

Chapter 7

Summary and conclusion

7.1 SUMMARY

Manipur is endowed with a myriad of flora, fauna, and microorganisms due to its diverse topographical features and climates eco-climatic zones. The state is a part of the Indo-Burmese biodiversity hotspots and the Eastern Himalayan region. It has enormous potential for the cultivation of a wide range of tropical, sub-tropical, and temperate fruits. Manipur is noted for its rich variety of wild edible fruits and vegetables that play a significant role in the daily lives of local communities. These wild edible fruits have been utilized by rural populations for generations as a source of income and livelihood security. The socio-economic well-being of rural people in Manipur is intricately linked to the presence of wild edible fruit plants, which provide food, materials such as fiber and dyes, and fodder for livestock. These fruits are essential not only for their nutritional value but also for their cultural, religious, and traditional significance. Furthermore, many of these wild fruits have been traditionally used for medicinal purposes, with local herbal healers relying on their therapeutic properties from centuries. However, the value and utilization of these wild edible fruits have witnessed a decline in recent times. On the other hand, wild edible fruit plants of Manipur are imperilled by deforestation and urbanization, putting them at risk of extinction. Considering these issues, the present study titled "**Assessment of wild edible fruit plants of Manipur, North-East India: Population structure,**

seedling survival, growth, and phytochemical characterization" aims to investigate the abundance and population of wild edible fruits in their natural habitats as well as how the local people harvest and utilize them for subsistence and commercial purposes. Evaluations of seed germination, seedling survival, and growth under different microclimatic conditions were conducted in order to determine the most optimal climatic variables for early development of selected wild edible fruit plants. To determine the nutritional value and biochemical properties of a few selected wild edible fruits, the phytochemical properties of fruit samples were analyzed. Following is a summary of the main findings of this thesis work.

Important findings

1. The two-community forest (Minou community forest and Machi community forest) of Manipur was subjected to a comprehensive investigation, resulting in the documentation of 124 species, of which 77 species were identified (61 genera under 38 families) and 47 were unidentified. Notably, the Minou community forest exhibited higher number of species, with *Quercus serratus* L. being the most abundant and dominant. Conversely, in the Machi community forest, *Cinnamomum verum* J. S. Presl and *Juglans nigra* L. were found to be the dominant species.
2. There were 31 wild edible tree species, distributed among 26 genera and 21 families. Among these, fruits of the 26 species were found to be commercially available in the local markets. Moreover, it was observed that 28 of these fruit species have a variety of uses in terms of fruits and medicine. The fruits have been widely utilized as a preventive remedy to treat various ailments, including skin and gastrointestinal issues, as well as other health-related concerns. During the study, *Sapria himalayana* Griffith, extremely rare root parasitic flowering plant that is on the verge of extinction, was successfully identified on the forest floor of Machi community forest. This discovery represents a significant contribution, as it establishes a new record for distribution in the Tengnoupal district of Manipur.
3. The investigation of micro-climatic conditions within shade nets of varying percentages, viz., 25%, 50%, and 75%, revealed notable differences in light

intensity, with September and October recording the highest values. The air temperature exhibited relative stability throughout the entire study duration, with only minor fluctuations. While there were some variations in humidity levels, they generally remained within a moderate range. The soil temperature, on the other hand, remained consistent and exhibited no significant changes over the course of the study.

4. Significant observations were made regarding the germination of wild edible fruits, indicating that open field settings are more favourable. The survivability and growth attributes of wild edible fruits were found to differ among various plant species when subjected to shaded environments. One of the key factors influencing growth and physiological responses, including photosynthesis rate and pigment content (chlorophyll a and b, and total carotenoid), was likely the variation in light intensity induced by different shade nets.
5. The physico-chemical and other chemical parameters of 15 wild edible fruits were investigated. The analysis revealed that mean moisture content of the fruits varied between 6.30% and 88.09%. *Averrhoa carambola* L. had the highest moisture content, followed by *Dillenia indica* L. (83.3%) and *Phyllanthus emblica* L. (82.37%). Conversely, the lowest moisture content was recorded in *Rhus semialata* Murr. (6.3%), attributable to its natural drying process upon maturation.
6. The mean ash content varied from 2.00% to 12.50%, with *S. betaceum* exhibiting the highest and *G. xanthochymus* displaying the lowest. Regarding fat content, *E. floribundus* had the lowest fat content of 0.40% and *G. xanthochymus* had the highest with 6.85%. Notably, high calorific values were found in all fifteen wild edible fruits, ranging from 198.48 to 458.59 kcal/100g. Among them, *R. semialata* displayed the highest calorific value, while *V. spinosa* had the lowest. The total carbohydrate content varied from 8.16% to 36.39%, while the total protein content ranged from 0.70 g/100g to 11.66 g/100g. *P. emblica* demonstrated the highest protein content, followed by *S. pinnata* (7.39 g/100g), while *E. floribundus* exhibited the lowest protein content.

7. The investigation conducted to analyse the phytochemical composition of wild edible fruits revealed varying levels of total phenol, flavonoid, and tannin contents in the fruit samples. The total phenol content was relatively lower compared to the flavonoid and tannin contents, ranging from 0.90 to 5.51 mg GAE/g. Among the fruits, *M. paniculata* exhibited the highest phenol content, followed by *R. semialata* (4.92 mg GAE/g), while *V. spinosa* displayed the lowest (0.90 mg GAE/g). The highest total flavonoid concentration was found in *P. emblica* (183.90 mg QE/g), followed by *D. indica* (94.09 mg QE/g) and *S. pinnata* (87.74 mg QE/g), with the lowest found in *G. pedunculata* had (4.34 mg QE/g). Notably, *P. emblica* had the highest content of flavonoids in all the studied fruit samples. The total tannin content varied from 15.71 to 76.74 mg TAE/g, with *A. carambola* exhibiting the highest value, followed by *S. pinnata* (67.63 mg TAE/g), while *A. bunius* displayed the lowest (15.71 mg TAE/g).
8. The antioxidant scavenging activity (DPPH) was assessed by measuring the inhibition percentage of wild edible fruit extracts at a concentration of 100 µg/mL. The results demonstrated that the inhibition percentages ranged from 14.30% to 60.11% among the fruit extracts. The lowest inhibition percentage was observed in *A. bunius* with IC₅₀ of 1325.08 µg/ml, while the highest inhibition percentage was recorded in *P. emblica* with IC₅₀ of 78.79 µg/ml. The antioxidant activity of the methanolic extract of wild edible fruits was assessed by determining the mean FRAP values. The FRAP values ranged from 2.23 to 42.57 mg/g among the fruit extracts, with *G. pedunculata* exhibiting the lowest value and *P. emblica* displaying the highest followed by *D. indica* (37.13 mg/g) and *A. carambola* (32.32 mg/g).
9. The analysis of vitamin C content in fresh samples revealed a range of 8.21 to 340.85 mg/100g, whereas the range in dried samples was 0.88 to 8.51 mg/100g. It was observed that fresh samples generally contained more vitamin C than dried samples. *P. emblica* displayed the highest vitamin C content in both fresh and dried samples, while *A. bunius* and *Z. mauritiana* exhibited the lowest vitamin C content in the fresh and dried samples, respectively.
10. It was determined that the content of vitamin B₁ and vitamin B₂ ranged from 0.03 to 2.40 mg/100g and 0.25 to 22.15 mg/100g, respectively. The lowest

vitamin B₁ content was observed in *F. cunia*, whereas *R. semialata* had the lowest vitamin B₂ content. On the other hand, among the studied fruit samples, *V. spinosa* exhibited the highest vitamin B₁ content while *E. floribundus* showed the highest vitamin B₂ content.

11. The potassium levels in the total of 15 fruits examined in this study varied significantly across the eight minerals analysed, ranging from 35.14 mg/100g to 8738.74 mg/100g. The potassium content exhibited a notable difference between the highest and lowest values. Interestingly, four fruit samples, namely *A. carambola*, *D. indica*, *F. cunia*, and *S. betaceum*, displayed an equal amount of potassium content at 8738.74 mg/100g, representing the highest content recorded. However, *G. xanthochymus* exhibited the lowest potassium content among the fruit samples.
12. The sodium content in the studied fruits ranged from 11.67 to 199.27 mg/100g. The lowest sodium content was found in *V. spinosa* (11.67 mg/100g), while the maximum was in *G. pedunculata* (199.27 mg/100g).
13. The magnesium content varied from 0.09 to 220.74 mg/100g among the fruit samples. *P. guajuva* had the lowest value with 0.09 mg/100g and the highest value was detected in *A. bunius* (220.74 mg/100g).
14. The calcium content ranged from 16.60 to 93.23 mg/100g. The sample of *M. paniculata* had the least calcium content (16.60 mg/100g), while *G. pedunculata* displayed the highest calcium content (93.23 mg/100g). Additionally, the potassium/sodium ratio was calculated, with *Z. mauritiana* showing the highest value and *G. xanthochymus* having the lowest.
15. Among the four micro-elements (Cu, Mn, Zn, and Fe), iron content was found to be relatively higher. The iron content ranged from 0.11 to 50.67 mg/100g. The minimum iron content was observed in *Z. mauritiana*, while the maximum was found in *F. cunia*. The copper content in the fruits ranged from 0.05 to 5.58 mg/100g. The lowest copper content was observed in *M. paniculata*, while the highest content was found in *D. indica*. The highest manganese content was found in *P. emblica* (15.79 mg/100g), while *P. guajuva* the lowest (0.12 mg/100g). Zinc content in the fruit samples ranged from 0.003 to 39.27

mg/100g. *S. pinnata* was found to have the lowest zinc content, while the highest content was found in the fruit of *A. carambola*.

16. Based on the findings of the FT-IR spectra, all the fruit samples exhibited four distinct peaks within the range of 1500-4000 cm^{-1} . OH-groups or carboxylic acid functional groups were detected in all the fruit samples. Alkenes (C=C stretch) groups were observed in all the fruits except *R. semialata*.
17. A variety of test organisms were used to assess the antimicrobial activity of the aqueous and ethanolic extracts obtained from wild edible fruits. According to the findings, both extracts displayed activity, however the ethanolic extract was more efficient than the aqueous extract.
18. The compound profiling of seven wild edible fruits was conducted using LC-MS technique. The results revealed that the alkaloids and their derivatives made up the dominant group of identified metabolites in this study, which constituted between 3.91% to 40.47% of the total composition. Organic acids were also found to contribute significantly, ranging from 3.24% to 39.35% of the identified metabolites. The sugar content of the analysed fruits ranged from 3.8% to 31%. The fatty acid/lipid content of the fruits ranged from 3.59% to 19.94%. Various phenolic compounds were detected, accounting for a range of 1.55% to 17.62% of the total fruit composition. It was found that 4.67% to 17.46% of the total composition of the fruits was made up of benzenoids and their derivatives. Tannin metabolites were observed in varying amounts, ranging from 0% to 15.04% of the total composition. Additionally, the analysis also revealed the presence of various flavonoids, contributing to a range between 0.53% and 14.68% of the total composition. The LC-MS analysis further identified additional steroid compounds, including physalin I, in the wild edible fruits of Manipur.

7.2 CONCLUSION

The thesis work presents comprehensive information on the wild edible fruits found in Manipur. It includes data on the availability of these fruits in their natural habitats, as well as their survivability under different micro-climatic conditions provided by shade houses. The study also analyses the physical properties, nutrient composition, and bio-active compounds of these fruits. The results indicate that many of the analysed fruits possess nutritional value comparable to or even superior to popular commercially available fruits. These wild fruits are often referred to as "natural functional products" due to their rich content of biologically active substances such as ascorbic acids, anthocyanins, phenols, and flavonoids. They offer a cost-effective source of nutrients with various potential health benefits for treating different ailments. Therefore, it is recommended to consume seasonal wild edible fruits to supplement daily nutritional needs. The study highlights the importance of proper utilization, optimal exploitation, and conservation of these wild fruits, considering the threats they face from land use change, habitat destruction, and over-grazing. The findings suggest the need for further research into the cultivation of wild edible fruits under agro-climatic conditions to promote domestication. Furthermore, thorough research on pharmacological traits and bioactive phytonutrients of these wild edible fruit species is of most paramount. Such initiatives would not only improve nutrition and health but also help to income generation and address unemployment problems in Manipur.

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