploitation are recognized as one of the major environmental and economic problems resulted in rapid loss of forest (Mani and Parthasarathy, 2006; Baraloto et al., 2013). The tropical forest is disappearing at fast rates globally, reducing the current area by 1 to 4 % annually (Laurance, 1999). Therefore, floristic structure and composition analysis are crucial to know species richness, distribution, and vegetation conservation (Bano et al., 2018).

WEVs in Mizoram state have great economic value and are highly linked with the socio-economic development of the tribal community. Therefore, the present study aims to gather information on quantitative ethnobotanical data, marketing value, evaluation of multipurpose species, ethnomedicinal properties, exploration of the traditional recipes, and phytosociological study of WEVs among two ethnic groups of Aizawl district, Mizoram which will certainly provide information on its potential aspects for the mankind.

## 3.2. Methodology

### 3.2.1. Description of the study area

The study was confined to the Aizawl district of Mizoram, Northeast India. Aizawl is the state capital of Mizoram. It has geo-coordinates of 24°25′16.04″ to 23°18′17.78″ N latitudes and 92°37′03.27″ to 93°11′45.69″ E longitudes with an elevation of 1132 meter above sea level (3714ft). The total geographical area is 3576.31 $km^2$ and accounts for 16.96% of the total geographical area of the state, comprising geographical features like agricultural plains and hilly terrains. Aizawl district received a direct influence of both the northeast and southwest monsoon and having a humid and moderate tropical climatic condition. Generally, it is warm and humid in summer and moderately cold in winter and experience four seasons primarily: winter (December to February) with temperature ranging between 10°C -22°C with little or no rain, Summer (March-May) with temperature varying between 19°C-30°C with pre-monsoon thunderstorm and rain, monsoon (June- August) with temperature ranging between 20°C-30°C characterised by storms and monsoon rain causing severe landslides in some places and Autumn season (September- November) with a pleasant climate during day and night time.


**Figure 3.1:** Geographical map of Aizawl district, Mizoram showing the study area.

Within Aizawl district, two villages i.e., N.E Tlangnuam and Phuaibuang were selected for ethnobotanical data collection, in which two major ethnic tribes are residing in the region. The major ethnic tribe of N.E Tlangnuam village is 'Paihte'. According to the 2011 census of Mizoram, it has a population of 658 with 318 males and 340 females resided in 97 households. The communication language is Paihte. It is 187kms away from Aizawl. However, in Phuaibuang village, the major ethnic tribe is Hmar. It has a population of 2134 (1087 male and 1047 female) with 398 households. Major communication languages are Hmar and Lusei. It is 170kms away from the state capital Aizawl.


**Figure 3.2**: Location of the study sites. A) N.E Tlangnuam village; B) Phuaibuang village.

### 3.2.2. Ethnobotanical survey and data collection

The field survey was carried out from August 2015 - August 2016 and information on WEVs from two ethnic groups of Aizawl district such as Hmar and Paihte was collected. Ethnobotanical data were documented through direct field observations, semi-structured interviews and questionnaires as per the method described by Martin (1995) and Alexiades (1996). The questionnaire focused on the local name, habit, part used, mode of consumption, availability period, and ethnomedicinal uses of WEVs. Collection of data was done using local language, i.e. 'Mizo' to get clear pictures of the knowledge about the plant species.

#### 3.2.2.1. Selection of informants

Ethnobotanical data were collected from randomly selected informants, 72 local informants from two ethnic groups (Paihte comprising 32 informants; 14 male and 18 females with an age group between 25-65, Hmar people comprises of 40 informants; 17 male and 23 females having an age group of 30-70) were interviewed **(Table 3.1)**. Among the 72 informants, 41 were female and 31 were male with an age group of 25-70. The informants were divided into five aged groups; 25-35, 36-45, 46-55, 56-65, and 66-70 **(Figure 3.3)**. The major group of informants was within the age range of 56-65 (14 male and 16 female). The basic criterion for the selection of these informants was based upon their knowledge of utilization of

WEVs, their nativity, and the duration of settlement in the study areas. Besides this, direct field observations were conducted with knowledgeable local people to collect the specimen, and photographs were taken for documentation.

**Table 3.1:** Demographic characteristics of local informants of Aizawl District, Mizoram.

| **Distribution of informants** | **Ethnic groups** | | **Total** |
|---|---|---|---|
| | Paihte | Hmar | |
| Informants | 32 | 40 | 72 |
| Male | 14 | 17 | 31 |
| Female | 18 | 23 | 41 |
| Age range (Years) | 25-65 | 30-70 | - |
| Year of the survey | February 2016, August 2016 | February 2015 August 2015, October 2015, | - |

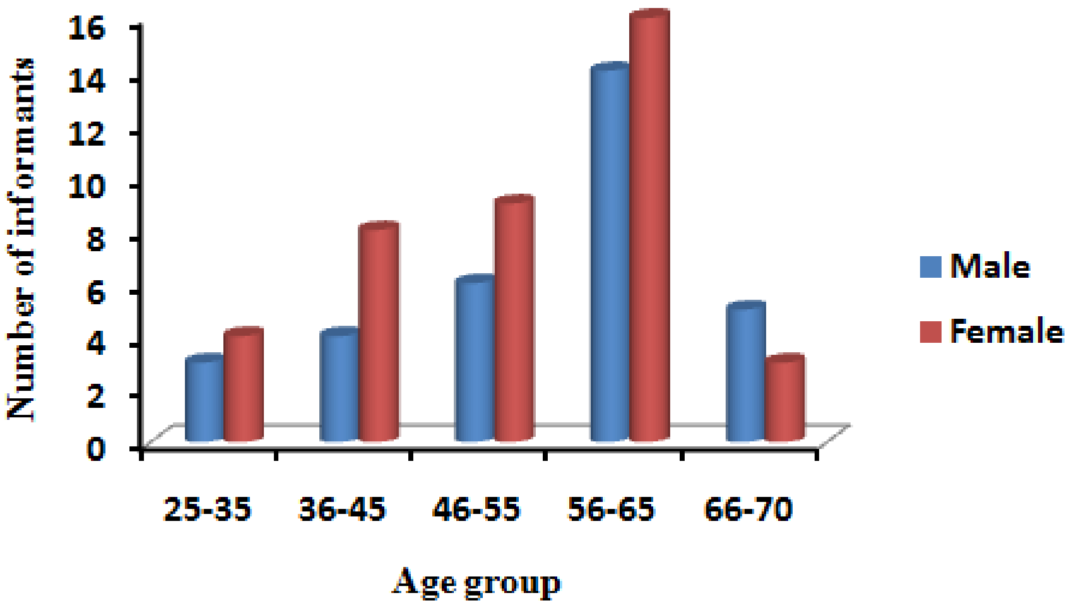


**Figure 3.3:** Distribution of number of informants with age group.

### 3.2.3. Herbarium specimen preparation and identification

All the specimens collected were pressed in herbarium sheet and were identified using a book of "Flora of Mizoram" (Singh et al., 2002). An authentication certificate was taken from BSI, Eastern regional circle, Shillong (Meghalaya) in 2016. Voucher specimens were deposited in Department of Botany, Mizoram University.

### 3.2.4. Data analysis

Data collected from informants on WEVs were analysed using two ethnobotanical indices: (a) Informant's consensus factor ($F_{ic}$) and (b) Fidelity level (Fl).

#### 3.2.4.1. Informant's consensus factor ($F_{ic}$)

This test was used to evaluate the homogeneity of knowledge about the species documented. For the ailment category, all the diseases were broadly classified into various groups before performing the analysis (Heinrich et al., 1998). $F_{ic}$ was calculated (Trotter and Logan, 1986),

$$F_{ic} = \frac{Nur - Nt}{Nur - 1}$$

Where,

Nur = No. of use reports from informants for a particular plant use category
Nt = No. of species used for each category mentioned by all informants.

#### 3.2.4.2. Fidelity level (Fl)

Fidelity level was used to determine the most important species used by the local people in the study area (Friedman et al., 1986). All the ailments were grouped into different classes to obtain the fidelity level. Fl was calculated according to Alexiades, (1996).

$$Fl\ (\%) = \frac{Np}{N}\ x\ 100$$

Where,

Np = No. of informants that reported the use of plants for the treatment of a particular disease.

N= No. of informants who used the plants as medicine to treat any given disease

### 3.2.5. Direct matrix Ranking (DMR)

Direct Matrix ranking (DMR) was evaluated to know the multipurpose use of frequently use important wild edibles species and to a greater extent of its utilization over dominance. Five informants were assigning to give value about the multipurpose use of the selected WEVs as per the following rating; 5=best, 4=very good, 3=good, 2=less, 1=least used and 0=not used. The values given by the informants were summed up and the rank was given for each plant species (Martin, 1995).

### 3.2.6. The Market survey

A market survey was conducted in Bara bazaar; the biggest local market within Aizawl district to observe and collect the market price of commonly sold WEVs. Survey was conducted from January 2016- December 2017 depending on the season in which WEVs are available. A total of 38 vendor informants were interviewed (31 women and 7 men). The survey was based on the methodology adopted by Alexiades (1996) and Cunningham (2001).

### 3.2.7. Exploration of traditional food recipe

Traditional food recipes were collected randomly during field surveys from 35 households (14 households from Paihte, 21 households from Hmar communities), and all the recipes which were prepared from WEVs were documented through interviews. The name of the local dishes and method of preparations were recorded in Mizo language. The entire documented recipes were photographed and the description is given in English.

### 3.2.8. Floristic Compositions and Phytosociological Studies of WEVs

#### 3.2.8.1. Quadrat sampling

The floristic analysis was conducted during June-July 2016 in the two-forest area such as N.E Tlangnuam forest and Phuaibuang forest. A total of 25 quadrats of 10m x 10m ($100m^2$) size were randomly laid down to study tree species, shrub 5m x 5m ($25m^2$), and herbs 1m x 1m ($1m^2$) as per the method of Misra (1968). The tree species include all the saplings present in the study area.

### 3.2.8.2. Analysis of vegetation

The vegetation data recorded was quantitatively analyzed following the method of Curtis & McIntosh (1950) and the detailed parameters used and formula are given below

**Density**

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}}$$

**Frequency (%)**

$$\text{Frequency} = \frac{\text{Number of quadrats in which the species occur}}{\text{Total number of quadrats studied}} \times 100$$

**Abundance**

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which the species occured}}$$

**Basal area**

$$\text{Basal area} = \frac{(\text{CBH})^2}{4\pi}$$

Where,

CBH = Circumference at breast height

**Important value Index**

$$\text{IVI} = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance}$$

Where,

$$\text{Relative density} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Number of occurences of a species}}{\text{Number of occurences of all the species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of a species}}{\text{Total basal area of all the species}} \times 100$$

### 3.2.8.3. Diversity indices

Shannon-wiener diversity index (Shannon and Wiener, 1963) and Simpson's index of dominance (Simpson, 1949) were evaluated using past software (Hammer et al, 2001).

#### 3.2.8.4. Pattern of distribution (A/F) (Whitford, 1948)

Abundance to frequency (A/F) ratio was calculated to know the dispersion of plant species

$$\text{Distribution pattern} = \frac{\text{Abundance of each species}}{\text{Frequency of each species}}$$

When, A/F ratio is ≤0.025, >0.025 to ≤0.05, >0.05, it indicates as regular, random and clumped/contagious dispersion respectively.

#### 3.2.8.5. Sorenson index of similarity (Sorenson, 1948)

$$\text{Similarity index} = \frac{2C}{A+B} \times 100$$

Where,

A = Total number of species in site I
B = Total number of species in site II
C = Number of species common to both the sites

## 3.3. Results

### 3.3.1. Ethnobotanical survey of WEVs

#### 3.3.1.1. Taxonomic diversity

The studies recorded a total of 70 WEVs belonging to 36 families and 58 genera **(Table 3.2)**. Among the species documented, Cucurbitaceae and Fabaceae represent the highest number of species (5 species each), followed by Amaranthaceae, Araliaceae, Arecaceae, Poaceae, Asteraceae and Solananceae (4 species each). Following this, the family Musaceae and Araceae represent 3 species each. The remaining 26 families comprise 1 to 2 species **(Figure 3.4).** The highest number of genera was contributed by *Solanum* (4 species) followed by *Acmella*, *Amaranthus, Aralia*, *Calamus*, *Caryota*, *Dendrocalamus*, *Dioscorea*, *Marsdenia*, *Momrdica*, and *Musa* (2 species each), and the remaining genera constitute 1 species each **(Table 3.2).**

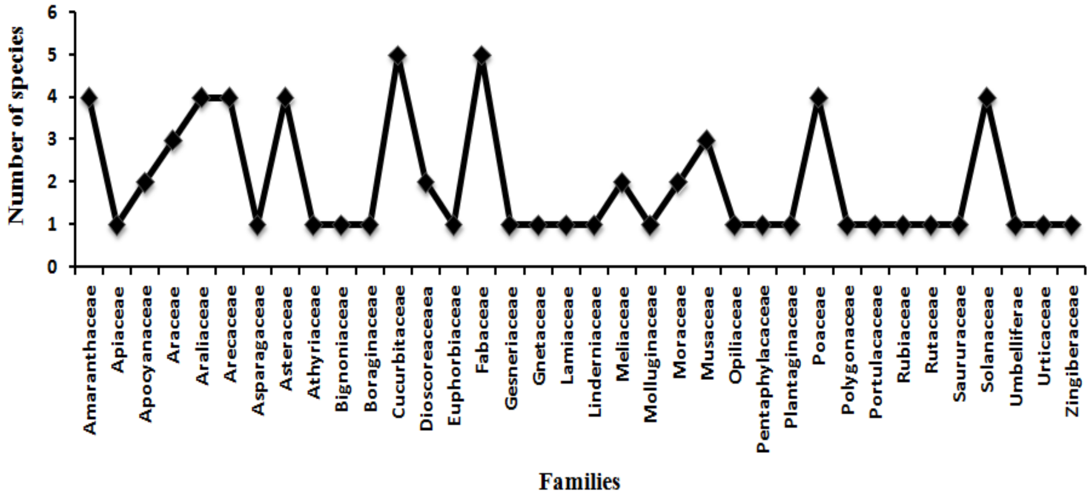


**Figure 3.4:** Family wise contribution of WEVs among two ethnic communities.

### 3.3.1.2. Life forms

Life forms indicated that 70 species of WEVs were dominated by herbs (39%) followed by trees (21%), climbers (17%), shrubs (11%), bamboos (6%) and minimum were recorded for palms and canes (3% each) **(Table 3.2, Figure 3.5)**.

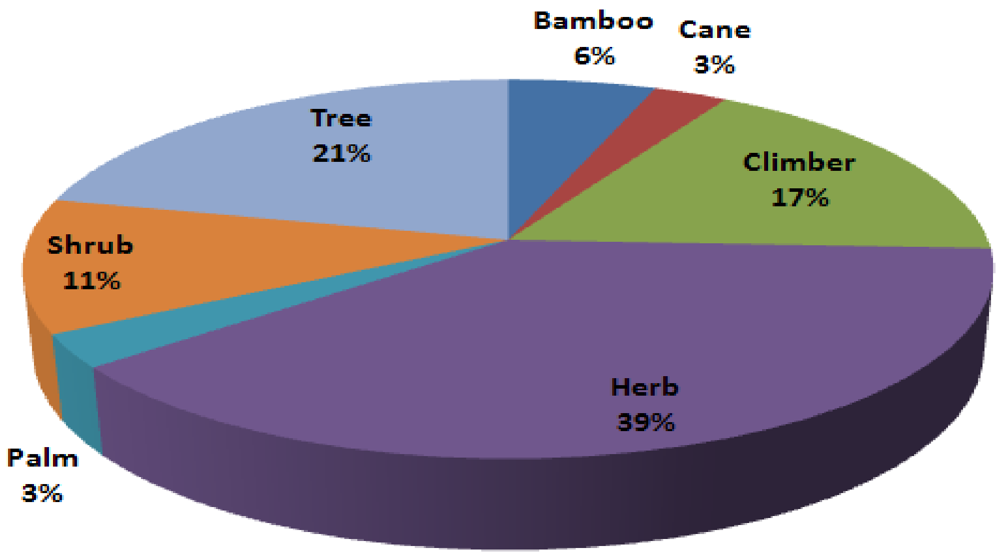


**Figure 3.5:** Life- form distributions of WEVs documented among two ethnic communities.

### 3.3.1.3. Plant parts consumed

The study revealed that different plant parts were consumed by the inhabitant in the study area. Out of 70 species, the leafy vegetable was the most frequently consumed plant parts (39 species), followed by shoot vegetables (28 species), fruits (8), flower bud, inflorescence, whole plants and tuber (3 species each) and there was one species where the flower was taken as a vegetable **(Table 3.2; Figure 3.6)**.

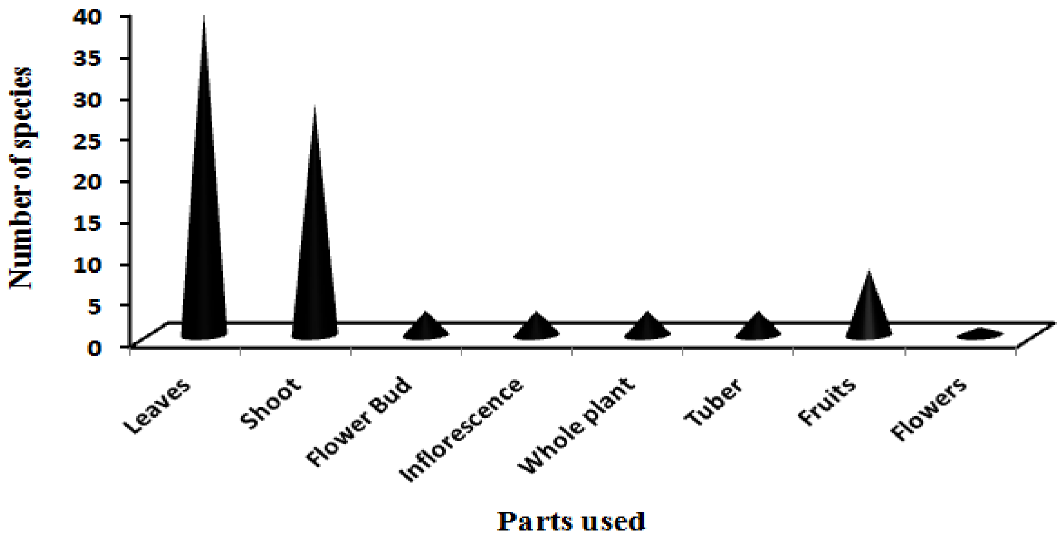


**Figure 3.6**: Frequency of plant parts used as vegetables among two ethnic communities.

#### 3.3.1.4. Modes of consumption

With regards to the mode of consumption of WEVs, 31 plants were consumed in fried form, 28 plants in boiled form, 14 plants in combination with fermented pork, 9 plants in combination with meat, 7 plants as salad preparations, 6 plants as raw food, 5 plants in combination with other vegetables, 4 plants each were cooked in combination with rice and with fermented soya bean, 3 plants as pickle and sun-dried form, while 1 plant was consumed in combination with dried fish **(Table 3.2**, **Figure 3.7)**.

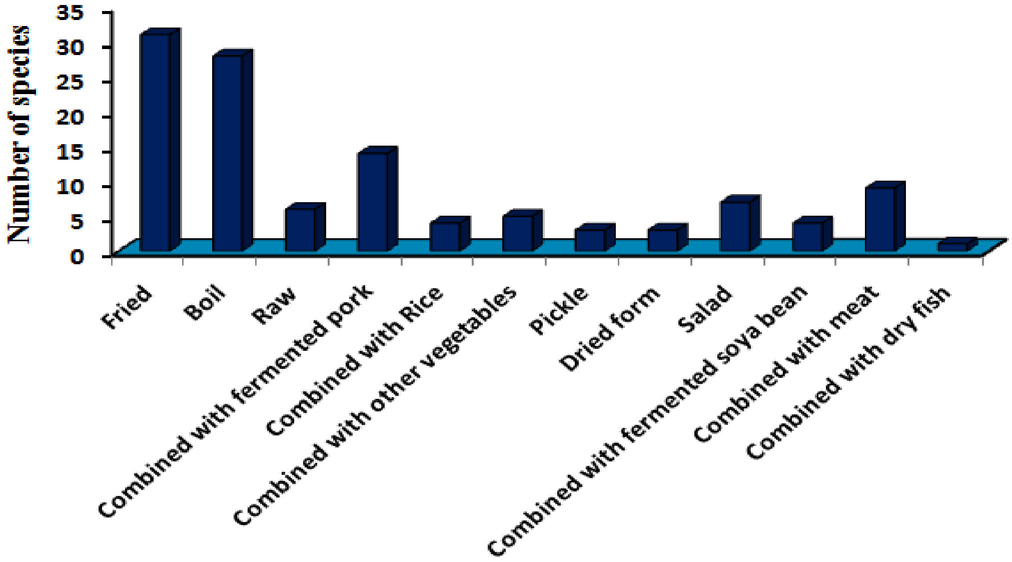


**Figure 3.7:** Different modes of consumption of WEVs.

### 3.3.1.5. Seasonal Availability of WEVs

In the present study, WEVs were found to be available throughout the year **(Table 3.2, Figure 3.8)**. The majority of the WEVs investigated were harvested by the local people from April to September, mostly during the rainy season and the peak of availability was observed in August where 80% of the plant species were available for harvest. Minimum WEVs were harvested during the dry period, January (28.57%) and December (32.86%), where the amount of rainfall decreases during this period.

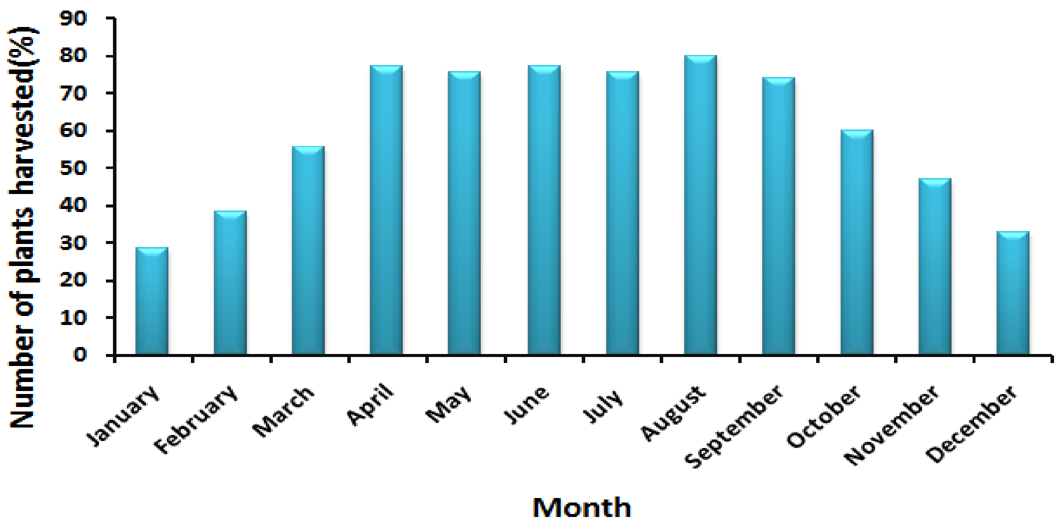


**Figure 3.8:** Seasonal availability of WEVs in the study site.

### 3.3.2. Informant consensus factor ($F_{ic}$) of food used category

To understand the level of agreement among informants of the two tribal communities, the informant's consensus factor ($F_{ic}$) was evaluated. The edible Phyto taxa were classified into 12 main categories. $F_{ic}$ for the food used categories ranges from 0.39 to 1.00. The categories with highest $F_{ic}$ was found in combination with dry fish (1.00) having 32 user report for 1 plant species, followed by dried formed (0.95) having 39 user report for 3 species and so on **(Figure 3.9)**. While the least agreement among informants was observed for plant used in fried formed (0.39) with 50 user reports for 31 species. The high $F_{ic}$ value indicated that the informants used relatively fewer taxa to make the given food.

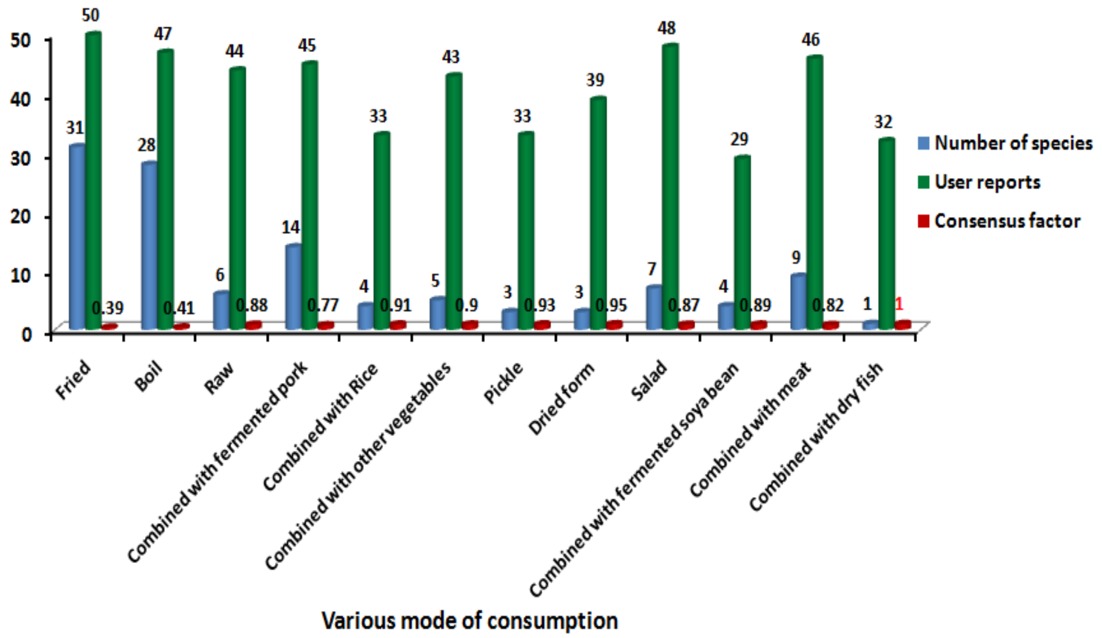


**Figure 3.9:** Informant consensus factor ($F_{ic}$) of food used category.

**Table 3.2:** List of WEVs documented during field survey with local name, Family, Life form, Available season, Part(s) use and Mode of consumption. ***Different ethnic groups: H- Hmar, P- Paihte**

| Sl/no | Botanical name/ Accession no. | Local name | Family | Life-Forms | Available season | Part(s) use | Mode of consumption |
|---|---|---|---|---|---|---|---|
| 1 | *Acmella oleracea* (L.) R.K.Jansen /MZUBOT0201 | P; Ansalai<br>H; Ansapui | Asteraceae | Herb | Feb-Nov | Leaves/ shoots | Salad/fried/ Boiled |
| 2 | *Acmella paniculata* (Wall. ex DC.) R.K.Jansen/MZUBOT0202 | H; Ansate<br>P; Ansa malngat | Asteraceae | Herb | Feb-Nov | Leaves/ shoots | Boiled/ Fried/ Salad |
| 3 | *Aganope thyrsifolia* (Benth.) Polhill. /MZUBOT0203 | H, P; Hulhu | Fabaceae | Climber | Feb- Apr | Leaves/Shoots | Boiled/ fried |
| 4 | *Alocasia* fornicata (Roxb.) Schott/MZUBOT0204 | H, P; Baibing | Araceae | Herb | Jul- Sep | Flower bud | Boiled/ Fried |
| 5 | *Alternanthera sessilis* (L.) R.Br.ex DC./MZUBOT0205 | H;An-ngharil<br>P; Nghagilkhate | Amaranthaceae | Herb | Mar-Sep | Leaves | Fried |
| 6 | *Amaranthus spinosus* L./ MZUBOT0206 | H; Lenhling hling nei<br>P; Lenling nei | Amaranthaceae | Herb | Apr-Sep | Leaves/Shoots | Combined with other vegetables |
| 7 | *Amaranthus viridis* L./ MZUBOTO207 | H; Lenhling hling neilo<br>P; Lenling neilo | Amaranthaceae | Herb | Apr-Sep | Leaves /Shoots | Combined with other vegetables |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | *Amomum dealbatum* Roxb./MZUBOT0208 | H;Aihri (Aidu)<br>P;Aigechil | Zingiberaceae | Herb | Jan- Apr | Inflorescence | Boiled/Fried |
| 9 | *Amophophallus nepalensis* (Wall.)/MZUBOT0209 | H, P; Telhawngpa | Araceae | Herb | Aug- Dec | Tuber | Boiled/Fried |
| 10 | *Antidesma bunius L*/ MZUBOT0210 | P; Tuaitit<br>H; Mang Tuaitit | Euphorbiaceae | Tree | Mar-Aug | Leaves | combined with meat |
| 11 | *Aralia foliolosa* Seem. ex C.B.Clarke/ MZUBOT0211 | H;Hlingthufir<br>P;Lingdawng | Araliaceae | Shrub | Mar-Aug | Leaves /Shoots | Boiled/Fried |
| 12 | *Aralia dasyphylla* Miq./MZUBOT0212 | H;Hlingthufir suak<br>P;Lingdawng suag | Araliaceae | Shrub | Mar- Aug | Leaves /Shoots | Boiled/Fried |
| 13 | *Asparagus officinalis* L./MZUBOT0213 | H; Thingribuk | Asparagaceae | Climber | Apr- Sep | Shoot | Fried |
| 14 | *Azadirachta indica* A. Juss/ MZUBOT0214 | H, P; Neem | Meliaceae | Tree | Jan-Oct | Leaves | Fried/ Salad |
| 15 | *Bambusa tulda* Roxb/ MZUBOT0215 | H: Rawthing<br>P: Rawting | Poaceae | Bamboo | May – Oct | Tender shoot | Combined with fermented pork |
| 16 | *Blumea myriocephala* DC. / MZUBOT0216 | P, H; Buardap | Asteraceae | Herb | Aug-Nov | Leaves | Boiled |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 17 | *Brassaiopsis hainla* (Buch. -Ham.) Seem. /MZUBOT0217 | H; Antumbu<br>P; Antumbu | Araliaceae | Tree | Apr-Sep | Leaves/Shoot | Boiled |
| 18 | *Calamus erectus* Roxb. / MZUBOT0218 | H; Hruizik<br>P; Chingzik | Arecaceae | Cane | whole year | Tender shoot | Boiled |
| 19 | *Calamus tenuis* Roxb. / MZUBOT0219 | H, P; Thilthek | Arecaceae | Cane | whole year | Tender shoot | Boiled |
| 20 | *Caryota mitis* Lour. / MZUBOT0220 | H; Meihle<br>P; Meile | Arecaceae | Palm | whole year | Shoots | Boiled |
| 21 | *Caryota urens* L./MZUBOT0221 | H, P; Tum | Arecaceae | Palm | whole year | Shoots | Boiled |
| 22 | *Centella asiatica* L./ MZUBOT0222 | H; Lambak<br>P; Lambak | Umbelliferae | Herb | Apr-Oct | Whole plants | Raw |
| 23 | *Chenopodium album* L./ MZUBOT0223 | H; Kawlbuh | Amaranthaceae | Herb | Mar-May | Leaves /Shoot | Combined with rice |
| 24 | *Clerodendrum bracteatum* Wall. ex Walp./ MZUBOT0224 | H,P;Phuihnam/ Anphui | Lamiaceae | Tree | Jan- Oct | Leaves | Combined with meat/ other vegetables |
| 25 | *Cordia dichotoma* G. Forster /MZUBOT0225 | H; Muk | Boraginacea | Tree | April-Oct | Leaves | combined with meat |

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|---|---|---|---|---|---|---|---|
| 26 | *Crotalaria tetragona* Roxb. Ex Andr. / MZUBOT0226 | H; Tumthang | Fabaceae | Shrub | Sep- Dec | Flowers | Combined with meat |
| 27 | *Dendrocalamus hamiltonii* Arn. ex Munro/MZUBOT0227 | H; Phulrua<br>P; pul lua | Poaceae | Bamboo | May – Oct | Tender shoot | Combined with fermented pork |
| 28 | *Dendrocalamus longispathus* (Kurz)/MZUBOT0228 | H; Rawnal<br>P;Rawnal | Poaceae | Bamboo | May – Oct | Tender shoot | Combined with fermented pork |
| 29 | *Dioscorea alata* L./MZUBOT0229 | H, P; Ram bahra | Dioscoreaceaea | Climber | whole year | Tuber | Boiled |
| 30 | *Dioscorea bulbifera* L/ MZUBOT0230 | H,P;Bachhim | Dioscoreaceaea | Climber | Aug- Nov | Tuber | Boiled |
| 31 | *Diplazium esculentum* / (Rets.) Sw. MZUBOT0231 | H; Chakawk | Athyriaceae | Herb | Mar- Nov | Leaves | fried/boiled/ Salad |
| 32 | *Dysoxylum excelsum* Blume/ MZUBOT0232 | H; Thingthupui<br>P; Singthupi | Meliaceae | Tree | Apr- Sep | Leaves / shoots | Boiled/ Fried |
| 33 | *Elatostema rupestre* (Buch. -Ham. ex D.Don) Wedd /MZUBOT0233 | H;Mangmanmim | Urticaceae | Herb | whole year | Leaves | Combined with rice |
| 34 | *Ensete superbum* (Roxb.) Cheesman /MZUBOT0234 | H; Saisua/saisu<br>P; Saisuang | Musaceae | Herb | whole year | Shoots | combined with fermented pork |

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|---|---|---|---|---|---|---|---|
| 35 | *Eryngium foetidum* L/. MZUBOT0235 | H, P; Bachikhawm | Apiaceae | Herb | Mar-Nov | Whole plant | Raw |
| 36 | *Eurya acuminata*.DC/ MZUBOT0236 | H, P; Sihzo/ Sihneh | Pentaphylacaceae | Tree | whole year | Leaves | Combined with rice Dried form /Combined with meat |
| 37 | *Fagopyrum tataricum* (L.) Gaertn. / MZUBOT0237 | H, P; Anbawng | Polygonaceae | Herb. | Mar-Sep | Leaves | Combined with fermented pork |
| 38 | *Ficus auriculata* Lour. /MZUBOT0238 | H; Theibal | Moraceae | Tree | Whole year | Leaves | Cook with dry fishes |
| 39 | *Glinus oppositifolius* (L.) Aug. DC. / MZUBOT0239 | L; Bakhate | Molluginaceae | Herb | Apr-Nov | Leaves | Fried |
| 40 | *Gnetum gnemon* L/ MZUBOT0240 | L; Pelh | Gnetaceae | Herb | Jun-Sep | Leaves | Fried |
| 41 | *Gynura cusimbua* (D.Don)/ MZUBOT0241 | H; Tlangnal<br>P; Tangnal | Asteraceae | Herb | Mar-July | Leaves/ shoots | Fried |
| 42 | *Houttuynia cordata* Thunb. / MZUBOT0242 | L, H; Uithinthang | Saururaceae | Herb | Feb-Aug | Leaves | Salad |
| 43 | *Lepionurus sylvestris* Blume/ MZUBOT0243 | H; Anpangthuam<br>P: Anpangthuam | Opiliaceae | Shrub | Whole year | Tender leaves | Raw/ cooked with fermented pork |

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|---|---|---|---|---|---|---|---|
| 44 | *Luffa acutangula* (L.) Roxb./ MZUBOT0244 | H, P; Awmpawng | Cucurbitaceae | Climber | Apr- Aug | Fruits | Fried |
| 45 | *Marsdenia formosana* Masam/MZUBOT0245 | H; Phai ankhate<br>P; Ankhaneu | Apocyanaceae | Climber | whole year | Leaves / Shoots | Cook with fermented pork |
| 46 | *Marsdenia maculata* Hook. /MZUBOT0246 | H; Ankhapui<br>P; Ankhapi | Apocyanaceae | Climber | whole year | Leaves / Shoot | Cook with fermented pork |
| 47 | *Meloccana baccifera (*Roxb.) Kurz /MZUBOT0247 | H, P: Mautak | Poaceae | Bamboo | Apr- Sep | Shoots | Pickle/ Fried/ Combined with fermented pork/ meat/ Boiled/ dried form |
| 48 | *Momordica charantia* L./ MZUBOT0248 | H; Kharek/ Changkhate<br>P; Tangkhamal neu | Cucurbitaceae | Climber | Apr-Oct | Fruits/ Leaves | Fried |
| 49 | *Momordica dioica* Roxb. ex Willd./ MZUBOT0249 | H, P; Maitamtawk | Cucurbitaceae | Climber | May –Jun | Fruits | Fried/boiled |
| 50 | *Morus indica L.*/ MZUBOT0250 | H; Thing theihmi | Moraceae | Tree | Whole year | Leaves | combined with meat |
| 51 | *Musa balbisiana* Colla/ MZUBOT0251 | H; Tumbu<br>P; Nahtangum | Musaceae | Herb | whole year | Inflorescence | Boiled/ Pickle/ Combined with fermented soya bean |
| 52 | *Musa. x paradisiaca* L./ MZUBOT0252 | H P; Lairawk | Musaceae | Herb | whole year | Inflorescence | Boiled/ Pickle/ Combined with fermented soya bean |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 53 | *Oroxylum indicum* (L.) Kurz /MZUBOT0253 | H; Pualchangkawk/ Archangkawng | Bignoniaceae | Tree | Aug-Nov | Fruits | Salad |
| 54 | *Parkia timoriana* (DC.) Merr/. MZUBOT0254 | H, P; Zawngtah | Fabaceae | Tree | Oct-Apr | Fruits | Raw/ fried/ mixed with fermented pork |
| 55 | *Picria fel-terrae* Lour/. MZUBOT0255 | H, P; Tlungkha/ khatual | Linderniaceae | Herb | May – Dec | leaves / Shoot | Combined with meat, Dried form |
| 56 | *Plantago major* L./ MZUBOT0256 | H; Vawkna-an<br>P; Vawkbilte | Plantaginaceae | Herb | Mar – Sep | Leaves | fried |
| 57 | *Portulaca oleraceae* L./ MZUBOT0257 | H; Bawk ek an | Portulacaceae | Herb | Mar- Nov | Whole plant | Fried |
| 58 | *Rhynchotechum ellipticum* Wall/MZUBOT0258 | H; Tiarrep<br>P;Chiaklep | Gesneriaceae | Shrub | Apr-Aug | Leaves | Combined with fermented soyabean or pork |
| 59 | *Senegalia pennata* (L.)/ MZUBOT0259 | H; Khanghu<br>P; Khanghmuk | Fabaceae | Tree | Mar-May | Leaves/Shoot | Boiled/fried |
| 60 | *Senna occidentalis* L./ MZUBOT0260 | H; Rengan<br>P; Lengan | Fabaceae | Shrub | May- Jul | Leaves | Combined with rice |
| 61 | *Solanum americanum* L./ MZUBOT0261 | H;Mit-thut/Anhling<br>P; An zo | Solanaceae | Herb | Feb-Oct | Leaves / Shoot | Fried/ Boiled |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 62 | *Solanum torvum* Sw./ MZUBOT0262 | H; Tawkpui<br>P; Samphawk pi | Solanaceae | Shrub | May –Jul | Fruits | Fried/Raw |
| 63 | *Solanum anguivi* Lam./ MZUBOT0263 | H; Tawkte<br>P; Samphawk neu | Solanaceae | Shrub | Apr-Jul | Fruits | Boiled with other vegetables |
| 64 | *Solanum lycopersicum* var. *cerasiforme* Dunal /MZUBOT0264 | H, P; Tomato te | Solanaceae | Climber | Feb-Dec | Fruits | raw/salad |
| 65 | *Solena heterophylla* Lour. / MZUBOT0265 | H;Uiluvun | Cucurbitaceae | Climber | Apr-Jun | Leaves/Shoot | Cook with fermented pork |
| 66 | *Thladiantha cordifolia* (Blume) Cogn./MZUBOT0266 | H; kangmang<br>P; Mang kang | Cucurbitaceae | Climber | Sept-Apr | Leaves | Combined with fermented pork |
| 67 | *Trevesia palmata* (Roxb.ex Lindl.) Vis./ MZUBOT0267 | H; Kawhtebel<br>P; Uilusing | Araliacea | Tree | Feb-April | Flower bud | Boiled/ Fried |
| 68 | *Typhonium horsfieldii* (Miq.)/ MZUBOT0268 | H, P; Telhawngnu | Araceae | Herb | Aug – Dec | Bulb | Boiled/ Fried |
| 69 | *Wendlandia budleioides* Wall. / MZUBOT0269 | H; Ba-tling<br>P; Bating | Rubiaceae | Tree | Feb-April | Flower bud | Boiled/ Fried |
| 70 | *Zanthoxylum rhetsa* (Roxb).Dc/MZUBOT0270 | H, P: Chingit | Rutaceae | Tree | Aug- Dec | Leaves /shoot | Combined with other vegetables or fermented soya bean/ fried |

### 3.3.3. Ethnomedicinal uses of WEVs

During the investigation and documentation of WEVs, there was a strong association between the wild food and the ethnomedicinal plants, which implies that some of the ethnomedicinal plants, in turn, was used as a food by the local inhabitant. Although therapeutic aspects were not the main focus of this study, edible Phyto taxa of medicinal used were also documented **(Table 3.3)**. The local informants mentioned 35 WEVs as medicine to treat several diseases. The investigated plants used for treating various ailments were grouped and classified into 22 categories based on the diseases it can be treated **(Table 3.3)**. Eight (8) plant species each were used to treat diabetes and dysentery, 7 species as hypertension, 6 species as stomach problem, 5 species as the dermatological problem, 4 species each as anthelmintic, anti-diarrheal, boils, fever and snake bites, 3 species to treat urinary problem, 2 species each were used as breast milk inducer, food poisoning, gynaecological problem, indigestion, liver problem, toothache and malaria, 1 species each as an antiseptic, sleep inducer and convulsion **(Figure 3.10)**.

**Table 3.3:** WEVs used as a medicine reported by informants from the study sites.

| Sl/No | Diseases category | Plants used |
|---|---|---|
| 1 | Anthelmintic | *Acmella paniculata, Solanum americanum, Zanthoxylum rhetsa, Acmella oleraceae* |
| 2 | Anti- Cancer | *Rhynchotechum ellipticum, Dioscorea bulbifera* |
| 3 | Anti-diabetic | *Musa balbisiana, Momordica charantia, Centella asiatica, Picria fel-terrae, Dioscorea bulbifera, Oroxylum indicum, Plantago major, Lepionurus sylvestris* |
| 4 | Anti-diarrheal | *Musa balbisiana, Dysoxylum excelsum, Parkia timotiara Fagopyrum tataricum,* |
| 5 | Antiseptic | *Solanum anguivi* |
| 6 | Boils | *Solanum anguivi, plantago major, Solanum torvum, Solanum americanum,* |
| 7 | Breast milk inducer | *Momordica charantia,Glinus oppositifolious,* |
| 8 | Convulsion | *Ensete superbum* |
| 9 | Dermatological problem | *Picria- fel- terrie,Solanum anguivi,Solanum torvum, Azadirachta indica, portulaca oleraceae,* |
| 10 | Dysentery | *Musa balbisiana, Oroxylum indicum, Aganope thyrsifolia, Dysoxylum excelsum, Calamus tenuis, Asparagus* |

| | | |
|---|---|---|
| | | *officinalis, Parkia timotiana, Eryngium foetidum* |
| 11 | Fever | *Ensete superbum, Picria fel-terrae, Solanum anguivi, Plantago major* |
| 12 | Food poisoning | *Senegalia pennata, Dysoxylum excelsum* |
| 13 | Gynae problem | *Cordia dichotoma, Fagopyrum tataricum* |
| 14 | Hypertension | *Momordica charantia, Clerodendrum bracteatum, Centella asiatica, Marsdenia macrophylla, Marsdenia formosana. Senna occidentalis, Picria fel-terrae* |
| 15 | Indigestion | *Fagopyrum tataricum, Parkia timoriana* |
| 16 | Liver problem | *Ensete superbum, Glinus oppositifolius* |
| 17 | Malaria | *Plantago major, Eryngium foetidum* |
| 18 | Sleep inducer | *Amomum dealbatum* |
| 19 | Snake bites | *Musa balbisiana, Amaranthus viridis, Ensete superbum , Antidesma bunius* |
| 20 | Stomach problem | *Oroxylum indicum, Centella asiatica, Aganope thyrsifolia, Fagopyrum tataricum, Eryngium foetidum, Azadirachta indica* |
| 21 | Toothache | *Acmella oleraceae, Solanum americanum* |
| 22 | Urinary problem | *Solanum americanum, Senna occidentalis, Portulaca oleraceae* |

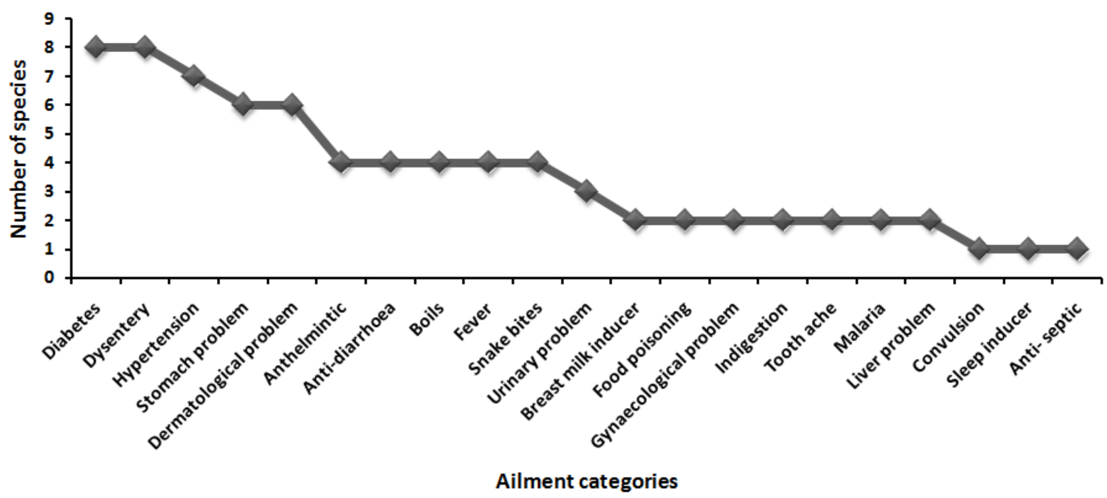



**Figure 3.10:** Distribution frequency of number of ethnomedicinal plants based on the ailments it can be treated.

#### 3.3.3.1. Informant's consensus factor ($F_{ic}$) of disease categories

$F_{ic}$ value of WEVs used as ethnomedicine was calculated after it had been grouped into twenty-two categories based on the user report **(Table 3.3).** The results showed that $F_{ic}$ ranges from 0.75 to 1 with highest report for convulsion ($F_{ic}$ =1; 1 species; 39 user report), sleep inducer ($F_{ic}$=1;1 species; 37 user report) and antiseptic ($F_{ic}$=1; 1 species; 34 user report) followed by anti-cancer and breast milk inducer ($F_{ic}$=0.98; 2 species; user report=43 and $F_{ic}$=0.98; 2 species; user report=51 respectively), indigestion and tooth-ache ($F_{ic}$ = 0.97 each), urinary problem ($F_{ic}$= 0.96), liver problem ($F_{ic}$=0.94), Anti-diarrhoea and anthelmintic ($F_{ic}$=0.93 each). The least agreement among informants was evaluated for the plants used to treat snake bites ($F_{ic}$=0.79; 4 species; user report=15) and malaria ($F_{ic}$=0.75; 2 species; 5 user report) **(Figure 3.11)**.

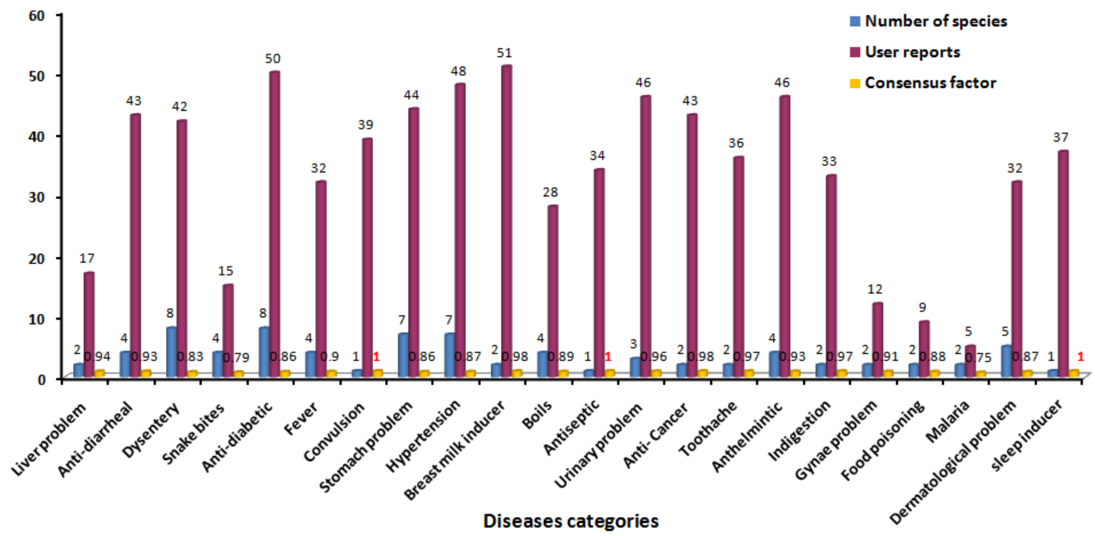



**Figure 3.11:** Informant's consensus factor ($F_{ic}$) of various diseases indication.

#### 3.3.3.2. Fidelity level (%) of commonly reported ethnomedicinal plants

Fidelity level (Fl) values help in identifying the most preferred and important plant species for the treatment of a particular disease or ailment. The Fl value was calculated for the 35 most common ethnomedicinal plants reported by the informants within the study area. The study reports the Fl values varying from 30.77 % to 100% in all the disease categories. The highest Fl values were obtained for *Picria fel-terrae* (100%) implying that it was the most preferred ethnomedicinal plant by the informants for the treatment of hypertension. This was followed by *Solanum anguivi*

(FL= 97%), *Picria fel-terrae* (95%) recommended for the treatment of diabetes, and *Dysoxylum excelsum* (94.74%) for antidiarrhoeal. On the contrary, the least Fl value was recorded for *Senegalia pennata* (30.77%) for the treatment of food poisoning and *Eryngium foetidum* (36.36%) for the treatment of malaria **(Table 3.4)**.

**Table 3.4:** Fidelity level (Fl) values of medicinal plants commonly reported against various diseases/ailment categories

| Ethnomedicinal plants | Diseases categories | Np | N | FL (%) |
|---|---|---|---|---|
| *Picria fel-terrae* | Anti-diabetic | 19 | 20 | 95 |
| *Momordica charantia* | | 28 | 30 | 93 |
| *Lepionurous sylvestris* | | 12 | 15 | 80 |
| *Musa balbisiana,* | Diarrhoea | 16 | 24 | 66.67 |
| *Dysoxylum excelsum,* | | 18 | 19 | 94.74 |
| *Musa balbisiana,* | Dysentery | 9 | 15 | 60 |
| *Eryngium foetidum* | | 12 | 27 | 44.44 |
| *Dysoxylum excelsum,* | | 21 | 23 | 91.30 |
| *Musa balbisiana* | Snake bites | 21 | 32 | 65.63 |
| *Ensete superbum,* | Fever | 18 | 35 | 51.43 |
| *Ensete superbum* | Convulsion | 39 | 47 | 82.98 |
| *Oroxylum indicum* | Stomach problem | 16 | 20 | 80 |
| *Fagopyrum tataricum* | | 13 | 16 | 81.25 |
| *Clerodendrum bracteatum* | Hypertension | 20 | 22 | 90.91 |
| *Centella asiatica* | | 15 | 19 | 78.95 |
| *Picria fel-terrae* | | 14 | 14 | 100 |
| *Momordica charantia* | Breast milk | 35 | 61 | 57.38 |
| *Glinus oppositifolious* | | 39 | 45 | 86.67 |
| *Solanum anguivi* | Antiseptic | 34 | 35 | 97.14 |
| *Solanum anguivi* | Boils | 21 | 25 | 84 |
| *Solanum americanum* | | 19 | 23 | 82.61 |
| *Portulaca* | Urinary problem | 20 | 30 | 66.67 |
| *Solanum americanum* | | 26 | 35 | 74.29 |
| *Rhynchotechum ellipticum* | Anti-cancer | 12 | 17 | 70.59 |
| *Dioscorea bulbifera* | | 31 | 45 | 68.89 |
| *Acmella oleraceae,* | Tooth ache | 28 | 36 | 77.78 |
| *Acmella oleraceae* | Anthelmintic | 44 | 50 | 88 |
| *Fagopyrum tataricum* | Indigestion | 23 | 36 | 63.89 |
| *Parkia timoriana* | | 10 | 18 | 55.56 |
| *Fagopyrum tataricum* | Gynaecological problem | 6 | 15 | 40 |
| *Senegalia pennata* | Food poisoning | 4 | 13 | 30.77 |
| *Eryngium foetidum* | Malaria | 4 | 11 | 36.36 |
| *Solanum anguivi,* | Dermatological problem | 9 | 14 | 64.29 |
| *Azadirachta indica* | | 11 | 25 | 44 |
| *Amomum dealbatum* | Apetizer | 37 | 50 | 74 |
| *Ensete superbum* | Liver problem | 10 | 19 | 52.63 |

FL= Fidelity Level, Np = Number of informants that reported the use of a plants for treatment of a particular disease.

N= Number of informants who used the plants as a medicine to treat any given disease.

### 3.3.4. Direct matrix ranking (DMR):

DMR was considered a good tool to know the status of plants whether it was under stress condition or not, and the corresponding factor that threatens the plant. In this study, 13 multipurpose species of WEVs were selected and 4 used categories were listed for 5 informants to assign the multipurpose use of the species. Accordingly, *Dysoxylum excelsum* was highly utilized by the inhabitant for multipurpose and ranked first (DMR=64); *Antidesma bunius* (60) ranked second; *wendlandia budleioides* (56) ranked third; *Musa balbisiana* ranked fourth (51) and *Azadirachta indica* ranked fifth (50). The lowest rank was observed for *Rhynchotechum ellipticum* (30) **(Table 3.5)**.

**Table 3.5:** Average DMR score of five informants for most commonly used WEVs

| **Species** | **Use Categories** | | | | | |
|---|---|---|---|---|---|---|
| | **Fuel wood** | **Fodder** | **Construction** | **Medicine** | **Total** | **Rank** |
| *A. oleraceae* | 0 | 23 | 0 | 21 | 44 | 7th |
| *A. bunius* | 21 | 15 | 12 | 18 | 60 | 2nd |
| *A. indica* | 22 | 0 | 10 | 23 | 50 | 5th |
| *B. tulda* | 4 | 7 | 20 | 0 | 31 | 11th |
| *D. hamiltonii* | 8 | 7 | 19 | 0 | 34 | 10th |
| *D. excelsum* | 25 | 0 | 15 | 25 | 64 | **1st** |
| *E. acuminate* | 23 | 15 | 6 | 0 | 41 | 9th |
| *F. tataricum* | 0 | 23 | 0 | 21 | 44 | 7th |
| *M. baccifera* | 7 | 12 | 23 | 0 | 43 | 8th |
| *M. balbisiana* | 0 | 25 | 3 | 21 | 51 | 4th |
| *R. ellipticum* | 0 | 9 | 0 | 21 | 30 | 12th |
| *S. americanum* | 0 | 20 | 0 | 25 | 45 | 6th |
| *W. budleioides* | 4 | 18 | 14 | 0 | 56 | 3rd |

Based on use criteria (5=best; 4=very good; 3=good; 2=less used; 1=least used; 0=no value).


*Acmella paniculata*


*Acmella oleracea*


*Aganope thyrsifolia*


*Alocasia fornicata*


*Amaranthus spinosus*


*Amaranthus viridis*


*Amomum dealbatum*


*Amophophallus nepalensis*


*Antidesma bunius*


*Aralia foliolosa*


*Aralia dasyphylla*


*Asparagus officinalis*


*Azadirachta indica*


*Bambusa tulda*


*Blumea myriocephala*


*Brassaiopsis hainla*


*Calamus erectus*


*Calamus tenuis*


*Caryota mitis*


*Caryota urens*


*Centella asiatica*


*Chenopodium album*


*Clerodendrum bracteatum*


*Cordia dichotoma*


*Crotalaria tetragona*


*Dendrocalamus hamiltonii*


*Dioscorea alata*


*Dioscorea bulbifera*


*Dysoxylum excelsum*


*Elatostema rupestre*


*Ensete superbum*


*Eryngium foetidum*


*Eurya acuminata*


*Fagopyrum tataricum*


*Ficus auriculata*


*Glinus oppositifolius*


*Gnetum gnemon*


*Gynura cusimbua*


*Houttuynia cordata*


*Lepionurous sylvestris*


*Marsdenia formosana*


*Marsdenia maculata*


*Meloccana baccifera*


*Momordica charantia*


*Momordica dioica*


*Morus indica*


*Musa balbisiana*


*Oroxylum indicum*


*Parkia timoriana*


*Picria fel-terrae*


*Plantago major*


*Portulaca oleraceae*


*Rhynchotechum ellipticum*


*Senegalia pennata*


*Senna occidentalis*


*Solanum americanum*


*Solanum torvum*


*Solanum anguivi*


*Solanum lycopersicum* var. *cerasiforme*


*Solena heterophylla*


*Thladiantha cordifolia*


*Trevesia palmata*


*Typhonium horsfieldii*


*Wendlandia budleioides*

*Zanthoxylum rhetsa* *Dendrocalamus longispathus* *Diplazium esculentum*

**Figure 3.12:** Photograph of WEVs documented during field survey.

### 3.3.5. Market survey of WEVs

Markets play a significant role in socio-economic development promoting income generation for rural communities and are common especially during a food shortage. During the 24-months survey, a total of 47 WEVs were found to be sold in the Bara bazaar (market) in Aizawl. Based on the vendors' attributes, most of these WEVs were gathered directly by the villager from the forest and either directly sold by them or handed over to some commission agents. Thus, the price ranges were somewhat fluctuated depending on the adequacy supply chains and seasonal availability. The parts sold and local market prices of WEVs were given below **(Table 3.6).**

**Table 3.6:** List of common WEVs sold by vendors in the local market

| Sl/no | Botanical name | Parts sold | Market price |
|---|---|---|---|
| 1 | *Acmella oleracea* | Leaves & shoot | Rs 10-20 / Bundle |
| 2 | *Aganope thyrsifolia* | Leaves &shoot | Rs 20-30/ Bundle |
| 3 | *Alocasia fornicata* | Flower bud | Rs 10-20/ Bundle |
| 4 | *Amaranthus viridis* | Tender shoot & leaves | Rs 20/ Bundle |
| 5 | *Amomum dealbatum* | Inflorescence | Rs 20-30/ Pack |
| 6 | *Amophophallus nepalensis* | Bulb | Rs 20-30/ Cup |
| 7 | *Aralia foliolosa* | Tender shoot & leaves | Rs 20 / Bundle |
| 8 | *Bambusa tulda* | Tender shoot | Rs 50-100/ Bundle |
| 9 | *Calamus erectus* | Tender shoot | Rs100/ Pack |
| 10 | *Calamus tenuis* | Tender shoot | Rs 200/ Pack |
| 11 | *Caryota mitis* | Tender shoot | Rs 50-100/ Pack |
| 12 | *Caryota urens* | Tender shoot | Rs 50-100/ Pack |
| 13 | *Centella asiatica* | Whole plant | Rs 10-20/ Bundle |
| 14 | *Chenopodium album* | Tender shoot & leaves | Rs 2-30/ bundle |
| 15 | *Clerodendrum bracteatum* | Tender leaves | Rs10- 20/ Bundle |
| 16 | *Crotalaria tetragona* | Flower | Rs20-30/ pack |

| | | | |
|---|---|---|---|
| 17 | *Dendrocalamus hamiltonii* | Tender shoot | Rs 50- 100/ Bundle |
| 18 | *Dendrocalamus longispathus* | Tender shoot | Rs 50- 100/ Bundle |
| 19 | *Diplazium esculentum* | Leaves | Rs10- 20/ Bundle |
| 20 | *Dysoxylum excelsum* | Tender shoot & leaves | Rs 20-60/ Bundle |
| 21 | *Ensete superbum* | Aerial pseudo stem | Rs10- 20/ Bundle |
| 22 | *Eryngium foetidum* | Leaves | Rs 10-20/ bundle |
| 23 | *Eurya acuminata.* | Leaves | Rs 10-20/ Bundle |
| 24 | *Glinus oppositifolius* | Whole plant | Rs20-30/ Bundle |
| 25 | *Gnetum gnemon* | Tender leaves & fruits | Rs 10-20/ Pack |
| 26 | *Houttuynia cordata* | Leaves | Rs 20/ Bundle |
| 27 | *Lepionurus sylvestris* | Leaves | Rs20/ bundle |
| 28 | *Marsdenia formosana* | Leaves | Rs10-20/ Bundle |
| 29 | *Marsdenia maculata*. | Shoot & leaves | Rs10-20/ Bundle |
| 30 | *Meloccana baccifera* | Tender shoot | Rs 50- 100/ Bundle |
| 31 | *Momordica charantia* | Fruits & leaves | Rs 10-30/ Bundle |
| 32 | *Momordica dioica* | Fruits | Rs 30-80/ Kg |
| 33 | *Musa balbisiana* | Inflorescence | Rs 10/inflorescence |
| 34 | *Musa. x paradisiaca* | Inflorescence | Rs 10/ Kg |
| 35 | *Oroxylum indicum* | Fruits | Rs 10-20/ Pod |
| 36 | *Parkia timoriana* | Fruits | Rs 5-10/ Pod |
| 37 | *Picria fel-terrae* | Leaves | Rs 10/ bundle |
| 38 | *Rhynchotechum ellipticum* | Leaves | Rs10-20/ Bundle |
| 39 | *Senegalia pennata* | Tender leaves & shoot | Rs 30-40/ Bundle |
| 40 | *Senna occidentalis* | Leaves | Rs 10-20/ Bundle |
| 41 | *Solanum americanum* | Tender shoot & leaves | Rs10- 20/ Bundle |
| 42 | *Solanum torvum* | Fruits | Rs 10- 20/ pack |
| 43 | *Solanum anguivi* | Fruits | Rs10- 20/ Pack |
| 44 | *Solanum lycopersicum* var. *cerasiforme* | Fruits | Rs 20-30/ Pack |
| 45 | *Trevesia palmata* | Flower bud | Rs 30-70/ Pack |
| 46 | *Wendlandia budleioides* | Flower bud | Rs 20/ bundle |
| 47 | *Zanthoxylum rhetsa* | Tender leaves & shoot | Rs10-20/ Bundle |

### 3.3.6. Enumeration of traditional recipe

During the field survey, twenty-four (24) types of traditional food recipes consumed by two ethnic groups of Aizawl district, Mizoram where documented according to their seasonal availability. Accordingly, 24 species of WEVs traditionally used by the ethnic group for the preparation of various recipes were listed and presented in **Table 3.7.** A diverse group of WEVs was documented that comprises 19 families.

The life-form depicted that trees were dominating (11 species) followed by herb (6 species), 2 species each of shrub**,** bamboo, climber, and 1 species of palm. The leaf and shoot vegetables were the most frequently plant parts used for the preparation of various traditional recipes. WEVs were readily available for consumption throughout the year and the majority of them were harvested by the local people mostly during the rainy season (April to September). Out of 24 species of WEVs documented, 16 species were of ethno medicinally importance **(Table 3.7)**. The results further showed that the affinities of choices in food consumption were more or less similar among the two ethnic groups. Some of the recipes had a complex method of preparation with several traditional seasonings added to them. It is important to note that several of these cuisines have been commercialized in local restaurants and hotels. The serving size of the traditional recipes documented in this study was calculated for 5 individuals and prepared accordingly.

**Table 3.7:** Lists of wild edible vegetables used for the preparation of traditional recipe.

| SL/No | Plant name | Family | Common name | Habit | Edible parts | Seasonal availability | ethnomedicinal value |
|---|---|---|---|---|---|---|---|
| 1 | *Brassaiopsis hainla* (Buch. -Ham.) Seem. | Araliaceae | Chuletro | Tree | Leaves and shoot | Apr-Sep | NA |
| 2 | *Eurya acuminata* DC. | Pentaphylacaceae | Tapering Leaf Eurya | Tree | Leaves | Whole Year | NA |
| 3 | *Ficus auriculata* Lour. | Moraceae | Elephant year fig tree | Tree | Leaves | Whole Year | NA |
| 4 | *Fagopyrum tataricum* (L.) Gaertn. | Poligonaceae | Buckwheat | Herb | Leaves | Mar-Sep | Gynaecological problem |
| 5 | *Amomum dealbatum* Roxb. | Zingiberaceae | Black cardamom | Herb | Flower bud | Jan- Apr | Sleep inducer |
| 6 | *Senegalia pennata* (L.) | Fabaceae | Climbing wattle | Climber | Tender leaves | Mar-Jun | Food poisoning |
| 7 | *Marsdenia maculata* Hook. | Apocyanaceae | Masculatus | Climber | Leaves and shoot | Whole Year | Hypertension |
| 8 | *Rhynchotechum ellipticum* (Wall. ex D. Dietr.) A. DC. | Gesneriaceae | Taiwan Rhynchotechum | Shrub | Leaves | Apr-Aug | Anti-cancer |
| 9 | *Ensete superbum* (Roxb.) Cheesman | Musaceae | Rock banana | Herb | Pseudo stem | Whole Year | Snake bite, Convulsion |
| 10 | *Solanum anguivi* Lam. | Solanaceae | Indian night shade | Shrub | Fruits | Apr-Jul | Anti-septic, boils |
| 11 | *Meloccana baccifera (*Roxb.) Kurz | Poaceae | Berry bamboo | Bamboo | Shoots | Apr- Sep | NA |
| 12 | *Aganope thyrsifolia* (Benth.) Polhill. | Fabaceae | Flame Tree | Tree | Young leaves and shoots | Feb- Apr | NA |
| 13 | *Caryota mitis* Lour. | Arecaceae | Fishtail palm | Palm | Tender shoots | Whole Year | NA |
| 14 | *Musa balbisiana* Colla | Musaceae | Wild banana | Bamboo | Inflorescence | Whole Year | Dysentery, snake bites |
| 15 | *Aralia dasyphylla* Miq. | Araliaceae | Spikenard | Tree | Tender Leaves and shoots | Mar-Aug | Nerve problem |
| 16 | *Centella asiatica* L. | Umbelliferae | Indian pennywort | Herb | Whole plants | Apr-Oct | Anti-diabetic, hypertension |
| 17 | *Dysoxylum excelsum* Blume | Meliaceae | NA | Tree | Leaves and shoots | Apr- Sep | Dysentery, Stomach problem |
| 18 | *Wendlandia budleioides* Wall. | Rubiaceae | NA | Tree | Flower bud | Feb-April | NA |
| 19 | *Parkia timoriana* (DC.) Merr | Fabaceae | Tree bean | Tree | Fruits and flower head | Oct-Apr | Indigestion, Anti-diarrheal |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 20 | *Trevesia palmata* (Roxb.ex Lindl.) Vis. | Araliaceae | Snowflake plant | Tree | Flower bud | Feb- April | Anti-diabetic |
| 21 | *Amaranthus viridis* L | Amaranthaceae | Wild amaranth | Herb | Tender shoots and leaves | Apr-Sep | Snake bite, kidney problem |
| 22 | *Gnetum gnemon* L | Gnetaceae | Joint-fir spinach | Tree | leaves | Jun-Sep | |
| 23 | *Oroxylum indicum* (L.) Kurz | Bignoniaceae | Indian trumpet flower | Tree | Fruits | Aug-Nov | Anti-diabetic, stomach problem |
| 24 | *Amophophallus nepalensis* (Wall.) | Araceae | Voodoo lily | Herb | Corm | Aug- Dec | NA |

**1) Antumbu Mung**

*Mung* is the simplest way of cuisine preparations among Hmar and Paihte communities [**Figure 3.13 (A)].** *Antumbu* (*Brassaiopsis hainla)* is the main ingredients for this recipe. It is the most prominent dish among Hmar and Paihte in the study area. The mode of preparation is simple, about 500g of young shoots and leaves were simply boiled for 15-30 minutes; the water is then discarded and is ready to serve. For better taste, dried chilies and salt is normally added.

**2) Chartang**

*Chartang* is a traditional dry meat-based recipe of Hmar tribe and is the most popular and delicious food. Approximately 1kg of dry meat is first cooked for 10-15 minutes in a pressure cookher, after this, an appropriate amount (~100g) of fresh leaves or dry leaves of *Sihzo* (*Eurya acuminata*) is added along with salt and two teaspoon of *chingal* (ash filtrate/lye) followed by the addition of few drops of *saum/ sathu* (fermented pork fat). All the content is mixed thoroughly and is ready to be served where *Eurya acuminata* is also a high preference for making another recipe **[Figure 3.13(B)]**.

**3) Theibal chhum**

This recipe can be prepared only when fish is available. To prepare, 500g of the dry or fresh fish is boiled with the tender leaves of *Ficus auriculata* (~500g) and an appropriate amount of salt is added to it [**Figure 3.13(C)]**. For better taste, crushed onion, garlic, ginger, and wild coriander are also added as per one's wish.

**4) Bai**

*Bai* can be prepared by mixing different types of vegetables and is considered essential to complete the meal of two tribal groups. This study documented five methods of preparation of *Bai* from different vegetables such as:

***i) Anbawng bai***: The main ingredient of Anbawng bai is *Fagopyrum tataricum*. In this recipe, 500g of the leaves of *Anbawng* are chopped into small pieces and cooked in 2-3 cups of hot water or depending upon the number of vegetables used. Then, salt and an adequate amount of crushed chili are added along with 3 teaspoon of ash filtrate and a few drops of fermented pork fat. All the contents are stirred up well and are ready to be served **[Figure 3.13(D)]**.

***ii) Aihritil Bai***: It is a popular dish among Hmar tribal group. 200g of the flower buds of *Amomum dealbatum* are cut into small pieces, mixed with dried chili, and are added to pre-boiled water. To this, an equal amount of *Khanghu/khanghmuk (Sennegalia pennata*) and *Sihzo/sihneh* (*Eurya acuminata)* are added with an appropriate amount of ash water. The mixture is stirred up well and foamed is developed. After the addition of a subsequent amount of *saum*, the dish is ready to be served **[Figure 3.13(E)]**.

***iii) Ankhapui Bai:*** It is a typical dish prepared from the shoot and leaves of *Marsdenia maculate,* mostly prepared by the two ethnic groups of the study area [**Figure 3.13(F)]**. For preparation, 200g of the shoot and leaves are placed over a fire for about 2 minutes to soften the skin. The skin of the shoot is peeled off and cut into small pieces and are added to pre-heated water, followed by the addition of salts and an appropriate amount of *chingal, bekang-um* (Fermented soybean), and *saum*. It is bitter and is often served with steamed pork.

***iv) Tiarhrep Bai:*** It is a typical food of Hmar and is highly preferable when the staple foods are not available. To prepare, 300g of the leaves of *Rhynchotechum ellipticum* are chopped into small pieces and introduced into hot water with *dawlzik* (*Colocasia esculenta*). To this, an appropriate amount of *chingal* is added along with salt, chili, and wild coriander. Lastly, a few amounts of *bekang-um* is used as a seasoning **Figure 3.13(G)]**.

***v) Saisu Bai:*** It is a prominent dish among the two ethnic groups. The main ingredient is the shoot of *Ensete superbum* [**Figure 3.13(H)]**. It is mostly prepared in combination with other vegetables. To prepare, approximately 500g of *Ensete superbum* shoot is cut into small pieces and added to pre-boiled water. An equal amount of leaves of cowpea (*Vigna unguiculata*) are added along with chili and salts. A few drops of cooking oil and baking soda are added. For better taste, wild coriander and steamed pork can be added.

**5) Tawkte buhpawk**

It is a typical porridge-type food of Hmar and Paihte [**Figure 3.13(I)]**. For preparation, around 100g of rice grains are first boiled in water for about 20 minutes, when the rice grains become soft, an equal amount of green fruits of *Solanum indicum* are simply added along with salt and a pinch of baking soda. Then, the entire mixture becomes semi-solid. and has a bitter taste.

**6) Beipenek**

Hmar tribal group usually prepared *beipenek* on a special occasion and during their feast. It is a highly popular dish prepared using rice flour. There are two types of *beipenek*: 1) vegetarian *beipenek* and 2) non-vegetarian *beipenek* (prepared with fresh and smoked meats). This study documented *Beipenek* prepared from *Meloccana baccifera* **[Figure 3.13(J)]**. 1kg of the young shoot of *Meloccana baccifera* is cut into small pieces and fried with cooking oil. Turmeric powder is added along with salt, chili, crushed onion, garlic, and wild coriander to get a pleasant fragrance and hot water is added depending upon the content of the bamboo shoot and cooked for a few minutes. At the same time, the pre-soaked rice is ground in the wooden mortar to get flour. This rice flour is then suspended into cold water with turmeric powder and added to the mixture to make it *Nawng* (gravy). It is continuously stirred up until and unless it is ready to serve. For the preparations of non-vegetarian *beipenek*, fresh or smoked meats are used and the same method of preparation is followed.

**6) Hulhu Zeu:**

To prepare *hulhu zeu*, 500g of the tender leaves and shoots of *Aganope thyrsifolia* are boiled for 1 hour. The water is discarded and added repeatedly while cooking. After the last cooking, water is removed; it is deep fried with cooking oil. Salt, onion, garlic can be added for a better taste. It is a popular dish among the two ethnic groups [**Figure 3.13(K)]**.

**7) Meihle Tlak:**

Different types of vegetables can be used for making *Tlak.* This study deals with *Tlak* prepared from *Meihle* (*Caryota mitis*) **[Figure 3.13(L)]**. The tender shoot of *Meihle* is sliced into 1-2 inches long (~1kg) and boiled for about 40 minutes. When it becomes soft, smoked roselle leaves are added to enhance the taste. Salt and chilies can be added as per one's wish.

**8) Tumbuvui thukthawlh**

It is a prevalent dish among the two tribal communities; the main ingredient is the inflorescence of *Musa* species (~1kg). The whole inflorescence is simply put over the fire for about one hour and the skin is peeled off to get the tender inflorescence and it is ready to serve with dried chili and salt [**Figure 3.13(M)]**.

**9) Hlingthufir zeu**

It is also a common dish among Hmar ethnic group. Tender leaves and shoots of *Aralia dasyphylla* (~500g) are first boiled in water and then are fried using cooking oil [**Figure 3.13(N)]**. Wild coriander and garlic are crushed and added at the time of serving to enhance the smell. This dish is highly preferred by Hmar community during the time of availability.

**10) Lambak tauh**

The main ingredients are the whole plant of *Centella asiatica* and dried peanut. To prepare, a fresh plant of *Centella asiatica* (~200g) is chopped into small pieces and then first fried with cooking oil for 2 minutes. Meanwhile, a peanut is fried separately and then ground nicely. The two ingredients are mixed and then crushed onion, garlic, ginger, red chili, and wild coriander are added to it [**Figure 3.13(O)]**.

**11) Thingthupui kan**

The young shoot and leaves of *Dysoxylum excelsum* (~500g) are first boiled with water. The water is discarded and is simply fried in oil along with onion, dry chili, turmeric powder, and salt [**Figure 3.13(P)]**.

**12) Batling par tauh**

This dish serves as an important food among Hmar and Paihte communities during the period of food shortage. *Wendlandia budleioides* flower bud is the main ingredient for this recipe [**Figure 3.13(Q)]**. After the flower bud (~250g) is boiled for several minutes, all the water is then squeezed out and the flower bud is cut into small pieces. Wild corianders, red chili, king chili, turmeric, and sesame seed are crushed and finally, all the content is mixed together and fried in preheated oil for 5 minutes.

**13) Zawngtah bilbawlawk bawl**

This recipe is particularly common among Hmar although it is unfamiliar among Paihte people in the study area. It is often taken with plain rice as a side dish. The dense flower-heads of *Parkia timoriana* (tree bean) are the main ingredients [**Figure 3.13(R)]**. The inflorescences (~500g) are rubbed off and the skins of the flower heads are peeled off. It is sliced into a thin circular shape and is boiled for 2 minutes to reduce the bitter taste. After that, the water is discarded and the flower head is kept aside. Green king chili is put over a fire and ground well which is again mixed with flower head and salt. Finally, one tablespoon of fermented pork fat is added by constant stirring and is ready for serving with plain rice.

**14) Zawngtah bawl**

The main ingredient is the fruit of *Parkia timoriana*. It is a popular and delicious food among the two communities but the methods of preparation are more or less different among the tribal groups. Tree beans can be eaten raw or by mixing with the fermented pork. But the taste might be different because it has a mildly bitter taste without boiling. To prepare, the skin of the pods (~500g) is peeled off by using *ziahkur* (sharp utensil made from iron). It is sliced into small pieces and introduced into pre-boiled water for 1 minute. All the water is removed and the contents are mixed with 1 tablespoon of *chingal*, salt, and 2 tablespoon fermented pork fat with continuous stirring [**Figure 3.13(S)].**

**15) Kawhtebel kan**

The flower buds of *Trevesia palmata* are taken off and transferred(~500g) into a pressure cooker for 10 minutes, all the water is discarded, and the remaining food is kept aside. Chopped onion, garlic, and coriander are first fried with tomato for 5 minutes and finally, the flower buds are added and all the contents are mixed well and are ready to serve [**Figure 3.13(T)]**.

### 16) Lenhling kan

*Lenhling kan* is a typical Paihte food consumed as a main dish. The tender shoot and leaves of *Amaranthus viridis* (~500g) are finely chopped and boiled for 10 minutes, the water is then discarded. The heated oil is added to the well-cooked plants, along with chopped king chili, onions, and garlic. Masala and salts are added to enhance the taste [**Figure 3.13(U)].**

### 17) Pelh kan

Pelh is a local name for *Gnetum gnemon*. For preparation, chopped onions are fried with chili and then the leaves of *pelh* (~100g) are added by constantly stirring. Salt is added according to taste. The mixture after frying for 5-7 minutes is ready to serve **[Figure 3.13(V)]**.

### 18) Archangkawm Tauh

The fruits of *Oroxylum indicum* (~500g) are placed over the fire and the skin is peeled off using *ziahkur*. After this, it is washed thoroughly with water, chopped into thin pieces, and kept aside. To this, fried and crushed peanut is added and mixed with onion, ginger, garlic, tomato, chili, salt, and *dangpuithu* to enhance the taste [**Figure 3.13(W)]**.

### 19) Telhawng bawl

*Amorphophallus nepalensis* commonly called *telhawng-pa* is a typical Mizo food. Since the parts of the plants contain irritable substances causing itchiness on the throat, it needs a long process to make it edible **(Figure 3.14)**. For preparation, the outermost covering of the corm is removed and sliced into small pieces, boiled in *chingal* for 4 hours to reduce the irritable substance. After this, *chingal* was removed and the content is crushed carefully in a typical wooden mortar and pestle. The crushed corm is again boiled in an ash filtrate for 4-7 hours and left to cool. After cooling, *chingal* is discarded, soaked in clean water by changing the water several times to remove the ash filtrate. From this preparation, ~1kg of *telhawng* is taken out and mixed with 4-5 drops of fermented pork fat, salt and chilly as per one’s desire [**Figure 3.13 (X)].** Although the process of preparation takes time and effort, this food is highly preferred due to its deliciousness in taste.


**Figure 3.13:** Different traditional recipes prepared by the ethnic communities of Aizawl district.


**Figure 3.14:** Traditional method of *Telhawng* processing in Mizoram.

### 3.3.7. Floristic composition and phytosociological structure

#### 3.3.7.1. Taxonomic level of distributions

Floristic composition revealed that a total of 52 species of WEVs belonging to 45 genera and 28 families with 1526 individuals were encountered from Phuaibuang and N.E Tlangnuam forest area during the study period **(Figure 3.15).**

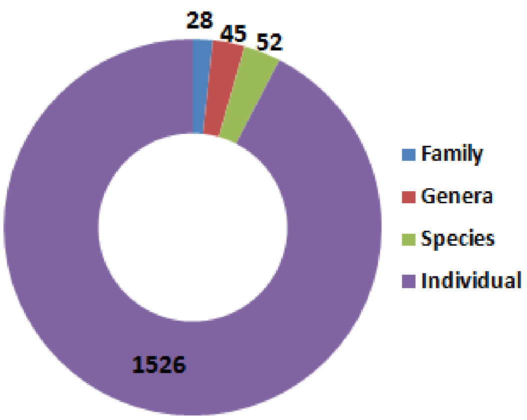



**Figure 3.15**: Total number of families, individual, genera and species of all the WEVs documented in the two study sites.

### 3.3.7.2 Herbaceous species

The present study recorded a total of 688 individuals of herbaceous WEVs with 26 species from 20 genera belonging to 15 families. It has a total stand density of 27.52 ($ha^{-1}$) comprising the highest number of species as compared to shrub and tree species. The highest numbers of individual and density were represented by *Acmella oleracea* (70 and 2.8 $ha^{-1}$), followed by *Fagopyrum tataricum* (67 and 2.68 $ha^{-1}$) and *Centella asiatica* (66 and 2.64 $ha^{-1}$), all together contributed to 29.51% of the total stand density The species with the lowest number of individual and density was *Solanum lycopersicum* var. *cerasiforme* (3 and 0.12 $ha^{-1}$), followed by *Amophophallus nepalensis*, *Momordica dioica* and *Thladiantha cordifolia* (6 individual and 0.24 $ha^{-1}$ each) **(Figure 3.16, Table 3.8)**. The maximum frequency was found in *Centella asiatica* (84%) and the lowest frequency was recorded for *Diplazium esculentum* (8%) **(Table 3.8)**. A/F ratio revealed that 23 (88.46%) species showed a contagious pattern of distribution, 3species (11.54%) showed random i.e., without a regular pattern of distribution **(Table 3.10)**.

**Table 3.8:** Quantitative analysis of herbaceous species of WEVs of Phuaibuang forest area showing Density ($ha^{-1}$), Frequency (%), Abundance, and abundance-to-frequency ratio (A/F).

| Sl/No | Species | Family | D ($ha^{-1}$) | F (%) | A | A/F ratio |
|---|---|---|---|---|---|---|
| 1 | *Acmella oleracea* | Asteraceae | 2.8 | 56 | 5 | 0.09 |
| 2 | *Acmella paniculata* | Asteraceae | 1.52 | 56 | 2.71 | 0.05 |
| 3 | *Alternanthera sessilis* | Amaranthaceae | 0.6 | 24 | 2.5 | 0.10 |
| 4 | *Amaranthus spinosus* | Amaranthaceae | 0.4 | 12 | 3.33 | 0.28 |
| 5 | *Amaranthus viridis* | Amaranthaceae | 1.08 | 40 | 2.7 | 0.07 |
| 6 | *Amomum dealbatum* | Zingiberaceae | 0.32 | 16 | 2 | 0.13 |
| 7 | *Amophophallus nepalensis* | Araceae | 0.24 | 20 | 1.2 | 0.06 |
| 8 | *Blumea myriocephala* | Asteraceae | 0.88 | 28 | 3.14 | 0.11 |
| 9 | *Centellaasiatica* | Umbelliferae | 2.64 | 84 | 3.14 | 0.04 |
| 10 | *Chenopodium album* | Amaranthaceae | 1.12 | 40 | 2.8 | 0.07 |
| 11 | *Diplazium esculentum* | Athyriaceae | 0.4 | 8 | 5 | 0.63 |
| 12 | *Elatostema rupestre* | Urticaceae | 1.48 | 36 | 4.11 | 0.11 |
| 13 | *Eryngium foetidum* | Apiaceae | 1.36 | 24 | 5.67 | 0.24 |
| 14 | *Fagopyrum tataricum* | Polygonaceae | 2.68 | 44 | 6.09 | 0.14 |
| 15 | *Glinus opposititfolius* | Molluginaceae | 0.48 | 12 | 4 | 0.33 |
| 16 | *Gynura cusimbua* | Asteraceae | 1.08 | 32 | 3.38 | 0.11 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | *Houttuynia cordata* | Saururaceae | 1.96 | 20 | 9.8 | 0.49 |
| 18 | *Momordica charantia* | Cucurbitaceae | 0.32 | 28 | 1.14 | 0.04 |
| 19 | *Momordica dioica* | Cucurbitaceae | 0.24 | 20 | 1.2 | 0.06 |
| 20 | *Picria fel-terrae* | Linderniaceae | 1.04 | 32 | 3.25 | 0.10 |
| 21 | *Plantago major* | Plantaginaceae | 1.6 | 40 | 4 | 0.1 |
| 22 | *Solanum americanum* | Solanaceae | 1.36 | 36 | 3.78 | 0.10 |
| 23 | *Solanum lycopersicum* var. *cerasiforme* | Solanaceae | 0.12 | 12 | 1 | 0.08 |
| 24 | *Solena heterophylla* | Cucurbitaceae | 0.88 | 32 | 2.75 | 0.09 |
| 25 | *Thladiantha cordifolia* | Cucurbitaceae | 0.24 | 16 | 1.5 | 0.09 |
| 26 | *Typhonium horsfieldii* | Araceae | 0.68 | 12 | 5.67 | 0.47 |
| | **Total** | | **27.52** | **780** | **90.86** | **4.18** |

D-density, F- Frequency, A- Abundance

In the N.E Tlangnuam forest area, 421 individuals of herb which belong to 22 species from 18 genera with 13 families were recorded **(Table 3.9**. The total stand density was 16.84 (ha$^{-1}$). The highest number of individuals and density was observed in *Gynura cusimbua* (41 and 1.64 ha$^{-1}$) followed by *Plantago major* (39 and 1.56 ha$^{-1}$), *Acmella paniculata* (31 and 1.24 ha$^{-1}$) and *Centella asiatica* (31 and 1.24 ha$^{-1}$) constituting 33.73% of the total stand density. On the contrary, the lowest number of individuals and density was recorded in *Amomum dealbatum* (3 and 0.12 ha$^{-1}$) **(Figure 3.16)**. The distribution of frequency (%) revealed that *Centella asiatica* and *Plantago major* had the highest frequency (44% each) while lowest frequency (12%) was obtained in *Amomum dealbatum* and *Luffa acutangula* **(Table3.9).** A/F ratio revealed that 20 (90.91%) species which followed a contagious pattern of distribution, while 2 (9.09%) species had a random distribution. There was no regular pattern of distribution among the species **(Table 3.10)**.

**Table 3.9:** Quantitative analysis of WEVs (Herb) in N.E tlangnuam forest: Density (ha$^{-1}$), Frequency (%), Abundance and Abundance-to-frequency ratio (A/F).

| **Sl/No** | **Species** | **Family** | **D (ha$^{-1}$)** | **F (%)** | **A** | **A/F ratio** |
|---|---|---|---|---|---|---|
| 1 | *Acmella oleracea* | Asteraceae | 1.16 | 28 | 4.14 | 0.15 |
| 2 | *Acmella paniculata* | Asteraceae | 1.24 | 40 | 3.1 | 0.08 |
| 3 | *Alocasia fornicate* | Araceae | 0.52 | 28 | 1.86 | 0.07 |
| 4 | *Amaranthus spinosus* | Amaranthaceae | 0.84 | 32 | 2.63 | 0.08 |
| 5 | *Amaranthus viridis* | Amaranthaceae | 0.8 | 28 | 2.86 | 0.10 |
| 6 | *Amomum dealbatum* | Zingiberaceae | 0.12 | 12 | 1 | 0.08 |
| 7 | *Centella asiatica* | Umbelliferae | 1.24 | 44 | 2.82 | 0.06 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | *Elatostema rupestre* | Urticaceae | 0.8 | 20 | 4 | 0.2 |
| 9 | *Eryngium foetidum* | Apiaceae | 1 | 28 | 3.57 | 0.13 |
| 10 | *Fagopyrum tataricum* | Polygonaceae | 1.08 | 16 | 6.75 | 0.42 |
| 11 | *Gynura cusimbua* | Asteraceae | 1.64 | 40 | 4.1 | 0.10 |
| 12 | *Houttuynia cordata* | Saururaceae | 1 | 16 | 6.25 | 0.39 |
| 13 | *Luffa acutangula* | Cucurbitaceae | 0.16 | 12 | 1.33 | 0.11 |
| 14 | *Momordica charantia* | Cucurbitaceae | 0.36 | 28 | 1.29 | 0.05 |
| 15 | *Momordica dioica* | Cucurbitaceae | 0.36 | 24 | 1.5 | 0.06 |
| 16 | *Picria fel-terrae* | Linderniaceae | 0.88 | 28 | 3.14 | 0.11 |
| 17 | *Plantago major* | Plantaginaceae | 1.56 | 44 | 3.55 | 0.08 |
| 18 | *Solanum americanum* | Solanaceae | 0.68 | 28 | 2.43 | 0.09 |
| 19 | *Solanum lycopersicum* var. *cerasiforme* | Solanaceae | 0.48 | 32 | 1.5 | 0.05 |
| 20 | *Solena heterophylla* | Cucurbitaceae | 0.28 | 20 | 1.4 | 0.07 |
| 21 | *Thladiantha cordifolia* | Cucurbitaceae | 0.28 | 20 | 1.4 | 0.07 |
| 22 | *Typhonium horsfieldii* | Araceae | 0.36 | 20 | 1.8 | 0.09 |
| | **Total** | | **16.84** | **588** | **62.41** | **2.64** |

D-Density, F- Freqeuncy, A-Abundance

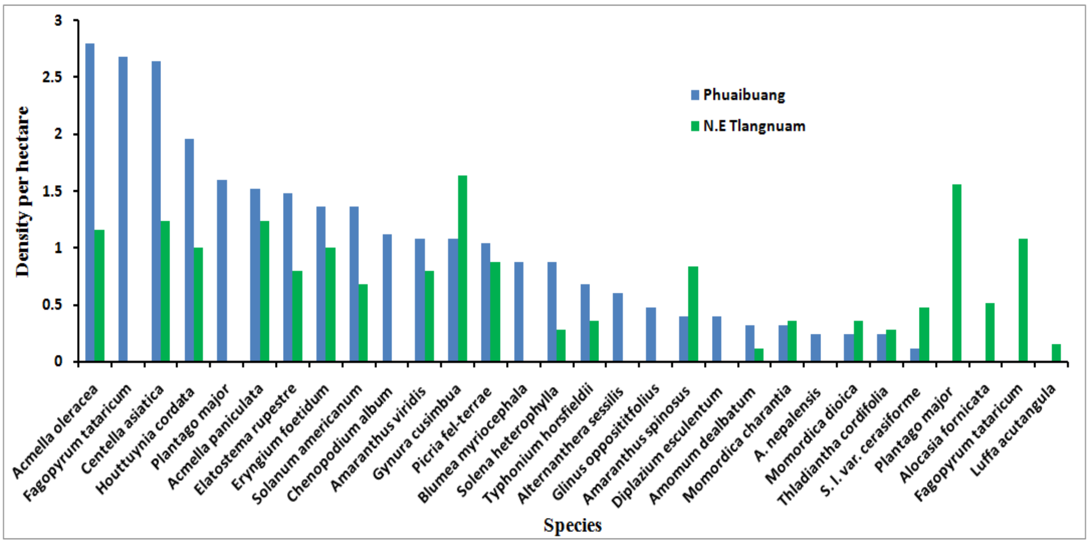



**Figure 3.16:** Comparison between Densities (ha$^{-1}$) of the individual herb species in the two study sites.

**Table 3.10:** Distribution pattern of herbaceous species of the two study areas.

| **Distribution** | **Phuaibuang forest** | | **N.E Tlangnuam forest** | |
|---|---|---|---|---|
| | **No.of species** | **% of species** | **No.of species** | **% of species** |
| Regular (<0.025) | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Random (0.025-0.05) | 3 | 11.54 | 2 | 9.09 |
| Contagious (>0.05) | 23 | 88.46 | 20 | 90.91 |

### 3.3.7.3. Shrub species

Shrub contained a fewer number of species as compared to herb and tree species. The study records a total of 118 individuals from 7 genera and 9 species belonging to 6 families from Phuaibuang forest area. The whole stand density was 4.72 (ha$^{-1}$) **(Table 3.11)**. The highest number of individuals and density was represented by *Rhynchotechum ellipticum* (38 and 1.52 ha$^{-1}$), followed by *Asparagus officinalis* (16 and 0.64 ha$^{-1}$) and *Senna occidentalis* (14 and 0.56 ha$^{-1}$) together account for 57.63 % of the entire stand density. On the contrary, the lowest number of individuals and density was found in *Marsdenia maculata* (2 and 0.08 ha$^{-1}$) **(Figure3.17)**. The highest frequency was recorded in *Rhynchotechum ellipticum* (64%) while the lowest frequency was observed in *Marsdenia maculata* (8%) **(Table 3.11)** out of 9 shrub species documented in the Phuaibuang forest area, 6 species (66.67%) showed a random distribution pattern while the other 3 species (33.33%) showed a contagious pattern of distribution **(Table 3.13)**.

**Table 3.11:** Quantitative analysis of WEVs (Shrub species) in Phuaibuang forest area: Density (ha-$^{1}$), Frequency (%), Abundance, and distribution pattern (A/F).

| Sl./No | Species | Family | D (ha$^{-1}$) | F (%) | A | A/F ratio |
|---|---|---|---|---|---|---|
| 1 | *Aralia dasyphylla* | Araliaceae | 0.4 | 28 | 1.43 | 0.05 |
| 2 | *Asparagus officinalis* | Asparagaceae | 0.64 | 48 | 1.33 | 0.028 |
| 3 | *Senna occidentalis* | Fabaceae | 0.56 | 24 | 2.33 | 0.097 |
| 4 | *Crotalaria tetragona* | Fabaceae | 0.48 | 32 | 1.5 | 0.05 |
| 5 | *Marsdenia formosana* | Apocynaceae | 0.2 | 12 | 1.67 | 0.14 |
| 6 | *Marsdenia maculata* | Apocynaceae | 0.08 | 8 | 1 | 0.125 |
| 7 | *Rhynchotechum ellipticum* | Gesneriaceae | 1.52 | 64 | 2.38 | 0.04 |
| 8 | *Solanum torvum* | Solanaceae | 0.44 | 40 | 1.1 | 0.03 |
| 9 | *Solanum anguivi* | Solanaceae | 0.4 | 32 | 1.25 | 0.04 |
| | **Total** | | **4.72** | **288** | **13.99** | **0.59** |

D-Density, F-Frequency, A- Abundance

In the N.E Tlangnuam forest, a total of 42 individuals from 5 genera and 7 species belonging to 5 families of shrub species were recorded **(Table 3.12)**. The total stand density was 1.68($ha^{-1}$), the highest density and an individual was observed in *Rhynchotechum ellipticum* (0.6 $ha^{-1}$ and 15), followed by *Solanum torvum* (0.36 $ha^{-1}$ and 9) accounting for 57.14 % of the entire stand density. In contrast to these, *Crotalaria tetragona* had the lowest individual (2) resulting in the lowest density (0.08 $ha^{-1}$) **(Figure 3.17)**. The maximum frequency was recorded in *Solanum torvum* (32%) followed by *Rhynchotechum ellipticum* (28%) while the minimum frequency was recorded for *crotalaria tetragona* (4%) **(Table 3.12)**. The distribution of shrub species in the N.E Tlangnuam forest revealed that one species (14.29%) showed a random pattern while the other 6 species showed a contagious distribution pattern (85.71%) and there were no species showing regular distribution **(Table 3.13)**.

**Table 3.12:** Quantitative analysis of WEVs (Shrub species) in N.E tlangnuam forest area: Density (ha-$^{1}$), Frequency (%), Abundance and distribution pattern (A/F).

| Sl/ No | Species | Family | D ($ha^{-1}$) | F (%) | A | A/F ratio |
|---|---|---|---|---|---|---|
| 1 | *Aralia dasyphylla* | Araliaceae | 0.2 | 8 | 2.5 | 0.31 |
| 2 | *Crotalaria tetragona* | Fabaceae | 0.08 | 4 | 2 | 0.5 |
| 3 | *Marsdenia formosana* | Apocynaceae | 0.12 | 12 | 1 | 0.08 |
| 4 | *Marsdenia maculata* | Apocynaceae | 0.16 | 12 | 1.33 | 0.11 |
| 5 | *Rhynchotechum ellipticum* | Gesneriaceae | 0.6 | 28 | 2.14 | 0.08 |
| 6 | *Solanum torvum* | Solanaceae | 0.36 | 32 | 1.13 | 0.04 |
| 7 | *Solanum anguivi* | Solanaceae | 0.16 | 16 | 1 | 0.06 |
| | **Total** | | **1.68** | **112** | **11.10** | |

D-Density, F-Frequency, A- Abundance

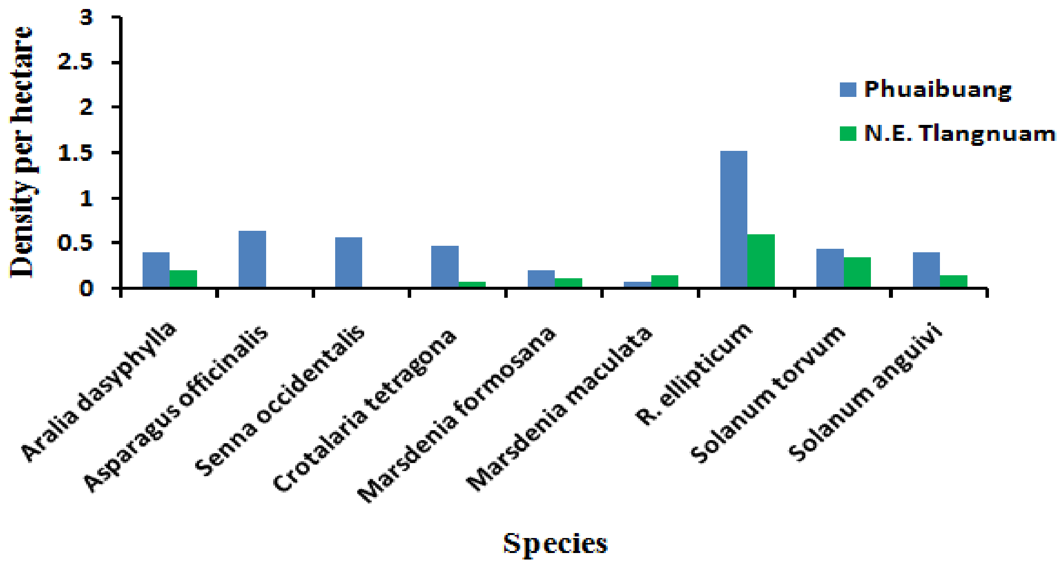



**Figure 3.17**: Comparison between Densities (ha$^{-1}$) of individual shrub species of the two study sites.

**Table 3.13**: Pattern of distribution of shrub species in the two study sites.

| Distribution | Phuaibuang forest | | N.E Tlangnuam forest | |
|---|---|---|---|---|
| | No. of species | % of species | No. of species | % of species |
| Regular (<0.025) | 0 | 0 | 0 | 0 |
| Random (0.025-.05) | 6 | 66.67 | 1 | 14.29 |
| Contagious (>0.05) | 3 | 33.33 | 6 | 85.71 |

### 3.3.7.4. Tree species

The vegetation compositions of the tree species of Phuaibuang forest consist of a total of 147 individuals representing 13 species and 13 genera belonging to 9 families. Out of 13 species, *Dysoxylum excelsum* (23) recorded the highest number of individuals followed by *Aganope thyrsifolia* (21), *Trevesia palmata* (19), and *Eurya acuminata* (17) all together contributed 54.42 % of the total stand density (5.88 ha$^{-1}$) **(Table 3.14)**. The highest density and frequency was recorded in *Dysoxylum excelsum* (0.92 ha$^{-1}$ and 64%) while the lowest density and frequency was found in *Morus indica* (0.08 ha$^{-1}$ and 8%) **(Figure 3.18, Table 3.14)**. The distribution pattern of tree species indicated that out of 13 species documented 1 species (7.69%) showed a regular pattern of distribution. 8 species (61.54%) showed random and another 4 species (30.77%) followed a contagious pattern of distribution **(Table 3.16).**

**Table 3.14:** Quantitative analysis of WEVs (Tree species) in Phuaibuang forest area: Density ($ha^{-1}$), Frequency (%), Abundance, IVI and A/F ratio.

| Species | Family | D ($ha^{-1}$) | F (%) | A | R D | RF | RDo | IVI | A/F |
|---|---|---|---|---|---|---|---|---|---|
| *A. thyrsifolia* | Fabaceae | 0.84 | 40 | 2.1 | 14.29 | 10.10 | 2.49 | 26.88 | .05 |
| *A. indica* | Meliaceae | 0.28 | 20 | 1.4 | 4.76 | 5.05 | 9.12 | 18.94 | .07 |
| *B. hainla* | Araliaceae | 0.52 | 36 | 1.44 | 8.84 | 9.09 | 13.45 | 31.38 | .04 |
| *C. bracteatum* | Lamiaceae | 0.4 | 24 | 1.67 | 6.80 | 6.06 | 2.68 | 15.54 | .07 |
| *C. dichotoma* | Boraginaceae | 0.16 | 16 | 1 | 2.72 | 4.04 | 17.03 | 23.79 | .06 |
| *D. excelsum* | Meliaceae | 0.92 | 64 | 1.44 | 15.65 | 16.16 | 4.35 | 36.16 | .02 |
| *E. acuminata* | Pentaphylacaceae | 0.68 | 36 | 1.89 | 11.56 | 9.09 | 7.50 | 28.16 | .05 |
| *F. auriculata* | Moraceae | 0.2 | 20 | 1 | 3.40 | 5.05 | 11.45 | 19.91 | .05 |
| *M. indica* | Moraceae | 0.08 | 8 | 1 | 1.36 | 2.02 | 9.57 | 12.95 | .13 |
| *O. indicum* | Bignoniaceae | 0.36 | 28 | 1.29 | 6.12 | 7.07 | 3.98 | 17.18 | .04 |
| *S. pennata* | Fabaceae | 0.24 | 24 | 1 | 4.08 | 6.06 | 1.54 | 11.68 | .04 |
| *T. palmata* | Araliaceae | 0.76 | 48 | 1.58 | 12.93 | 12.12 | 7.65 | 32.7 | .03 |
| *W. budleioides* | Rubiaceae | 0.44 | 32 | 1.38 | 7.48 | 8.08 | 9.17 | 24.74 | .04 |
| Total | | 5.88 | 396 | 18.18 | 100 | 100 | 100 | 300 | .71 |

D-Density, F-Frequency, A- Abundance, RD- Relative density, RF-Relative frequency, RDo-Relative dominance, IVI-Important value index, A/F-Abundance to frequency ratio

The tree species of WEVs in N.E Tlangnuam forest area comprises a total of 110 individuals' species of WEVs belonging to 13 species with 13 genera from 9 families. The total stand density was 4.4 ($ha^{-1}$) **(Table 3.15)**. The highest number of individuals and density was observed in *Eurya acuminata* (16 and 0.64 $ha^{-1}$) followed by *Aganope thyrsifolia* (14 and 0.56 $ha^{-1}$), and *Trevesia palmata* (10 and 0.4 $ha^{-1}$) together accounting for 36.36% of the total stands density (4.4$ha^{-1}$) **(Table 3.15) (Figure 3.18)**. The lowest density was observed in *Parkia timoriana* (0.08). A tree with maximum frequency was recorded in *Eurya acuminata* (44%) and the lowest number of frequency was represented by *Parkia timoriana* (8%) **(Table 3.15).** Out of 13 species documented, 6 species (46.15%) followed a random pattern and 7 species (53.85%) followed contagious distribution pattern. There were no species that followed a regular distribution pattern **(Table 3.16).**

**Table 3.15:** Quantitative analysis of WEVs (Tree species) in N.E Tlangnuam forest: Density (ha$^{-1}$), Frequency (%), Abundance, Relative density, Relative frequency, Relative dominance, IVI and abundance-to-frequency ratio (A/F).

| Species | Family | D (ha$^{1}$) | F (%) | A | R D | RF | RDo | IVI | A/F |
|---|---|---|---|---|---|---|---|---|---|
| *A. thyrsifolia* | Fabaceae | 0.56 | 40 | 1.4 | 12.73 | 12.66 | 2.75 | 28.14 | 0.04 |
| *A. indica* | Meliaceae | 0.2 | 16 | 1.25 | 4.55 | 5.06 | 12.21 | 21.82 | 0.08 |
| *B. hainla* | Araliaceae | 0.32 | 28 | 1.14 | 7.27 | 8.86 | 14.76 | 30.89 | 0.04 |
| *C. bracteatum* | Lamiaceae | 0.28 | 20 | 1.4 | 6.36 | 6.33 | 2.33 | 15.02 | 0.07 |
| *D. excelsum* | Meliaceae | 0.36 | 28 | 1.29 | 8.18 | 8.86 | 5.14 | 22.18 | 0.05 |
| *E. acuminata* | Pentaphylacaceae | 0.64 | 44 | 1.45 | 14.55 | 13.92 | 6.86 | 35.33 | 0.03 |
| *F. auriculata* | Moraceae | 0.24 | 24 | 1 | 5.45 | 7.59 | 11.49 | 24.53 | 0.04 |
| *O. indicum* | Bignoniaceae | 0.32 | 20 | 1.6 | 7.27 | 6.33 | 3.16 | 16.77 | 0.08 |
| *P. timoriana* | Fabaceae | 0.08 | 8 | 1 | 1.82 | 2.53 | 20.65 | 25 | 0.13 |
| *S. pennata* | Fabaceae | 0.32 | 16 | 2 | 7.27 | 5.06 | 1.35 | 13.69 | 0.13 |
| *T. palmata* | Araliaceae | 0.4 | 24 | 1.67 | 9.09 | 7.59 | 6.54 | 23.22 | 0.07 |
| *W. budleioides* | Rubiaceae | 0.36 | 32 | 1.13 | 8.18 | 10.13 | 8.47 | 26.77 | 0.04 |
| *Z. rhetsa* | Rutaceae | 0.32 | 16 | 2 | 7.27 | 5.06 | 4.29 | 16.63 | 0.13 |
| Total | | 4.4 | 316 | | 100 | 100 | 100 | 300 | |

D-Density, F-Frequency, A- Abundance, RD- Relative density, RF-Relative frequency, RDo-Relative dominance, IVI-Important value index, A/F-Abundance to frequency ratio

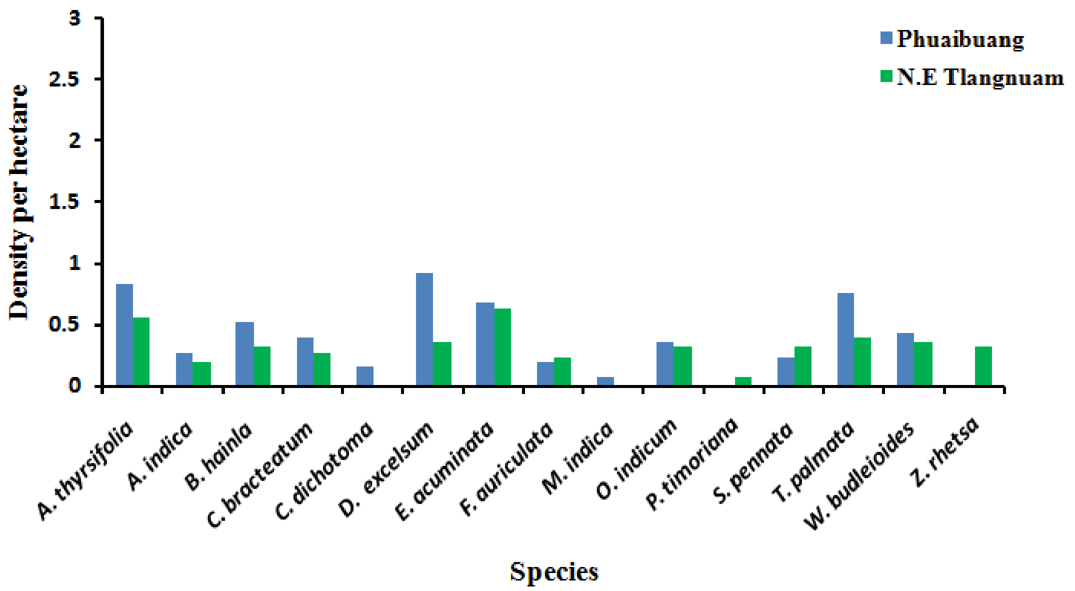



**Figure 3.18:** Comparison between Densities (ha$^{-1}$) of individual tree species of the two study areas.

**Table 3.16:** Distribution pattern of the tree species in the two study sites.

| Distribution | Phuaibuang forest | | N.E Tlangnuam forest | |
|---|---|---|---|---|
| | **No.of species** | **% of species** | **No. of species** | **% of species** |
| Regular (<0.025) | 1 | 7.69 | 0 | 0 |
| Random (0.025-0.05) | 8 | 61.54 | 6 | 46.15 |
| Contagious (>0.05) | 4 | 30.77 | 7 | 53.85 |

### 3.3.7.4.1. Important value Index (IVI) of tree species

The IVI value of tree species in Phuaibuang forest ranges from 11.68 - 36.13 and 13.69-35.33 in N.E Tlangnuam forest. $Log_{10}$ IVI against species sequences curve of Phuaibuang forest showed a comprehensible dominance of *Dysoxylum excelsum* (36.16) and the lowest IVI was recorded in *Senegalia pennata* (11.68) **(Figure 3.19)**.

$Log_{10}$ IVI against species rank of N.E Tlangnuam forest revealed that *Eurya acuminata* (35.33) was the most important and dominant tree species among other and the lowest IVI value was recorded in *Senegalia pennata* (13.64) **(Figure 3.20)**.

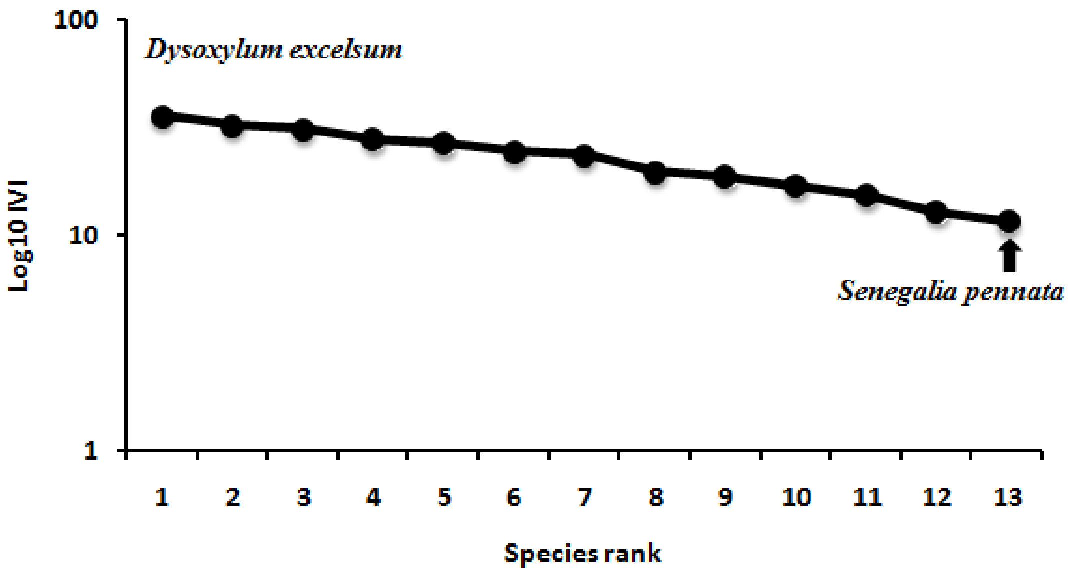



**Figure 3.19:** IVI curves for tree species of WEVs in Phuaibuang forest.

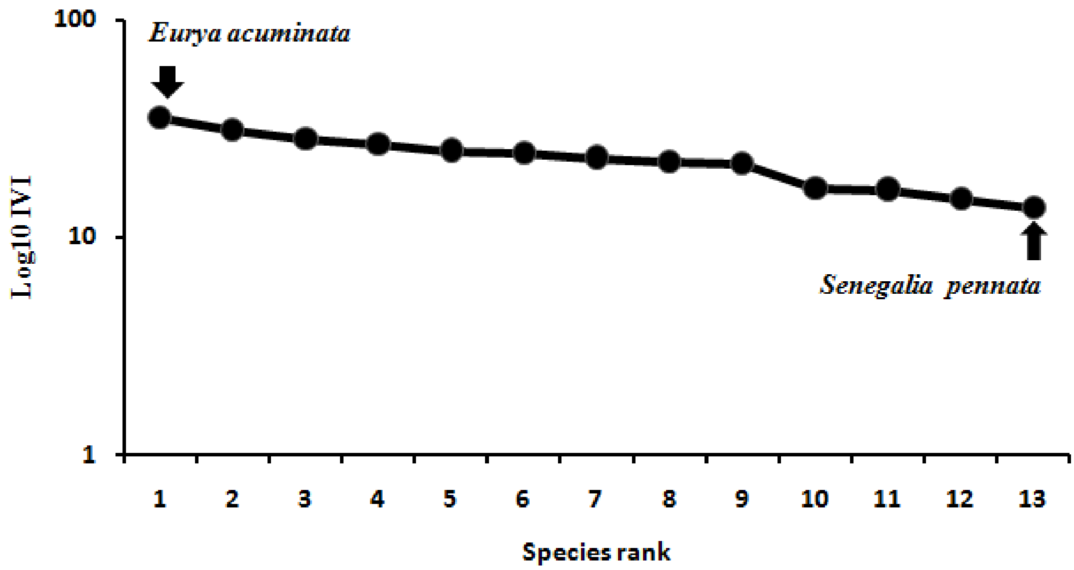



**Figure 3.20:** IVI curves for tree species of WEVs in N.E Tlangnuam forest.

### 3.3.7.5. Diversity indices of different vegetation of two study sites

Shannon diversity index (H') of the herb species was higher in Phuaibuang forest (3) than in the N.E Tlangnuam forest (2.921). Simpson (1-D) index of dominance was 0.9411 in Phuaibuang forest and 0.94 in the N.E Tlangnuam forest. The result of diversity indices of shrub species indicated that the Shannon diversity index (H') and Simpson (1-D) index of dominance were higher in Phuaibuang forest (H' = 1.964; 1-D= 0.8284) than in N.E Tlangnuam forest area (H' = 1.733; 1-D= 0.7868). The Shannon-wiener diversity index (H') of tree species in Phuaibuang forest area (H'= 2.392) was lower than N.E Tlangnuam forest (H'= 2.921) signifyin the dominance of tree species in N.E Tlangnuam forest area (1-D= 0.9104) over Phuaibuang forest area (1-D = 0.8972 (**Table 3.17)**.

**Table 3.17:** Comparison between Phytosociological attributes of WEVs in the two study sites.

| Atrributes | Phuaibuang forest | | | N.E Tlangnuam forest | | |
|---|---|---|---|---|---|---|
| | **Tree** | **Shrub** | **Herb** | **Tree** | **Shrub** | **Herb** |
| Number of individuals | 147 | 118 | 688 | 110 | 42 | 421 |
| Number of genera | 13 | 7 | 20 | 13 | 5 | 18 |
| Number of species | 13 | 9 | 26 | 13 | 7 | 22 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Stand density ($ha^{-1}$) | 5.88 | 4.72 | 27.52 | 4.4 | 1.68 | 16.84 |
| Shannon diversity Index (H') | 2.392 | 1.964 | 3 | 2.48 | 1.733 | 2.921 |
| Simpson dominance Index(1-D) | 0.897 | 0.828 | 0.941 | 0.910 | 0.786 | 0.94 |

#### 3.3.7.6. Similarity index (Sorenson index)

The results of the similarity index evaluated for WEVs between Phuaibuang forest and N.E Tlangnuam forest was 84.44% which was extremely high indicating that there was similar vegetation presents in both the forest area. A total of 38 species were found to be commonly present in both Phuaibuang and N.E Tlangnuam forest area.

## 3.4. Discussion

WEVs serve as an important daily food supplement among the two ethnic groups of Mizoram. The present ethnobotanical survey documented 70 species of WEVs belonging to 36 families from their natural habitat. Of these, Fabaceae, Cucurbitaceae, Amaranthaceous, and Asteraceae represented the most diverse groups. These results were similar to the previous work where 74 WEVs were documented from Mardin-Turkey with Fabaceae and Asteraceae representing the dominant family (Yesil et al., 2019). Bhatia et al. (2018) reported 90 WEVs with Fabaceae being the dominant family from Udhampur district, Jammu and Kashmir. Faruque et al. (2018) reported Asteraceae as the largest family and Fabaceae as the third largest family in the ethnobotanical plants of Bangladesh. Thakur et al. (2017) reported 50 Phyto foods from western Himalaya. The present study revealed that the ethnic communities more or less depend on WEVs for several purposes. This high utilisation of WEVs demonstrated a deep knowledge of ethnobotanical plants that are easily available and poor economic status of the local populace (Bhatia et al., 2018).

The life- forms of WEVs in the present study reported that herbs were the most dominating species which was in accordance with the previous findings of Lhoba people, Tibet (Li et al., 2015). On the contrary, Teklehaymanot and Giday (2010) reported trees as the most consumed growth form followed by shrub and this difference may come from the ecological variance and vegetation types of the study area. Amente (2017) further reported that shrub exhibited the most dominant growth form of WEVs in Ethiopia. The present study further indicated that leafy vegetables were the most highly consumed part by the inhabitant, which was supported by a similar study from Bandipora District of Kashmir Himalaya (Singh et al., 2016).

Owing to their diverse edible parts and their seasonality, different WEVs were available and can be harvested in different seasons of the year. In the present study, majority of the WEVs were harvested during the rainy season which was also earlier reported as the peak season (Kiran et al., 2019). The rainy season coincides with the time when most species were re-sprouting, flowering, and fruiting resulting in increasing availability (Ojelel et al., 2019). Some of the flowers and fruit vegetables had a specific time of harvest. The local people know the exact harvesting period of WEVs which could also help in the conservation. However, the method of harvesting as recorded in the present study area was rudimentary thereby causing deleterious effects to the plant species. The methods involved the cutting of the whole tree rather than plucking off the edible portion to harvest WEVs like *Dyxosylum excelsum, Wendlandia budloides,* and *Xanthoxylum rhetsa*, etc. which hampered the phenology of the plants. This implies that proper management and harvesting pattern needs to be considered to minimize the detrimental effects (Ojelel et al., 2019). Generally, WEVs provide a good source of nutrients and also provide ecological security because of the disease's resistance, growth in adverse climatic conditions, and habitats (Kiran et al., 2019). This makes human diets more diverse during the period of food shortage and globally recognized as key components in ecosystem-based adaptation and food scarcity (Perez et al., 2010). This condition could inspire the local people to conserve WEVs resources and encourages domestication.

The study of $F_{ic}$ of food used categories revealed that a high level of agreement among the informants in all used categories, which further indicates a more consistent use of WEVs among the two ethnic groups under study. $F_{ic}$ of food used categories werew high for vegetables combined with dried fish ($F_{ic}$=1) in the present study. These may be due to the high number of user reports for only one particular species consumed (Kafoutchoni et al., 2018). Similar results of high $F_{ic}$ values have also been reported from various parts of India (Bhatia et al., 2015 and Singh et al., 2016). The $F_{ic}$ value also possesses a good tool to elaborate on the frequency of usage of various medicinal plants for disease categories. According to Mesfin et al.

(2013), $F_{ic}$ plays a significant role in plant species selection for further research concerning their chemical compositions used against various ailments. The highest $F_{ic}$ value for Antiseptic ($F_{ic}$=1) in the present study was also reported by other studies conducted in Pakistan (Hassan et al., 2017). The least $F_{ic}$ value recorded for snakebite (0.79) in the present study was also comparable with the previous work (Tareen et al., 2016), however, was found in contrary where $F_{ic}$ value was highest for snake bites (Bibi et al., 2014). The low $F_{ic}$ values indicated that the informants have very low agreement on the usage of many of the species mentioned and documented (Asowata-Ayodele et al., 2016). The present findings indicated that the two ethnic groups share the same cultural tradition, informants have good knowledge of WEVs which was shared to a great extent among the local inhabitants and also these WEVs being presently in use among major local populace as food and medicine as well.

The indigenous communities were found to utilize wild plants not only for food but also to treat various diseases. In the study area, most people preferred to take ethnomedicine of wild plants in the form of food except for the plants that are used to treat dermatological problems in which the raw plants were rubbed between the fingers and directly applied onto the infected area of the skin. There was no standardized effective dosage of administrations on the particular medicinal plants but normally taken as a food, for example, *Solanum americanum* was boiled for about 20 minutes and all the content was consumed as food while treating the urinary problems at the same time. Decoction was the most common method of medicine preparation among the informants. Interestingly it was found that some of these ethnomedicinal plants tended to treat more than one disease. For example, *Solanum anguivi* was used to treat three different ailments such as dermatological problems, boils, and antiseptic. Likewise, *Musa balbisianas* was employed for the treatment of both diarrhoea and snake bites. This study revealed that most of the informants use these medicinal plants orally which is also recorded in earlier study (Poonam and Singh, 2009; Kadir et al., 2012).

Fidelity level (Fl) was evaluated for most common ethnomedicinal plants cited by the informants in the study area based on the effectiveness to treat different mentioned diseases. The result further indicated that *Picria-fel terrae* exhibited 100% and 95% fidelity for the treatment of hypertension and diabetes as per the reports of two ethnomedicinal plants of Pakistan (Tareen et al., 2016). The medicinal plants with high fidelity showed the preference of the given species by the informants for the treatment of a particular disease (Bibi et al., 2014,). It became obvious from the value that hypertension and diabetes were the most common diseases in the area. The plant with high fidelity may be suggested for further investigations of the bioactive compounds for its high potential value (Giday et al., 2016). *Azadirachta indica* was used to treat dermatological problems in the present study and this is supported by the previous study (Ofori et al., 2012) and was also reported to treat malaria (Asase et al., 2010). *Momordica charantia* exhibited 93% fidelity level for the treatment of diabetes, which was also in agreement with the previous studies (Rahmatullah et al., 2009; Samoisy and Mahomoodally, 2015). The low fidelity level value of *Acacia pennata* and *Eryngium foetidum* for the treatment of food poisoning and malaria may be due to the rare occurrence of these diseases and hence the narrow distribution of information about their remedy in the study area.

The output of the DMR results showed that some of the important WEVs were at high risk due to overuse by the local people for different purposes. This describes clearly how the biotic pressure acts on the plant species of the area and investigations on the same have been observed that multipurpose uses create conservations threat for trees and other plants (Panhwar et al., 2007; Razaq et al., 2010). Species like *Dysoxylum excelsum* ranked first for multipurpose use in the present studies which indicated that it was highly exploited not only for its food value but also for fuel wood, construction, and medicine. This was also similar to the work in which over-harvesting of multipurpose species was the main factor responsible for threatening of the plant species (Mussarat et al., 2014). Generally, those multipurpose species were trees, bamboo, shrub, and herb. They are under threat and are currently more exploited for fodder, construction, fuel wood, and medicine besides their food source, thus rendering the scarcity of the plants.

WEVs play a significant role in the daily life of the ethnic groups under-investigated. In addition to the food value, the documented 47 species were marketable providing an opportunity to supply household income for the local people. Some of these WEVs were of greater demand with high marketing value such as cane and bamboo species similarly reported by Uprety et al. (2012) in Nepal. This gave an indication of traditional resource usage as well as the dependency of WEVs for promoting cash income. Some of the WEVs with good economic values were getting depleted due to overexploitation and habitat destruction (Uprety et al., 2012). Sustainable utilization of commercialized WEVs would be necessary for the development of sustainable use programs contributing to rural income programs (FAO, 1995). Multi-tier WEVs garden would be an effective measure to conserve WEVs and proper utilization of jhum land to generate income and production of WEVs throughout the year (Kar and Borthakur, 2008).

In tribal areas and society, culture, tradition, and food habits cannot be separated as they were all interconnected (Singh et al., 2016). The traditional food processing technique of the Mizo people had been studied (Lalthanpuii et al., 2015). Since rice is considered as a stable food and vegetables and meat were considered as side dishes in Mizoram, more diverse wild plants were used and consumed during the period of scarcity of agricultural crops. These surveys also documented 24 traditional recipes prepared from WEVs among two ethnic groups of Mizoram. The affinity of choices in wild plant consumption was almost similar among Hmar and Paihte ethnic group. This may be due to the intermixing of culture and tradition, mixed habitation, and the sharing of resources among the two ethnic communities. For instance, Hmar and Paihte tribal groups mainly resided in Mizoram adjacent to Manipur state. Many species of WEVs in the present study were also used by the local tribes of Manipur, but the complex preparation of the recipe was not found (Konsam et al., 2016).

Since some of the Hmar and Paihte people migrated from Manipur and resided in Mizoram, some of the ingredients used for recipe preparation were found very similar. Preparation of Saum/Sathu of Mizo tribe was found very similar to the sathu prepared by Manipuri tribe (Singh et al., 2018) and chingal (ash filtrate) formation was also similar to the Assamese ‘Kolakhar’ which used banana species ashes (Kalita and Kander, 2014). But, the formation of chingal by the Mizo tribe does not have a specific tree or plant. In Mizo cuisine, vegetables and meat cooked with rice grain also known as ‘Beipenek’ was the common delicious food item of the study communities, this recipe was also very common among the tribal people of Manipur (Singh et al., 2018) but the method of preparations might be different among various ethnic groups. Taken into accounts, the diversities of traditional food products can be identified to explore its potentials in terms of commercialization (Singh and Singh, 2007).

Community structure, species composition, and function are very essential since it gives basic properties of the community (Mandal and Joshi, 2014) which can be correlated with variations in community and anthropogenic variables (Dar and Sundarapandian, 2015). Diversity is a combination of two factor-number of species present also known as species richness and distribution of individuals among species also known as species evenness (Thoa et al., 2013). Keeping in mind the importance of species diversity of WEVs and their population in the wild, the present study also highlights phytosociological characteristics of WEVs. A total of 48 WEVs were recorded from Phuaibuang forest and 42 species from N.E Tlangnuam forest which were found to be higher in number compared to the previous studies of vegetations [Thoa et al., 2013 (43 species); Nabi et al., 2016 (21 species); Amberber et al., 2014 (35 species)]. However, it was lower than the species recorded previously [Berihun and Molla, 2017 (77 species); Belem et al., 2017 (80 species)]. The low diversity of shrub species in the present study may be due to insufficient sunlight received by the sub-canopy, as the high large canopy trapped most of the light energy which results in the low growth rate of shrub species as previously stated by Bahuguna et al. (2010). Fabaceae, Amaranthaceae, Solanaceae, Asteraceae, and Cucurbitaceae were among the most dominant family in this present investigation. Similar result was also reported from the beer hills of Pakistan (Bano et al., 2018).

The reason for maximum availability of herbaceous species rather than tree and shrub in the two study sites may be due to environmental factor, availability of moisture and human disturbance, which was indicated by the multipurpose use of tree and shrub species especially for highly timber extraction by the nearby villages and similar pattern of observations was also found (Sharma and Upadhyaya, 2002). The diversity index in both the study site of the herbaceous layer was also comparable with the earlier reported value H'=3.28 (Deka et al., 2012). Nabi et al. (2016) reported H' index ranges between 2.77 to 2.54 from spring to autumn season. Comparatively, the Shannon diversity index (H') of the herbaceous layer also falls within the range of study carried out by Yadav and Gupta (2007). The entire vegetation layer in the present study forest areas showed relatively high WEVs diversity. Concentrations of dominance (0.94) for the herb in both the study forests were higher than the previously reported value of 0.06 to 0.08 (Nabi et al., 2016). This indicated that two study forests were relatively disturbed through anthropogenic activities such as agriculture, over-harvesting of WEVs, collection of timber, and fodder.

The tree species of WEVs in both the study area comprised of 13 species each in Phuaibuang and N.E Tlangnuam forest area, which was lowered than the analysis of tree species (18 species) reported from tropical wet evergreen forests in and around Namdapha National Park, northeast India (Nath et al., 2005). The diversity index of tree species in the two study sites was higher than the value (0.70 to 2.02) reported from tropical wet evergreen forests of Arunachal Pradesh (Bhuyan et al., 2003). Dominance index for wild edible trees species of Phuaibuang and N.E Tlangnuam were 0.8972 and 0.9104 respectively and inversely related to the Shannon diversity index (H') which falls within the range of 0.1 to 1 in accordance with Kumar et al. (2010). The highest IVI value was represented by *Dysoxylum excelsum* (36.16) in Phuaibuang forest and *Eurya acuminata* (35.33) in N.E Tlangnuam forest, which was also similarly reported from agricultural land in Mizoram (Thong et al., 2016). These indicated that the species have good power of regeneration, more competitive ability to survive, and out compete with other tree species in the study area. It might also be because of the ability to take up nutrient than the other trees which made them more dominant (Kumar et al., 2013). These important tree species could be essential to fascinate the available resources (Bahuguna et al., 2010). The diversity index for shrub species in Phuaibuang forest area was found to be higher (H’=1.964) than N.E Tlangnuam forest (H’= 1.733) in the present study, which was found to be almost comparable to the work reported by Bahuguna et al. (2010) from central Himalaya.

The distribution pattern of the species depends on the physicochemical properties of soil beside the biological characteristics of the environment (Mandal and Joshi, 2014). The herbaceous vegetation of the present study followed a random and contagious pattern of distribution in the two-study area which was also supported by the previous work from different forest ecosystems (Shameem et al., 2010; Ilorkar and Khatri, 2003). Clumped/contagious dispersion pattern is the most common form which could be due to significant variations in the environmental conditions while random distribution was also found only in a very uniform environment (Odum, 1971). Tree species of Phuaibuang forest showed regular (1 species), random (8 species) and contagious pattern of distribution (4 species), these results were also in accordance with the previous work (Nandy and Das, 2012). The shrub species of the present study followed random pattern of distributions which was also in accordance with the results reported by Yaqoob et al. (2014). Variations in the distribution pattern among sites and vegetation composition were associated with micro environmental and biotic factors (Singhal and Soni, 1989).

The present study of all vegetation revealed that herbs were dominating over shrub and tree species. The dominance of herbaceous vegetables in both the present study sites may be due to forest disturbance (Sahu et al., 2012), improper utilization of land by the tree crop and regularly pre-mature felling may be another factor responsible for the lower diversity of tree and shrub vegetables (Hitimana, 2004). Sorenson's similarity index revealed a high degree of similarity between two sites (84.44%) which could be due to similar environmental conditions.

CHAPTER IV

# 4. Phenological observations of selected WEVs

## 4.1. Introduction

The term phenology is derived from the Greek word 'Phiano' which means to show or appear (Leith, 1974). Phenology scientifically explained the recurring biological events in plants, animals, microbes, and detects how the environment influences the timing of those events (Davi et al., 2011). In plants, it can include the vegetative and reproductive phases such as the visible changes in appearance like leaf flushing, leaf fall, flowering, fruiting, seeds formation and senescence besides their temporal variation which occurs naturally in periodic fashion over the year (Chuine, 2010; Nanda et al., 2014). Phenological observations are prime significant for perceptive biological processes, tropical trees, and ecosystems functioning (Tesfaye et al., 2011). With the change in climatic conditions globally, the timing and duration of growth in plants have changed since the temperature, rainfall and photoperiods are having great biological influences (Singh and Kushwaha, 2006). Phenology has a direct impact on the forest ecosystem productivity and its biodiversity (Rodriguez et al., 2014) used for characterization of vegetation type (Opler et al., 1980) and natural forest regeneration potential (Upadhyay and Mishra, 2010).

The timing of phenological events is very responsive to environmental changes; it measures the condition of the physical, chemical, and biological environment (Haggerty and Mazer, 2008). Thus, phenological observations determine the relationship between environmental changes and associated biological reactions. Understanding these relationships is fundamentally important not only for forecasting ecosystem responses to climatic changes but also to identify the seasonal exchanges of water and energy between the land surface and the atmosphere (Chen and Xu, 2012)

The species interaction of ecological communities is determined by the timing of reproduction (Davi et al., 2011). All the trophic levels inside the food web are more or less dependent on phenology. The timing of flowering phenology is a significant event for plant reproductive success and survival which is different in species to species due to alteration of a variety of events like pollinator chances, inductive photo-period and timing of fruit ripening and seed dispersal (Vashistha et al., 2009; Khan et al., 2018). Thus, flowering phenology can serve as a dividing mechanism in plant speciation (Newstrom et al., 1994). Earlier flowering results from the previous leaf expansion, nutrient uptake, and root formation. This alteration of the flowering calendar will affect the competitive interaction of different species within the community causing disturbance of the ecosystem structure (Bhat, 1992).

Temperature is an important factor that could function in the plant developmental process but an increase in temperature will also drastically lead to earlier switching to the next ontogenetic stage (Badeck et al., 2004). Rainfall, photoperiod, and moisture are other important factors influencing phenology (Borchert, 1983) whereas precipitation and soil moisture content were a less limiting factor as reported by (Ibáñez et al., 2010). Global climate changes need to be taken seriously as ambient variables like temperature, photoperiod, and rainfall influence plant phenological events (Hamann, 2004). The study of phenology of WEVs is crucial for understanding the ecological adaptation in the community as well as in conservation and forestry management.

Over the past few decades, the studies associated with phenology such as variations among species have been ignored in plant ecology. Moreover, a systematic study on the phenology of WEVs has never been conducted in Mizoram. Therefore, considering the scarcity of kinds of literature, the present work was undertaken to observe the phenology of WEVs over three years from the tropical and sub-tropical forest of Aizawl district, Mizoram, and to know their adaptability to different environmental conditions, the periodicity of seasons and its reproductive success. Although, many of these important WEVs are fast dwindling due to anthropogenic activities including commercial, agriculture, and urbanization. These studies will certainly be crucial for understanding the ecological adaptation in the community as well as in conservation and forestry management.

## 4.2. Methodology

### 4.2.1. Recording the phenological events

14 wild edible vegetables under different family were randomly selected from the different forest in Aizawl district **(Table 4.1)**. Five mature and healthy individuals for each species (having a sign of previous year seed production) were selected for assessment. From five individuals per tree, one healthy branch each was selected and marked with a blue tape and observations were made weekly to see new leaf formation, leaf maturation, flower bud formation, flower, completion of flower, fruiting, seed formation, seed shedding, leaf fall initiation and complete leaf fall (in deciduous and annual/perennial plants) during the period of three years (January 2015 - December 2017) as per method of (Newstrom et al., 1994) and (Castro-Díez and Gabriel, 1998). Phenological calendar for each species was made to interpret the overall results. For all the studied species, the occurrence of phenological events in each month was calculated for the year 2015-2017. In the same period, rainfall and temperature data were collected and the data were presented in an average of monthly values.

### 4.2.2. Statistical analysis

Phenological event of five individuals in each species was compiled by recording the monthly activity of the plants. The percentage of the number of plant species showing different phenophases in each month was evaluated. Spearman's correlation coefficient was employed for any correlation between phenological events with monthly mean temperature and monthly mean rainfall using PASW statistical 18 software and all the available data were analysed using Microsoft excel 2010.

## 4.3. Results

### 4.3.1. Climatic condition of the study area

A monthly record of rainfall and temperature during the three years of study (2015-2017) is presented in **Figure 4.1**. The meteorological data was collected from Department of Agriculture, Government of Mizoram. The annual total rainfall differed between three years with the highest record in 2017 (3673.4mm) followed by 3081.5mm in 2016 whereas it was 2732.2mm in 2015. During the first year

(2015), continuous rainfall occurred from January (27.9mm) with little rain and monsoon rain started from June to September. In the second year (2016), continuous rainfall occurred from January till November and monsoon rain occurred between May to September **(Figure 4.1).** However, in 2017 the pre-monsoon rain started in February while monsoon rain started in June and continued till October. The rainiest month during 2017 was observed in June (760.9mm), while it was recorded in August (589.1mm) and June (511.1mm) during the year 2015 and 2016 respectively. The maximum air temperature at noon was recorded in June (29.5°C) during the year 2015, while it was observed in March (21.32°C) and October (22.65°C) during 2016 and 2017 respectively.

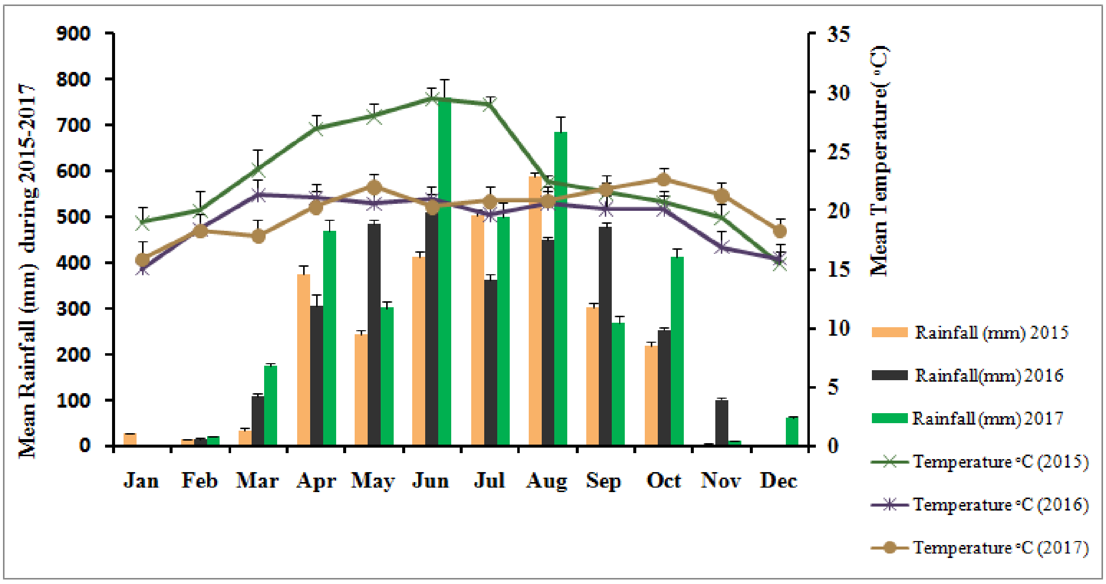



**Figure 4.1**: Monthly mean rainfall (mm) and mean temperature (°C) distribution in Aizawl district during 2015-2017.

### 4.3.2. Phenological records

The phenological observation was made from 14 healthy wild edible species belonging to 7 families from January 2015 to December 2017 **(Table 4.1)**. All the 14 plant species showed the timing of different phenophases like duration of new leaf formation, flower bud formation, flowering, fruiting, seed formation and the period of seed shedding **(Figure 4.2)**. The phenophases for individuals of the same species for flowering and fruiting are represented in a ranges type **(Table 4.2 and Table 4.3)**.

**Table 4.1:** List of plant species observed with their Family, Life-forms , Leaf habit, Fruit type, Mature fruit colour, colour of flower.

| Sl. No | Botanical name | Family | Life-Forms | Leaf habit | Fruit type | mature fruit colour | Flower colour |
|---|---|---|---|---|---|---|---|
| 1 | *Senegalia pennata* | Leguminosae | Woody climber | Deciduous | Pod | Green | White |
| 2 | *Aganope thyrsifolia* | Leguminosae | Woody climber | Evergreen | Pod | Dark Brown | White |
| 3 | *Senna occidentalis* | Leguminosae | Shrub | Perennial | Pod | Dark green | Yellow |
| 4 | *Crotalaria tetragona* | Leguminosae | Shrub | Perennial | Pod | light Brown | Yellow |
| 5 | *Parkia timoriana* | Leguminosae | Tree | Deciduous | Pod | Green | White |
| 6 | *Brassaiopsis hainla* | Araliaceae | Shrub | Evergreen | Berry | Green | White |
| 7 | *Trevesia palmata* | Araliaceae | Tree | Evergreen | Capsule | Dark green | White |
| 8 | *Azadirachta indica* | Meliaceae | Tree | Evergreen | Drupe | Brown | White |
| 9 | *Dysoxylum excelsum* | Meliaceae | Tree | Evergreen | Drupe | Brown | White |
| 10 | *Clerodendrum bracteatum* | Lamiaceae | Tree | Deciduous | Berry | Blue | White |
| 11 | *Oroxylum indicum* | Bignoniaceae | Tree | Evergreen | Pod | Dark brown | Purple |
| 12 | *Solanum torvum* | Solanaceae | Shrub | Evergreen | Berry | Green | White |
| 13 | *Thladiantha africana* | Cucurbitaceae | Climber | Evergreen | Globose | Red | Yellow |
| 14 | *Solena heterophylla* | Cucurbitaceae | Climber | Perennial | Globose | Red | White |

### 4.3.2.1. Leafing phenology

From the three years data, the maximum percentage of species showed new leaf peak formation during March and April in 2016(71.43% of total species), 2015(64.28%) and 2017 (64.28%) and continued till May before the outset of Monsoon **(Figure 4.3A)**. Among the Leguminosae family, *Aganope thyrsifolia* and

*Senna occidentalis* showed similar leaf flushing activity from February till May. At the same time, the longest leaf flushing duration was observed for three species such as *Senegalia pennata, Solanum torvum* and *Crotalaria tetragona* which lasted for 17 weeks each in three consecutive years and continued till mature leaf production.

In the case of deciduous and perennial plants, leaf fall was observed. The peak leaf fall (complete leaf fall) occurred in eight species from January to April and December which coincides with the dry seasons **(Figure 4.2).** Complete leaf fall was followed by the formation of new leaf buds at the beginning of the pre-monsoon rains and continued till the onset of rainy seasons. The duration of mature leafing for all the species is presented in **Figure 4.2**.

#### 4.3.2.2. Flower bud phenology

In each year, maximum species showed flower bud formations in two different peak seasons i.e. during the short (March) and long rainy seasons (July and August). The maximum percentage of plant species showed bud formation during March (35.71%), July and August (35.71%) in all the three years except in August 2015 where the peak was not observed (28.57%) **(Figure4.3B).** Several species like *Dysoxylum excelsum, Aganope thyrsifolia, Parkia timoriana, Brassaiopsis hainla, Trevesia palmata, and Crotalaria tetragona* characterized prominent buds before flowering (>5 weeks). On the other hand, for species like *Senegalia pennata, Solena heterophylla, Oroxylum indicum, Azadirachta indica, Senna occidentalis, Thladiantha africana, Clerodendrum bracteatum* and *Solanum torvum*, bud formation more or less coincided with the flowering period **(Figure 4.2)**. The longest period for bud formation was observed in (*Dyxosylum excelsum*), which lasted for 18 weeks during 2015 (May 4th week to August 6th week). However, in *Thladiantha africana* bud formation occurred 1-2 week(s) before flowering i.e. it coincided with the flowering trend.

#### 4.3.2.2. Floral phenology

The flowering intensity in all three years was more or less similar although it was high during pre-monsoon rainfall and gradually increased during the rainy seasons. All the studied species bloomed once in a year. The highest peak of flowering was observed during August 2016 (50%) and another small peak in April every year during the studied period **(Figure 4.3C).** The average duration of the flowering period (counting from the first day of flower formation) for all the species ranged between 33 days (*Azadirachta indica*) to 139 days (*Solanum torvum*) **(Table 4.2)**. In *Azadirachta indica,* first floral bud formation occurred during 11th- 16th February in the year 2015 while the opening of first floral bud formation occurred by the end of March till the beginning of April (29th March to 4th April) in 2016 and mid of March (14th March to 19th March) in 2017**(Table 4.2)**. The recording of phenological data was complicated because there was a great overlap between the flower and the fruit formation even in the same branch as in the case of *Solanum torvum.* Moreover, the duration of flowering was long (136 days -139 days per year) **(Table 4.2)**. In the first year (2015) and third year of observations (2017), the flower initiation started at the beginning of March for all the individuals while in 2016, the first floral formation occurred at the beginning of April (1st April- 5th April) **(Table 4.2)**. A total of 12 plant species flowered between the pre-monsoon and monsoon period. On the other hand, *Crotalaria tetragona* and *Brassaiopsis hainla* produced flowers only after the monsoon period (September to November) **(Figure 4.2)**.

**Table 4.2**. Date of floral initiation (range of 5 individuals) and average days of blooming of selected WEVs.

| Species | Year | | | | | |
|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | 2017 | |
| | **Date of first floral initiation** | **Average days of blooming** | **Date of first floral initiation** | **Average days of blooming** | **Date of first floral initiation** | **Average days of blooming** |
| *S. pennata* | $8^{th}$ -$10^{th}$ Apr | 60 days | $18^{th}$ - $21^{st}$ May | 76 days | $15^{th}$ -$20^{th}$ May | 63 days |
| *A.thyrsifolia* | $17^{th}$ -$19^{th}$ Apr | 50 days | $21^{st}$ -$23^{rd}$ Apr | 42 days | $22^{nd}$ -$25^{th}$ Apr | 41 days |
| *S.occidentalis* | $28^{th}$ -$30^{th}$ Jul | 60 days | $7^{th}$ -$11^{th}$ Aug | 59 days | $13^{th}$ - $18^{th}$ Aug | 43 days |
| *C. tetragona* | $3^{rd}$ - $6^{th}$ Oct | 60 Days | $9^{th}$ - $13^{th}$ Oct | 53 Days | $19^{th}$ - $21^{st}$ Oct | 43 Days |
| *P. timoriana* | $23^{rd}$ Aug- $3^{rd}$ Sep | 87 Days | $27^{th}$ Aug- $5^{th}$ Sep | 66 days | $30^{th}$ Aug-$7^{th}$ Sep | 63 days |

| | | | | | | |
|---|---|---|---|---|---|---|
| *B. hainla* | 19th -23rd Sep | 65Days | 2nd Oct- 7th Oct | 61days | 1st - 11th Oct | 57Days |
| *T. palmata* | 21st -25th Mar | 40 Days | 23rd -26th Mar | 34Days | 30thFeb- 9th Mar | 49 Days |
| *A. indica* | 11th -16th Feb | 52 Days | 29thMar- 4thApr | 33 Days | 14th-19th Mar | 47 Days |
| *D. excelsum* | 10th -22nd Aug | 65 Days | 16th -19th Aug | 45 Days | 13th - 17th Aug | 49 Days |
| *C. bracteatum* | 14th -17th Aug | 79 Days | 21st -24th Aug | 67 Days | 29th Jul- 3rd Aug | 63 Days |
| *O. indicum* | 2nd - 9th Jul | 60 Days | 4th - 11th Jul | 58 Days | 29th Jun- 13th Jul | 48 days |
| *S. torvum* | 1st - 6th Mar | 136 days | 1st -5th Apr | 139 days | 1st -3rd Mar | 136 days |
| *T. africana* | 13th - 16th Mar | 82 days | 9th -12th Mar | 74 days | 23rd -25th Mar | 70 days |
| *S. heterophylla* | 25th -29th May | 68 days | 30th Apr-4th May | 67 days | 29thApr- 2ndMay | 66 days |

#### 4.3.2.3. Fruiting phenology

The period of fruiting initiation for all the species proceeded mostly in the rainy seasons and continued till the post-monsoon period. It coincided with the mature leafing pheno-phase **(Figure 4.2)**. There were no variations other than the few days' difference that occurred between individuals of a species. The duration of the fruiting period varied following the peak of flowering time from species to species. The fruiting deviated from 32 days long as in *Senna occidentalis* to 156 days long as in *Azadirachta indica* **(Table 4.3)**. Following these, the date of first fruit formations as in the case of *Senna occidentalis* differed for the three years. In the year 2015, the first young fruit is seen between 17th September to 21st September whereas, in 2016, it was observed in the mid of October while it was at the end of September to mid of October in 2017 **(Table 4.3)**. Maximum percentage of plant species showing fruit formation was in October (57.14%), July to September/ November in 2017(50%), June to September/November in 2016 (50%) and June/August/November in 2015(50%) **(Figure 4.3D)** resulting in maximum seed formation during the dry seasons. Generally, fruiting phenology lasted for about one to five months depending upon the species observed.

**Table 4.3**: Initial date of fruit formation (5 individual ranges) and average days of fruit maturation of WEVs.

| Species | Year | | | | | |
|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | 2017 | |
| | **Initial date of fruiting** | **Average days of fruiting** | **Initial date of fruiting** | **Average days of fruiting** | **Initial date of fruiting** | **Average days of fruiting** |
| *S. pennata* | 28th Jun-1st Jul | 71 days | 20th -22nd Jun | 77 days | 21st -25th Jun | 81 days |
| *A.thyrsifolia* | 6th -10th Jun | 118 days | 10th - 14th Jun | 126 days | 11th - 16th Jun | 147 days |
| *S.occidentalis* | 17th -21st Sep | 49 days | 3rd - 5th Oct | 44 days | 30th Sep-3rd Oct | 32 days |
| *C. tetragona* | 26th -30th Oct | 43 Days | 2nd -7th Nov | 42 days | 28th Oct- 1st Nov | 51days |
| *P. timoriana* | 17th - 23rd Oct | 137 days | 21st - 29th Oct | 129 days | 26th Oct- 1st Nov | 128 days |
| *B. hainla* | 21st - 26th Nov | 41 Days | 29th Nov- 3rd Dec | 33 days | 27th Nov - 4th Dec | 35 days |
| *T. palmata* | 26th Apr- 7th May | 42 days | 30th Apr- 5th May | 36 days | 27th Apr- 6th May | 34 days |
| *A. indica* | 22nd -27th Apr | 156 days | 26th -30th Apr | 146 days | 30th Apr-4th May | 156days |
| *D. excelsum* | 6th -13th Oct | 92 days | 30th Sep- 5th 0ct | 84 days | 8th -12th Oct | 87 days |
| *C. bracteatum* | 12th - 15 Oct | 62 days | 17th - 21st Oct | 56 days | 21 -25th Oct | 48 days |
| *O. indicum* | 11th -20th Aug | 132 days | 27th Jul- 7th Aug | 120 days | 16th - 27 Jul | 123 days |
| *S. torvum* | 26th - 30th Mar | 156 days | 1st-2nd Apr | 136 days | 29th Mar-1st Apr | 137days |
| *T. africana* | 27th -30th Mar | 140 days | 29th Mar-1st Apr | 136 days | 1st - 3rd Apr | 136 days |
| *S. heterophylla* | 5th -9th Jun | 98 days | 7th -12th Jun | 92 days | 11th -13th Jun | 98 days |

### 4.3.2.4. Seed production and seed shedding

Fruit ripening phase was generally characterized by changing fruit colour from green to brown/ dark green in most of the species except for *Thladiantha africana* and *Solena heterophylla* where the mature seed is characterized by red colour **(Table 4.1).** Mature seed production mostly occurred during the dry season where mature leaves were still present but in the case of *Parkia timoriana* and *Oroxylum indicum,* maximum seed formation coincided with the occurrence of complete leaf fall **(Figure 4.2)**. Generally, seed formation till seed shedding lasted for about 5 to 10 weeks. However, the longest period of seed formation was observed in *Oroxylum indicum* (>9 weeks) during the three years of study **(Figure 4.2)**. The maximum percentage of seed production was observed during December 2017 (50%of the total species) **(Figure 4.3E).** The seed shedding initiation until complete seed fall varied with species and also with the years **(Figure 4.2)**. However, the longest period of seed fall initiation till complete seed fall was observed in *Solanum torvum,* which lasted for 8 weeks in 2015 (2$^{nd}$ week October to a whole week of November) as compared to the shortest seed shedding period of *Brassaiopsis hainla* (March 1st to 3$^{rd}$ week) in 2017. Seed shedding mostly occurred during the dry seasons (November/December) and continued until the onset of the pre-monsoon rainfall **(Figure 4.2).** Out of 14 plant species investigated, 35.71% exhibited complete seed fall in February 2015 and 2017 where the same percentage of plant species shed their seed during November 2016 **(Figure 4.3F)**. In the case of the deciduous and annual/perennial plants, complete seed shedding coincided with the leaf fall period. But, in evergreen plants, the occurrence of complete seed fall coincided with the mature leafing (*Thladiantha africana, Dysoxylum excelsum, Solanum torvum,* and *Solena heterophylla*) and sometimes, it corresponded to the formation of the new leaf as in the case of *Trevesia palmata* and *Aganope thyrsifolia* **(Figure 4.2).**

| Species | Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Senegalia pennata* | 2015 | ○ | ♠ | ♠ | ♠●◘ | ♠♣◘ | ♣◘♦ | ♣♦ | ♣♦■ | ♣■ | ♣□ | □○ | ○ |
| | 2016 | ○ | ♠ | ♠ | ♠ | ♠♣●◘ | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣♦■ | ♣■□ | □○ | ○ |
| | 2017 | ○ | ♠ | ♠ | ♠ | ♣●◘ | ♣◘♦ | ♣◘♦ | ♣♦ | ♣♦■ | ♣■ | □○ | ○ |
| | | | | | | | | | | | | | |
| *Aganope thyrsifolia* | 2015 | ♣■□ | □♠ | ♠● | ♠●◘ | ♣◘ | ♣◘♦ | ♣♦ | ♣♦ | ♣♦ | ♣■ | ♣■ | ♣■ |
| | 2016 | ♣□ | ♠ | ♠● | ♠●◘ | ♣◘ | ♣♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦■ | ♣■ | ♣■ |
| | 2017 | ♣■ | □♠ | ♠● | ♠●◘ | ♣◘ | ♣◘♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦■ | ♣■ |
| | | | | | | | | | | | | | |
| *Senna* ***Occidentalis*** | 2015 | ○ | ♠ | ♠ | ♠ | ♣ | ♣● | ♣●◘ | ♣◘ | ♣◘♦ | ♣♦ | ○♦■ | □○ |
| | 2016 | ○ | ♠ | ♠ | ♠ | ♣ | ♣ | ♣● | ♣●◘ | ♣◘ | ♣◘♦ | ♣♦■ | □○ |
| | 2017 | ○□ | ○ | ♠ | ♠ | ♣ | ♣ | ♣● | ♣●◘ | ♣◘♦ | ♣♦ | ○■ | ○■ |
| | | | | | | | | | | | | | |
| *Crotalaria tetragona* | 2015 | ■♣ | □○ | ○ | ○ | ♠ | ♠ | ♠♣ | ♠♣ | ♣● | ♣●◘♦ | ♣◘♦ | ♦♣■ |
| | 2016 | ■♣ | ■□○ | ○ | ♠ | ♠ | ♠ | ♠♣ | ♠♣ | ♣● | ♣●◘ | ♣◘♦ | ♦♣ |
| | 2017 | ■♣ | □○ | ○ | ○ | ♠ | ♠ | ♠♣ | ♠♣ | ♣● | ♣●◘♦ | ♣◘♦ | ♦♣■ |
| | | | | | | | | | | | | | |
| *Parkia timoriana* | 2015 | ○♦ | ○♦ | ○■ | ♠□ | ♠ | ♣ | ♣● | ♣●◘ | ♣●◘ | ♣◘♦ | ♣◘♦ | ♦○ |
| | 2016 | ○♦ | ○♦ | ○■ | ♠□ | ♠ | ♣ | ♣● | ♣●◘ | ♣●◘ | ♣◘♦ | ♣♦ | ♦○ |
| | 2017 | ○♦ | ○♦ | ○■ | ♠□ | ♠♣ | ♣ | ♣● | ♣●◘ | ♣●◘ | ♣◘♦ | ♣♦ | ♦○ |
| | | | | | | | | | | | | | |
| *Brassaiopsis hainla* | 2015 | ■♣ | □♣ | ♠ | ♠ | ♠♣ | ♣ | ♣ | ♣● | ♣●◘ | ♣◘ | ♣◘♦ | ♣♦■ |
| | 2016 | ■♣ | ■♣□ | □♣ | ♠ | ♠ | ♠ | ♣ | ♣● | ♣● | ♣●◘ | ♣◘♦ | ♣♦■ |
| | 2017 | ■♣ | ■♣□ | □♣ | ♠ | ♠ | ♠ | ♣ | ♣● | ♣● | ♣●◘ | ♣◘♦ | ♣♦■ |
| | | | | | | | | | | | | | |
| *Trevesia palmata* | 2015 | ♣● | ♣● | ♣●◘ | ♣◘♦ | ♣♦ | ♣♦ | ♣■ | ♣■ | ♠♣□ | ♣♠□ | ♣ | ♣● |
| | 2016 | ♣● | ♣● | ♣●◘ | ♣◘♦ | ♣◘♦ | ♣♦ | ♣■ | ♣■ | ♣■ | ♣♠□ | ♣ | ♣ |
| | 2017 | ♣● | ♣●◘ | ♣●◘ | ♣◘♦ | ♣ ♦ | ♣■ | ♣■ | ♣■ | ♣♠□ | ♣♠□ | ♣ | ♣● |
| | | | | | | | | | | | | | |
| *Azadirachta indica* | 2015 | ♠ | ♠●◘ | ♣●◘ | ♣◘♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦■ | ♣■ | ♣■○ | □○ |
| | 2016 | ♠ | ♠● | ♠♣●◘ | ♣●◘♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦■ | ♣■ | ■○□ | □○ |
| | 2017 | ♠ | ♠● | ♣●◘ | ♣◘♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦ | ♣♦■ | ♣♦■ | ♣■○ | □○ |
| | | | | | | | | | | | | | |
| *Dysoxylum excelsum* | 2015 | ♣♦■ | ♣■□ | □♣ | ♠ | ♠● | ♠♣● | ♣● | ♣●◘ | ♣◘ | ♣◘♦ | ♣♦ | ♣♦ |
| | 2016 | ♣■ | ♣□ | ♠ | ♠ | ♠● | ♠♣● | ♣● | ♣●◘ | ♣◘♦ | ♣♦ | ♣♦ | ♣♦■ |
| | 2017 | ♣♦■ | ♣□ | ♠ | ♠ | ♠● | ♠♣● | ♣● | ♣●◘ | ♣◘ | ♣♦ | ♣♦ | ♣♦■ |
| | | | | | | | | | | | | | |
| *Clerodendrum bracteatum* | 2015 | ♠□ | ♠ | ♠ | ♠ | ♣ | ♣ | ♣● | ♣●◘ | ♣◘ | ♣◘♦ | ♦■○ | ♦■□○ |
| | 2016 | □○ | ♠ | ♠ | ♠ | ♣ | ♣ | ♣● | ♣●◘ | ♣◘♦ | ♣◘♦ | ♦■○ | ♦■○ |
| | 2017 | □♠ | ♠ | ♠ | ♠ | ♣ | ♣ | ♣●◘ | ♣●◘ | ♣◘♦ | ♣♦ | ♦○■ | ♦■□○ |
| | | | | | | | | | | | | | |
| *Oroxylum indicum* | 2015 | ○■ | ○□ | ♠ | ♠ | ♠● | ♣● | ♣●◘ | ♣◘♦ | ♣♦ | ♣♦ | ♦○ | ♦○■ |
| | 2016 | ○■ | ○□ | ♠ | ♠ | ♠● | ♣● | ♣●◘♦ | ♣◘♦ | ♣♦ | ♣♦ | ♦○ | ○■ |
| | 2017 | ○■ | ○□ | ♠ | ♠ | ♠ | ♣●◘ | ♣●◘♦ | ♣◘♦ | ♣♦ | ♣♦ | ♦○ | ○■ |
| | | | | | | | | | | | | | |
| *Solanum torvum* | 2015 | ♠ | ♠● | ♠♣●◘♦ | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣♦■ | ♣■ | ♣■□ | ♣□ | ♠ |
| | 2016 | ♠ | ♠ | ♠♣● | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣■ | ♣■ | ♣□ | ♣ |
| | 2017 | ♠ | ♠● | ♠♣●◘♦ | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣♦ | ♣■ | ♣■ | ♣□ | ♠ |
| | | | | | | | | | | | | | |
| *Thladiantha Africana* | 2015 | ♠ | ♠ | ♠●◘♦ | ♣◘♦ | ♣◘♦ | ♣◘♦ | ♣♦ | ♣♦■ | ♣■ | ♣■□ | ♣□ | ♣ |
| | 2016 | ♠ | ♠ | ♠●◘♦ | ♣◘♦ | ♣◘♦ | ♣♦ | ♣♦ | ♣♦■ | ♣■ | ♣■□ | ♣□ | ♣ |
| | 2017 | ♠ | ♠ | ♠●◘ | ♣●◘♦ | ♣◘♦ | ♣♦ | ♣♦ | ♣♦ | ♣■ | ♣■ | ♣□ | ♣ |
| | | | | | | | | | | | | | |
| *Solena heterophylla* | 2015 | ○ | ♠ | ♠ | ♠● | ♠♣●◘ | ♣◘♦ | ♣◘♦ | ♣♦ | ♣♦■ | ♣■ | □○ | ○ |
| | 2016 | ○ | ♠ | ♠ | ♠●◘ | ♠♣●◘ | ♣◘♦ | ♣◘♦ | ♣♦ | ♣♦■ | ♣■ | ♣■□ | □○ |
| | 2017 | ○ | ♠ | ♠ | ♠●◘ | ♠♣●◘ | ♣◘♦ | ♣◘♦ | ♣♦ | ♣♦■ | ♣■ | ♣■□ | □○ |

**♠ New leaf** **♣ Mature leaf** **● Flower Bud** **♦ Fruit**

**○ Leaf fall** **◘ Flower** **■ Seed** **□ Seed shed**

**Figure 4.2**: Phenological calendar of 14 WEVs belonging to 7 families showing new leaf, mature leaf, Flower bud formation, flowering, fruiting, seed formation, leaf fall and seed shedding during three consecutive years.

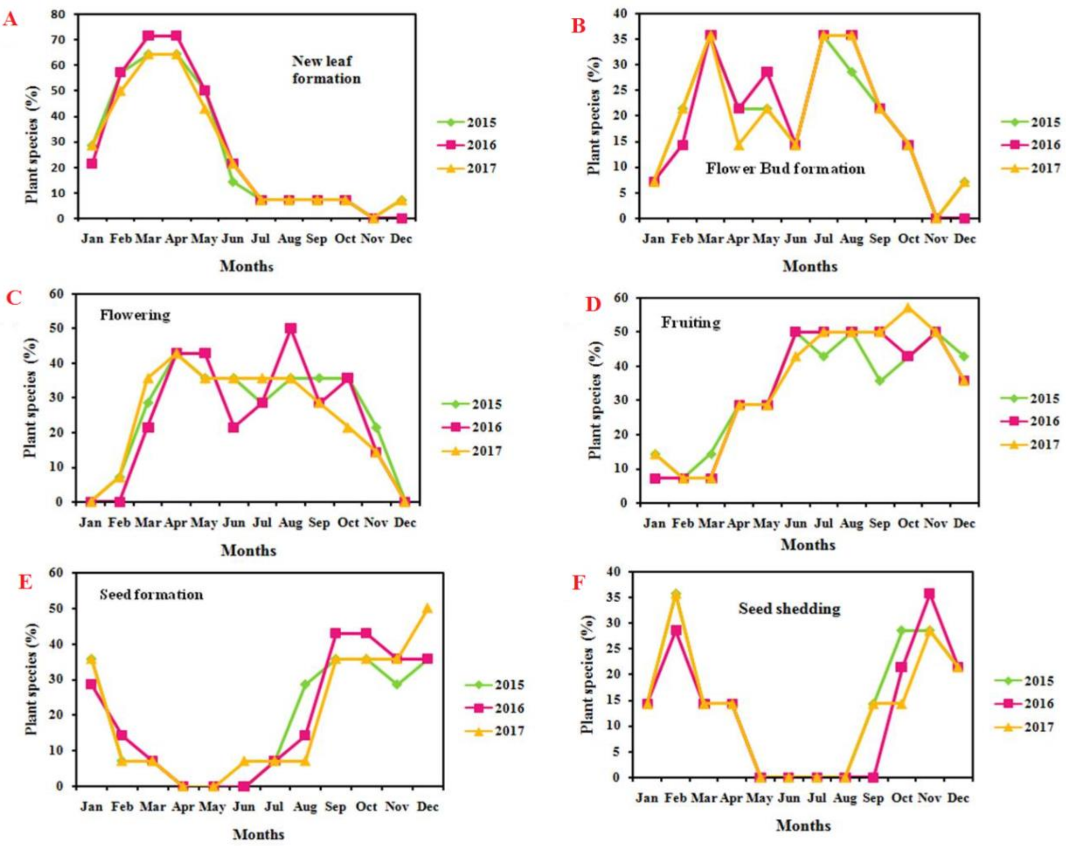



**Figure 4.3**: Number of Plant species (%) under study showing various phenological events: (A) New leaf, (B) Flower bud formations, (C) Flowering, (D) Fruiting, (E) Seed formation and (F) Seed shed.

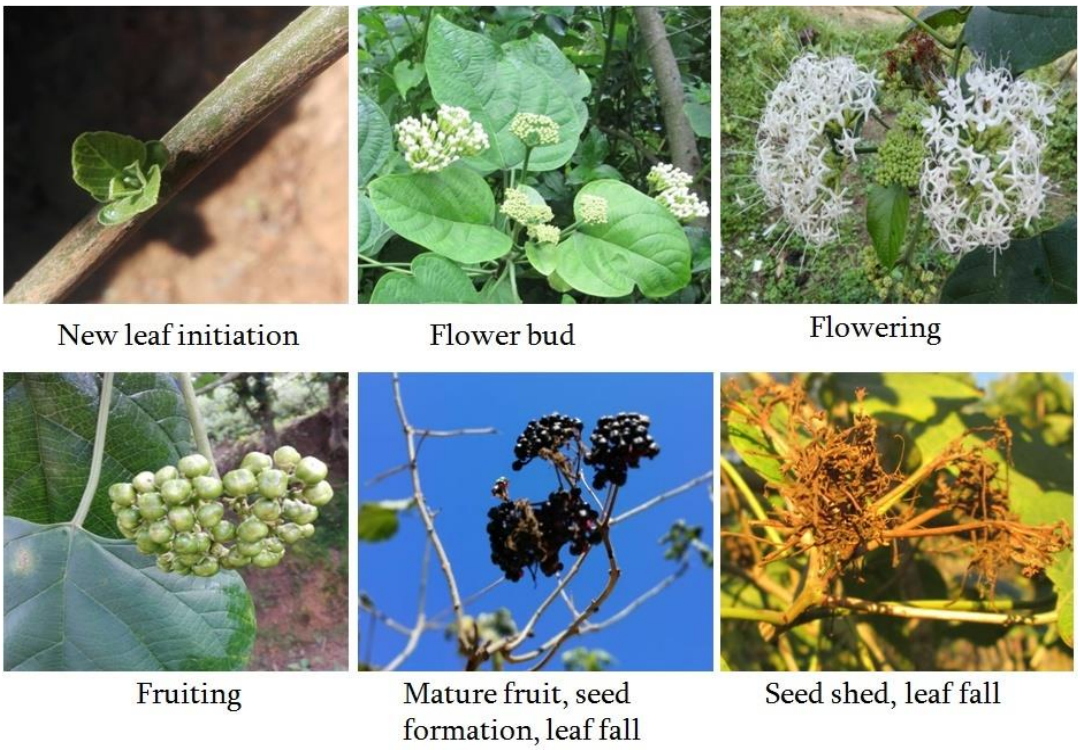



**Figure 4.4**: Phenophases of *Clerodendrum bracteatum*.


**Figure 4.5:** Phenophases of *Aganope thyrsifolia*.


**Figure 4.6:** Phenophases of *Dysoxylum excelsum*.

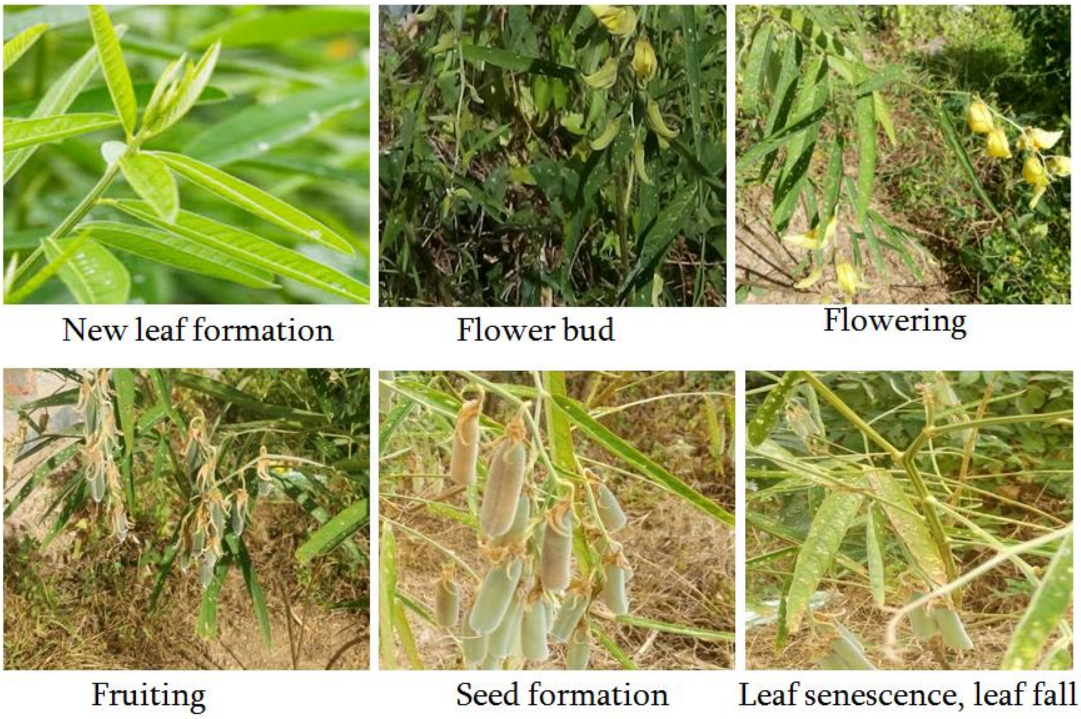



**Figure 4.7:** Phenophases of *Crotalaria tetragona*.

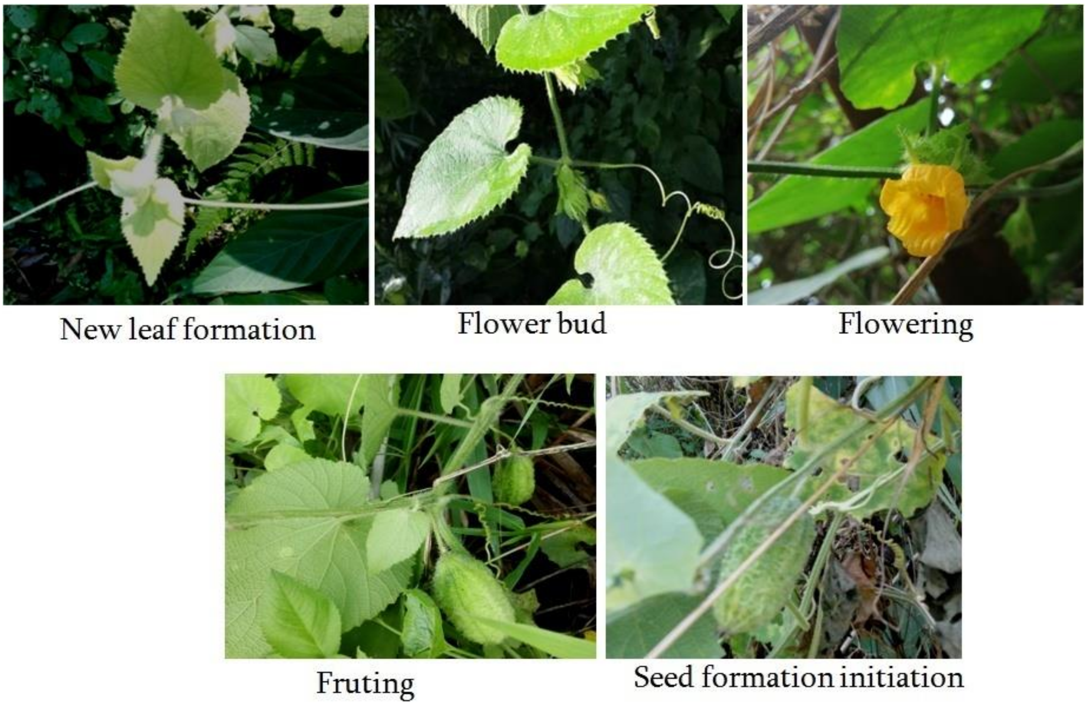



**Figure 4.8:** Phenophases of *Thladiantha Africana*.


**Figure 4.9:** Phenophases of *Trevesia palmata*.

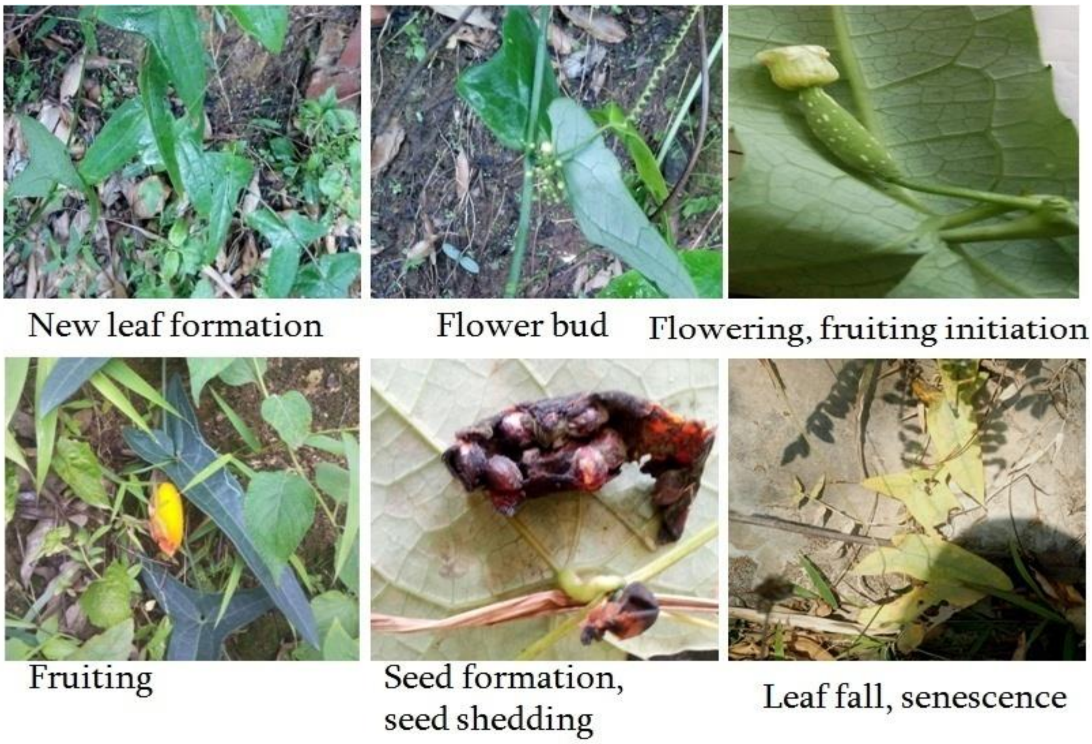



**Figure 4.10:** Phenophases of *Solena heterophylla*.

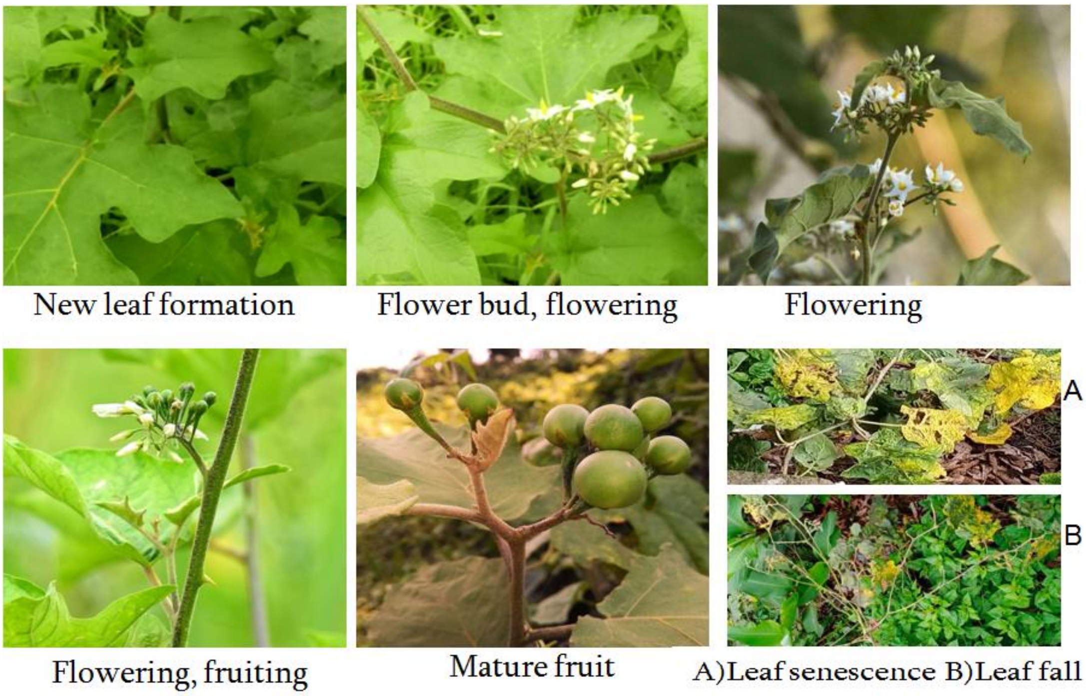



**Figure 4.11:** Phenophases of *Solanum torvum*.

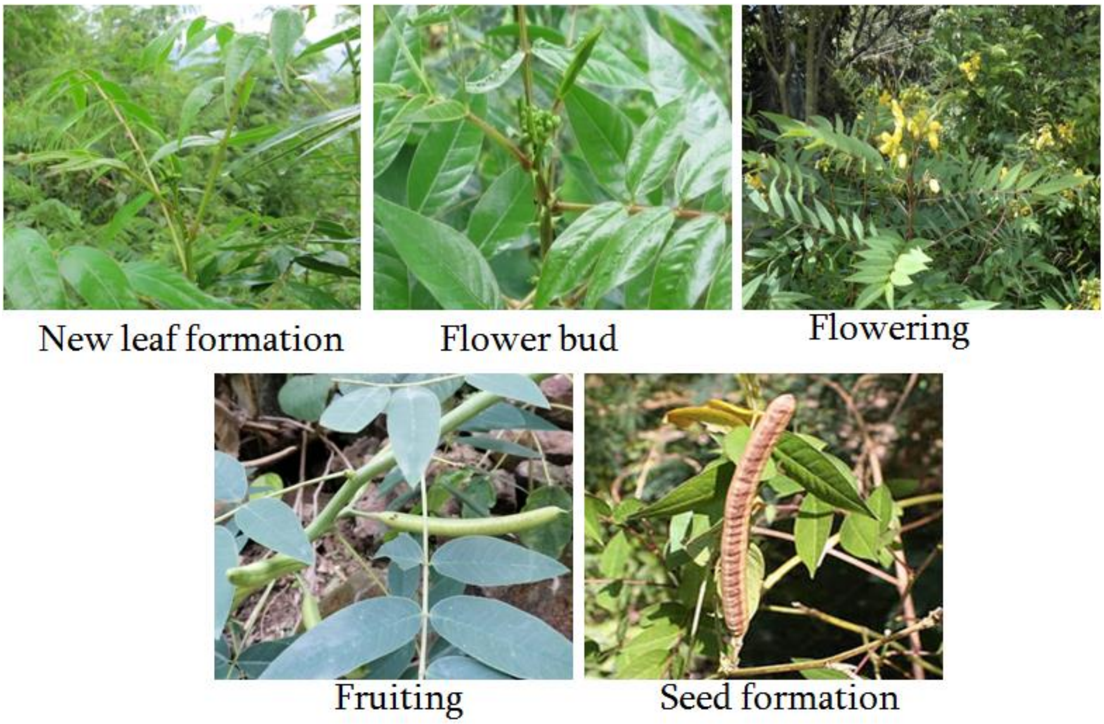



**Figure 4.12:** Phenophases of *Senna occidentalis*.

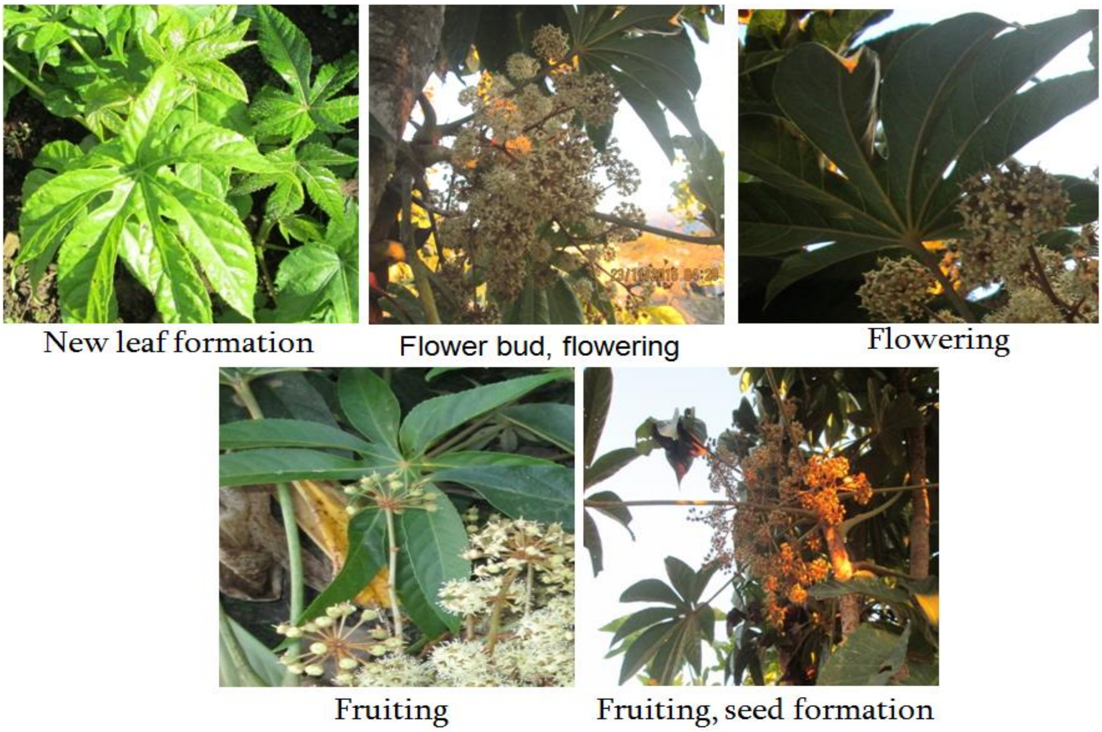



**Figure 4.13:** Phenophases of *Brassaiopsis hainla*.

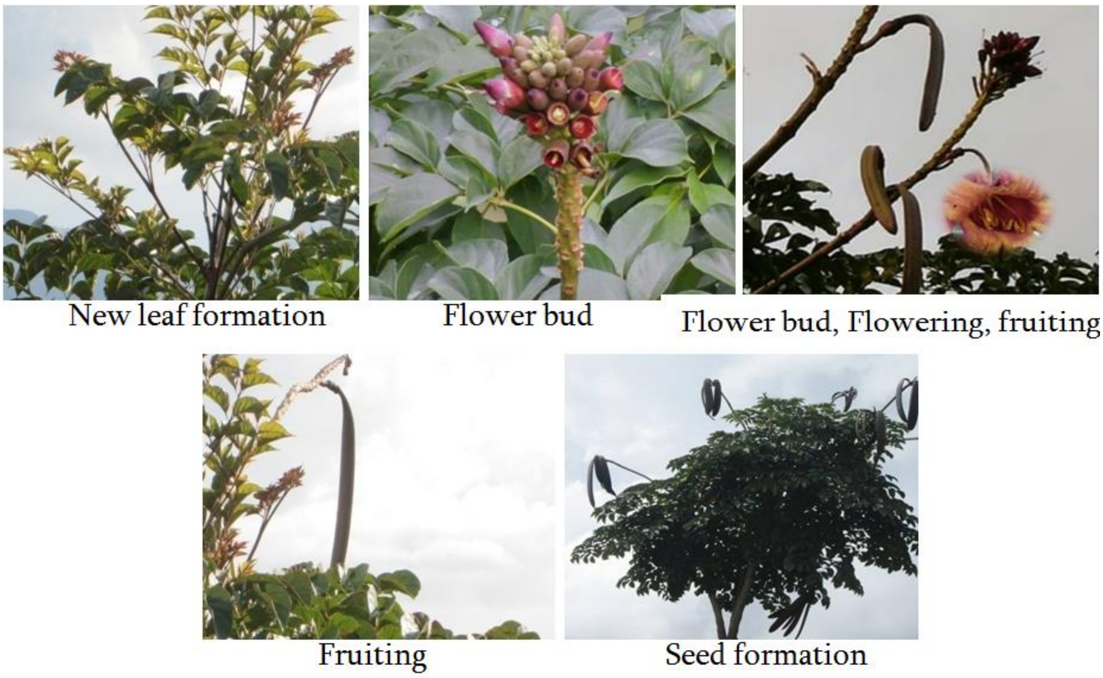



**Figure 4.14:** Phenophases of *Oroxylum indicum*.

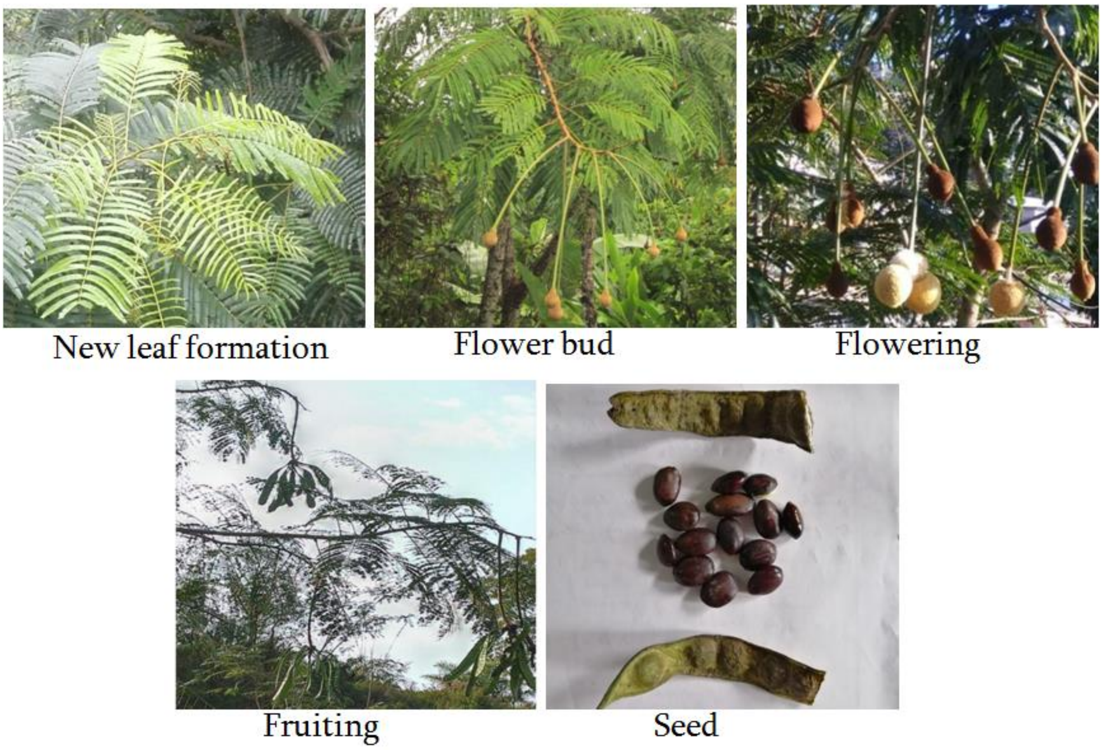



**Figure 4.15:** Phenophases of *Parkia timoriana*.

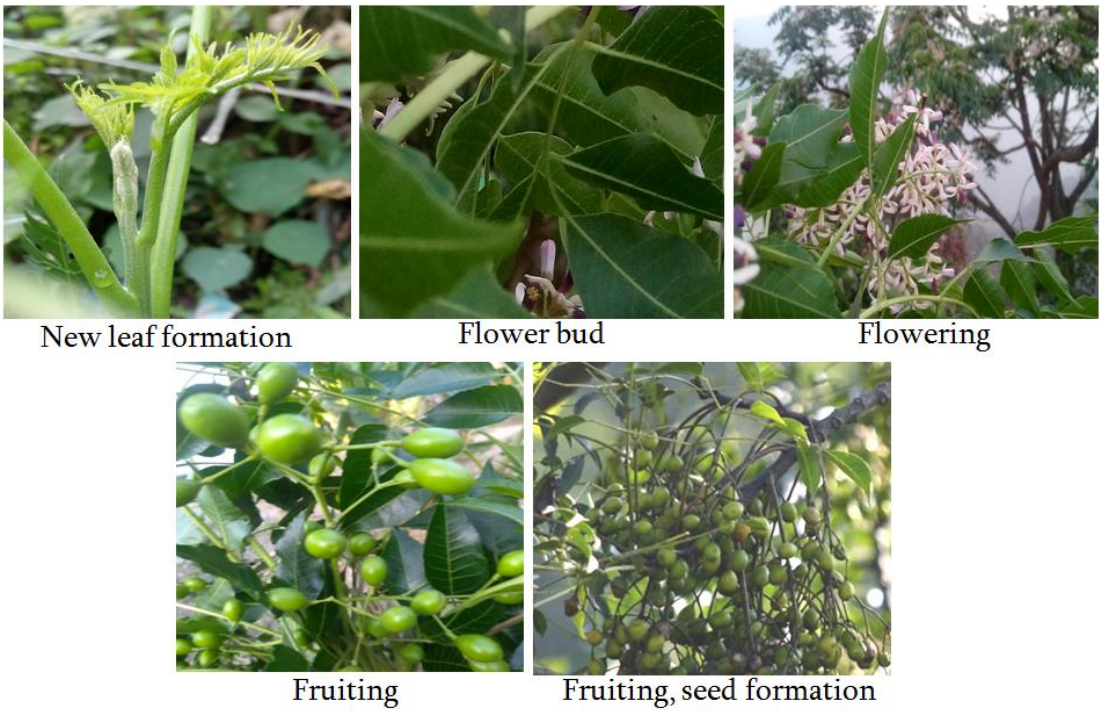



**Figure 4.16:** Phenophases of *Azadirachta indica*.

### 4.3.3. Correlation between different phenophases with climatic variables

Spearman's correlation between wild edible vegetables in different phenophases and climatic factors are presented in table 4. A positive and significant correlation ($P < 0.05$) was observed between new leaf formation and monthly mean temperature in the year 2015 and 2016. This indicated that temperature plays an important role in the new leaf formation of the studied plants. At the same time, both rainfall ($r = 0.616$, $P = 0.033$) and temperature significantly correlated ($r = 0.616$, $P = 0.033$) with bud formation in the year 2015 and there was also a positive relationship between bud formation with temperature ($r = 0.687$, $P=0.014$) in the year 2016. The correlation between the number of species flowering in each month and monthly mean rainfall revealed that flowering in the studied plants occurred more dominantly in rainy seasons than in dry seasons because there was a statistically significant positive correlation ($P < 0.01$) between monthly mean rainfall and flowering. Monthly mean temperature also has an impact on the flowering periods and has a positive and significant correlation with flowering formations in 2015 ($r = 0.684$, $P = 0.014$) and 2016 ($r = 0.712$, $P = 0.009$). Fruit formation also positively correlated with temperature in the year 2017 ($r = 0.757$, $P = 0.004$). In contrast to these, there was a negative and significant correlation ($r = -0.782$, $P= 0.003$) between seed formations and mean monthly temperature in the year 2015and 2016 ($r = - 0.589$, $P= 0.044$). Moreover, significant negative correlation ($P <0.01$) was observed between seed shedding and monthly mean rainfall in the year 2015, 2016 and 2017 and also with monthly mean temperature ($r= -0.805$, $P=0.002$) in the year 2015 signifying that rainfall and temperature has an impact at the time of seed formation and seed shedding **(Table 4.4).**

**Table 4.4:** Correlations between phenological events with physical parameters.

| Year | Climatic variables | New leaf formation | | Bud formation | | Flowering formation | | Fruit formation | | seed formation | | Seed shed | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **R value** | **p-value** | **R value** | **p-value** | **R value** | **p-value** | **R value** | **p-value** | **R Value** | **p-value** | **R value** | **p-value** |
| 2015 | Monthly Mean Rainfall | .007 | .982 | .616* | .033 | .731** | .007 | .331 | .293 | -.402 | .196 | -.819** | .001 |
| | Monthly Mean Temperature | .636* | .026 | .616* | .033 | .684* | .014 | .153 | .635 | -.782** | .003 | -.805** | .002 |
| 2016 | Monthly Mean Rainfall | .359 | .252 | .569 | .053 | .712** | .009 | .527 | .078 | -.447 | .145 | -.841** | .001 |
| | Monthly Mean Temperature | .582* | .047 | .687* | .014 | .712** | .009 | .527 | .078 | -.589* | .044 | -.557 | .060 |
| 2017 | Monthly Mean Rainfall | -.036 | .911 | .476 | .188 | .774** | .003 | .425 | .168 | -.507 | .092 | -.856** | .001 |
| | Monthly Mean Temperature | -.522 | .082 | .061 | .851 | .251 | .432 | .757** | .004 | -.033 | .918 | -.366 | .242 |

*Correlation is significant at the 0.05 level

**Correlation is significant at the 0.01 level

### 4.3.4. Discussion

The phenology events of 14 WEVs showed a high diversity phenophases under similar environmental conditions during the studied three years (2015-2017). These phenological observations have a major impact on forest ecosystem management, productivity, and characterization of various vegetation types. The present study revealed that most of the leaf flushing activity occurred during the dry seasons (March/April) when the air temperature was high. The results of this study showed that leaf formation was positively correlated with the atmospheric temperature. Leaf flushing during the dry seasons and just before the rainy season has also been reported by several workers (Shukla and Ramakrishnan, 1980; Zhang et al., 2015). Peak leaf flushing was also recorded in April with the onset of rain in the subtropical forest of Jaintia hills, Meghalaya (Upadhaya, 2016). A similar pattern was observed from other seasonal tropical and subtropical forest in India (Kikim and Yadava, 2001; Yadav, 2008). New leaf formation period may take between 5 weeks to 17 weeks depending upon the length of the rainy seasons. In *Crotalaria tetragona*, the beginning of new leaf formation occurred during the onset of the rainy season which was also an inconsistency with the reports that the new leaf formation coincided with the onset of rainfall (Broadhead et al., 2003). In the case of the deciduous and annual/perennial plants, the species shed leaves to tolerate the dry conditions which regain the leaves and continued to grow during the rainy seasons (Fagg and Allison, 2004; Singh and Kushwaha, 2006). Out of the 14 species studied, 9 species underwent leaf fall during winter and continued before the pre rain flash which could lead to water deficiency and or it may also be one of the physiological mechanisms to maintain shoot turgidity as described by Singh and Kushwaha (2006). In the present study, the leafless period of the deciduous plants sometimes lasted for more than 2-3 months. This long period of leaflessness may strongly influence the water relation which could affect the selection of low-density wood with larger storage (Singh and Kushwaha, 2005). During the dry period, tropical evergreen species also shed some parts of their old leaves to produce new leaf (Elliott et al., 2006). This revealed that the formation of the new leaf before rainy seasons is likely to optimize the photosynthetic gain in tropical forest (Kikim and Yadava, 2001).

Atmospheric temperature and precipitation can strongly influence the development of flower bud and floral formation (Khan et al., 2018). This study revealed that floral formation always occurred during pre-rainfall and rainy seasons (March, July /August). In line with this, (Günter et al., 2008) and (Sulistyawati et al., 2012) also observed earlier where the flowering peak was high from May to July. There was a positive correlation between flower formation with mean monthly temperature and rainfall in our study which was in accordance with Tandon et al. (2001) that reported members of Leguminosae family prefers flowering during the rainy season. In line with this observation (Omondi et al., 2016) also found similar results. Most of the Leguminosae family in the present investigations also flowered in the rainy season, which was similarly reported (Holbrook et al., 1995) and also in *Acacia* species within the woodland and other tropical species (Singh and Kushwaha, 2006). *Solanum torvum* produced flowers for 136-139 days during three years of study at the individual level, such similar observations of extended flowering events were also reported from the sub-tropical forest of Manipur, Northeast India (Kikim and Yadava, 2001) and also from the tropical forest of Costa Rica (Fenner, 1998). Extension of flowering at an individual level would be an important ecological and evolutionary mechanism for spreading the risk of uncertain pollination (Rathcke and Lacey, 1985). Such plant species with an extended period of flowering may also be helpful for ecosystem functioning; to provide food to the insect. Moreover, it might also act as a keystone species. A maximum flowering activity during the rainy seasons may be related to high insect population and extreme birds' activity for food competition (Stiles, 1978). Therefore, understanding the phenological events in a forest community is not only important for the structural organization but can also act as a functional aspect of an ecosystem thereby helping plant-animal interaction in space and time. The present study indicated that variation in flower events between different species signifies plant-animal interaction.

Although, different species under study exhibit different fruiting events which lasted for about 3 to 7months (it may differ by weeks) during the three years. There was a uniform distribution of fruit formation from June to November during the study period which allowed the fruit to grow and undergo fruit maturation since fruit production during the rainy seasons needs a lot of photosynthates (Lieberman, 1982). However, the peak fruit formation understudied occurred during the dry period (October- November) in 2017 which always coincided with the formation of seed. There was also positive correlation between peak fruiting formations with monthly mean temperature in the year 2017. A similar report was also observed (Chapman et al., 2005) to gain post dispersal process. This highlights tropical deciduous and evergreen species correspond to change in hydro-periodicity and temperature in an ecosystem (Borchert, 1983). Fruiting events in *Parkia timoriana* and *Oroxylum indicum* coincided with the complete leaf fall period occur during the dry season in our study. This may further retain high stem water potential enabling them to undergo reproductive phenology during water scarcity situations (Schöngart et al., 2002). For producing mature fruits and seeds, rainfall is predominantly important during the preceding months.

Fruit maturation, production of seed and presence of suitable conditions for seed shedding was closely synchronized in tropical dry forest species due to distinct biotic and abiotic conditions between dry and wet seasons (Griz and Machado, 2001). In our study, maximum seed production occurred at the end of the dry season and at the beginning of the year (January) which resulted in the complete shedding of seed during February where no rainfall or little rainfall was observed. The peak formation of fruits during the end of dry seasons and during January/ February was also reported (Kikim and Yadava, 2001). To validate our results, there was a negative and significant relationship between temperature and seed formation, seed shedding with temperature and rainfall during the study period. The period of fruit development in our study varied between different species from 4- 25 weeks. In contrast to our results, Kikim and Yadava, (2001) reported 4- 20 weeks for the fruit development. With the onset of dry seasons, almost all the fruits were matured and ripened producing seed which was ready for dispersal. In most of the dry ecosystem, strong winds commonly influenced seed dispersal (Devineau, 1999) as it was also in the case of almost all the species studied (in some cases it may take more than one month to completely disperse the seeds). At the same time, all the studied species are edible; they provide suitable sources of food for herbivorous animals which could also be dispersers of the species. However, some of these species showed winter dormancy and with the onset of favourable environmental conditions, the seeds were broken up and germination started. . Similar observations have also been reported from tropical evergreen (Frankie et al. 1974) and subtropical evergreen forest of Himalaya (Boojh and Ramakrishnan, 1981).

# CHAPTER V

## 5. Nutritional Evaluation, Mineral and Heavy Metal Content of Selected WEVs

### 5.1. Introduction

WEVs comprise inorganic and organic potential bio-molecules (Kris-Etherton et al., 2002) having high nutraceutical values widely used for the treatment of various ailments such as cancer, diabetes, inflammatory and cardiovascular diseases (Shad et al., 2013). They are vital, inexpensive sources of essential biochemicals like carbohydrate, protein, fats, vitamins, and minerals that maintain the proper physiological functioning of the body (Saikia and Deka, 2013). Proteins are made up of amino acid molecules and play many important roles in cell growth, cell metabolism, and differentiation (Vincentea et al., 2014). The recommended daily allowance (RDA) for protein is 56g and 46g per day for men and women respectively (Food and Nutrition Board, 2005). Carbohydrates are the structural framework of the cells and served as storage of reserve energy (Nelson et al., 2008). Carbohydrates and proteins provide 4 kcal/g of energy, while fats yield 9 kcal/g of energy value (Vincentea et al., 2014). In addition, moisture, fibre, ash, and energy content of particular plants are essential for maintaining good health and anticipation of various diseases. Moisture is the most plentiful material of fresh fruits and leafy which are up to 95% of the total mass (Vincentea et al., 2014). The moisture content of leafy vegetables and fruits is an excellent source of water required by the body that accounts for 20% of the total water consumption which is satisfied by WEVs (Food and nutrition board, 2005). It is suggested that more intake of fresh wild plants may reduce the chance of getting the risk of diseases like cancer, heart attack, diabetes, etc. (Aregheore, 2012).

Green leafy vegetables supplied negligible amount of calories to the human diet (Pachkore et al., 2010) and are an excellent source of minerals and nutrients which play an important role in human nutrition (Prasad and Bist, 2011) Therefore, the consumption of WEVS may contribute to meet the basic nutritional requirement by overcoming micronutrient deficiency at minimum cost (Saikia and Deka, 2013). Proximate and nutrient analysis of WEVs plays an important role in measuring their nutritional importance. Since many WEVS are also used as medicine by consuming the edible parts, evaluation of their nutritional value can help to understand the values of certain plant species (Pandey et al., 2006).

The human body requires a number of minerals in order to maintain good health and is built up in different parts of the plants (Ajasa et al., 2004). Metals serve as structural components of tissues and function in cellular metabolism and water and acid-base balance (Essiett et al., 2011). However, WEVS also contain both essential and toxic elements over a large range of concentration having numerous toxicological properties on the human body (Orisakwe et al., 2012). WHO highly recommended the analysis of heavy metal in certain plants along with biological, chemical, and environmental investigation (Garg, 2014). There are many factors that are responsible for the absorbance of heavy metals by plants such as atmospheric deposition, nature of the soil, and maturity of the plant species (Singh and Singh, 2014). It is generally taken up in plants by absorbing on the fruits and vegetable surface either from the soil or from the use of pesticides and fertilizers (Ramadan and Al-ashkar, 2007).

Essential micronutrients like iron, manganese, molybdenum, zinc, copper, nickel are important for normal growth, and take part in the redox reaction; electron transfer and other metabolic processes in plants and the deficiency or excess are both harmful that may lead to metabolic disorders (Narzary and Basumatary, 2017). Heavy metals that are considered non-essential like lead, arsenic, cadmium, etc. are highly toxic to plants (Sahito et al., 2003). It has been reported that the normal intake of elements such as sodium, magnesium, potassium, calcium, manganese, copper and zinc could reduce the high risk of factors related to cardiovascular disease (Jabeen et al., 2010).

Most of the metals are activators for enzyme-catalyzing reactions. For example, magnesium plays a structural role in the chloroplast membrane and a cofactor for biomolecules synthesis (Karimi et al., 2008). Iron is involved in chlorophyll synthesis and catalyzed reaction for ferredoxin nitrate reductase (Nookabkaew et al., 2006). Furthermore, potassium is involved in the synthesis of amino acids and proteins. Calcium is also an important component of bone and tooth formation; also plays a crucial role in photosynthesis, biomolecules metabolism, and binding agent of cell walls. Zinc is another important micronutrient that is linked with a number of enzymes like those for the synthesis of RNA. Copper and zinc are essential for normal plant growth and development since they are important constituents of enzymes and other proteins. Nutritional analysis of WEVs could allow better food selection and consequent improvement in the nutritional status of the local diet in Mizoram.

## 5.2. Methodology

### 5.2.1. Selection and collection of plant material

Plants were selected based on dependency and preferences by the local people from the study area and some selected WEVs were of medicinally important. Nine important species of WEVs were selected and collected from two villages of Aizawl district to evaluate the nutritional quality, phytochemical, antioxidant, and antimicrobial activity **(Table 5.1)**.

**Table 5.1:** List of WEVs selected for nutritional, phytochemical, antioxidant and antimicrobial activity.

| Species | Material used | Ethnomedicinal uses | Pharmacological activities reported |
|---|---|---|---|
| *Picria fel-terrae* Lour.<br>*Family: Linderniaceae* | Whole plant | Diabetes, Hypertension, fever, skin disease | Skin disease (Perry,1980)<br>Anti-diabetic (Huang et al., 1994)<br>Antioxidant (Thuan et al., 2007) |
| *Dysoxylum excelsum* Blume<br>Family:Meliaceae | Young leave and shoot | Diarrhoea, dysentery | |
| *Rhynchotechum ellipticum* ( Wall. ex D. Dietr.) A. DC.<br>Family: Gesneriaceae | Leave | Cancer | Anti-diarrhoeal, Analgesic, antimicrobial (Azad et al., 2020) |
| *Aganope thyrsifolia* (Benth.) Polhill.<br>Family: Fabaceae | Young leave | Stomach ache, dysentery | |
| *Centella asiatica* L.<br>Family: Apiacea | Whole plant | Diabetes, hypertension, stomach problem | antioxidant, antiulcer, anti inflammatory and cytotoxic activities (Vohra et al., 2011) |
| *Fagopyrum tataricum* (L.) Gaertn.<br>Family: Polygoniaceae | Leave | Diarrhoea, stomach problem | Anti-haemorrhagic (Chang et al., 2002) |
| *Crotalaria tetragona* Roxb. Ex Andr.<br>Family: Fabaceae | Flower | Not known | |
| *Trevesia palmata* (Roxb.ex Lindl.) Vis.<br>Family: Araliaceae | Flower bud | Not known | Antimicrobial activity (Arifin et al., 2017) |
| *Clerodendrum bracteatum* Wall. ex Walp.<br>Family: Lamiaceae | Young leave | Hypertension | Anti-inflammatory (Deb et al., 2013);<br>Antidiabetic (Devi and Sharma, 2004) |

#### 5.2.1.1. Short Description of Plant Material

1) *Picria fel-terrae* Lour

*Picria fel-terrae* Lour belonging to family Scrophulariaceae and locally known as 'Khatual' or 'Tlungkha'. It is a smooth, prostrate herb with the slender branch, 60-90 cm long, rooting at the lower nodes. It is mostly occurring in shaded place and offers an economic value for many people. The whole plant is edible and provides important ethnomedicinal properties. The local people in the study area frequently used to treat diabetes, skin problem, fever, and hypertension.

2) *Dysoxylum excelsum* Blume

*Dysoxylum excelsum* Blume is an evergreen tree that belongs to Meliaceae family. The local name is 'Thingthupui'. The tree can grow up to 35m high. It supplies food, medicine, and is often exploited for its valuable timber. The tender leaves and shoots are edible. A decoction of the leaves is used to treat diarrhoea and dysentery by the local people.

3) *Rhynchotechum ellipticum (*Wall. ex D. Dietr.) A. DC.

*Rhynchotechum ellipticum* is an important WEVs belonging to Gesneriaceae family. It is a shrub with erected stem, woody branch or unbranched. The leaves are taken as vegetables, form a part of household food security, and provides income generation for the rural inhabitant. The plant is also used for the treatment of cancer.

4) *Aganope thyrsifolia* (Benth.) Polhill.

It is an evergreen climber, belonging to family Fabaceae and locally known as 'Hulhu'. It is mostly grown in the secondary forest, along the roadside, in open and highly disturbed areas. This plant is also used to treat stomach aches and dysentery by the local people. The leaves are taken as vegetables. It serves as an important food especially during the dry season where the staple food is scarce.

5) *Centella asiatica* L

*Centella asiatica* L, commonly known as 'Hnahbial or lambak' is an herbaceous perennial plant under the flowering plant family Apiaceae. The stem is slender, creeping on to the ground. Flowers are small, white, and pinkish to red in colour. It is widely used to treat diabetes, hypertension, and gastric problems by the local people.

6) *Fagopyrum tataricum* (L.) Gaertn.

*Fagopyrum tataricum*, locally known as 'Anbawng' is an annual herb belonging to family Polygonaceae. The leaves are edible and prepared in combination with fermented pork. Traditionally, they are used to treat diarrhoea and stomach problems.

7) *Crotalaria tetragona* Roxb. Ex Andr.

*Crotalaria tetragona* locally known as 'Tumthang' is an erect shrub, growing up to 2m tall, belonging to family Fabaceae. They are mostly grown in an open forest area and secondary forest. The flower parts are edible but ethnomedicinal uses of these plants by the local people are not known.

8) *Trevesia palmata* (Roxb.ex Lindl.) Vis.

*Trevesia palmata* locally known as 'Kawhtebel' is a prickly evergreen tree growing up to 8m tall belonging to family Araliaceae. The demand of this vegetable is extremely high during the available period. The flower bud can be consumed either as fried or boiled form however, ethnomedicinal use of this plant by the local people is not known.

9) *Clerodendrum bracteatum* Wall. ex Walp.

*Clerodendrum bracteatum* is a middle sized tree under the family Lamiaceae. It is a small deciduous tree; mostly growing in secondary forest and disturbed area. The young leaves and shoots are taken as a vegetable. Traditionally, a decoction of the leaves is used to treat hypertension by the local people.

**Figure 5.1:** WEVs selected for nutritional, antioxidant and antimicrobial activity.

### 5.2.2. Nutritive value evaluation of selected WEVs

#### 5.2.2.1. Total moisture content

Total moisture content was determined by following Association of Official Analytical Chemistry (AOAC, 1990). 5g of fresh sample was taken to determine moisture content and was dried in an oven at 100$^{o}$C for overnight. The sample was then cooled and weight till a constant weight was observed. The differences in weight were then taken to represent the loss of moisture and were expressed as the percentage of oven-dry weight.

$$\text{Moisture (\%)} = \frac{Fresh\ weight - Dry\ weight}{Fresh\ weight}\ x\ 100$$

**5.2.2.2. Total ash content** (AOAC, 1990)

1g of oven-dried sample was taken in a crucible and was ignited in a muffle furnace with a temperature of 550ºC for three hours and weighed. The process was repeated until a constant weight is observed.

$$\text{Ash (\%)} = \frac{Weight\ of\ ash}{Weight\ of\ sample}\ x\ 100$$

**5.2.2.3. Total Fat Determination** (AOAC, 1990)

50g of dried powder sample was introduced into Soxhlet apparatus (boiling point 60-80ºC) with 600ml of petroleum ether for 8hrs. The extracted fat was dried at room temperature, weighed, and expressed in percentage.

$$\text{Percentage (\%) of Fat} = \frac{Mass\ of\ fat\ extracted\ (g)}{Sample\ weight\ (g)}\ x\ 100$$

**5.2.2.4. Total Protein Content**

Total protein content was determined using Lowry assay (Lowry et al., 1951). In this method, 0.1g of each dried powdered plant samples were crushed with 10ml of phosphate buffer (Ph-7.4). It was centrifuged at 10000rpm for 10 minutes. The pellets were discarded and the supernatant was collected in a clean test tube. 0.1ml of each extract was taken and it was diluted with 0.9ml of miliQ water to make up to 1 ml volume. 2ml each of the analytical reagent was added to it. It was incubated at room temperature for 10 minutes. After this, 0.2ml of Folin-ciocalteau reagent (1N) was added and incubated again at room temperature for 30 minutes. The colour developed from dark green to blue colour was read at 660nm using a UV vis-spectrophotometer. The amount of protein present in the given sample was determined from the standard curve prepared using Bovine serum albumin (1mg/ml) with concentration ranges of 0.01mg/ml-0.2mg/ml. The results were expressed in mg/g of dry weight sample.

**5.2.2.5. Total carbohydrate content**

Total carbohydrate content was determined by Anthrone reagent following Hedge and Hofreiter (1962). In this method, 100mg or 0.1g of plant sample was hydrolyzed with 10 ml of 80% ethanol. It was centrifuged at 8000rpm for 5 minutes. The supernatant was collected and 0.1ml of each extract was taken and volume was made upto 1ml. Then, 4ml of Anthrone reagent was added to each extract and the content was heated in a water bath at 60ºC for 5 minutes and then cooled at room temperature. The formation of green colour to dark green was read at 630nm using a UV vis- spectrophotometer. The amount of carbohydrates present in the plant sample was calculated from the standard curve prepared from glucose (1mg/ml) with concentration ranges 10 μg/ml-100μg/ml. The results were expressed in mg/g of dry weight sample.

**5.2.2.6. Estimation of calorific value**

The total energy content of WEVs was determined by the value obtained for protein, carbohydrates, and fats multiplied by 4.00, 4.00, and 9.00 respectively, and adding up the values (AOAC, 2000).

$$\text{Energy Kcal/100g} = \text{Amount of carbohydrates in gram} \times 4 + \text{amount of protein in gram} \times 4 + \text{amount of fat content in gram} \times 9$$

**5.2.3. Determination of mineral and heavy metal contents of WEVs**

Mineral and heavy metal content were estimated using wet diacid digestion method (Badran et al., 2018). 0.1g of dried plant sample was kept in 10 ml of Conc. $HNO_3$ in 50 ml volumetric flask and it was heated in a hot plate for 30 minutes. When approximately 1ml of the solution was left, another 10ml of conc. $HNO_3$ was added. Again, it was heated on a hot plate for another 20 minutes. $H_2O_2$ was added dropwise until colourless solution was obtained. When 1-2ml of the solution was left, the flask was removed. The final volume was made at 100ml with miliQ water. It was filtered with a syringe filter and Whatmann number1. The analysis of Carbon and Nitrogen were done using CHNS elemental analyzer. Magnesium, sodium, and potassium were analyzed using Mp-AES elemental analyzer. Nickel, Iron, Zinc, Manganese, Copper, Lead, and calcium were analyzed by Atomic absorption spectroscopy (AAS).

**5.2.4. Statistical analysis**

The results were expressed in mean ± SEM of the values obtained in triplicates and analyzed by one-way analysis of variance (ANOVA) followed by Duncan's multiple range tests for comparison of statistical significance ($P < 0.05$) using PASW statistical software version 18.

### 5.3. Results

#### 5.3.1. Nutritional analysis of selected WEVs

Nutritional analysis of selected WEVs showed different quantities in all the parameters calculated. All the nutritive value studied is given in the table below **(Table 5.2).**

**Table 5.2:** Nutritional compositions of selected WEVs.

| Plant species | Moisture (%) | Ash (%) | Fat (%) | Carbohydrate (mg/g) | Protein (mg/g) | Energy (Kcal/100g) |
|---|---|---|---|---|---|---|
| *P. fel-terrae* | 65.23±0.15$^{f}$ | 7.7±0.5 $^{cd}$ | 2.04± 0.06$^{b}$ | 58.27± 0.01$^{b}$ | 29.08±0.03$^{c}$ | 53.3 |
| *D. excelsum* | 80.2±0.04$^{d}$ | 8.3±0.09$^{c}$ | 7.64±0.05$^{a}$ | 7.89±0.04 $^{h}$ | 5.03±0.06$^{h}$ | 73.93 |
| *R. ellipticum* | 96.85±0.08$^{a}$ | 10.3±0.08$^{b}$ | 0.8±0.03$^{e}$ | 14.92±0.09 $^{e}$ | 35.56±0.11$^{a}$ | 20.91 |
| *A. thyrsifolia* | 83.84±0.2$^{c}$ | 5.9±0.2$^{e}$ | 1.1±0.04$^{de}$ | 9.38±0.20 $^{g}$ | 17.8±0.03$^{d}$ | 20.77 |
| *C. asiatica* | 87.4±0.07$^{b}$ | 9.7±0.03$^{b}$ | 1.14±0.1$^{de}$ | 75.20±0.01$^{a}$ | 16.03± 0.04$^{e}$ | 37.52 |
| *F. tataricum* | 88.1± 0.09$^{b}$ | 11.5±0.1$^{a}$ | 1.52±0.2$^{cd}$ | 48.47±0.01$^{c}$ | 14.24±0.08 $^{f}$ | 38.76 |
| *C. tetragona* | 79.27±0.03$^{de}$ | 6.1±0.08$^{e}$ | 1.72±0.09$^{bc}$ | 9.06±0.03g$^{h}$ | 16.29±0.02$^{e}$ | 25.62 |
| *T. palmata* | 80.54±0.05$^{d}$ | 7.1±0.07$^{cde}$ | 2.02±0.07$^{b}$ | 24.19 ± 0.06$^{d}$ | 32.15± 0.00$^{b}$ | 40.72 |
| *C. bracteatum* | 76.6±0.01$^{e}$ | 7±0.06$^{de}$ | 1.32±0.07$^{cd}$ | 12.90 ± 0.05$^{f}$ | 10.66±0.01$^{g}$ | 21.304 |

*Means of three replicates (Mean ± SE) followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) (P<0.05). Means followed by same letter within same column are not significantly different.*

##### 5.3.1.1. Total moisture content (%)

The nutritional evaluation of nine WEVs revealed that a relatively high amount of moisture content in the entire test sample **(Table 5.2).** The highest moisture content (96.85%) was observed for *Rhynchotechum ellipticum* followed by *Fagopyrum tataricum* (88.1%), *Centella asiatica* (87.4%), *Aganope thyrsifolia* (83.84%) *Trevesia palmate* (80.54%), *Dysoxylum excelsum* (80.2%), *Crotalaria* *tetragona* (79.27%) and *Clerodendrum bracteatum* (76.6%). The lowest moisture content was observed for *Picria fel-terrae* (65.23%) **(Figure 5.2).**

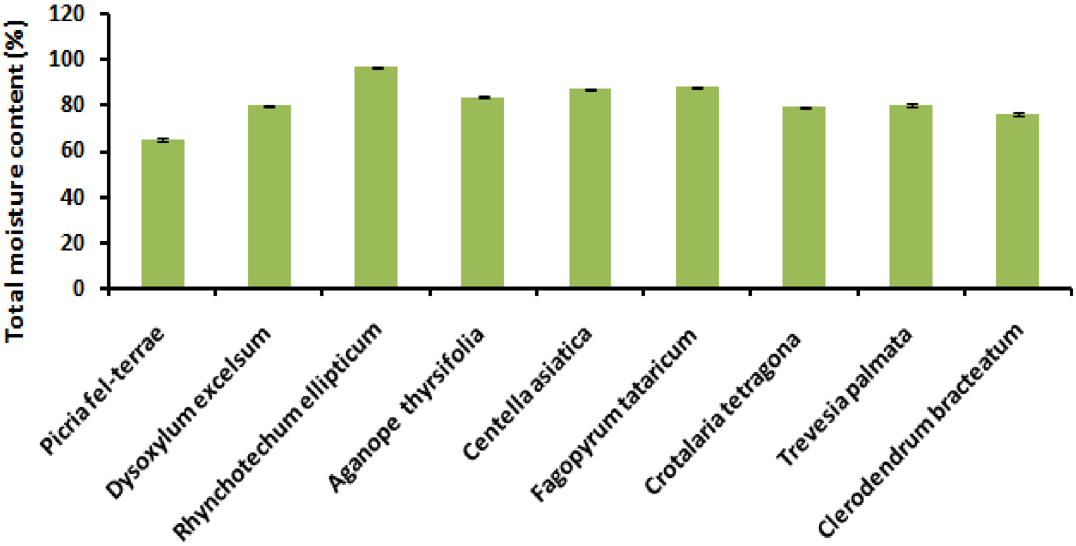



**Figure 5.2:** Total moisture content (%) of selected WEVs.

#### 5.3.1.2. Total ash content (%)

The total ash content of selected WEVs was in the range of 5.9% to 11.5% **(Table 5.2).** The highest ash value was found in *Fagopyrum tataricum* (11.5%) followed by *Rhynchotechum ellipticum* (10.3%), *Centella asiatica* (9.7%), *Dysoxylum excelsum* (8.3%), *Picria fel-terrae* (7.7%), *Trevesia palmata* (7.1%), *Clerodendrum bracteatum* (7%), *Crotalaria tetragona* (6.1%), and the least content was recorded for *Aganope thyrsifolia* (5.9%) **(Figure 5.3)**.

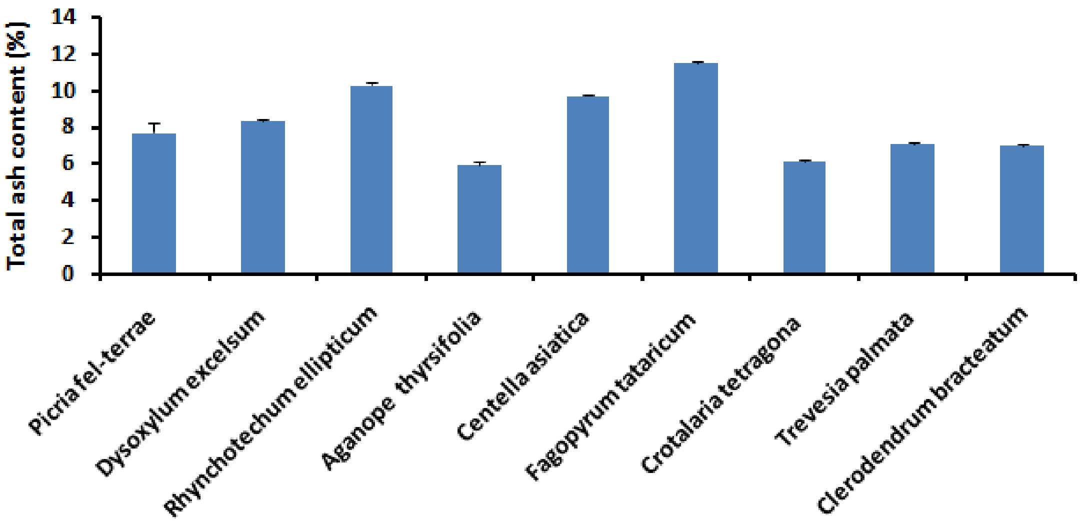



**Figure 5.3:** Total ash content (%) of selected WEVs.

### 5.3.1.3. Total Fat Content (%)

Evaluation of total fat content of selected WEVs revealed that *Dysoxylum excelsum* (7.64%) contained the maximum amount of fat, followed by *Picria fel-terrae* (2.04%), *Trevesia palmata* (2.02%), *Crotalaria tetragona* (1.72%), *Fagopyrum tataricum* (1.52%), *Clerodendrum bracteatum* (1.32%), *Centella asiatica* (1.14%), and *Aganope thyrsifolia* (1.1%) and the least amount of fats content was observed for *Rhynchotechum ellipticum* (0.8%) **(Figure 5.4)**.

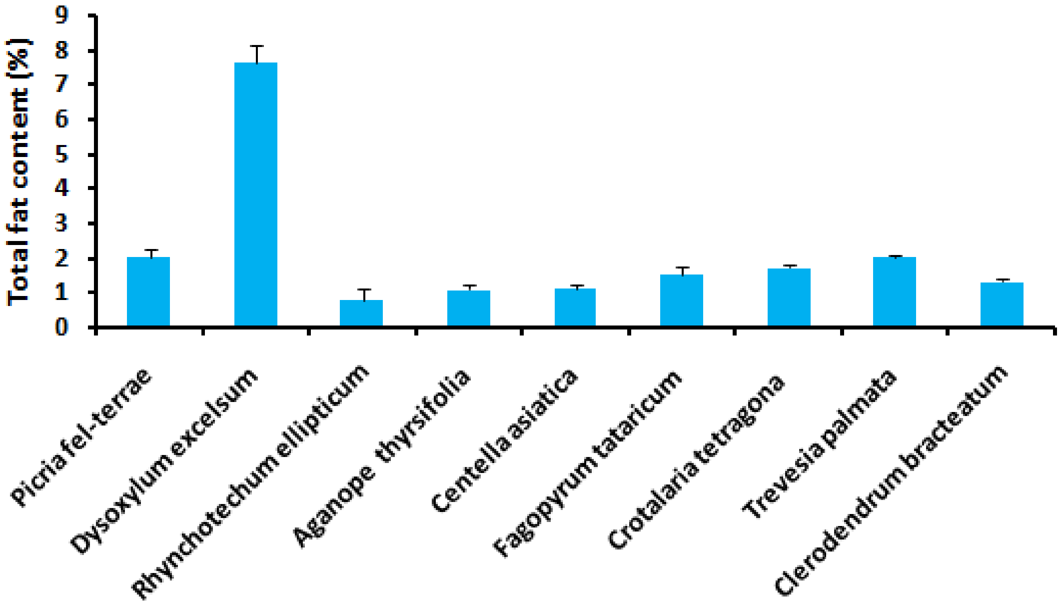



**Figure 5.4:** Total fat content (%) of selected WEVs.

### 5.3.1.4. Total Carbohydrate Content

Carbohydrate was determined from a regression equation for the calibration curve of glucose (Y=0.009x+0.032, $R^2$=0.999) **(Figure 5.5)**. The nutritional evaluation stated that selected WEVs contained high amount of carbohydrates in each different plant parts analysed **(Table 5.2).** The total carbohydrate content was observed to be highest in *Centella asiatica* (75.20 mg/g), followed by *Picria fel-terrae* (58.27 mg/g), *Fagopyrum tataricum* (48.47 mg/g), *Trevesia palmata* (24.19 mg/g), *Rhynchotechum ellipticum* (14.92 mg/g), *Clerodendrum bracteatum* (12.90mg/g), *Aganope thyrsifolia* (9.38 mg/g), *Crotalaria tetragona* (9.06 mg/g), and minimum carbohydrate content was observed for *Dysoxylum excelsum* (7.89 mg/g) **(Figure 5.6).**

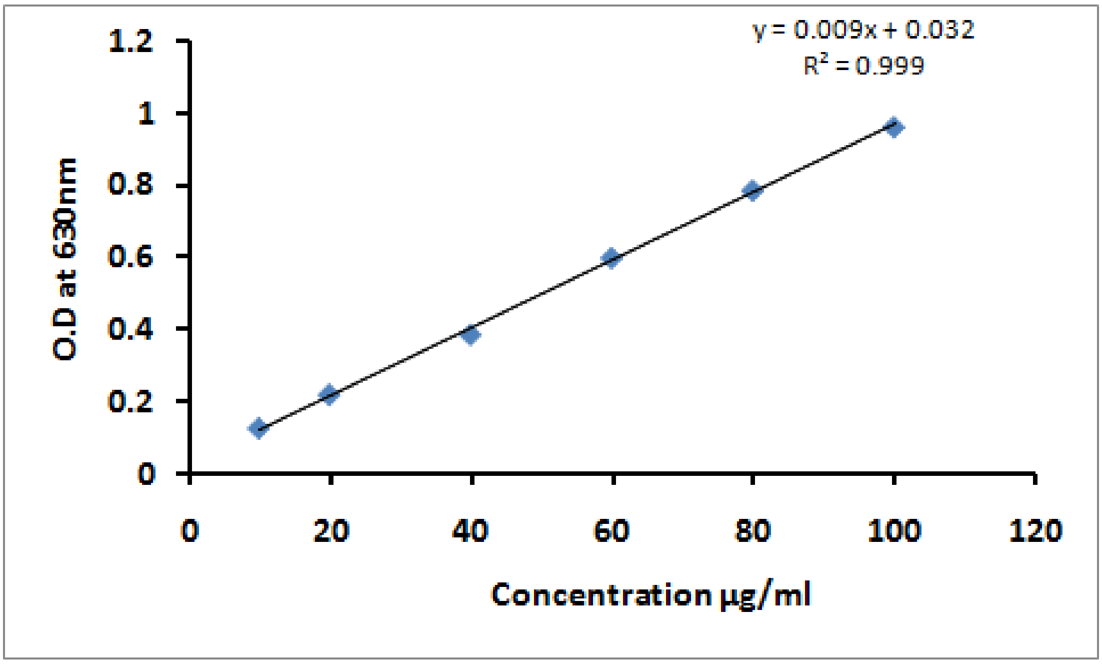



**Figure 5.5:** Standard curve of glucose (µg/ml)

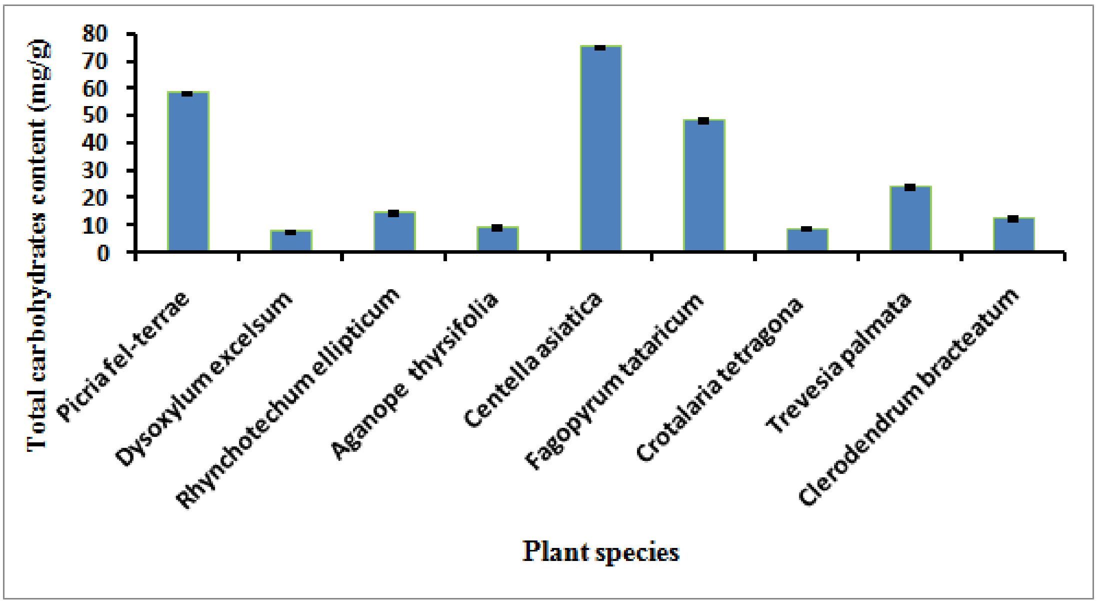



**Figure 5.6:** Total carbohydrate content of selected WEVs (mg/g) Dry weight.

### 5.3.1.5. Total Protein Content

The amount of total protein was determined from the standard curve of Bovine serum albumin using the standard curve equation: (Y= 3.899x + 0.096, $R^2$ = 0.998) as given below **(Figure 5.7)**.

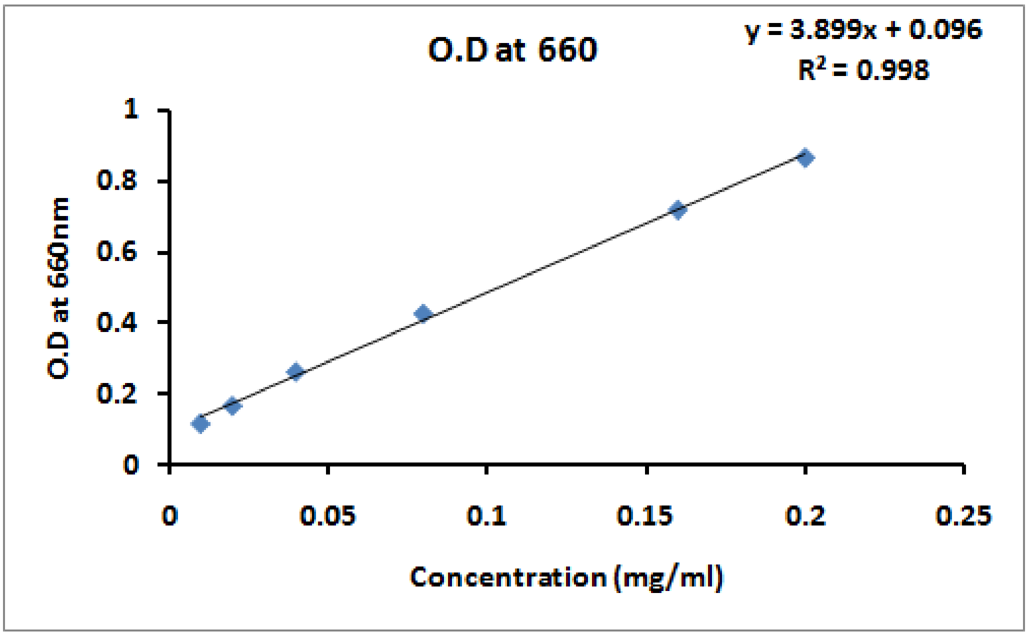



**Figure 5.7:** Standard curve of Bovine serum albumin (BSA)

The total protein content of selected WEVs ranged between 5.03 mg/g to 35.56 mg/g **(Table 5.2).** Among the nine plants observed *Rhynchotechum ellipticum* (35.56 mg/g), *Trevesia palmata* (32.15 mg/g), *Picria fel-terrae* (29.08 mg/g) were found to contain high amount of total protein and the lowest total protein content was observed in *Dysoxylum excelsum* (5.03 mg/g). Species like *Aganope thyrsifolia*, *Crotalaria tetragona*, *Centella asiatica*, *Fagopyrum tataricum* and *Clerodendrum bracteatum* were found to contain a medium value of total protein content (17.8mg/g, 16.29 mg/g, 16.03mg/g, 14.24mg/g and 10.66 mg/g respectively) **(Figure 5.8).**

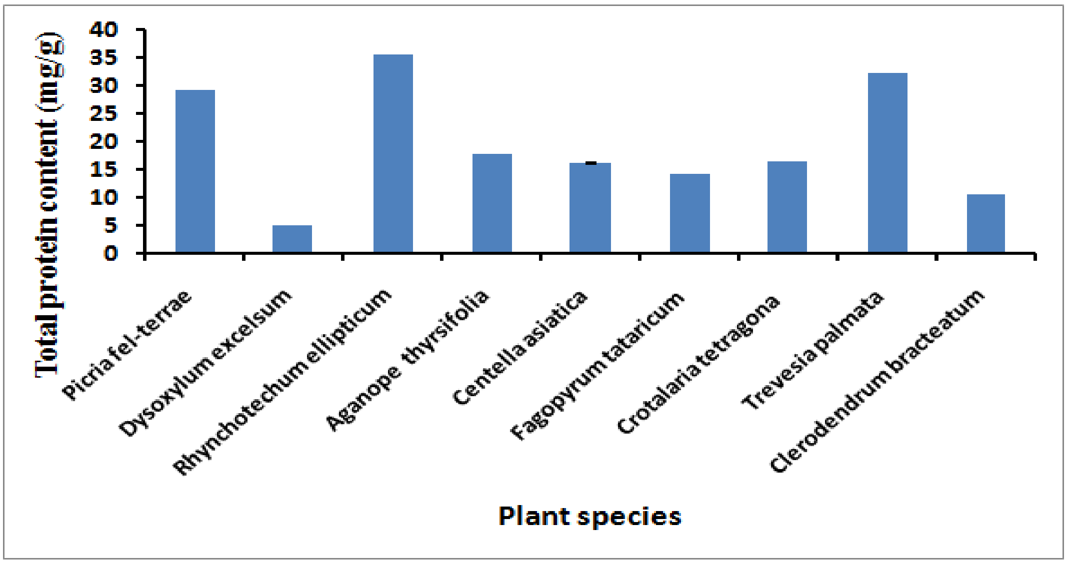



**Figure 5.8:** Total protein content (Mg/g DW) of selected WEVs.

#### 5.3.1.6. Total energy content/ Calorific value

According to the results evaluated for total energy content of WEVs, *Dysoxylum excelsum* has the highest calorific value (73.93Kcal/ 100g) followed by *Picria fel-terrae* (53.3Kcal/100g), *Trevesia palmata* (40.72Kcal/100g), *Fagopyrum tataricum* (38.76 Kcal/100g), *Centella asiatica* (37.52Kcal/100g), *Crotalaria tetragona* (25.62 Kcal/100g), *Clerodendrum bracteatum* (21.304 Kcal/100g) *Rhynchotechum ellipticum* (20.91 Kcal/100g), and least energy content was observed for *Aganope thyrsifolia* (20.77 Kcal/100g) **(Table 5.2)**.

### 5.3.2. Mineral content of selected WEVs

The mean concentration level of mineral analyzed for WEVs was presented in (**Table 5.3)**. It was found that most of the elements under study were presented in a detectable amount. Iron content ranges between 17.00 mg/100g in *Fagopyrum tataricum* to 126.00 mg/100g in *Rhynchotechum ellipticum*. Nickel concentration was highest in *Aganope thyrsifolia* (2.00mg/100g) and was not detectable in five plants. Manganese was present in the entire test sample where *Rhynchotechum ellipticum* (124mg/100g) had the highest manganese content and lowest content was observed for *Fagopyrum tataricum* and *Dysoxylum excelsum* (2.00mg/100g each). Calcium content was detected highest for *Trevesia palmata* (516.00mg/100g) while the lowest content was recorded for *Fagopyrum tataricum* (22.00mg/100g). Magnesium content was found to be highest in *Rhynchotechum ellipticum* (484.00mg/100g) whereas it was lowest in *Clerodendrum bracteatum* (87.00mg/100g). *Aganope thyrsifolia* has the highest content of sodium (1751.00mg/100g) among the nine plant analyzed, *Picria fel-terrae* contained 429.00mg/100g of sodium representing the lowest sodium content. Potassium content varied in the range of 326.00mg/100g in *Fagopyrum tataricum* to 1844.00mg/100g in *Rhynchotechum ellipticum*. Nitrogen content was determined highest in *Clerodendrum bracteatum* (7.00%) and the lowest value was observed in *Picria fel-terrae* (2.19%). Carbon was abundantly present for all the investigated plants with the highest record being found in *Centella asiatica* (21.29%), the lowest content was observed in *Rhynchotechum ellipticum* (17.40 mg/100g).

Overall, highest mean level of Iron (126.00mg/100g), Manganese (124.00 mg/100g), Magnesium (484.00mg/100g) and Potassium (1844.00mg/100g) were found in

*Rhynchotechum ellipticum*. The highest value of Nickel (2.00mg/100g) and Sodium (1751.00mg/100g) were recorded for *Aganope thyrsifolia.* Calcium (516.00mg/100g) was highest in *Trevesia palmata*, Nitrogen (7.00%) was found to be highest in *Clerodendrum bracteatum* and Carbon (21.29%) in *Centella asiatica* (**Table 5.3).**

**Table 5.3:** Mineral content of selected WEVs.

| Plant species | Fe (mg/100g) | Ni (mg/100g) | Mn (mg/100g) | Ca (mg/100g) | Mg (mg/100g) | Na (mg/100g) | K (mg/100g) | N (%) | C (%) |
|---|---|---|---|---|---|---|---|---|---|
| *Picria fel-terrae* | 56 ± .32$^{c}$ | ND | 8 ±. 2$^{e}$ | 436 ± .6$^{b}$ | 230 ± .5$^{g}$ | 429± .04$^{h}$ | 1314±.6$^{e}$ | 2.19 ±.04$^{g}$ | 19.38±2.14$^{c}$ |
| *Dysoxylum excelsum* | 30± .21$^{f}$ | 1.00 ±.2$^{b}$ | 2 ±. 3$^{g}$ | 271 ± .6$^{e}$ | 348 ± 1.2$^{e}$ | 620± .07$^{g}$ | 1570±1.12$^{c}$ | 5.84 ±.03$^{b}$ | 18.35±1.56$^{d}$ |
| *Rhynchotechum ellipticum* | 126 ±.07$^{a}$ | 0.4 ±. 1$^{c}$ | 124 ± 1.4$^{a}$ | 357 ± .8$^{c}$ | 484 ± 1.8$^{a}$ | 907± .63e | 1844± 1.2$^{b}$ | 2.44 ±.04$^{f}$ | 17.40±1.09$^{e}$ |
| *Aganope thyrsifolia* | 37 ± .3$^{e}$ | 2.00 ±.43$^{a}$ | 22 ± .04$^{d}$ | 135 ± .0$^{g}$ | 268 ± 2.6$^{f}$ | 1751±1.03a | 1433±2.5$^{d}$ | 6.94 ±.01$^{a}$ | 18.13± .09$^{d}$ |
| *Centella asiatica* | 71 ± .25$^{b}$ | ND | 92 ± .7$^{b}$ | 271 ± 2.0$^{e}$ | 410 ± 4.0$^{c}$ | 1347± 1.2c | 119±.34$^{i}$ | 2.93 ±.02$^{e}$ | 21.29±2.53$^{a}$ |
| *Fagopyrum tataricum* | 17 ± .07$^{g}$ | 0.1±. 05$^{c}$ | 2 ± .1$^{g}$ | 22 ± .2$^{h}$ | 141 ± .9$^{h}$ | 945± .04d | 326 ± .6$^{h}$ | 5.48 ±.02$^{c}$ | 19.38±2.14$^{c}$ |
| *Crotalaria tetragona* | 29 ± .02$^{f}$ | ND | 8 ± .2$^{e}$ | 281 ± .2$^{d}$ | 405 ± 1.5$^{d}$ | 620± .08g | 1035±.9$^{f}$ | 5.84 ±.04$^{b}$ | 18.35±1.56$^{d}$ |
| *Trevesia palmata* | 35± .02$^{e}$ | ND | 32 ± .1$^{c}$ | 516 ± .34$^{a}$ | 470 ± 1.1$^{b}$ | 1390±2.1b | 1723±1.2$^{a}$ | 4.72 ±.03$^{d}$ | 17.40 ±1.09$^{e}$ |
| *Clerodendrum bracteatum* | 52 ± .06$^{d}$ | ND | 7± .2$^{f}$ | 151 ± 5.0$^{f}$ | 87 ± .9$^{i}$ | 814± .43 f | 401± .12$^{g}$ | 7 ± .2$^{a}$ | 20.44 ± .03$^{b}$ |

*ND – Not detectable, Values are means of three replicates (mean± SD). Means followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) ($P<0.05$). Means followed by same letter within same column are not significantly different.*

### 5.3.3. Heavy metal content of selected WEVs

The mean levels of heavy metal content of WEVs are given in the **Table 5.4**. The level of Lead content was in the range between 0.03mg/kg Dw to 0.06mg/kg Dw with highest being observed in three plants such as *Rhynchotechum ellipticum*, *Trevesia palmata* and *Clerodendrum bracteatum* having similar concentration levels of 0.06mg/kg Dw. The least lead content was found in *Picria fel-terrae* (0.03mg/kg Dw). The copper concentration was in the ranged between 22.7mg/kg Dw in *Trevesia palmata* to 2.00mg/kg Dw in *Fagopyrum tataricum.* Zinc was found to be present in all the species which was determined to be highest in *Centella asiatica* (22.00mg/ kg Dw) and the lowest was observed for *Clerodendrum bracteatum* (4.00mg/kg Dw). These results further indicated that heavy metal content of all selected WEVs was below the permissible limit of FAO/WHO safe limit (2001).

**Table 5.4:** Mean concentration of heavy metal content of selected WEVs.

| Plant species | Lead (mg/kg) | Copper (mg/kg) | Zinc (mg/kg) |
|---|---|---|---|
| *Picria fel-terrae* | $0.03 \pm 0.01^{c}$ | $20.00 \pm 0.5^{c}$ | $11 \pm 0.3^{d}$ |
| *Dysoxylum excelsum* | $0.04 \pm 0.01^{bc}$ | $18.4 \pm 0.2^{d}$ | $15 \pm 0.2^{c}$ |
| *Rhynchotechum ellipticum* | $0.06 \pm 0.01^{a}$ | $9.8 \pm 0.24^{f}$ | $19 \pm 0.8^{b}$ |
| *Aganope thyrsifolia* | $0.05 \pm 0.00^{ab}$ | $10.00 \pm 0.5^{f}$ | $9.00 \pm 0.3^{f}$ |
| *Centella asiatica* | $0.04 \pm 0.00^{bc}$ | $11.6 \pm 0.4^{e}$ | $22 \pm 0.1^{a}$ |
| *Fagopyrum tataricum* | ND | $2.00 \pm 0.1^{g}$ | $9.00 \pm 0.3^{f}$ |
| *Crotalaria tetragona* | $0.04 \pm 0.00^{bc}$ | $21.00 \pm 0.2^{b}$ | $8.00 \pm 0.5^{g}$ |
| *Trevesia palmata* | $0.06 \pm 0.00^{a}$ | $22.7 \pm 0.7^{a}$ | $10.00 \pm 0.3^{e}$ |
| *Clerodendrum bracteatum* | $0.06 \pm 0.01^{a}$ | ND | $4.00 \pm 0.2^{h}$ |
| **FAO/WHO safe limit (2001)** | **0.300** | **73.00** | **99.40** |

*ND – Not detected, Values are means of three replicates (mean± SD) *Source a = Adu et al., 2012). Means followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) (P<0.05).*

## 5.4. Discussion

Evaluation of nutritional, mineral and heavy metal content of WEVs is one of the necessary steps in determining their nutritive value. Moisture content measures the quantity of water present in the plant material. In the present investigations, all the nine plants possessed moisture content ranging from 65.23% to 96.85% as mentioned above. The moisture content of the vegetables could also be different in the same species due to many environmental factors like humidity, harvested period of time, and temperature (Datta et al., 2019). The moisture content of *Rhynchotechum ellipticum* in this study was much higher than the previously reported value of 81.67% (Chaudhuri et al., 2018) which further showed that proper conservancy is necessary because of the high chance of microbial degradations (Kwenin et al., 2011). *Centella asiatica* exhibited 87.4% of total moisture content in the present study which was in accordance with the previous finding of 87.7% observed by Das (2011). On the contrary, a low level of moisture content of *Centella asiatica* (12.3%) was reported by Upadhyaya and Saikia (2012) from Tinsukia localities of Assam. *Fagopyrum tataricum* of the present investigation was found to contain 88.1% of total moisture, supported by the findings of Mann et al. (2012). Similarly, *Trevesia palmata* (80.54%) in the present study was in close proximity to the previously reported value of 75.70 % (Tin, 2008). Furthermore, the total moisture content of *Clerodendrum bracteatum* in the present study was higher than the previous work reported value of 55.25% (Seal, 2011). Furthermore, the plant with high moisture content would also possess a high activity of water-soluble enzymes (Iheanacho and Udebuani, 2009).

The ash content defined the amount of mineral present in the vegetables (Gopalan et al., 2004). Total ash content in this study varying between species from *Aganope thyrsifolia* (5.9%) to *Fagopyrum tataricum* (11.5%). The ash content of nine WEVs under study was found to be similar to the previous work on WEVs of Meghalaya (Seal, 2011). However, the range was found to be higher in comparison with WEVs consumed by Bodos (0.661- 3.412 g/100g) of N. E India (Basumatary and Narzary, 2017). The ash content of *Fagopyrum tataricum* in the present study was similar with the previous work reported value of 2.4g/100g (Mann et al., 2012) and higher than the reported value of 1.8% dry matter (Bonafaccia and Fabjan, 2003). Ash content of *Rhynchotechum ellipticum* of the present investigation (10.3%) was higher than the similar work reported by Chaudhuri et al. (2018) who found 6.62% of the ash content from the leaves. The ash content of *Centella asiatica* (9.7%) in the present study was also higher than the previously reported value of 2.70% (Ranovona et al., 2019). The Ash value of *Trevesia palmata* reported in this study (7.1%) was lower than the value (9.95%) reported by Tin (2008). Similarly, the total ash content of *Clerodendrum bracteatum* in the present investigations was found comparable with the previously reported value of 7.23% (Seal, 2011). The total ash content of *Crotalaria tetragona* (5.9%) reported by Jain and Jain (2004) was also very similar to the present reported value of 6.1% w/w.

Fats provide linoleic and linolenic acids which can be obtained only from the food and helps in the absorption of lipid-soluble vitamins like vitamin A and carotene in the body (Gopalan et al., 2004). The total fat content (%w/w) of *Rhynchotechum ellipticum* (0.8%) in the present study was lower when compared with 1.37 % (Panmei et al., 2016) and 1.52% (Chaudhuri et al., 2018) found in the previous study. However, the total fat content reported in six WEVs from Bodos of N.E India (Basumatary and Narzary, 2017) was lower than the present investigation. The total fat content of certain species like *Centella asiatica* (1.14%) in the present investigation was lower than the reported value (Upadhyaya and Saikia, 2012; Ranovona et al., 2019). Similarly, *Crotalaria tetragona* was found to contain1.72% of total fat in this study, while 4.3% fat content from the seed was observed by Maroyi (2011) in the same species. The total fat content of *Clerodendrum bracteatum* (1.32%) was found in close proximity to the previously reported value of 1.72% (Seal, 2011).

The total carbohydrate content of selected WEVs in the present investigation ranges from 7.89mg/g DW to 75.20mg/g DW which was in agreement with the WEVs consumed by the Bodos of North-East India (Basumatary and Narzary, 2017). On the other hand, was found to be lower when compared to the WEVs of Northeast India (Seal and Chaudhuri, 2016). The carbohydrate content of *Rhynchotechum ellipticum* in the present study was also found to be lower when compared to the previous reported value (Chaudhuri et al., 2018). *Centella asiatica*, in the present investigation, showed a total carbohydrate content of 75.20mg/g which was higher than the reported value (Hashim, 2011) and in accordance with the same species reported by Odhav et al. (2007). The total carbohydrate content of *Trevesia palmata* flower bud was found to be 24.19mg/g which was in agreement with Tin (2008). Similarly, Das et al. (2013) observed a higher percentage of the carbohydrate content in *Clerodendrum bracteatum* than the present investigation.

The total protein content of WEVs in this study ranges between 5.03mg/g and 35.56mg/g, which were comparatively lower than the previously reported value of WEVs from Meghalaya, India (Seal, 2012, 2011). However, it was almost in accordance with the WEVs consumed by the Bodos of North East India (Basumatary and Narzary, 2017). Furthermore, the protein content of *Trevesia palmata* (32.15mg/g*)*, *Picria fel-terrae* (29.08mg/g), *Rhynchotechum ellipticum* (35.56mg/g) were higher when compared with the commercial leafy vegetables like cabbage (1.8%) Cauliflower (2.6), potato (1.62%), spinach (2.00%) (Gopalan et al., 2004) and was also higher than the ripe mango (0.60%) and papaya (0.50%) (Sundriyal and Sundriyal, 2004). The total protein content of *Centella asiatica* in this study was in close proximity with the previous study (Joshi and Chaturvedi, 2013) but also found lower in comparison with Das (2011) and Upadhyaya and Saikia (2012) from different localities of Assam. Similarly, the total protein content of *Trevesia palmata* in this study was also lower than the previously reported value from the fresh flower bud (Tin, 2008). The total protein content of *Clerodendrum bracteatum* in this study was also comparable with the previously reported value (Seal, 2011).

The calorific value of selected WEVs in the present investigation ranges between 20.77 to 73.93Kcal/100g which was almost similar with the reported calorific value (29.48 to 67.42kcal/100g) from the fresh sample (Narzary et al., 2015). Comparisons between the calorific value of the present investigated plants revealed that WEVs showed superiority over conventional commercial vegetables and fruits **(Table 5.5)**. Furthermore, the calorific value of *Dysoxylum excelsum* (73.93Kcal/100g) and *Picria fel-terrae* (53.3Kcal/100g) in the present investigation was found higher than those commercial fruits like an apple (58 kcal/100g) (Sundriyal and Sundriyal, 2004) and vegetables like broad beans (48Kcal/100g) (Gopalan et al., 2004). *Trevesia palmata* (40.72Kcal/100g) was also higher than Ripe papaya (32Kcal/100g), *Fagopyrum tataricum* (38.76Kcal/100g) and *Centella asiatica* (37.52Kcal/100g) also had a higher calorific value compared to some commercial vegetables like lettuce (21Kcal/100g), brinjal (24Kcal/100g), Cabbage (27 Kcal/100g), Cauliflower (30 Kcal/100g), spinach (26 Kcal/100g) (Gopalan et al., 2004; Sundriyal and Sundriyal,

2004) **(Table 5.5).** These results further indicated that WEVs provides a good calorific value and thus further be recommended for formulations of numerous nutritional supplements and can be considered as a good human diet.

**Table 5.5:** Comparison of total energy content between WEVs and conventional commercial vegetables and fruits (Gopalan et al., 2004; Sundriyal and Sundriyal, 2004).

| **WEVs** | **Energy (Kcal/100g)** | **Commercial crop** | **Energy (kcal/100g)** |
|---|---|---|---|
| *Picria fel-terrae* | 53.3 | Apple | 58 |
| *Dysoxylum excelsum* | 73.93 | Brinjal | 24 |
| *Rhynchotechum ellipticum* | 20.91 | Broad beans | 48 |
| *Aganope thyrsifolia* | 20.77 | Cabbage | 27 |
| *Centella asiatica* | 37.52 | Lettuce | 21 |
| *Fagopyrum tataricum* | 38.76 | Spinach | 26 |
| *Crotalaria tetragona* | 25.62 | Ripe papaya | 32 |
| *Trevesia palmata* | 40.72 | Ripe Mango | 74 |
| *Clerodendrum bracteatum* | 21.304 | Potato | 97 |

Mineral analysis of selected WEVs showed that all of them contain a rich source of mineral elements. The amount of mineral content by different plants was significantly different ($p<0.05$) which could be due to difference in soil condition, temperature, and plant nutrition (Hamurcu et al., 2010). Calcium content in this study was similar with the previously reported value (Seal et al., 2013; Hussain et al., 2011). Similar result was observed in *Rhynchotechum ellipticum* for calcium content which was in agreement with the earlier study (Chaudhuri et al., 2018). However, calcium content of *Centella asiatica* in the present study was found to be 271mg/100g, which was much higher than 174 mg/100g reported earlier in the same species (Joshi and Chaturvedy, 2013) but found to be lower than the reported value of Odhav et al. (2007) from South Africa. Calcium content of *Clerodendrum* *bracteatum* in the present study was higher than the similar studies reported by Devi et al. (2014) and lower than the value reported by Seal (2011) in the same species. This study indicated the potential aspects of WEVs that were considered as a good source of calcium for the human diet besides their role in blood coagulation and normal functioning of cardiac muscles (Sundriyal and Sundriyal, 2004).

Some elements such as sodium concentration in WEVs were found higher than cultivated vegetables (Gopalan et al., 2004) suggesting that they are a good source of sodium as compared to several cultivated crops. The reported concentration of sodium, magnesium, and potassium (Datta et al., 2019) was found to be lower when compared with the present study. The previous study reported magnesium, sodium, and potassium content of *Rhynchotechum ellipticum* with 1.32mg/g,0.48 mg/g, and 20.66mg/g respectively (Chaudhuri et al., 2018) which were also lower than the present findings. Similar is the case in *Centella asiatica*, *Clerodendrum bracteatum* when compared with the previous work (Joshi and Chaturvedi, 2013; Seal, 2011), but found lower in *Fagopyrum tataricum* than earlier work by Mann et al. (2012) in the seed grains. These variations in the mineral content among the same species could also depend on the analytical method, biotic, and abiotic factors (Joshi and Chaturvedi, 2013). This further indicated that WEVs understudy supplies substantially in the diet in terms of mineral necessity.

The manganese concentration in the present study ranged between 2mg/100g to 124mg/100g which was also comparable with the WEVs of Meghalaya (Seal et al., 2013), but found higher than 0.009 to 0.021 mg/g reported by Datta et al. (2019). Manganese content of *Rhynchotechum ellipticum* was found to be higher than a similar studied reported value (0.057mg/g) by Chaudhuri et al. (2018). Similarly in *Centella asiatica* (92.0mg/100g) of the present finding was higher than the value (23mg/100g) reported by Odhav et al. (2007). 0.191mg/g of manganese was reported from the leaves of *Clerodendrum bracteatum* (Seal, 2011) which was also in accordance with the present study value.

Iron plays a significant role in the binding of oxygen to haemoglobin besides their role as a catalyst for many enzymes such as cytochrome oxidase (Geissler and Powers, 2005). A high concentration of Iron was found in the present investigation that ranged from 17.0mg/100g to 126.0mg/100g which was comparatively higher than most of the reported value such as 21.30mg/100g to 33.40mg/100g from Nigerian WEVs (Mohammed and Sharif, 2011), 11-85mg/100g from traditional leafy vegetables of South Africa (Odhav et al., 2007), etc. *Rhynchotechum ellipticum* alone was found to contain 126.00mg/100g of iron in the present study, which was higher than the earlier reported value of the same species (Chaudhuri et al., 2018). Odhav et al., 2007 reported the iron content of *Centella asiatica* as 18mg/100g which was also lower than the present reported value (71.0mg/100g). The iron content of *Fagopyrum tataricum* (17.0mg/100g) leaves of present finding was much higher than the iron content reported from the seed grains (15.92mg/100g) (Mann et al., 2012). A daily iron requirement for the human body was 15mg and the deficiency may cause anaemia (Sekeroglu et al., 2006). Consequently, the selected WEVs had sufficient iron content which could be recommended in the diets for reducing anaemia.

Nitrogen is the most essential nutrient for the growth of plants. In the present study, nitrogen content ranged between 2.19 % to 7.00% which was in accordance with the previous study (Mahadkar et al., 2012). However, the nitrogen content of the present study was much higher than the previous works that ranged from 0.35% to 1.70% reported from the WEVs (Turan et al., 2003) and 0.15 % in celery and 0.57% in radish (Gopalan et al., 2004).

WEVs also contain both essential and non-essential elements. Although Zinc and copper are important micro-essential elements, they are considered as heavy metals. The maximum tolerable daily intake of Zinc is 0.3-1 mg/ kg (WHO, 1982). The deficiency may cause growth failure and poor development of gonadal function (Ihedioha and Okoye, 2011). Zinc concentration in the present study ranged between 4.00mg/kg to 22mg/kg which was similar to the level reported in WEVs of Meghalaya (Seal, 2012) and lower than the level reported by Seal et al., 2013. Lead is a toxic element that could be harmful to the plants. In many plants, lead accumulation can exceed several hundred times the threshold of maximum level permissible for human consumption (Farooq et al., 2008). Copper is an essential micronutrient that functions as a biocatalyst, required for body pigmentation along with iron and interconnected with the function of zinc and iron in the body (Akinyele and Osibanjo, 1982). The heavy metals content detected of all the selected plants were comparatively lower than the previous work of Subramanian et al. (2012). Overall, the heavy metals content of all investigated plants were within the permissible level of FAO/WHO (2001) in vegetables (Adu et al., 2012), implying that all the selected plants were safe to be consumed as a local diet. In view of the ongoing research in WEVs globally, it possess high nutritional value. Based on the above findings it can be ascertained that these WEVs can be exploited as sources of minerals and nutritional compounds to be incorporated as functional ingredients of food for maintenance of overall health.

**CHAPTER VI**

# 6. Phytochemical evaluation, antioxidant and antimicrobial activities of selected WEVs

## 6.1. Introduction

Phytochemicals are the biologically active organic compounds that are naturally present in plants; differ extensively in their structure, mechanisms of action, and biological properties (Pistollato and Battino, 2017). They are generally present in all the plant cells, but leaves are the main site of their accumulation which may vary depending upon the season, climate, and particular growth phase (Mensah et al., 2008). Compounds like phenols, flavonoids, tannins, steroids, and alkaloids are the most important bioactive compounds present in plants (Jeruto et al., 2011). These compounds possess many biological properties such as antioxidants, antimicrobial, anticancer, and many other activities (Gul et al., 2003). Moreover, plants used them as defense systems against a wide range of diseases and help them undergo stress conditions (Dipak et al., 2010). Certain secondary metabolites such as triterpenoids are derivatives of terpenoids that function in transcription and growth factor regulations, further involved in intracellular signaling pathways in cancer cell proliferation and apoptosis (Patlolla and Rao, 2012). Furthermore, alkaloids are used as analgesic and antihypertensive agents (Arnold, 1989), while saponin is used traditionally as medicinal preparations (Asl and Hosseinzadeh, 2008). Tannins are water-soluble polyphenol having anti-carcinogenic and antimutagenic potentials and protect the cell against oxidative damage (Chung et al., 1998). Fruits and vegetables contain reducing sugars which work as reducing agents, stabilizing the oxidation reactions (Liu, 2011).

For the past few years, phenolic and flavonoid rich natural diets with antioxidant capacity have promoted interest in nutrition and food sciences (Lee et al., 2002). Polyphenols are the group of plant secondary metabolites characterized into simple phenol, phenolic acid, flavonoid, tannin, and lignin responsible for bitterness, colour, flavour, odour and numerous biological activities like antioxidant (Kartika et al., 2007). Among the polyphenols, phenolic acid has numerous health benefits against various diseases such as chronic diseases, stroke, and cancer (Hollman and Katan, 1999). The antioxidant activity of phenolic compounds is attributed to their strong chain-breaking and free radical scavenging activity, thereby protecting reactive oxygen species (ROS) (Podsędek, 2007). Flavonoids are the smaller part of phenolic compounds containing many derivatives such as flavones, flavanol, isoflavone, flavanone, and chalcone which also inhibit lipid peroxidation either by scavenging free radicals or by quenching of singlet oxygen and chelating of metal ions (Yanishlieva-Maslarova, 2001). Flavonoids are characterized by the presence of a flavan nucleus. The flavan nucleus is synthesized by the plant tissues for protecting the plants against UV radiation, pathogens, and herbivores (Hakkinen et al., 1999).

Many of the indigenous WEVs are potential sources of natural antioxidant compounds like phenolic, flavonoid, tannin and other metabolites (Matkowski, 2006; Uusiku et al., 2010), thereby providing a fruitful protective against oxidative stress from oxidizing agents and free radicals (Kaur and Kapoor, 2002). Many epidemiological studies highlighted the consumption of leafy wild vegetables containing phenolic and flavonoid compounds with antioxidant potential is linked with a lower chance of getting cardiovascular diseases, cancer, diabetes, and neurodegenerative diseases (Adebooye et al., 2008). WEVs play an important role among various ethnic groups since ancient times not only as vegetables but also as medicine. Thus, more intakes of these WEVs can play a significant role in chemoprevention of diseases and pathophysiology in ROS (Odukoya et al., 2005). Elucidation of antioxidant activity of important WEVs is essential to obtain readily available and inexpensive antioxidants for the prevention of various diseases arising from oxidative stress (Sarikurkcu et al., 2009).

In recent years, the search for dietary supplements and drugs derived from plants has been tremendously increasing. In the past few decades, with the emergence of a clinical microbial strain that is resistant to one or several antibiotics, the demand for natural antimicrobial agents has increased (Fehri et al., 2007). Today's microbial infections, resistance to antibiotic drugs, are responsible for the death of millions of people worldwide (Gupta et al., 2019). This antibiotic resistance has caused the existing antibiotic drugs to be ineffective or less effective (Baym et al., 2016). Moreover, the usages of antibiotic drugs are reported to have some undesirable side effects; causing allergy and immunosuppression (Al- Ahmad et al., 2014). Due to these side effects, plants with antimicrobial properties are needed to treat infectious diseases with little or no side effects. To overcome the scenario of antibiotic resistance, several research groups were exploiting different sources and described natural products as the leading source for active antimicrobial compounds (Bazzaz et al., 2018). The contribution of phytochemicals in this regard is crucial which can be employed directly or in combination with antibiotics (Shakeri et al., 2018). The wild plant provides a source of natural antimicrobial agents, which are mainly due to the presence of compounds synthesized in secondary metabolism of the plant (Prusti et al., 2008) which inhibit the growth of human pathogens.

## 6.2. Methodology

### 6.2.1. Plant material

Fresh plant materials (as mentioned in Chapter 5) were collected from different locations of the study sites. It was air-dried at room temperature, pulverized, and was stored in an airtight container. It was kept in the refrigerator until further use.

### 6.2.2. Extraction of plant material

Plant materials were extracted following Harborne (1998). 50g-100g of powdered plant sample was extracted using petroleum ether (40°C-60°C) and methanol (60°C-80°C) in Soxhlet apparatus until the solution becomes colourless. The extracted plant materials were concentrated at room temperature. The yield percentages of the extracts were calculated using the formula given below and antioxidant properties were analyzed (Kuluvar et al., 2009).

$$\text{Yield percentage (\%)} = \frac{Sample\ extract\ (g)}{Weight\ of\ dry\ powder\ sample\ (g)}\ x\ 100$$

### 6.2.3. Preliminary Phytochemical group testing

Preliminary phytochemical screening of methanol and petroleum ether extract of selected plants was performed following Harborne (1998). The extracts were dissolved in DMSO and filtered with Whatman filter paper number 1.

**Table 6.1:** List of compounds used for phytochemical screening, test used and indications.

| Compounds | Test used | Indications |
|---|---|---|
| *Alkaloids* | **Mayer's test:** 2ml of extract were taken with 2N HCl and then added one or more drops of Mayer's reagent. | Formation of white ppt or turbidity. |
| *Phenols* | **Ferric chloride test:** 10mg extract was treated with few drops of ferric chloride solution. | Formation of bluish color. |
| *Saponin* | **Foam test:** 2ml of test solution was added to water and shaken vigorously and stand for 15 minutes. | Formation of foamy leather. |
| *Flavonoid* | **$H_2SO_4$ test:** Extract was treated with few drops of sulphuric acid. | Formation of orange color. |
| *Tannins* | **Ferric chloride test:** 2ml of extract was mixed with $H_20$ and heated on a water bath. The mixture was filtered and few drops of ferric chloride wad added | Formation of dark green colour. |
| *Carbohydrates* | **Fehling's test:** 2ml of test solution was mixed with Fehling solution A and B and heated. | Formation of Brick red ppt. |
| *Terpenoid* | **Salkowski test:** 5mg of extract was mixed with 2ml of chloroform and 3ml of sulphuric acid. | Formation of reddish-brown colour layer in inner surface. |
| *Protein* | **Biuret test:** 0.5mg of extract was treated with 1ml of 40% NaOH and two drops of 1% $CuSO_4$. | Formation of violet color. |
| *Fats and oils* | **Spot test:** The test solution was applied between filter paper and pressed. | Oil staining or transparent appearance on the filter paper. |

### 6.2.4. Evaluation of antioxidant activity of selected WEVs

#### 6.2.4.1. Total phenolic content determination

The amount of total phenolic content was determined by Folin ciocalteau method (Kujala et al., 2000) with few modifications. Briefly, a stock solution of methanolic extract (1mg/ml) was prepared. Gallic acid standard solution (100µg/ml) was also prepared by adding 10mg of gallic acid to 100ml of water. From this stock solution, different concentration (50µg/ml-500µg/ml) of Gallic acid was prepared. 100 µl of plant extract (20µg/ml) was mixed with 900µl $H_20$ and 500 µl of 50% Folin ciocalteu (1N). After 5 minutes of incubation, 1.5ml 0f 7% $Na_2CO_3$ was added and the final volume was made up to 10ml with Millipore water. Optical density was taken at 760 nm after 2 hours of incubation time. The same procedure was also followed for standard curve preparation. The total phenolic content was determined from the standard curve and the results were expressed as mg Gallic acid equivalents/gram (mg GAE/g) of dry weight.

#### 6.2.4.2. Total flavonoid content determination

Total flavonoid content was determined by aluminium chloride method (Chang et al., 2002). Different concentration of Quercetin (10µg/ml -100µg/ml) was prepared from the stock solution (1mg/ml). Likewise, methanol plant extract (1mg/ml) was also prepared. 500µl of plant extract solution was mixed with 1.5ml methanol, 0.1ml aluminium chloride, 0.1 ml potassium acetate and final volume was made to 5ml and incubated at room temperature for 30 minutes. OD was taken at 415nm using UV-VIS spectrophotometer. Blank was prepared exactly same as the above without plant extract. Therefore, total flavonoid content was determined from the standard curve of Quercetin and the results were expressed as mg of Quercetin equivalent/gram (mg QE/g) of dry weight.

#### 6.2.4.3. Determination of DPPH free radical scavenging activity

DPPH (2,2'-diphenyl-2-picrylhydrazyl) free radical scavenging activity of methanolic extract was determined by Braca et al 2001 with some modifications. Briefly, from the stock solution (1mg/ml), different concentrations of methanolic plant extract (20 µg/ ml - 200µg/ ml) were prepared. 1ml of plant extract was mixed with 2ml of DPPH solution (0.004%W/V) and incubated in the dark at room temperature for 60 minutes and optical density was taken at 517nm. 1ml of methanol and 2ml of DPPH was mixed and used as a negative control. Ascorbic acid was used as a positive control. The percentage of scavenging activity of sample to DPPH free radical was evaluated based on the following equation given below:

$$\text{DPPH scavenging activity (\%)} = \frac{Control\ OD - Sample\ OD}{Control\ OD}\ x\ 100$$

### 6.2.4.5. Determination of ABTS free radical scavenging activity

The 2,2'-azinobis, 3-ethylbenzothiazoline-6- sulfonic acid (ABTS) radical scavenging activity was determined by the method of Seal et al., (2017a). Briefly, ABTS solution (7mM) was prepared using distilled water and ABTS radical was developed by adding 2.45mM potassium persulfate solution. The mixture was incubated in the dark room for 14 hours to complete the reaction. From this stock solution, working standard was prepared; 1ml of ABTS radical was taken out and diluted with 60% methanol to adjust the absorbance of 0.699±0.01 at 734nm. Methanol was added until the absorbance reaches 0.699. Different concentration of plant extract (20µg/ml - 200µg/ml) was prepared from 1mg/ml stock solution, and the volume was made up to 100µl by diluting it with methanol. 100µl of extract solution was mixed with 100µl of ABTS radical in the 96 well plate and OD was taken at 734nm in the plate reader spectrophotometer against methanol as blank after 3 minutes of the initial mixing. Ascorbic acid (20 µg/ ml - 200µg/ ml) was used as a positive control to compare the analysed data. The percentage of radical scavenging activity was calculated as equation below

$$\text{ABTS scavenging capacity (\%)} = \frac{Control\ OD - Sample\ OD}{Control\ OD}\ x\ 100$$

The inhibition curved was plotted and were expressed as mean % ± standard deviation.

### 6.2.4.6. Screening for Antimicrobial Activity

Antimicrobial screening of methanolic plant extract were performed against four bacterial strains [Gram positive bacteria: (*Staphylococcus aureus* MTCC-96, and *Micrococcus luteus* NCIM-2170); Gram negative bacteria: (*Pseudomonas aeruginosa* MTCC-2453 and *Escherichia coli* MTCC-739).The pathogens were obtained from Microbial Type Culture Collection (MTCC), Chandigarh, and

National Collection of Industrial Microorganisms (NCIM), Pune, India. Crude methanolic extracts of the selected plants were diluted in different concentrations using 10% DMSO and used for antimicrobial activity following agar well diffusion method (Saadoun and Muhana, 2008). The test pathogenic bacteria were spread on nutrient agar plate and wells were prepared by using sterile cork borer of 6 mm diameter. In each of the plates, 50 µl clear supernatant of plant extract were dispensed into individual wells and the plates were incubated at $37^0$ C for 24 h. The anti-microbial activities were observed by measuring the inhibition zone around each well.

#### 6.2.4.7. Statistical analyses

The results were expressed in means of triplicate (Mean ± SD) and analyzed by one-way analysis of variance (ANOVA) followed by Duncan's multiple range tests for comparison of statistical significance ($P$<0.05). $IC_{50}$ was calculated using Graph Pad prism software (version 6.04; Graph Pad Software, Inc., La Jolla, CA, USA). Pearson correlation coefficients were calculated in order to measure the linear correlation between variables. All statistical calculations were performed using PASW statistical software version 18.

## 6.3. Results

### 6.3.1. Yield percentage and physical appearance of selected plants extract

The yield percentages and physical appearance of the two extracts showed a wide range of results with different colour and consistency **(Table 6.2).** The yield percentage (%) of the methanolic extract of all selected species was higher than petroleum ether extract. Among the methanolic extract, *Picria fel-terrae* exhibited the highest yield percentage (36.85%) with an appearance of dark brown colour, sticky and semi-solid in consistency, followed by *Centella asiatica* (27.86%) with an appearance of dark brown colour and semi-solid inconsistency. The lowest yield percentage (5.87%) was found in *Crotalaria tetragona.* The results of petroleum ether extract indicated that *Centella asiatica* was found to contain the highest yield percentage (15.12%) with an appearance of light yellow and solid in consistency, followed by *Aganope thyrsifolia* (11.25%) with sticky semi-solid having a light green appearance and lowest yield percentage was observed in *Crotalaria* *tetragona* (2.13%) with an appearance of yellow and solid in consistency **(Table 6.2)**.

**Table 6.2:** Yield percentage and physical appearance of selected plants extract.

| Sample | Parts extract | Sample wt (g) | Solvent used | Yield (%w/w) | Consistency | Appearance |
|---|---|---|---|---|---|---|
| *P. fel-terrae* | Leaves | 100 | Pet. ether (625ml) | 10.65% | Semi solid | Light brown |
| | | | Methanol (625ml) | 36.85% | Sticky semi solid | Dark brown |
| *D. excelsum* | Leaves | 100 | Pet. ether (625ml) | 6% | Semi solid | Light green |
| | | | Methanol (625ml) | 13% | Semi solid | Dark brown |
| *R. ellipticum* | Leaves | 64 | Pet. ether (400ml) | 8.3% | Semi solid | Light yellow |
| | | | Methanol (400ml) | 13.66% | Sticky Semi solid | Dark brown |
| *A. thyrsifolia* | Leaves | 100 | Pet. ether (625ml) | 11.25% | Sticky Semi solid | Light green |
| | | | Methanol (625ml) | 19.51% | Sticky Semi solid | Dark brown |
| *C. asiatica* | Whole plants | 100 | Pet. ether (625ml) | 15.12% | Solid | Light yellow |
| | | | Methanol (625ml) | 27.86% | Semi solid | Dark brown |
| *F. tataricum* | Leaves | 50 | Pet. ether (350ml) | 4.24% | Semi solid | Light green |
| | | | Methanol (350ml) | 10.76% | Semi solid | Dark green |
| *C. tetragona* | Flower | 100 | Pet. ether (625ml) | 2.13% | Solid | Yellow |
| | | | Methanol (625ml) | 5.87% | Solid | Light brown |
| *T. palmata* | Flower bud | 100 | Pet. ether (625ml) | 7.42% | Solid | Light brown |
| | | | Methanol (625ml) | 16.02% | Solid | Dark brown |
| *C.bracteatum* | Leaves | 100 | Pet. ether (625ml) | 9.78% | Semi solid | Light green |
| | | | Methanol (625ml) | 13.47% | Sticky semi solid | Dark green |

### 6.3.2. Qualitative phytochemical group testing of WEVs

The results of the qualitative phytochemical analysis revealed that methanol extract showed the presence of at least one phytoconstituents. Following these, methanol extract of different species shows the presence of alkaloid, flavonoid, carbohydrate, protein, phenol, oil, and fats. Terpenoid was positive for 6 plant extracts. Saponin was present in three extracts such as *Rhynchotechum ellipticum*, Fagopyrum *tataricum*, and *Trevesia palmata*. Tannin was presents in three extracts such as *Picria fel-terrae*, *Dysoxylum excelsum* and *Rhynchotechum ellipticum.* On the contrary, petroleum ether extract of selected WEVs specified that tannin was absent in all the tested samples while oil and fats were present in all the extracts. Alkaloid was positive for four extracts, flavonoid, phenol, and protein were present in four species each extract. Carbohydrate was positive in five plant extracts **(Table 6.3)**. From the above results, methanol extract gave better results for preliminary phytochemical screening. Therefore, methanol extract was chosen for further analysis such as antioxidant and antimicrobial activities of selected WEVs.

**Table 6.3:** Qualitative phytochemical group testing of wild edible vegetables

| **Plant Name** | **Solvents** | **Phytoconstituents** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Alk** | **Fla** | **Tan** | **Sap** | **Ter** | **Car** | **Pro** | **Phe** | **O & f** |
| *P. fel-terrae* | Pet. ether | + | + | - | - | + | + | - | + | + |
| | Methanol | + | + | + | - | + | + | + | + | + |
| *D. excelsum* | Pet. ether | + | - | - | + | - | - | + | - | + |
| | Methanol | + | + | + | - | - | + | + | + | + |
| *R. ellipticum* | Pet. ether | + | + | - | + | + | - | + | + | + |
| | Methanol | + | + | + | + | + | + | + | + | + |
| *A. thyrsifolia* | Pet. ether | - | - | - | - | + | + | - | - | + |
| | Methanol | + | + | - | - | + | + | + | + | + |
| *C. asiatica* | Pet. ether | - | + | - | - | - | - | - | + | + |
| | Methanol | + | + | - | - | - | + | + | + | + |
| *F. tataricum* | Pet. ether | - | - | - | - | - | + | - | - | + |
| | Methanol | + | + | - | + | - | + | + | + | + |
| *C. tetragona* | Pet. ether | - | - | - | - | + | + | - | - | + |
| | Methanol | + | + | - | - | + | + | + | + | + |
| *T. palmata* | Pet. ether | - | - | - | - | + | + | + | - | + |
| | Methanol | + | + | - | + | + | + | + | + | + |
| *C.bracteatum* | Pet. ether | + | + | - | - | + | - | + | + | + |
| | Methanol | + | + | - | - | + | + | + | + | + |

Alk-Alkaloids, Fla-Flavonoid, Tan-Tannin, Sap-Saponin, Ter-Terpenoid, Car-Carbohydrate, Pro-Protein, Phe-Phenol, O&f- Oil and fats, -absent, + present

### 6.3.3. Determination of antioxidant activity of selected WEVs

#### 6.3.3.1. Total flavonoid content

The total flavonoid content of selected plants was determined from the standard curve of quercetin with a linear regression curve (Y=0.010x+0.036, $R^2$=0.0998) **(Figure 6.1),** and the results was expressed as mg quercetin equivalent QE/g dry extract. Total flavonoid content was determined to be highest in the extract of *Fagopyrum tataricum* (73.40mg QE/g), followed by *Trevesia palmata* (34.49mg QE/g), *Dysoxylum excelsum* (27.00mg QE/g), *Picria fel-terrae* (23.69mg QE/g), *Crotalaria tetragona* (23.37 mg QE/g), *Clerodendrum bracteatum* (21.59mg QE/g), *Rhynchotechum ellipticum* (19.74mg QE/g), *Aganope thyrsifolia* (15.98mg QE /g) and the lowest content was observed in *Centella asiatica* (13.42mg QE/g) **(Table 6.4)**.

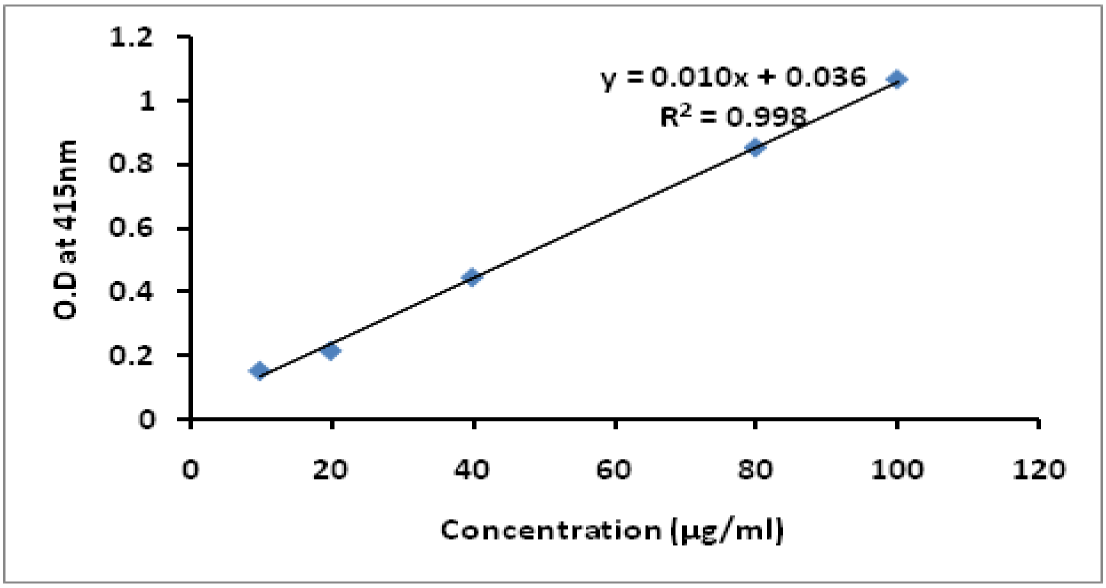



**Figure 6.1:** Standard curve of quercetin.

#### 6.3.3.2. Total phenol content

The total phenol content of methanolic extract of different samples were determined from the linear regression curve of standard Gallic acid (Y=0.001x+0.064, $R^2$= 0.999) (**Figure 6.2)** and was expressed as mg Gallic acid equivalents/g dry extract. The results further demonstrated that the maximum content of phenol was observed in *Picria fel-terrae* (97.61mg GAE /g) followed by *Fagopyrum tataricum* (50.54mg GAE/g), *Rhynchotechum ellipticum* (48.52mg GAE/g), *Centella asiatica*

(38.21±1.01 mg GAE/g), *Dysoxylum excelsum* (28.34mg GAE/g), *Aganope thyrsifolia* (24.31mg GAE/g), *Clerodendrum bracteatum* (20.95mg GAE/g), *Crotalaria tetragona* (18.71mg GAE /g). *Trevesia palmata* had the lowest phenol content (6.82mg GAE /g) **(Table 6.4)**.

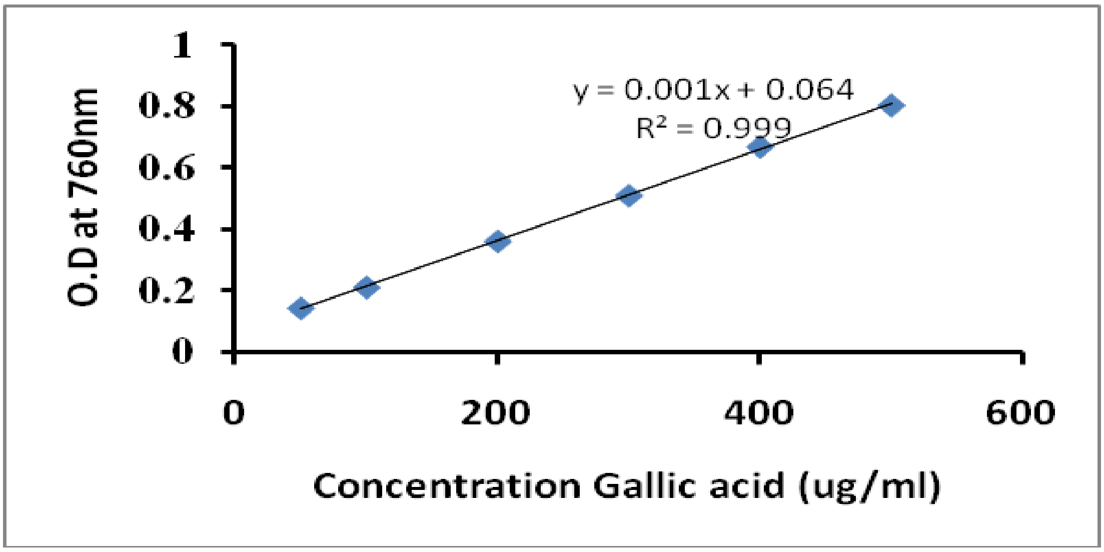



**Figure 6.2:** Standard curve of Gallic acid.

**Table 6.4:** Evaluation of antioxidant compound: total flavonoid and total phenol content of selected WEVs.

| **Plant Species** | **Total flavonoid (mg QE/g ± SD)** | **Total phenol (mg GAE/g ± SD)** |
|---|---|---|
| *Picria fel-terrae* | 23.69 ± 3.5$^{d}$ | 97.61± 1.27$^{a}$ |
| *Dysoxylum excelsum* | 27.00 ± 1.1$^{c}$ | 28.34 ± 0.34$^{d}$ |
| *Rhynchotechum ellipticum* | 19.74±0.60$^{e}$ | 48.52 ± 1.07$^{b}$ |
| *Aganope thyrsifolia* | 15.98 ± 1.96$^{f}$ | 24.31 ± 0.42$^{e}$ |
| *Centella asiatica* | 13.42 ± 0.42$^{f}$ | 38.21± 1.01$^{c}$ |
| *Fagopyrum tataricum* | 73.40 ± 2.71$^{a}$ | 50.54± 1.76$^{b}$ |
| *Crotalaria tetragona* | 23.37 ± 0.28$^{d}$ | 18.71± 0.82$^{g}$ |
| *Trevesia palmata* | 34.49 ± 0.79$^{b}$ | 6.82 ± 1.42$^{h}$ |
| *Clerodendrum bracteatum* | 21.59 ± 0.29$^{de}$ | 20.95 ± 1.75$^{f}$ |

*Means followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) (P<0.05). Means followed by same letter are not significantly different. Each value was represented as means ± SD (n=3)*

### 6.3.3.3. Determination of DPPH free radical scavenging activity

The DPPH radical scavenging activity of methanol extract of nine samples was found to be a concentration-dependent indicating that with an increase in concentration, the percentage of scavenging activity was also increasing **(Figure 6.3).** DPPH assays also exhibited a significant $IC_{50}$ variation between the plant's extract ($p<0.05$). Among the 9 plants extract, *Picria fel-terrae* extract exhibited a strong antioxidant potential with a lowest $IC_{50}$ value of 51.75µg/ml **(Table 6.5),** the percentage of scavenging activity reached 90.4% at a concentration of 180µg/ml and 200µg/ml respectively **(Figure 6.3)**. The decreasing order of antioxidant activity of 9 plant extract were: *P. fel-terrae* (51.75µg/ml), *R. ellipticum* (64.54µg/ml), *F. tataricum* (151.1µg/ml), *D.excelsum* (172.6µg/ml), *A.thyrsifolia* (187.3µg/ml), *C.tetr agona* (196.5µg/ml), *C. asiatica* (279.5µg/ml), *T palmata* (345.8µg/ml), *C. bracteatum* (372µg/ml A comparison between $IC_{50}$ of a plant extract with positive control (ascorbic acid, $IC_{50}$= 9.41µg/ml) indicates weak antioxidant activity of the plant extracts **(Table 6.5).**

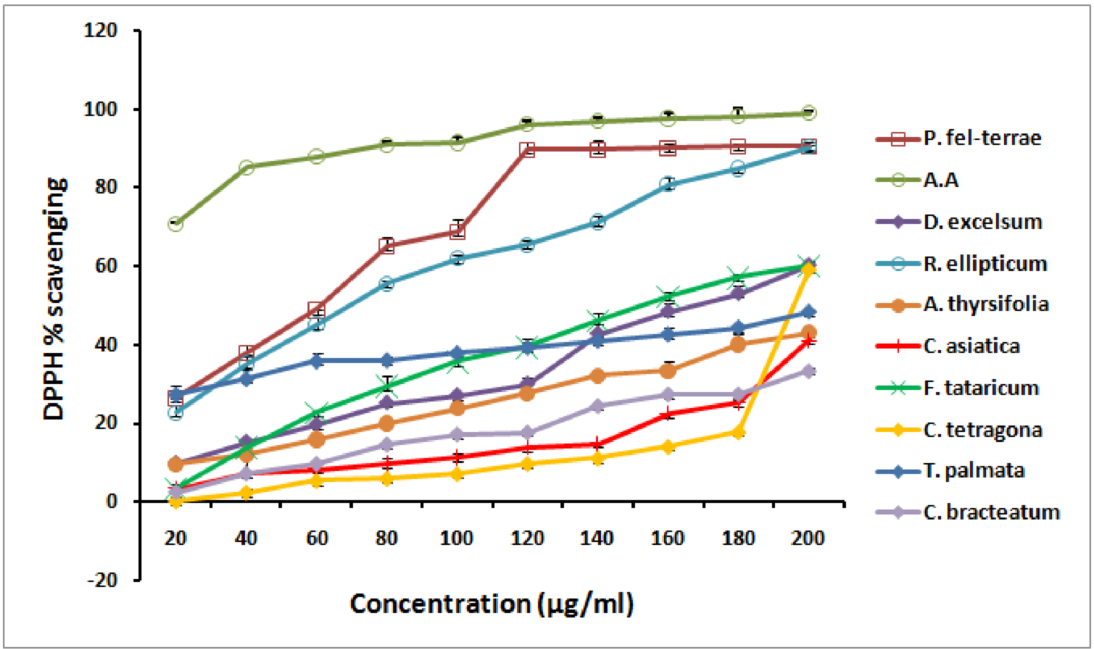



**Figure 6.3:** Comparisons between percentage of DPPH radical scavenging activity of methanolic plant extract with positive control ascorbic acid. Each value was represented as mean±SD (n=3).

### 6.3.3.4. Determination of ABTS free radical scavenging activity

The percentage of ABTS radical scavenging activity of nine plant extract was a dose-dependent manner **(Figure 6.4)**. ABTS assays also exhibited a significant $IC_{50}$ variation between the plants extract ($p<0.05$). The percentage of free radical scavenging activity was highest in *Picria fel-terrae* with a percentage of 76.68% at a concentration of 200µg/ml with an $IC_{50}$ of 75.17µg/ml whereas, the control, ascorbic acid was 90.27% with $IC_{50}$ of 36.81µg/ml **(Figure 6.4) (Table 6.5)**. The decreasing order of scavenging activity expressed as $IC_{50}$ values were: *P. fel-terrae* (75.17µg/ml), *F.tataricum* (143.1µg/ml), *D.excelsum* (146.3µg/ml), *R. elliptic um* (156.8µg/ml), *C.asiatica* (217.6µg/ml), *C.tetragona* (236.1µg/ml), *A.thyrsifolia* ( 273.7µg/ml), *T.palmata* (277.6µg/ml), *C. bracteatum* (290.8µg/ml). A comparison between plant extract and positive control (ascorbic acid) showed a strong antioxidant capacity ($IC_{50}$=36.81µg/ml) of positive control (A.A- Ascorbic acid) than the nine plants' methanol extract **(Table 6.5) (Figure 6.4)**.

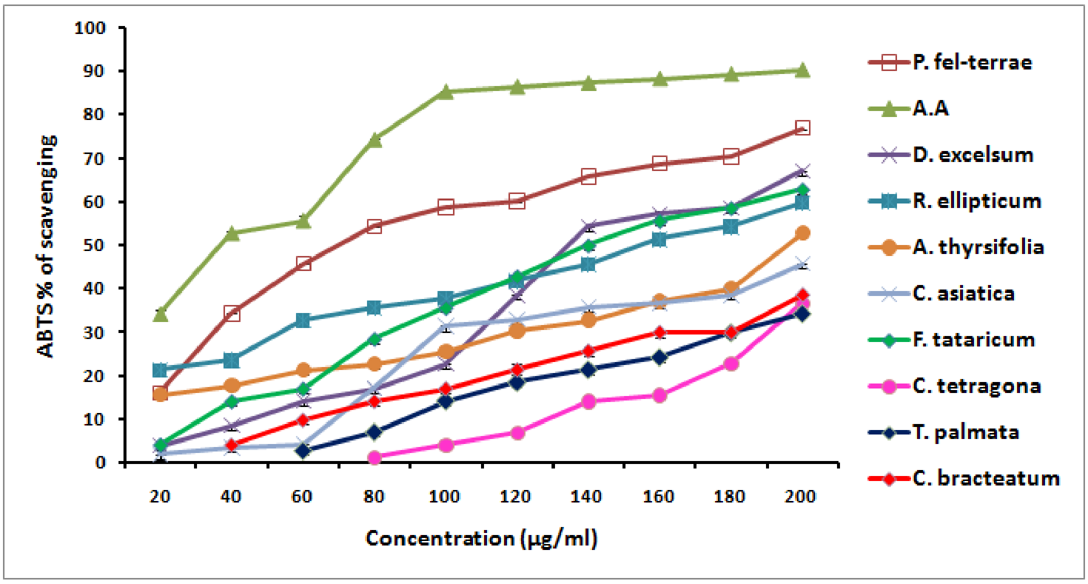



**Figure 6.4:** Comparisons between Percentage of ABTS radical scavenging activities of methanolic extract of 9 plant sample with standard ascorbic acid. Each value was represented as mean ± SD (n=3).

**Table 6.5:** $IC_{50}$ of the two antioxidant activity assays of nine plants extract.

| **Plant Name** | **DPPH** $IC_{50} \pm SD$**(μg/ml)** | **ABTS** $IC_{50} \pm SD$ **(μg/ml)** |
|---|---|---|
| *Picria fel-terrae* | $51.75 \pm 1.08^{h}$ | $75.17 \pm 4.28^{g}$ |
| *Dysoxylum excelsum* | $172.6 \pm 2.1^{e}$ | $146.3 \pm 6.85^{f}$ |
| *Rhynchotechum ellipticum* | $64.54 \pm 0.54^{g}$ | $156.8 \pm 3.4^{e}$ |
| *Aganope thyrsifolia* | $187.3 \pm 3.9^{d}$ | $273.7 \pm 5.4^{b}$ |
| *Centella asiatica* | $279.5 \pm 6.42^{c}$ | $217.6 \pm 9.2^{d}$ |
| *Fagopyrum tataricum* | $151.1 \pm 1.6^{f}$ | $143.1 \pm 5.65^{f}$ |
| *Crotalaria tetragona* | $196.5 \pm 7^{d}$ | $236.1 \pm 4.87^{c}$ |
| *Trevesia palmata* | $345.8 \pm 6.8^{b}$ | $277.6 \pm 4.04^{b}$ |
| *Clerodendrum bracteatum* | $372 \pm 2.7^{a}$ | $290.8 \pm 4.2^{a}$ |
| **Ascorbic acid (Positive control)** | $9.41 \pm 0.20^{i}$ | $36.81 \pm 2.49^{h}$ |

*Means followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) (P<0.05). Means followed by same letter are not significantly different*

### 6.3.4. Pearson's Correlation coefficient between antioxidant activity, total phenol and flavonoid content

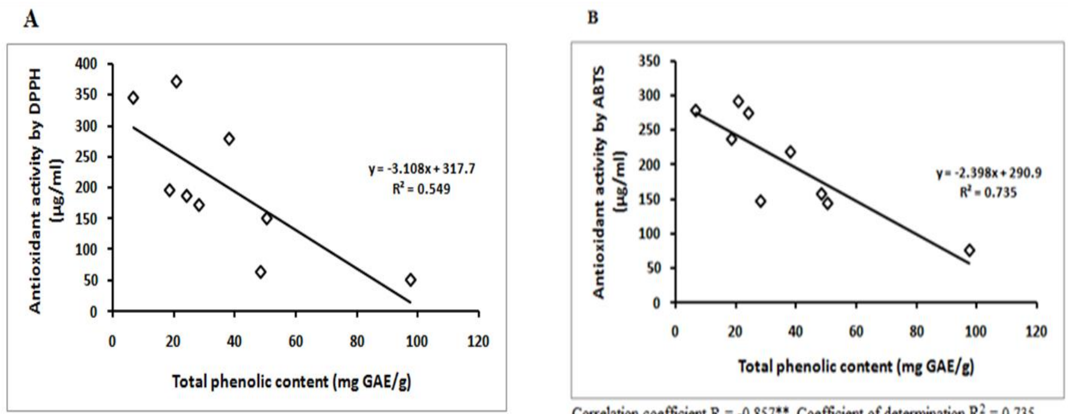
Pearson's Correlation (R and $R^2$) between antioxidant activities performed by two assays (DPPH, ABTS), total phenolic, and flavonoid content are given in **Table 6.6**. Considering the reliability of the ABTS and DPPH methods, linear regression analysis was also employed to study the antioxidant activity obtained through the two assays (Figure). The results indicated that negative and significant linear correlation (P<0.05, P<0.01) was observed between total phenolic content and antioxidant activity $IC_{50}$ (DPPH: R= -0.74*, R2= 0.549, P<0.05 and ABTS: R= -0.857**, $R^2$= 0.735, P<0.01) in both the assay **(Table 6.6) (Figure 6.5)**. These results suggested that phenol within the methanol extracts of understudy plants might be the major contributor to antioxidant activity. On the contrary, no correlation was observed between antioxidant activities $IC_{50}$ and total flavonoid content. The results further indicated that there might be some other bioactive compounds other than flavonoid which contributed to the antioxidant activity of the selected plants.

**Table 6.6:** Pearson's Correlation coefficients between antioxidant activity, total phenol and flavonoid content.

| Antioxidant assays | Total phenol | | Total flavonoid | |
|---|---|---|---|---|
| | **R value** | **P- Value** | **R value** | **P value** |
| DPPH radical scavenging activity | -0.741* | 0.02 | -0.098 | 0.803 |
| ABTS radical scavenging activity | -0.857** | 0.003 | -0.279 | 0.466 |
| Flavonoid | 0.102 | 0.795 | - | - |

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).




Correlation coefficient R= -0.741*, Coefficient of determination $R^2$ = 0.549.
*Correlation is significant at the 0.05 level (2-tailed)

Correlation coefficient R = -0.857**, Coefficient of determination $R^2$ = 0.735
** Correlation is significant at the 0.01 level (2 tailed)

**Figure 6.5:** Linear regression and correlation between total phenol content and antioxidant activity by (A) DPPH and (B) ABTS

### 6.3.5. Screening for Antimicrobial Activity

All the selected WEVs showed antibacterial activity against *E. coli* and *P. aeruginosa* **(Table 6.7)** within the inhibition diameter ranges from 8mm to 13.4mm. Very less antibacterial activity was found against *M. luteus*. Among all the selected vegetables, *Rhynchotechum ellipticum* showed the best activity against the tested bacterial pathogens inhibiting all the tested pathogens. Overall the selected plant species showed a broad spectrum of antibacterial activity which can further be taken up for further studies **(Figure 6.6)**.

**Table 6.7:** Antibacterial activity of selected wild vegetables against four bacterial pathogens

| Sample | Zone of inhibition(mm) using 10mg/ml extract | | | |
|---|---|---|---|---|
| | ***E. coli*** | ***P. aeruginosa*** | ***S. aureus*** | ***M. luteus*** |
| *Aganope thyrsifolia* | 10.00±0.1[d] | 13.00±0.5[a] | 7.00±0.3[d] | - |
| *Picria fel-terrae* | 11.00±0.4[c] | 10.00±0.3[c] | 10.00±0.2[b] | - |
| *Crotalaria tetragona* | 12.00±1[b] | 12.4±0.4[b] | 11.00±0.1[a] | - |
| *Clerodendrum bracteatum* | 12.00±0.3[b] | 13.00±0.3[a] | 11.00±1.00[a] | - |
| ***Rhynchotechum ellipticum*** | **10.00±0.4[d]** | **10.00±0.3[c]** | **8.00±0.3[c]** | **6.00±0.2** |
| *Trevesia palmate* | 8.00±0.4[e] | 8.00±0.1[d] | - | - |
| *Centella asiatica* | 10.00±0.5[d] | 10.00±0.4[c] | - | - |
| *Dysoxylum excelsum* | 13.00±0.6[a] | 12.00±0.4[b] | - | - |
| *Fagopyrum tataricum* | 13.4±0.4[a] | 8.00±0.6[d] | - | - |

*Means followed by different letters within same column are significantly different according to Duncan's multiple range comparisons (DMRTs) (P<0.05). Means followed by same letter are not significantly different.*

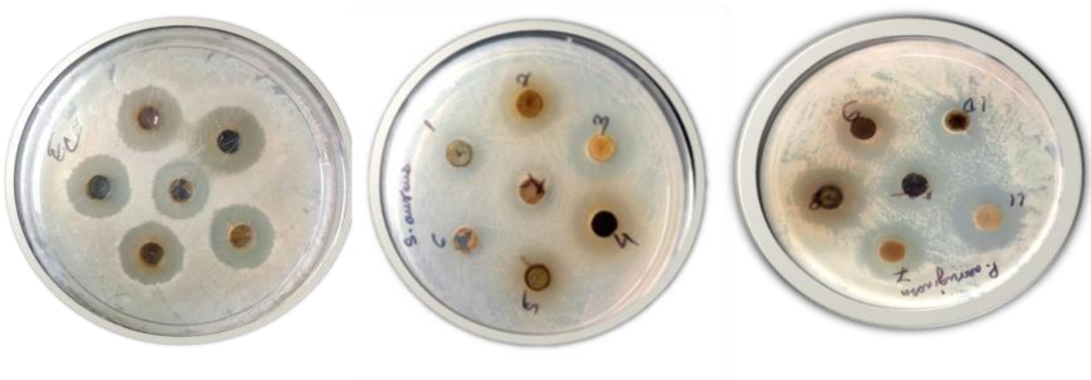


**Figure 6.6:** Antimicrobial activity of selected WEVs against bacterial pathogens

### 6.4. Discussion

Preliminary phytochemical screening represents the simplest method of detecting secondary metabolites in the plant extract. Although the specific role of all the phytochemical tested was not investigated in this study, the presence of three important plant secondary metabolites such as alkaloid, flavonoid, and phenolic compounds in the methanolic extract was a scientific validation for the long-used of understudy plants in case of medicinal purposes. The two solvent extracts of nine WEVs revealed the presence of many important plant bioactive compounds. Alkaloid, flavonoid, carbohydrate, phenol, terpenoid and fats were commonly present in both methanol and petroleum ether extracts. These results were also in accordance with the previous studies which showed the presence of phenol, alkaloid, flavonoid, and carbohydrates in both the methanol and petroleum ether extract (Gohain et al., 2014). The methanolic extract of *Dysoxylum excelsum* showed positive for alkaloid, flavonoid, tannin, carbohydrate, protein, phenol, and fats. A similar study showed the presence of alkaloid, flavonoid, saponin, terpenoid and tannin from aqueous extract of *Dysoxylum excelsum* (Larinzuali et al., 2016). *Rhynchotechum ellipticum* showed the presence of all the nine-phytochemicals tested from methanol extract and petroleum ether extract showed the presence of 7 phytochemicals. The same species showed the presence of Tannin, flavonoid, terpenoid, and alkaloid while saponin and phenol were absent (Faysal et al., 2019). The methanol extract of *Centella asiatica* also showed the presence of alkaloid, flavonoid, terpenoid, and saponin (Roy, 2018) which was also in agreement with the present study reported value. The methanol extract of *Clerodendrum bracteatum* was tested positive for alkaloid, flavonoid, terpenoid, protein, carbohydrate, phenol, and fats. Petroleum ether extract revealed the presence of alkaloid, flavonoid, terpenoid, protein, phenol, and fats. Das et al. (2013) previously reported the presence of phenol, flavonoid, carbohydrate, and alkaloid from methanolic extract of *C. bracteatum* from Northeast India. Terpenoid, flavonoid, and saponin detection was also reported from the methanol extract of *C. bracteatum* (Mahesh et al., 2015).

Alkaloid has been reported for its medicinal properties because of their analgesic, anti-spasmodic, anti-malaria, anti-dysenteric and antibacterial activity, and was also reported to be able to reduce headache associated with hypertension and capable to manage fever, cold and chronic catarrh (Gill, 1992). As mentioned earlier, the plants under study like *Picria- fel terrae, Dysoxylum excelsum, Aganope thyrsifolia, Centella asiatica, Fagopyrum tataricum and Clerodendrum bracteatum* were a common choice for the treatment of diabetes, dysentery, diarrhoea, fever, and hypertension among the ethnic group under study. This further indicated that the presence of alkaloids in all the nine plants methanolic extract was scientifically supported in the selection of these plants as an important medicinal plant used by the ethnic group of Mizoram.

Phenolic and flavonoids are an important antioxidant compound which is responsible for anti-inflammatory, antimicrobial, anti-allergic, and anti-cancer agents (Eleazu, 2012**).** In the present study, total phenolic content (TPC) of methanol extract of different sample varied significantly ($P>0.05$) from 6.82mg GAE/g to 97.61mg GAE/g which was almost similar to the finding reported by Satria et al. (2017) (92.88mg GAE/g) and much higher than the previous work reported value (17.71mg GAE/g) by Sitorus et al. (2017). Gohain et al., (2014) reported that methanol extract of *Picria fel-terrae* contained 268.61mg GAE/g of phenol. The TPC of *Dysoxylum excelsum* was determined to be 28.34mg GAE/g in the present study, which was comparatively lower than the previous work reported by Lalrinzuali et al. (2015) from the ethanol (77.61mg/g) and chloroform extract (48.87mg/g) at a concentration 2500 µg/ml. In case of *Rhynchotechum ellipticum*, TPC was found to be 48.52mg GAE/g while Chaudhuri et al. (2018) reported that phenol content is 265.93mg/100g, 29.23mg/100g, 43.97mg/100g and 91.41mg/100g in methanol, benzene, chloroform and acetone extract respectively and further reported that methanol was the best suitable solvents to extract and quantify the phenolic compound. The leave extract of *Fagopyrum tataricum* contained TPC of 50.54mg GAE/g in this study, which was lower than TPC of crushed grain (524.66mg GAE/g) reported by Mann et al. (2012). The TPC of *Centella asiatica* in the present study was in agreement with the study reported by Byakodi et al. (2018) who observed TPC of 43.7mg/g in the methanolic extract. *Trevesia palmata* was found to contain 6.82mg GAE/g of total phenolic content in this study which was lower than the previous work reported by Panyaphu et al. (2012). The TPC of *Clerodendrum bracteatum* was in accordance with the results reported by Devi et al. (2014) and lower than the value by Seal (2011). To the best of our knowledge, this is the first report of TPC from *Crotalaria tetragona* and Aganope *thyrsifolia* with a significant amount of phenolic content.

The total flavonoid content **(**TFC) in the methanolic extract of different samples varied from 73.40mg QE/g to 13.42mg QE/g dry extract. The high flavonoid content of methanol extract of *Fagopyrum tataricum* (73.4mgGAE/g) was also comparable with a previous reported value of 81.08mg RE/g Dw in early flowering and 76.40mg RE/g Dw in flowering and seed formations stage (Zielinska et al., 2012). In *Picria fel-terrae*, TFC was determined to be 23.69mg QE/g which was much higher than the previous work reported by Sitorus et al. (2017). Furthermore, TFC of *Rhynchotechum ellipticum* in this study was 19.74mg QE/g while Chaudhuri et al. (2018) reported TFC of 197.25mg/100g from the methanolic extract of the same species. TFC of *Centella asiatica* was 13.42mg QE/g, which was in agreement with the finding (13.2mg/g) reported from methanolic extract of *Centella asiatica* (Byakodi et al., 2018). *Clerodendrum bracteatum* was found to contain 21.59mg QE/g dry extract of the total flavonoid in the present study, which was in agreement with Devi et al. (2014), while, slightly lower than Das et al. (2013). Moreover, to the best of our knowledge, no literature was found for TFC of *Dysoxylum excelsum, Crotalaria tetragona, Trevesia palmata, Aganope thyrsifolia* therefore, the results were not comparable with the previous literature.

The antioxidant property was evaluated by two methods such as ABTS and DPPH since, many researchers (Shan et al., 2005; Surveswaran et al., 2007) proposed to use because of its accuracy, reliability and rapid process for assessing the antioxidant activity of different plant extract on a large scale as compared to FRAP assay (Surveswaran et al., 2007). However, Schlesier et al. (2002) and Apak et al. (2007) recommended using at least two methods for evaluating antioxidant activity. Thus, this recommendation was taken into account. The nine plant species determined in this study showed variable antioxidant properties. DPPH and ABTS radical scavenging activity results indicated that all the plant extracts were able to scavenge the free radical in a dose-response manner which was in agreement with the findings reported by Gandhiappan and Rengasamy (2012); Piluzza and Bullitta (2011) and Sagbo et al. (2017). In this study, DPPH $IC_{50}$ values of *Picria fel-terrae* were 51.75(μg/ml) and 75.17(μg/ml), which was lower than the DPPH $IC_{50}$ values of 98.74μg/ml and 166.90μg/ml reported earlier (Gohain et al., 2014; Satria et al., (2017). Similarly, *Rhynchotechum ellipticum* also showed a good DPPH $IC_{50}$ value, however, the reports of Chaudhuri et al. (2018) was comparatively lower. Similarly, is the case in *Dysoxylum excelsum,* found higher compared to the previously reported value from ethanol and chloroform extract (Lalrinzuali et al., 2016).

*Fagopyrum tataricum* in this study exhibited DPPH $IC_{50}$ values of 151.1µg/ml and ABTS IC50 values of 143.1µg/ml, which was lower than the DPPH $IC_{50}$ values of 190µg/ml, while higher than ABTS $IC_{50}$ value of 50µg/ml (Mann et al., 2012). Pittella et al. (2009) reported DPPH $IC_{50}$ value of 31.25µg/ml from *Centella asiatica* aqueous extract which was lower than the value reported in the present study. Similar is the case in *C. tetragona* (Chouhan et al., 2011), *Clerodendrum bracteatum* (Mahesh et al., 2015; Devi et al., 2014). On the contrary, DPPH $IC_{50}$ value of *Clerodendrum bracteatum* in this study was found lower than the previous work reported value (Seal, 2011). DPPH $IC_{50}$ value of *Trevesia palmata* in the present study was 345.8µg/ml which was lower than the previous reported value of 524.64µg/mL (Arifin et al., 2017). Since no literature was available for the evaluation of antioxidant activity by DPPH assay in *Aganope thyrsifolia,* and ABTS assays in *Dysoxylum excelsum, Aganope thyrsifolia, Centella asiatica, Crotalaria tetragona* and *Trevesia palmata,* therefore, no comparison can be done. Although, comparison between the free radical scavenging activity of the present study with other literature somehow exhibited different values, all the extracted samples were able to scavenge the free radical even at low concentrations. This result further showed that the strong free radical scavenging activity of *Picria fel-terrae* may be due to the presence of more antioxidant compounds than other phytochemicals which helps them to scavenge the free radical.

Pearson's correlation was employed to study the relationship between antioxidant activity and secondary metabolites content of nine WEVs. Thaipong et al. (2006) suggested that if R-value of $0.61 \leq R \leq 0.97$, it showed a high positive correlation, and if R-value of $-0.61 \leq R \leq -0.97$, it showed a high negative correlation (Fidrianny et al., 2018). The present study revealed that the antioxidant activity analyzed by two methods showed a high negative and significant correlation with the TPC ($p < 0.01$ and $p < 0.05$). This is consistent with the results of similar studies by Hesam et al. (2012) who reported a significant negative and significant linear correlation between

TPC and antioxidant activity. A high correlation between antioxidant activity and TPC was also reported by Fitriansyah et al. (2017) ($R= -0.943$, $p<0.01$) from *Sesbania sesban* leaves extract. Moreover, similar results were reported by Fidrianny et al. (2018) where negative correlation ($R= -0.744$, $P<0.05$) between antioxidant activity and TPC from various sweet potato extracts was observed. These results indicated that an increase in TPC will increase in antioxidant activities, which was stated by lower $IC_{50}$ DPPH and ABTS $IC_{50}$. It can be predicted that phenol compounds are the main contributor to antioxidant activity by the two tested assays.

Other studies showed that a positive linear correlation between antioxidant activity and TPC (Dorman et al., 2004, Djeridane et al., 2006). There was no significant relationship observed between antioxidant activity and TFC in the present study. Similar results were also observed by Fitriansyah et al. (2017) ($R= -0.396$, $p <0.291$); Yadav and Malpathak, 2016 ($R= 0.21$) in which no correlation was observed between antioxidant activity with TFC. In fact, the TFC does not incorporate all the antioxidants (Piluzza and Bullita, 2011). These results further indicated that secondary metabolites other than flavonoids are also responsible for antioxidant activity (Lagouri et al., 2010). The activity may also come from the other antioxidant secondary metabolites, such as volatile oils, carotenoids, and vitamins. Structure and the interaction between the antioxidants might also a major factor for antioxidant contributions (Javanmardi et al., 2003).

Antimicrobial activity of methanolic plant extracts exhibited strong activity against four pathogenic bacteria (*S. aureus*, *P. aeruginosa*, *M. luteus*, and *E.coli*). Five plant extracts showed activity against E.*coli*, *S.aureus*, and *P. aeruginosa* with an inhibition diameter ranging from 10.00mm to 12.00mm, 10.00mm to13.00mm, and 7.00mm to 11.00mm respectively. These findings were similarly reported by Mandal et al. (2015) and Xia et al. (2011). *Rhynchotechum eillipticum* was found to inhibit all the tested pathogens. Similar studies were reported by Azad et al. (2020) in which plant extracts inhibited two pathogens such as *S.aureus* and *E.coli*. *Clerodendrum bracteatum* inhibit three bacterial pathogens in the present study, which was in accordance with a similar study (Singh et al., 2018). *Centella asiatica* was also found to inhibit two bacterial pathogens. Similar results were also reported by Byakodi et al. (2018). *Crotalaria tetragona* showed activity against three pathogens such as, *P. aeruginosa*, *S. aureus*, and *E.coli* in the present study, which was also in accordance with the similarly reported study (Chouhan et al., 2011). All the selected plants possess significant antibacterial activities that could promote important ethnopharmacological use of these plants. Besides, the selected WEVs can be promoted for large scale cultivation for the benefit of the rural communities in terms of food and medicines.

# CHAPTER VII

## 7. Summary and conclusion

WEVs have been reported as important supplementary foods in different parts of the world, especially in the period of seasonal food shortage which served as a "buffer food" thereby reducing the chance of getting food insecurity for the local communities. Documentation is indeed very important because wild species are fast diminishing in the region due to various anthropogenic activities. The research for studying WEVs diversity and phytochemical helps in the conservation and bring economic benefits, creating identities in regional food culture. Prior to the present investigation, no comprehensive work has been carried out on studies of wild edible vegetables in Aizawl district, Mizoram. Accordingly, the present study entitled "**Diversity and Phytochemical Study of Some Wild Edible Vegetables in Aizawl District of Mizoram**" was designed to evaluate the importance of WEVs to the rural communities.

Ethnobotanical data of WEVs was collected among two ethnic groups (Hmar and Paihte) of Aizawl district, Mizoram resided in the two villages such as Phuaibuang and N.E Tlangnuam during August 2015 - August 2016. Ethnobotanical data were documented through direct field observations, semi-structured interviews, and questionnaires. The questionnaire was prepared for ethnobotanical information, market survey, and direct matrix ranking (DMR). 72 local informants from two ethnic groups (41 female and 31 male) with an age group of 25-70 were interviewed. The major group of informants was within an age range of 56-65 (14 male and 16 female). The basic criterion for the selection of these informants was knowledge of the utilization of WEVs, their nativeness, and the duration of residence in the study area. Data collection was used to determined informant consensus factor (Fic), fidelity level (Fl), direct matrix ranking (DMR). A total of 70 WEVs belonging to 36 families and 58 genera were documented from two ethnic groups. Among the species documented, Cucurbitaceae and Fabaceae represented the highest number of species. The highest number of genera was contributed by *Solanum* (4 species). Life form indicated that herbs (39%) were dominating followed by trees (21%), climbers (17%), shrubs (11%), bamboos (6%), palms, and canes (3% each).

Out of 70 species, the leafy vegetable was the most frequently plant parts consumed (39 species), followed by shoot vegetables (28 species), fruits (8), flower bud, inflorescence, whole plants, and tuber (3 species each) and flowers (1 species). Regarding the mode of consumption, 31 plants were consumed in fried formed, followed by boiled form (28 plants), combined with fermented pork (14 plants), combined with meat (9 plants), salad (7 plants), raw (6 plants), combined with other vegetables (5 plants), combined with rice and fermented soya bean (4 plants each), pickle (3 plants) and combined with dried fish (1 plant). WEVs were found to be available throughout the year in the present investigation; the majority of the WEVs investigated were harvested in April to September, mostly during the rainy season. The peak of availability was observed in August where 80% of the plant species were available for harvest.

Ethnobotanical collected through questionnaires were used to evaluate the Informant consensus factor ($F_{ic}$), fidelity level (Fl) value, and Direct matrix ranking. Informant consensus factor possesses a good tool to elaborate on the frequency of usage of food and various medicinal plants for disease categories among the study ethnic groups. The categories with highest $F_{ic}$ of food used categories was found for vegetables combined with dry fish ($F_{ic}$=1.00) having 32 user report for 1 plant species, while the least agreement among informants for food used categories was observed for plant used in fried formed ($F_{ic}$=0.39). Among the 70 species documented, 33 species of WEVs were of medicinally importance in which 8 plant species can be used to treat diabetes and dysentery. $F_{ic}$ ranges from 0.75 to 1 for disease categories with the highest being reported for convulsion, sleep inducer, and antiseptic. High $F_{ic}$ may be due to the high number of user reports for only one particular species consumed. This further indicated that information on the use of WEVs was shared among the informants of two tribal groups in the study area.

Fidelity level (Fl) was evaluated for most common ethnomedicinal plants cited by the informants in the study area based on the effectiveness to treat different diseases mentioned. The highest Fl values were obtained for *Picria fel- terrae* (100%) further indicated that this plant was the most preferred ethnomedicinal plants of the informants for the treatment of hypertension. It became obvious from the value that hypertension and diabetes were the most common diseases in the area. The plant with high Fl value may be suggested for further investigations of the bioactive compounds for its high potential value.

To know the multipurpose uses of species direct matrix ranking (DMR) was evaluated. Five informants were assigning to give value about the multipurpose use of the selected WEVs as per the following rating; 5=best, 4=very good, 3=good, 2=less, 1=least used and 0=not used. The results further indicated that *Dysoxylum excelsum rank* first (DMR=64) for multipurpose use in the present study which indicated that it was highly utilized by the inhabitant not only for its food value but also for fuel wood, construction, and medicine. The output of the DMR results showed that some of the important WEVs were at high risk due to overuse by the local people for different purposes.

A market survey was conducted in Bara bazaar, Aizawl during Jan 2016- Dec 2017 to observe and collect the market price of commonly sold WEVs. A total of 38 vendor informants were interviewed (31 women and 7 men). 47 WEVs were found to be sold in the Bara bazaar (market) in Aizawl at a great price. This indicated traditional resource usage as well as the dependency of WEVs for promoting cash income.

Traditional food recipe was also collected randomly during field surveys from 35 households (14 households from Paihte, 21 households from Hmar communities), and all the recipe which was prepared from WEVs were documented through interviews. 24 types of traditional food recipes consumed by two ethnic groups of Mizoram were documented according to their seasonal availability. The affinities of choices in food consumption were almost similar among the two ethnic groups. Vegetables and meat cooked with rice grain also known as 'Beipenek' was the common delicious food item of the study communities. To more extend several of these cuisines have been commercialized in the local restaurant and hotel.

Considering the importance of WEVs globally, floristic composition and phytosociological studies of WEVs was conducted during June-July 2016 in the two forest area such as N.E Tlangnuam forest and Phuaibuang forest. A random quadrat method of 25 each sampling plot ($10m^2$ for a tree, $5m^2$ for shrub and $1m^2$ for herb) were laid down to study the different vegetation layer. A total of 1526 individuals with 52 species and 45 genera of WEVs belonging to 28 families were encountered from the two forest areas. The total stand density of different vegetation layers [herb (27.52ha-1), shrub (4.72 ha-1), and tree (5.88 ha-1) of Phuaibuang forest were higher than N.E Tlangnuam forest area. $Log_{10}$ IVI of tree layer in Phuaibuang forest showed a comprehensible dominance of *Dysoxylum excelsum* (36.16) and the lowest IVI was recorded in *Senegalia pennata* (11.68) whereas, In N.E tlangnuam forest. IVI revealed that *Eurya acuminata* (35.33) was the most important and dominant tree species among other and lowest IVI value was recorded for *Senegalia pennata* (13.64).

The distribution pattern of the herb and shrub layer followed a random and contagious pattern in both the study area. Tree species of Phuaibuang forest followed a regular, random, and contagious pattern of distribution and the N.E Tlangnuam forest showed a random and contagious pattern of distribution.

Shannon-wiener diversity index (H') and Dominance index (1-D) of herb and shrub were higher in Phuaibuang forest than in the N.E Tlangnuam forest area. For tree species, diversity and dominance index were higher in the N.E Tlangnuam forest area. The results of the similarity index evaluated for WEVs between Phuaibuang forest and N.E Tlangnuam forest was 84.44%, which was extremely high indicating that there was similar vegetation presents in both the forest area. A total of 38 species was found to be commonly available in Phuaibuang and N.E Tlangnuam forest area.

The phenological study provides an idea about the plant reproductive success and is key bio-indicator providing temporal and spatial information about climate change. The study recorded phenophases of 14 WEVs from the different forests of Aizawl district, Mizoram Northeast India. Five healthy individuals of each species were selected to make out the timing and duration of various phenological events for three years consecutively. The study revealed that maximum plant species undergoing leaf initiation was highest during March and April for all the three years under investigations. The leaf fall was observed to occur in nine species which coincided with the dry seasons. The longest period for flower bud formation was observed in *Dyxosylum excelsum* lasting for 18 weeks in 2015. The flowering peak was observed during August 2016 (50%) and an alternative small peak in April for the three consecutive years. Comparing three years of data, the maximum seed formation was observed during December 2017 (50%). Among the species investigated, maximum seed fall was observed during February 2015, February 2017, and November 2016. Rainfall and temperature were significantly correlated ($P<0.01$) with the phenological events signifying that rainfall and temperature have an impact on phonological events.

Nine important species of WEVs were selected to evaluate the nutritional quality, phytochemical, antioxidant, and antimicrobial activity based on dependency and preferences by the local people from the study area and some selected WEVs were of medicinally important. Nutritional analysis of selected WEVs showed the presence of a good amount of nutritive value. Out of nine species selected *Rhynchotechum ellipticum* contained the highest moisture (96.85%) and protein (35.53mg/g).The highest carbohydrate was obtained in *Centella asiatica* (75.20mg/g) and highest ash content was observed in *Fagopyrum tataricum* (11.5%). Following these, total energy content was highest in *Dysoxylum excelsum* (73.93 Kcal/100g) and the least energy content was observed for *Aganope thyrsifolia* (20.77 Kcal/100g). Comparisons between the calorific value of the present investigated plants with commercial vegetables and fruits revealed that WEVs showed superiority over conventional commercial vegetables and fruits. These results further indicated that WEVs provides a good calorific value and thus further be recommended for formulations of numerous nutritional supplements and can be considered as a good human diet.

Mineral and heavy metal content of WEVs were evaluated using Atomic absorption spectroscopy (AAS), MP- AES, and CHNS analyzer and further indicated that most of the elements under study were presented in a detectable amount. The highest mean level of Iron (126.00mg/100g), Manganese (124.00mg/100g), Magnesium (484.00mg/100g), and Potassium (1844.00mg/100g) were found to be present in *Rhynchotechum ellipticum*. The highest value of Nickel (2.00mg/100g) and Sodium (1751.00mg/100g) were recorded for *Aganope thyrsifolia.* Calcium (516.00mg/100g), Nitrogen (7.00%), and Carbon (21.29%) were found to be highest in *Trevesia palmata*, *Clerodendrum bracteatum* and *Centella asiatica* respectively. Heavy metal analyzed namely Lead, Zinc and Copper of all selected WEVs were below the permissible limit of FAO/WHO safe limit (2001). These results further indicated that all the selected plants were safe to be consumed as a local diet.

Nine selected plants were air-dried and extracted using two solvents namely petroleum ether and methanol. The yield percentages of the extracts were calculated and the results indicated that it showed a wide range of yield with different colour and consistency. The yield percentage (%) of methanolic extract of all selected species was higher than petroleum ether extract. Among the methanolic extract, *Picria fel-terrae* exhibited the highest yield percentage (36.85%) with an appearance of dark brown colour, sticky and semi-solid in consistency. Whereas, *Centella asiatica* was found to contain the highest yield percentage (15.12%) in petroleum ether extract. Phytochemical screening of petroleum ether and methanol extract revealed the presence of different plant secondary metabolites which can be contributed to the various pharmacological potentialities of the plants. Methanol extract shows the presence of at least one phytoconstituents. From the above results, methanol extract gave better results for preliminary phytochemical screening. Therefore, methanol extract was chosen for further analysis such as antioxidant and antimicrobial activities of selected WEVs.

Quantitative estimation of methanolic plant extracts revealed the presence of a good amount of antioxidant compounds such as phenol and flavonoid with total flavonoid content being highest in *Fagopyrum tataricum* (73.40mg QE/g). Maximum phenol content was observed in *Picria fel-terrae* (97.61mg GAE/g) and *Trevesia palmata* had the lowest phenol content (6.82 mg GAE/g).

Different plant methanol extract also showed potent antioxidant activity with a marked scavenging effect on DPPH and ABTS activity. The DPPH and ABTS radical scavenging activity of methanol extract of nine samples were found to be a dose-dependent manner. The two assays also exhibited a significant $IC_{50}$ variation between the plants' extract ($p<0.05$). Among the nine selected plants, *Picria-fel-terrae* exhibited a strong antioxidant property showing better DPPH and ABTS radical scavenging activities, lowest $IC_{50}$ value in both the assays (DPPH $IC_{50}$= 51.75 (µg/ml), ABTS $IC_{50}$= 75.17(µg/ml).However, a comparison between DPPH and ABTS $IC_{50}$ of plant extracts with that of positive control (ascorbic acid) indicated that plant extracts showed weak antioxidant activity than the standard ascorbic acid.

Pearson's correlation was employed to study the relationship between antioxidant activity and secondary metabolites content of nine WEVs. The present study revealed that the antioxidant activity analyzed by two methods showed a high negative and significant linear correlation with the total phenolic content ($p< 0.01$ and $p<0.05$). It can be predicted that phenol compounds are the main contributor to antioxidant activity by the two tested assays. On the contrary, no correlation was observed between antioxidant activities $IC_{50}$ and total flavonoid content. These results further indicated that many other secondary metabolites are responsible for antioxidant activities other than flavonoids. The plants with higher antioxidant potential may probably be suggested for further analysis of anti-inflammatory, anti-cancer, antibacterial, and antirheumatic, etc.

Antimicrobial screening of methanolic plant extract was performed against four bacterial strains [Gram positive bacteria: (*Staphylococcus aureus* MTCC-96, and *Micrococcus luteus* NCIM-2170); Gram-negative bacteria: (*Pseudomonas aeruginosa* MTCC-2453 and *Escherichia coli* MTCC-739). All the selected WEVs showed antibacterial activity against *E. coli* and *P. aeruginosa* within the inhibition diameter ranges from 8mm to 13.4mm. Among all the selected vegetables, *Rhynchotechum ellipticum* showed the best activity against the tested bacterial pathogens inhibiting all the tested pathogens.

This work highlighted the rich diversity and phytochemical content of various species of WEVs from Aizawl district, Mizoram which provides baseline data for WEVs research in Mizoram, northeast India. The present findings indicated that the two ethnic groups share the same cultural tradition, informants have good knowledge of WEVs which was shared to a great extent among the inhabitants and also this WEVs being presently in use among major local populace as food and medicine as well. Diversity, documentation, and ethnobotanical survey of WEVs provide basic information for conservation, sustainable utilization of local WEVs, and preservation of local traditional knowledge. Taken into accounts, the diversities of traditional food products can be identified to explore its potentials in terms of commercialization. Based on the above findings it can be ascertained that these WEVs can be exploited as sources of minerals and nutritional compounds to be incorporated as functional ingredients of food for maintenance of better health. These preliminary nutritional assessments of WEVs should be essential for better food selection and consequent improvement of the nutritional status of the local diet of the various ethnic tribe of Mizoram. The knowledge of the antioxidant and nutraceutical potential of these plants will be useful in selecting plants as nutritional supplements as well in developing the antioxidant based drug. However, a further phytochemical investigation is required to isolate bioactive molecules from plants that may show a broad spectrum of pharmacological activities. This study further suggests the introduction of suitable modern techniques incorporating traditional knowledge which will provide a substantial base for the commercial exploration of WEVs for developing new food as well as for use in the pharmaceutical industry. Short term observations of phenological data could serve as important bio-indicator of future climatic variation and biodiversity changes and hence to know plants' survival and reproductive success. However, long - term study of phenology in response to environmental factors is suggested to understand their stability.

# Appendices

## Appendix 1

**Questionnaires on Ethnobotanical Data Collection of Wild Edible Vegetables**

1. Informants' detail

   Name/Hming : ............................................................

   Gender : Male ☐ / Famale ☐

   Age/ kum : ............................................................

   Community/ Hnam Hming : Hmar ☐/ Paihte ☐

2. Data on ethnobotanical importance of wild edible vegetables

   Local name of plant/ Thlai hming : ........................................................

   Habit of plant/ Nihphung : ........................................................

   Mode of consumption/ Chawhmeh a siam dan : ..........................................

   Part used as food :.........................................................

   Season of availability/ a awm hun : 1) Whole year / kumtluanin ☐

   2) From.............to................ (Month)

   Medicinal value (If any)/ Damdawi atan a hmanna : ........................................................................................................................

   Use report for other disease treatment (Natna dang a hmanna): ........................................................................................................................

I ........................................................ hereby give my full consent and willingly accepted to participate in this study and declare that the information provided by me during the course of interview was true and accurate to the best of my knowledge.

## **Questionnaires on Market survey of Wild Edible Vegetables**

1. Informants' detail

   Name/Hming : ..............................................................

   Gender : Male ☐ / Famale ☐

   Age/ kum : ..............................................................

2. Data on market value of Wild edible vegetables

   Local name of plant/ Thlai hming: ......................................................

   Place of collection/Lakna hmun : ......................................................

   Parts sold : ......................................................

   Market prize/ Zawrhna man zat : ......................................................

   Availability period/ a awm hun : 1) Whole year / kumtluanin ☐

   2) From.............to................ (Month)

I ......................................................... hereby give my full consent and willingly accepted to participate in this study and declare that the information provided by me during the course of interview was true and accurate to the best of my knowledge.

## **Questionnaires on Multipurpose use of wild edible vegetables.**

1. Informants' detail

   Name/Hming : ..............................................................

   Gender : Male ☐ / Female ☐

   Age/ kum : ..............................................................

3. Data on multipurpose plant species (DMR)

| **Plant/ Thlai hming** | **Fuel wood/ Tuahthing** | **Fodder/ Ranchaw** | **Construction/ Insakna** | **Medicine/ Damdawi** |
|---|---|---|---|---|
| *A.oleraceae* (Ansalai) | | | | |
| *A.bunius* (Tuaitit) | | | | |
| *A.indica* (Neem) | | | | |
| *B.tulda* (Rawthing) | | | | |
| *D.hamiltonii* (Phulrua) | | | | |
| *D.excelsum* (Thingthupui) | | | | |
| *E. acuminate* (Sihneh) | | | | |
| *F. tataricum* (Anbawng) | | | | |
| *M. baccifera* (Mautak) | | | | |
| *M.sylvestris* (Changel) | | | | |
| *R. ellipticum* (Tiarrep) | | | | |
| *S. americanum* (Anhling) | | | | |
| *W.budleioides* (Batling) | | | | |

* Criteria (5 = best/ Thaber; 4 = very good/ Tha lutuk; 3 = good/ pangai; 2 = less used/ Hmang tlem; 1 = least used/ Hmang manglo; 0 = no value/ Hmanglo).

I ......................................................... hereby give my full consent and willingly accepted to participate in this study and declare that the information provided by me during the course of interview was true and accurate to the best of my knowledge.

## Appendix II

## List of Publications


1. Lalmuanpuii, R., Zothanpuia., Zodinpuii, B and J. Lalbiaknunga (2020). Phenological observations of selected wild edible vegetables from tropical and subtropical forest of Mizoram, Northeast India. Springer *Vegetos* . https://doi.org/10.1007/s42535-020-00123-8

2. Lalmuanpuii,R., Laha,R.C.., Lalhriatpuia and Lalhriatpuia, P.C. (2018). Diversity assessment of Wild edible vegetables in Aizawl District, Mizoram, North East India. *International Journal of basic and applied Research.* 8(9).

3. Lalmuanpuii, R., Ralte, L., Laha, R.C (2016). Wild Edible Vegetables and Traditional Recipes among Two Ethnic Communities of Mizoram, Northeast India. *Proceedings of Mizoram Science Congress.* 47-52.

4. Lalmuanpuii, R., Zothanpuia and Laha, R.C (2017). Diversity assessment and documentation of wild edible vegetables in Darlawn forest division of Mizoram, North East India. *Proceedings of Biodiversity, Conservation and Utilization of Natural Resources with reference to North East India (BCUNRNEI).*

5. Laha, R.C, Lalhriatpuia, Lalmuanpuii, R, Ralte, L and Lalremruata, P.C (2018). Diversity and ethnobotanical study of wild edible fruits in Mizoram, North east India. *International Journal of Pharmacy and Biological Sciences.* 8(2): 132-142.

6. Laha, R.C, Lalhriatpuia, Lalmuanpuii, Ralte, L and Lalremruata, P.C (2016). Indigenous uses of antidiabetic plants by ethnic inhabitant of Mizoram, Northeast India. *Journal of medicinal plants Studies*. 4(6): 181-184.

7. Zothanpuia., Carrie W., Leo, V.V., Passari, A.K., Lalmuanpuii,R and Singh, B.P (2020). *In-vitro* Evaluation of Actinobacteria for its Potential in Bio-control of Fungal Plant Pathogens. *Science and Technology Journal.* 7:80-85.

## Appendix III

## List of Presentations

1. Presented paper on Quantitative analysis and ethnobotanical study of wild edible plants among Paihte tribe of Mizoram , North east India at *The 12$^{th}$ Annual convention of association of Biotechnology and Pharmacy (ABAP ) & International conference on Biodiversity, Environment and Human Health: Innovations and Emerging Trends (BEHIET 2018)* at Mizoram University.

2. Presented paper on Diversity assessment and documentation of wild edible vegetables in Darlawn forest division of Mizoram, North East India at *National conference on Biodiversity, Conservation and Utilization of Natural Resources with reference to Northe East India (BCUNRNEI)* (30-31 March, 2017)

3. Presented paper on Wild Edible Vegetables and Traditional Recipes among Two Ethnic Communities of Mizoram, Northeast India in *Science and technology for shaping the future of Mizoram, Mizoram Science Congress, 2016.*

4. Presented paper on Ethnobotanical survey of wild edible vegetables commercialized in Bara Bazar, Dawrpui, Aizawl, Mizoram in *the mizoram Science Congress, a national conference, held at Pachhunga University College, 2018.*

5. Presented paper on Antimicrobial Potential of Selected Wild Edible Vegetables of Mizoram, Northeast India in *the three days International Webinar organized by the Department of Biotechnology, Pachhunga University College (PUC), and Mizoram University (MZU) from 24th-26th June 2020.*

## Appendix IV

Conferences/ Seminars/ Workshops Attended

1. Participated in one week course on Research methodology for Research scholar held from 20-26 June 2016 organized by University Grants Commission (HRDC).

2. Participated in National level workshop on "Biostatistics and Bioinformatics" held during 01-07 September, 2016 organized by Department of Biotechnology, Mizoram University sponsored by Bioinformatics Infrastructure Facility, Department of Biotechnology (DBT), New Delhi.

3. Participated training on "Mushroom Production technology" organized by Department of Biotechnology, Mizoram University, India sponsored by UCAR-Directorate of Mushroom Research (ICAR-DMR), Himachal Pradesh, India from 21$^{st}$-22$^{nd}$ January, 2016.

4. Attended workshop on 'Pathways in Drug Discovery: from Forest to Drugstore' organized by DBT's Institutional Level Biotech Hub, Department of Pharmacy, RIPANS during 7-11$^{th}$ March, 2016.

5. Attended National workshop on "Statistical and computing method for life science data analysis" organized by The Biological Anthropology Unit, Indian Statistical Institute, Kolkata (05-10, March, 2018) at Department of Botany, Mizoram University.

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# ABSTRACT

# DIVERSITY AND PHYTOCHEMICAL STUDY OF SOME WILD EDIBLE VEGETABLES IN AIZAWL DISTRICT OF MIZORAM

**A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY**

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# ABSTRACT

# DIVERSITY AND PHYTOCHEMICAL STUDY OF SOME WILD EDIBLE VEGETABLES IN AIZAWL DISTRICT OF MIZORAM

**BY**

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**Department of Botany**

**Supervisor: Dr. J. Lalbiaknunga**

**Submitted**

**In partial fulfilment of the requirement of the Degree of Doctor of Philosophy in Botany of Mizoram University, Aizawl.**

## Abstract

Assessment of Wild edible vegetables (WEVs) from the ethnobotanical approach is a significant key for developing the understanding of indigenous knowledge systems. WEVs provide supplementary food, as well as promoted income generation for the rural communities, thus offering a variety of diets and contribute to household food security. It contains many essential bio-chemicals and offers potential sources of natural antioxidant compounds. As a result of this, interest has been focus on the search of exogenous antioxidants from natural sources and believed to have lesser side effects as compared to their synthetic counterparts. Due to the dramatic loss of traditional knowledge of WEVs resulted in largely ignored in land use planning and implementation and biodiversity conservation, it is necessary to document and investigate the importance of WEVs. Prior to the present investigation, no comprehensive work has been carried out on studies of wild edible vegetables in Aizawl district, Mizoram. Accordingly, the present study entitled "Diversity and Phytochemical Study of Some Wild Edible Vegetables in Aizawl District of Mizoram" was designed with the following objectives:

1. Diversity, identification and ethnic study of wild edible species.
2. Phenological study of different wild vegetables.
3. Phytochemical analysis and anti-oxidant activity of important wild edible vegetables.

Ethnobotanical data of WEVs was collected among two ethnic groups (Hmar and Paihte) of Aizawl district, Mizoram (24°25′16.04″ to 23°18′17.78″ N latitudes and 92°37′03.27″ to 93°11′45.69″ E longitudes) resided in the two villages such as Phuaibuang (23.926554 E Longitude, 93.121517 N Latitude) and N.E Tlangnuam (23.926553E Longitude, 94.121516 N Latitude) during August 2015 - August 2016. Ethnobotanical information was documented from 72 local informants from two ethnic groups with an age group of 25-70 through semi-structured interviews and questionnaires besides direct field observations. The entire collected specimens were pressed in the herbarium sheet and authenticated at BSI Shillong. Voucher specimens were deposited in the Department of Botany, Mizoram University. A total of 70 WEVs belonging to 36 families and 58 genera [herbs (39%), trees (21%), climbers

(17%), shrubs (11%), bamboos (6%), palms and canes (3% each)] were documented from two ethnic groups. The highest number of genera was contributed by *Solanum* (4 species). Among the species documented, Cucurbitaceae and Fabaceae represented the highest number of species. Leafy vegetables were documented as the most frequently consumed parts, out of 70 species documented; fried form represented the most common mode of consumption of WEVs. The majority of the WEVs investigated were harvested in April to September, mostly during the rainy season and the peak season of availability was observed in August in which 80% of the plant species were available for harvest.

Informant's consensus factor (Fic) was evaluated to understand the level of agreement among informants of the two tribal communities. The categories with highest Fic were found in combination with dry fish (1.00) having 32 user report for 1 plant species, while the least agreement among informants for food used categories was observed for plant used in fried formed (0.39). Among the 70 species documented, 33 species of WEVs were of medicinally importance in which 8 plant species can be used to treat diabetes and dysentery. Fic ranges from 0.75 to 1 for disease categories with the highest being reported for convulsion, sleep inducer, and antiseptic. The highest fidelity level values were obtained for *Picria fel-terrae* (100%) implying that it was the most preferred ethnomedicinal plant of the informants for the treatment of hypertension. The results of direct matrix ranking (DMR) further indicated that *Dysoxylum excelsum* was highly utilized by the inhabitant for multipurpose and ranked first (DMR=64) and the lowest rank was observed for *Rhynchotechum ellipticum* (30).

A market survey was conducted in Bara bazaar, Aizawl during Jan 2016- Dec 2017 to observe and collect the market price of commonly sold WEVs. A total of 38 vendor informants were interviewed (31 women and 7 men). 47 WEVs were found to be sold in the Bara bazaar (market) in Aizawl with great prices promoting income generation for the local people.

Traditional food recipe was also collected randomly during field surveys from 35 households (14 households from Paihte, 21 households from Hmar communities), and all the recipe which was prepared from WEVs were documented through interviews. 24 types of traditional food recipes consumed by two ethnic groups of

Mizoram were documented according to their seasonal availability. The affinities of choices in food consumption were almost similar among the two ethnic groups. Some of the recipes had a complex method of preparation, to more extend several of these cuisines have been commercialized in the local restaurant and hotel.

Floristic composition and phytosociological studies of WEVs was conducted during June-July 2016 in the two-forest area such as N.E Tlangnuam forest and Phuaibuang forest, where the majority of the species attained their flowering period. A random quadrat of 25 each sampling plot (10m2 for a tree, 5m2 for shrub and 1m2 for herb) were laid down to study the different vegetation layer. A total of 52 species and 45 genera belonging to 28 families with 1526 individuals of WEVs were encountered from the two forest areas. The total stand density of different vegetation layers [herb (27.52ha-1), shrub (4.72 ha-1), and tree (5.88 ha-1) of Phuaibuang forest were higher than N.E Tlangnuam forest area. Log10 IVI of tree species in Phuaibuang forest and N.E Tlangnuam forest showed a comprehensible dominance of *Dysoxylum excelsum* (36.16) and *Eurya acuminata* (35.33) respectively. The distribution pattern of the herb and shrub layer followed a random and contagious pattern in both the study area. Tree species of Phuaibuang forest followed a regular, random, and contagious pattern of distribution and the N.E Tlangnuam forest showed a random and contagious pattern of distribution. Shannon-wiener diversity index (H') and Dominance index (1-D) of herb and shrub were higher in Phuaibuang forest than in the N.E Tlangnuam forest area. For tree species, diversity and dominance index were higher in the N.E Tlangnuam forest area. The results of the similarity index evaluated for WEVs between Phuaibuang forest and N.E Tlangnuam forest was 84.44% in which 38 species were found to be commonly available in Phuaibuang and N.E Tlangnuam forest area.

From the documented WEVs, fourteen important species of shrub, tree, and climber were further selected from a different forest of Aizawl district, Mizoram to observe various phenological events. Five healthy individuals of each species were selected to make out the timing and duration of various phenological events for three years consecutively. The study revealed that maximum plant species undergoing leaf initiation was highest during March and April for all the three years under investigations. The longest new leaf development period was observed in *Senegalia pennata*, *Solanum torvum* and *Crotalaria tetragona* which lasted for 17 weeks each in three consecutive years. The leaf fall was observed to occur in nine species which coincided with the dry seasons. The longest period for flower bud formation was observed in *Dyxosylum excelsum* lasting for 18 weeks in 2015. The flowering peak was observed during August 2016 (50%) and an alternative small peak in April for the three consecutive years. The duration of the flowering period for all the species was between 33 days (*Azadirachta indica*) to 139 days (*Solanum torvum*). 57.14% of plant species showed maximum fruiting during October 2017. Comparing three years of data, the maximum seed formation was observed during December 2017 (50%). Among the species investigated, maximum seed fall was observed during February 2015, February 2017, and November 2016. Rainfall and temperature were significantly correlated ($P<0.01$) with the phenological events.

Nine important species of WEVs were selected to evaluate the nutritional quality, phytochemical, antioxidant, and antimicrobial activity based on dependency and preferences by the local people from the study area and some selected WEVs were of medicinally important. Nutritional parameters such as moisture, ash, protein, fat, carbohydrate, energy contents were evaluated besides mineral and heavy metal content following standard protocol. Out of nine species selected *Rhynchotechum ellipticum* contained the highest moisture (96.85%) and protein (35.53mg/g).The highest carbohydrate was obtained in *Centella asiatica* (75.20mg/g) and the highest ash content was observed in *Fagopyrum tataricum* (11.5%). Following these, total energy content was highest in *Dysoxylum excelsum* (73.93 Kcal/100g) and least energy content was observed for *Aganope thyrsifolia* (20.77 Kcal/100g).

Mineral and heavy metal content of WEVs were evaluated using atomic absorption spectroscopy (AAS), MP- AES, and CHNS analyzer and further indicated that most of the elements under study were presented in a detectable amount. The highest mean level of Iron (126.00mg/100g), Manganese (124.00mg/100g), Magnesium (484.00mg/100g), and Potassium (1844.00mg/100g) were found to be present in *Rhynchotechum ellipticum*. The highest value of Nickel (2.00mg/100g) and Sodium (1751.00mg/100g) were recorded for *Aganope thyrsifolia.* Calcium (516.00mg/100g), Nitrogen (7.00%), and Carbon (21.29%) were found to be highest in *Trevesia palmata*, *Clerodendrum bracteatum* and *Centella asiatica* respectively. Heavy metal analyzed namely Lead, Zinc, and Copper of all selected WEVs was below the permissible limit of FAO/WHO safe limit (2001).

Methanolic crude extracts of nine selected WEVs were investigated to determine their phytochemical, antioxidant, and antimicrobial activities. The results of the qualitative phytochemical analysis revealed that methanol extract showed the presence of at least one phytoconstituents. The total flavonoid content of selected plants was determined to be highest in the extract of *Fagopyrum tataricum* (73.40mg QE/g) and the lowest content was observed in *Centella asiatica* (13.42mg QE/g). Maximum phenol content was observed in *Picria fel-terrae* (97.61mg GAE/g) and *Trevesia palmata* had the lowest phenol content (6.82mg GAE/g). Antioxidant activities of selected WEVs were determined by two assays, namely DPPH and ABTS. The DPPH and ABTS radical scavenging activity of methanol extract of nine samples was found to be a dose-dependent manner. The two assays also exhibited a significant $IC_{50}$ variation between the plants extract ($p<0.05$). Among the 9 plants extract, *Picria fel-terrae* extract exhibited a strong antioxidant potential with a lowest DPPH $IC_{50}$ value of 51.75µg/ml. The ABTS free radical scavenging activity was also highest in *Picria fel-terrae* with $IC_{50}$ of 75.17µg/ml. Comparison between DPPH and ABTS $IC_{50}$ of plant extracts with that of positive control (ascorbic acid) indicated that plant extracts showed weak antioxidant activity than the standard ascorbic acid. The negative and significant linear correlation ($P<0.05$, $P<0.01$) was observed between total phenolic content and antioxidant activity $IC_{50}$ in both the assays. On the contrary, no correlation was observed between antioxidant activities $IC_{50}$ and total flavonoid content.

Antimicrobial screening of methanolic plant extract was performed against four bacterial strains [Gram positive bacteria: (*Staphylococcus aureus* MTCC-96, and *Micrococcus luteus* NCIM-2170); Gram-negative bacteria: (*Pseudomonas aeruginosa* MTCC-2453 and *Escherichia coli* MTCC-739). All the selected WEVs showed antibacterial activity against *E. coli* and *P. aeruginosa* within the inhibition diameter ranges from 8mm to 13.4mm. Among all the selected vegetables, *Rhynchotechum ellipticum* showed the best activity against the tested bacterial pathogens inhibiting all the tested pathogens.

This work highlighted the rich diversity and phytochemical content of various species of WEVs from Aizawl district, Mizoram which provides baseline data for WEVs research in Mizoram, northeast India. The nutritional, antioxidant, and antimicrobial potential of WEVs were described which clearly showed the potentiality of WEVs in the field of nutraceutical and Pharmacological industry. Besides this, diversity, ethnobotanical data, exploration of traditional recipes, and the market survey provide scientific clues to select important and high-quality species in terms of medicine and food. Phenological investigation also provides baseline information in understanding the stability and timing of their biological events, which could also be a significant tool for the management and conservation of WEVs.