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Ethnobotanical Diversity and Semi-Quantitative Screening for Cyanogenic Potential (HCN) in Wild Edible Plants: A Comprehensive Review

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ABSTRACT

Wild edible plants are an important part of traditional diets, especially among indigenous and tribal populations. These plant food resources make an important contribution to food security and primary healthcare. In addition to their nutritional and medicinal values, wild edible plants also possess cyanogenic glycosides that can release hydrogen cyanide (HCN) when plant tissues are damaged. This is a major public health problem because of the cyanide toxicity. This review article critically evaluates ethnobotanical studies that highlight the diversity of wild edible plants. Emphasis is placed on the application of various semi-quantitative screening techniques for assessing the cyanogenic potential of wild edible plants. Particular emphasis is placed on plant families with cyanogenic potential. In this context, this review article highlights existing research gaps in ethnobotanical documentation and the cyanogenic potential of wild edible plants. This review article also highlights the importance of wild edible plants for food security and primary healthcare. Moreover, this article highlights the importance of wild edible plants in the nutraceutical and functional food industries.

Keywords: *Wild edible plants, Ethnobotany, Cyanogenic glycosides, Hydrogen cyanide, Semi-quantitative screening, Food safety.*

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1. Introduction

Wild edible plants have long played a significant role in the sustenance of human populations, particularly in developing countries. Wild edible plants have long been a source of food, nutrition, and sustenance for the global human population, particularly in developing countries. In fact, long before the evolution of agriculture as a food production system, people worldwide used wild edible plants as a source of food, nutrition, and sustenance. Today, wild edible plants are consumed as vegetables, fruits, tubers, seeds, and flowers, thereby providing essential nutrients, dietary fibre, and protein to the global human population. Wild edible plants offer an alternative food source for indigenous communities, especially in developing nations. Ethnobotanical studies have extensively documented traditional knowledge concerning the identification, collection, preparation, and consumption of wild edible species. This knowledge, passed down orally through generations, reflects enduring human–plant interactions and adaptive strategies developed in response to local ecological conditions [1]. Wild food plants in many traditional food systems not only contribute to food diversity but also have considerable value for their nutrient content, medicinal, cultural, and diversity values. Wild food plants, though very important, have remained underutilised and under studied in modern food systems and scientific research.

The challenge in the food system stems from the fact that wild food plants contain naturally occurring anti-nutritional and toxic compounds, such as alkaloids, oxalates, phytates, and cyanogenic glycosides, which release hydrogen cyanide (HCN) upon tissue damage from chewing, grinding, and improper food processing. Hydrogen cyanide is a powerful respiratory toxin with serious health implications for those who consume it in excess and over long periods.

The increased interest in the use of wild edible plants for nutraceuticals, pharmaceuticals, and functional foods has again emphasised the importance of safety evaluation, there is a lack of toxicological and chemical information for many wild edible plants commonly used. In such cases, semi-quantitative screening appears to be a viable option for the preliminary safety evaluation of the cyanogenic potential of wild edible plants, especially in ethnobotanical studies. In this review article, the existing ethnobotanical diversity of wild edible plants has been discussed in the context of semi-quantitative screening methods for evaluating their cyanogenic potential, and the scope of these methods for safe use and sustainable development of wild edible ethnobotanical resources [2].

2. Ethnobotanical Diversity of Wild Edible Plants

Ethnobotany investigates the intricate connections between human societies and plant resources, focusing on traditional knowledge systems concerning food, medicine, and cultural practices. Within this context, wild edible plants are of paramount importance, particularly for indigenous, tribal, and rural communities that depend on locally accessible biological resources for sustenance and nourishment [3]. Ethnobotanical investigations across Asia, Africa, and Latin America have documented a remarkable diversity of wild edible species, often numbering several dozen to several hundred taxa within specific regions [4]. Edible wild plants make a significant contribution to household food security by providing supplement food to the main crops, especially during food deficit periods, drought, seasonal unemployment, and crop failure. The use of leaves and shoots as leafy vegetables is very common due to their availability and high micronutrient content. Fruits and seeds also serve as sources of carbohydrates, fats, and energy [5-6]. Underground parts of the plants, such as tubers, rhizomes, and roots, are used as famine food, especially during adverse environmental or socio-economic conditions [7].

The selection and utilisation of wild edible plants are largely based on traditional ecological knowledge passed down through generations. Taste, seasonal availability, cultural values, and medicinal values are key determinants in deciding the selection and utilisation of wild edible plants [8]. In many indigenous cultures, the use of plants for food and medicine is closely linked with many wild plants serving both purposes [9]. Although these plants are widely used and recognised, scientific proof of their nutritional benefits and safety is still lacking for many edible species. Ethnobotanical studies have mostly focused on identifying plant species and how people use them. In contrast, a thorough investigation of their chemical makeup and possible toxicity has received less attention. This is especially important for species that may contain naturally occurring toxins, such as cyanogenic glycosides, which can be harmful if not handled correctly. Therefore, documenting ethnobotanical knowledge is a crucial first step in identifying species that require further study.

There is a growing recognition of the importance of combining research on ethnobotanical diversity, chemical properties, and food safety. This integration is essential for the safe use, conservation, and possible domestication of wild edible plants.

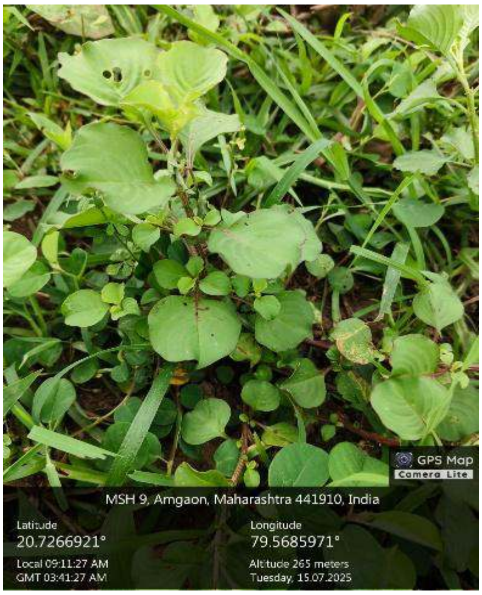
Recent studies have highlighted the importance of wild edible plants, both for their nutritional value and their role in environmental sustainability [10]. Documented a considerable variety of wild edible plants used by indigenous and rural populations. Their research highlighted the importance of traditional ethnobotanical knowledge for ensuring food security, particularly in areas facing food shortages [11]. In a related study the importance of traditional food systems for wild edible plants in their research. This research underscored the critical role these resources play in promoting sustainable nutrition, especially amid the heightened food insecurity caused by climate change [9].

The Food and Agriculture Organisation acknowledged, from a global policy standpoint, that wild foods are crucial components of sustainable diets, with significant potential to alleviate malnutrition and concurrently safeguard biodiversity [12]. Moreover, the report emphasised the importance of documenting and evaluating the safety of these wild food resources. The study offered a different view of wild edible plants. They used a method that combined ethnobotany, nutritional science, and food safety [13]. The research highlighted the nutritional benefits of these plants. However, the presence of natural toxin in them require careful scientific study. These investigations collectively underscore the imperative to integrate ethnobotanical studies with nutritional and food-safety research to promote the safe use of wild edible plants. In India, it is estimated that more than 800 species of wild edible plants are consumed by rural and tribal population [30]. So, aware these people before using wild edible plants.

Table 01: List of some wild edible plants

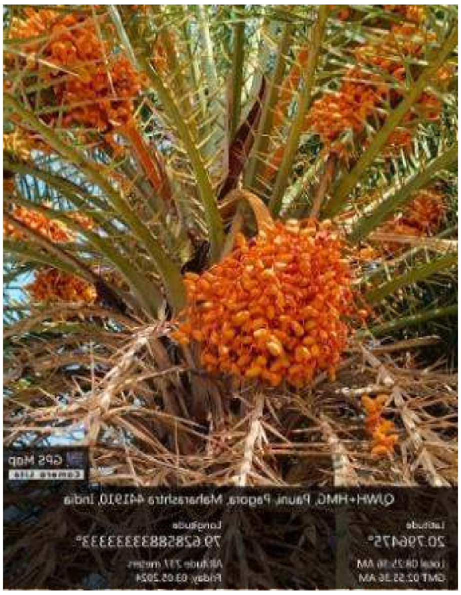
Sr. No.	Botanicala Name	Family	Vernacular Name	Parts used	Use as
1	*Amaranthus cruentus* Linn.	Amaranthaceae	Tandulka	Leaves	Vegetable
2	*Amaranthus spinosus* Linn.	Amaranthaceae	Mat bhaji	Leaves	Vegetable
3	*Bombax ceiba* Linn.	Malvaceae	Katesavar	Flower	Vegetable
4	*Buchanania lanzan* Spreng.	Anacardiaceae	Chara	Fruit	Raw fruit
5	*Butea monosperma* (Lam.) Kuntze	Fabaceae	Palas	Nector	Raw
6	*Commelina benghalensis Linn.*	Commelinaceae	Kena	Leaves	Pakoda
7	*Colocasia esculenta* Linn.	Araceae	Kochai	Leaves	Vegetable
8	*Cordia myxa* Linn.	Cordiaceae	Bhokar	Fruit	Raw fruit
9	*Cryptocoryne retrospiralis* (Roxb.)Kunth	Araceae	Pashan bhed	Leaves	Vegetable
10	*Diospyros melanoxylon*	Ebenaceae	Tembhrun	Fruit	Raw fruit
11	*Ficus religiosa* Linn.	Moraceae	Pimpal	Young leaf	Vegetable
12	*Grewia hirsuta Vahl*	Tiliaceae	Nagbala	Fruit	Raw fruit
13	*Holarrhena pubescens* Wall.ex G.Don	Apocynaceae	Kula	Flower	Vegetable
14	*Limonia acidissima* Linn.	Rutaceae	Kawat	Fruit	Raw fruit
15	*Luffa aegyptiaca* Mill.	Cucurbitaceae	Galgala	Fruit	Vegetable
16	*Manilkara hexandra (Roxb.) Dub.*	Sapotaceae	Khirani	Fruit	Raw fruit
17	*Olax scandens* Roxb.	Olacaceae	Aratphari	Young leaf	Vegetable
18	*Phoenix sylvestris* (L.) Roxb.	Aracaceae	Sindhi	Fruit	Raw fruit
19	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae	Chichbil	Fruit	Raw fruit
20	*Senna occidentalis* (L.) Link.	Fabaceae	Rantarota	Young leaf	Vegetable
21	*Sesbania grandiflora* (L.)Poir.	Fabaceae	Heti	Flower	Vegetable
22	*Tamarindus indica* Linn.	Fabaceae	Chinch	Fruit	Raw fruit
23	*Woodfordia fruticosa* (L.)Kurz	Lythraceae	Zilbuli	Flower	Vegetable
24	*Ziziphus mauritiana* Lam	Rhamnaceae	Bor	Fruit	Raw fruit
25	*Zizuphus oenoplia* (L.) Mill	Rhamnaceae	Yeroni	Fruit	Raw fruit

Fig. 01: Picture of some wild edible plants



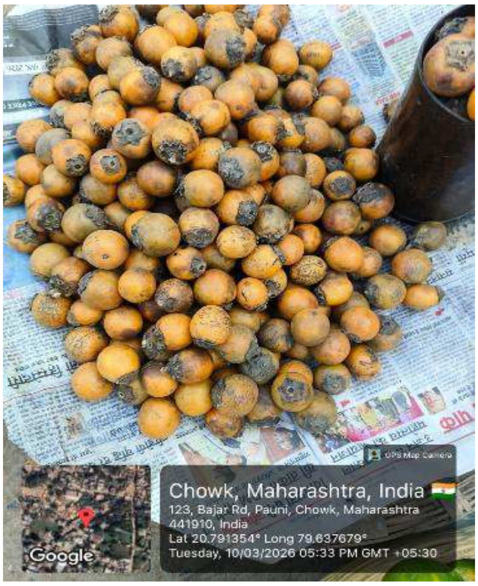
Phoenix sylvestris

Commelina benghalensis



Amaranthus cruentus

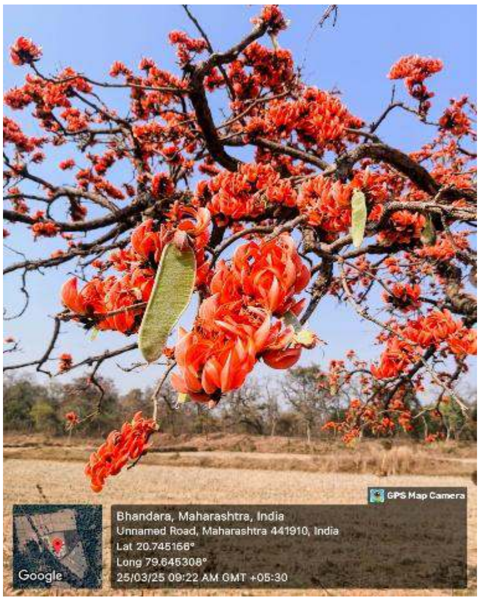
Luffa aegyptiaca



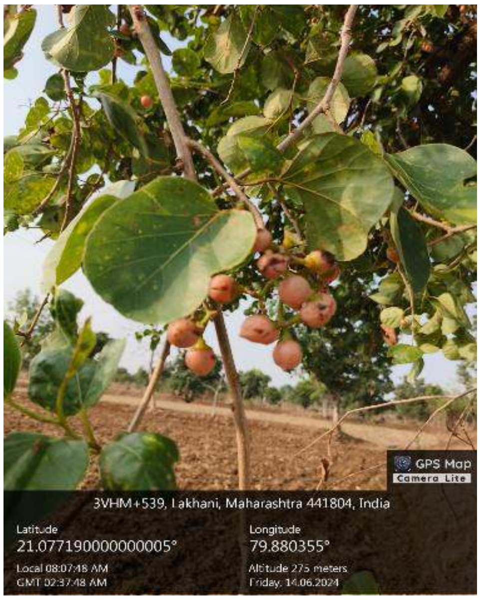
Diospyros melanoxylon

Cryptocoryne retrospiralis

Holarrhena pubescens



Butea monosperma



Cordia myxa

3. Cyanogenic glycosides, a type of secondary metabolite

They are common in the plant kingdom. It is estimated that over 2,500 plant species produce cyanogenic compounds as part of their secondary metabolism, which helps protect them from herbivores [14]. These compounds are stored in the plant's vacuoles in a stable and non-toxic form. Nevertheless, when plant tissues are compromised by mechanical actions such as chewing, grinding, or processing, the cyanogenic glycosides interact with the endogenous β-glucosidase present in the plant, leading to the hydrolysis of the glycosides and the subsequent release of hydrogen cyanide (HCN) [15]. Hydrogen cyanide, a highly toxic and volatile compound, harms the body by inhibiting cytochrome c oxidase in the mitochondrial electron transport chain. This interference then impairs cellular oxygen consumption, leading to his toxic hypoxia and, consequently, disrupting cellular respiration [16]. Acute exposure to cyanide can present with a variety of symptoms, such as headache, dizziness, rapid breathing, convulsions, and respiratory failure, which can ultimately be fatal in severe cases. Conversely, chronic cyanide exposure has been associated with various health consequences, such as konzo, a neurological condition, and tropical ataxic neuropathy, in addition to thyroid dysfunction, which affects iodine metabolism [17-18].

Cyanogenic plants are found across many plant groups. However, cyanogenic glycosides are particularly common in certain plant families, such as Fabaceae, Euphorbiaceae, Rosaceae, Linaceae, and Poaceae [19]. *Cassava, sorghum, bamboo shoots, flaxseed,* and *almonds,* which are all food plants from the families mentioned earlier, are known to accumulate significant amounts of cyanogenic glycosides [20-21].

In wild edible plants, levels of cyanogenic glycosides may vary considerably across species, parts, growth stages, and environments. Thus, despite the well-established hazards of cyanogenic glycosides, many wild edible plants contain these compounds, which are consumed without sufficient knowledge of their potential toxicity. Although conventional practices for preparing edible plants reduce cyanide levels, if preparation is not done correctly, it can lead to unsafe exposure to cyanides [22]. Therefore, it is essential to systematically screen and assess the cyanogenic potential of wild edible plants. A semi-quantitative screening method for these plants could provide useful information for identifying species with a higher risk, enabling further toxicological and food safety evaluations [23].

Cyanogenic glycosides, which are secondary metabolites in plants, have raised food safety concerns because they can release hydrogen cyanide (HCN) when plant tissues are damaged at the time of chewing, crushing or cooking. The EFSA, 2023 provided a detailed update concerning the presence of cyanogenic glycosides in food and feed, along with an assessment of the associated exposure and toxicological risks. The update highlighted a potential risk that prolonged consumption of certain plant-based foods might push some groups beyond established safety limits. This indicates a need to develop practical risk management strategies [24]. Re-examined cyanogenic glycosides in terms of their biochemical and ecological significance, including their biosynthesis, defensive role in the plant kingdom, and their impact on human health. This review emphasised that cyanogenic potential is highly variable across plant species and environmental conditions, making food safety assessment more complex [25]. In its 2024 report, the World Health Organisation (WHO) addressed the global public health implications of cyanide exposure, detailing the manifestations of both acute and chronic toxicity.

Furthermore, examined the toxicological effects of cyanogenesis in food plants, highlighting regulatory challenges posed by cyanogenic compounds. The researchers underscored the need to establish uniform international standards and reliable screening methods to safeguard consumer health.

These research articles highlight the need for thorough evaluation and subsequent regulations on cyanogenic glycosides in plant-based foods [26]. Wild Edible Plants with Documented Cyanogenic Potential a considerable body of research has identified the presence of cyanogenic glycosides in various species of wild and semi-domesticated food species. Various food species, such as bamboo shoots, wild yams, legumes, flaxseeds, wild almonds, and various sorghum species, have been identified as important food sources for humans and have been found to contain varying amounts of cyanogenic compounds [27]. These food species have been consumed in various parts of the world as delicacies and staples without an assessment of their cyanogenic potential.

The cyanogenic potential in wild edible plants varies greatly. Various biological and environmental factors contribute to this variation. The variation in cyanogenic compounds is species-specific. In some species, lower amounts of cyanogenic compounds have been observed. In contrast, in other species, considerable amounts of cyanogenic compounds have been recorded, which can be detrimental to health if not processed properly. In addition, cyanogenic compounds in wild edible plants are not uniformly distributed across all parts. More cyanide is found in seeds, kernels, and tubers compared to leaves and fruits. In contrast, some species have also shown this in young shoots and immature leaves [21].

4. Wild Edible Plants with Documented Cyanogenic Potential

Other factors that influence the cyanogenic potential include the developmental stage and seasonality. Several studies have documented that levels of cyanogenic glycosides increase during the early stages of plant development and decrease as plants mature [27]. Soil fertility, water stress, and climate conditions also influence cyanogenesis levels in plants, resulting in a high degree of intra- and inter-population variability [19]. Such a high degree of variability is likely to complicate risk assessment, and generalisation of safety guidelines for wild edible plants may be a concern. As a result, it is increasingly recognised that semi-quantitative screening methods are essential tools for rapid evaluation of cyanogenic potential for a variety of wild edible plants. This is necessary for prioritising those that require detailed quantitative and toxicological evaluation.

Thus, traditional food processing techniques are of significant importance in reducing the toxicity of cyanogenic plant foods, thus ensuring public health. The study give scientific support for the efficacy of traditional indigenous detoxification practices concerning cyanogenic foods. The study demonstrated that techniques such as soaking, boiling, drying, and fermenting these foods substantially diminish the presence of cyanogenic glycosides. Consequently, these methods facilitate the breakdown and removal of hydrogen cyanide, thereby reducing its concentration to a level deemed safe for consumption [30]. It is important to highlight that traditional knowledge systems are crucial to public health, especially in communities that rely heavily on plant-based foods [28]. Centred their review on fermentation as an effective and sustainable means for reducing cyanide in plant food products.

The authors' review highlighted the beneficial effects of microbial metabolism during the fermentation of food products, particularly its role in breaking down cyanogenic glycosides.
The review further revealed how fermentation is beneficial for the release and elimination of free cyanide. The authors also highlighted how fermentation improves nutritional, digestibility, and sensory properties. The authors further highlighted how fermentation is an inexpensive and environmentally friendly method.

5. Traditional knowledge systems

Many method have been instrumental in mitigating the toxic effects of cyanogenic glycosides within specific foodstuffs. Indigenous and local communities have utilised a range of traditional processing techniques to achieve this. These methods encompass soaking, boiling, fermentation, drying, and roasting, among others. All of these processing methods help reduce cyanogenic glycosides through different mechanisms of action [17]. This helps in the enzymatic hydrolysis of cyanogenic glycosides and the subsequent volatilisation of hydrogen cyanide or its leaching into the processing water, thus reducing the levels of cyanide in the food materials [29]. Ethnobotanical and food science studies have clearly shown that the application of traditional processing methods can reduce the cyanogenic potential of the relevant food materials to a level safe for human consumption. In the case of some of the staple and wild food materials, such as cassava, bamboo shoots, and some wild tuber species, the cyanide content is reduced by 80-90% through the application of traditional processing methods such as soaking, boiling, and fermentation [31]
However, changing socio-economic conditions, including urbanisation, shifts in food habits, and the loss of intergenerational knowledge transfer, have led to a gradual decline in the practice of food processing. Loss of food processing practices makes the population vulnerable to the risk of cyanide poisoning, especially in the case of wild edible plants that are processed in the wrong manner [25]. The commercialisation of food may further compound this risk without safety guidelines. Scientific validation of the efficacy of traditional food detoxification practices through the application of semi-quantitative screening approaches may provide a link between indigenous knowledge and conventional food safety assessment approaches. Such studies may help promote food safety practices in a culturally acceptable manner, thereby helping in the sustainable utilisation of the wild edible plants [19]. Research Gaps and Future Perspectives Despite increasing documentation of the ethnobotanical uses of wild edible plants, gaps persist in their safety evaluation, especially regarding potential toxicity, including cyanogenic glycosides and hydrogen cyanide. While most research has focused on species identification, traditional uses, and ethnobotanical importance, relatively few investigations have examined their chemical and toxicological properties. As a result, the cyanogenic potential of several commonly used wild edible plants remains to be fully characterised.
One of the major gaps in the evaluation of the safety of wild edible plants is the lack of databases that provide region-specific information on ethnobotanical uses relevant to cyanogenic risk assessment. Differences in plant parts, developmental stages, seasons, and environments make it difficult to establish standardised guidelines for safety evaluation. Similarly, traditional methods of detoxification, including soaking, boiling, and fermentation, although commonly used, remain scientifically invalidated.
Future research in this area should focus on large-scale investigations of semi-quantitative screening of these plants, including the effects of environmental and climatic factors, and on a multidisciplinary approach to developing guidelines for the safe utilisation of wild edible plants [32-33].

6. Conclusion

Wild edible plants represent a valuable, but underused resource in global food systems. Despite their nutritional and cultural importance, it is necessary to assess their potential for cyanogenic activity. For this purpose, semi-quantitative screening is a useful technique for assessing cyanogenic potential. Ethnobotany, in combination with scientific screening, is a significant tool for evaluating food safety, traditional knowledge, and the utilisation of wild edible plants.

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