Edible Weeds of India: Nutraceutical Potential and Cost-Effective Food Options

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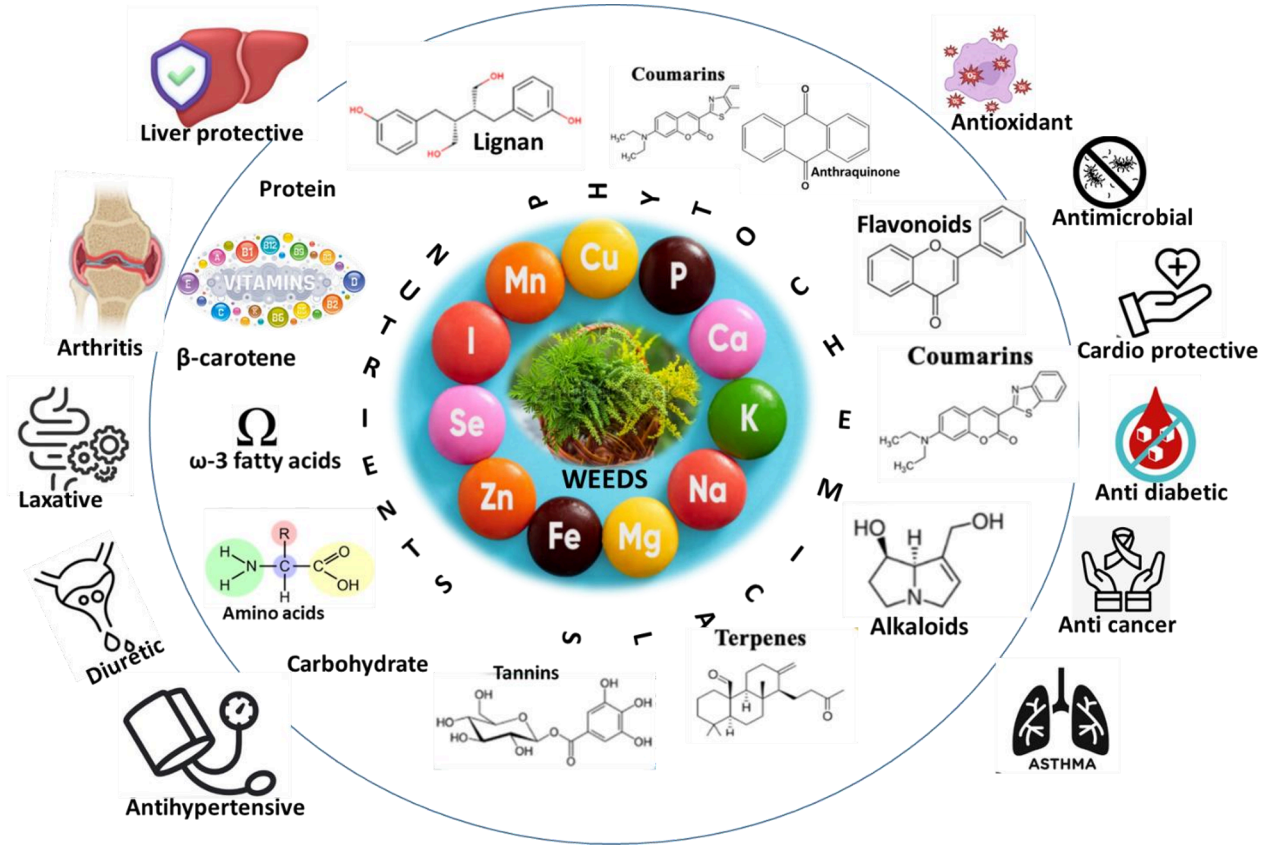
Abstract

India, renowned for its rich biodiversity, harbors a wide array of cultivated crops and wild weeds. Traditionally overlooked as agricultural waste, many weeds possess exceptional nutritional and medicinal value, positioning them as cost-effective alternatives for food and nutraceuticals. Edible weeds such as *Amaranthus viridis* Linn, *Achyranthes aspera* Linn, *Chenopodium album* Linn, *Euphorbia hirta* Linn, *Portulaca oleracea* Linn, and *Taraxacum officinale* are abundant in essential nutrients, including amino acids like lysine, valine, aspartic acid, and serine; vitamins K, B6, and E; and minerals such as iron, zinc, magnesium, and calcium. These plants are rich in bioactive compounds like alkaloids, flavonoids, phenolics, saponins, and terpenoids, contributing to their antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. Additionally, they demonstrate therapeutic potential in managing lifestyle diseases such as diabetes, cardiovascular disorders, and hypercholesterolemia, while offering wound-healing, diuretic, and immunomodulatory benefits. Incorporating edible weeds into rural and urban diets can enhance food security, improve nutrition, and reduce healthcare costs, aligning with sustainable agricultural practices. This study highlights the nutraceutical potential of edible weeds in India, emphasizing their role as affordable and nutritious food sources with significant health benefits.

Keywords : Nutraceuticals, Edible weeds, Nutritional value, Phytochemistry, therapeutical uses.



Introduction

India is recognized as a 12th most bio diverse country of the world. It is mostly known as agricultural nation. It has cultivated many crops like wheat, maize, pulses, rice and many more. During the pre and post cultivation there are several other unwanted plants known as weeds which prevents the growth of desirable plant known to us. Interestingly these weed have been integrated mainly into local diet by rural communities. These weeds have shown their effectiveness as a food and medicine. Such weeds could become as promising plant and cost- effective food options for our sustainable life. Some of the most widely consumed edible weeds in India include *Chenopodium album* and *Amaranthus viridis* from Northern India; *Alternanthera sessilis* and *Boerhavia diffusa* from Southern India; *Ipomoea aquatica*, *Glinus oppositifolius*, and *Enhydra fluctuans* from Eastern India; *Trigonella foenum-graecum* and *Amaranthus spinosus* from Western India; *Bacopa monnieri* and *Cassia tora* from Central India; and *Amaranthus tricolor* and *Basella alba* from the Northeastern region of India.

Weeds possess significant nutritive food supplement like vitamins, unsaturated fatty acids, protein, dietary fibre, minerals etc. They can help to boost the immune system, improve the blood cholesterol levels, help in repairing muscles, and keeping the digestive system healthy. They possess phytochemicals that helps in preventing various chronic diseases for example, cancer, diabetes, diarrhoea, epilepsy, wounds, burns etc. Terpenoids, alkaloids, cellulose, carbohydrates, flavonoids, glycosides, phenols, quinons, saponins, tannins, phenols, and steroids are among the phytochemicals responsible for therapeutic actions [1]. Figure 1 is showing the presence of various phytochemicals and therapeutic uses. Most important therapeutics are antioxidant, anti-inflammatory, antidiuretic, anthelminthic, antimicrobial, hepatoprotective, anti-septic property, antispasmodic, antinarcotic, antiulcer [2], anticancer, antidiabetics, antibacterial, lipid lowering properties etc [3]. While often overlooked or classified as invasive, edible weeds contribute to food security, especially in rural areas, and support sustainable dietary practices. The current study will explore potentials of various edible weeds as food and as well as medicine for various metabolic and life style diseases.

Nutritional, Bioactive Profiles and Therapeutic properties of edible weeds

1. Chenopodium album Linn

Chenopodium album Linn, commonly known as a fast-growing weed in temperate zones, belongs to the family Amaranthaceae. This plant's leaves and young shoots are also used in many other cuisines, including stuffed parathas, soups, and curries (4). This plant is a rich source of nutrients, including vitamins A, C, and B-complex, proteins, omega-3 fatty acids like alpha-linolenic acid, and minerals such as calcium, potassium, selenium, copper, iron, manganese, and zinc [5]. These mineral and dietary fibre are associated with managing anemia and boosting the immune system and reducing the risk of cardiovascular diseases. The secondary metabolites in the leaves include proanthocyanidins like catechin, flavonoids such as quercetin and kaempferol, phenolic acids like tannic acid and cinnamic acid amide, lignans, tannins [6], terpenes such as diterpene neophytadiene and monoterpene lactone like dihydroactinidiolide [7], alkaloids, sterols etc [8]. The plant infusion is traditionally used to treat rheumatism and exhibits laxative, diuretic, sedative, antioxidant, and anti-arthritic properties [9]. It has shown antibacterial activity against both Gram-positive and Gram-negative microorganisms [10]. The leaf extract has demonstrated anticancer potential by inhibiting cell growth and inducing apoptosis [11]. It also possesses anthelmintic [12], antifungal, and anti-ulcer activities, with the alcoholic extract being effective against ulcers caused by ethanol, cold restraint stress, and the pyloric ligation model [13]. Additionally, it exhibits hepatoprotective [14], anti-inflammatory [15], antidiabetic, and anti-hyperlipidemic properties [16].

2. Portulaca oleracea Linn

This perennial succulent herb, about 50 cm in length, is distributed across the country [17]. It is rich in nutrients like carbohydrates, proteins, vitamins, beta-carotene, omega-3 fatty acids, saturated fatty acids (e.g., lignoceric and palmitic acids), unsaturated fatty acids (e.g., alpha-linolenic and oleic acids), and minerals such as iron, magnesium, calcium, and phosphorus [18, 19]. Secondary metabolites include alkaloids, anthraquinone glycosides, cardiac glycosides, phenolic compounds (e.g., caffeic acid), flavonoids (e.g., catechin, quercetin, kaempferol), galloyl glucose, caffeoyl glucose, feruloyl glucose, terpenoids (e.g., beta-cyclocitral, menthol, carvone, limonene), and coumarins [19]. These phytochemicals contribute to treating burns, headaches, arthritis, and diseases related to the intestines, liver, and stomach [20]. The plant shows anticancer activity by inhibiting tumor growth in HeLa and HepG2 cells. It also helps regulate blood glucose and lipid metabolism in diabetes. Its anti-inflammatory effects are due to the suppression of NF-κB activation through inhibition of IκB and TNF-alpha binding [21]. Additionally, the water-soluble extract shows nephroprotective effects, potentially aiding in acute renal injury caused by nephrotoxins [22, 23].

3. Taraxacum officinale

Dandelion grows in temperate regions globally, thriving in moist soils along lawns, roadsides, and waterways [24]. It is rich in vitamins, minerals, beta-carotene, carotenoids, magnesium, zinc, copper, and selenium, which aid in treating conditions such as dyspepsia, liver disorders, hepatitis, anorexia, and spleen issues. Phytochemicals include phenolic compounds (e.g., chicoric acid, chlorogenic acid), flavonoids (e.g., quercetin, luteolin derivatives), terpenes (e.g., sesquiterpenoid lactones), coumarins, antioxidants, and essential oils [24]. Ethanolic extract of dandelion exhibit diuretic and anti-inflammatory effects by modulating NF-κB activity, which is stimulated by TNF-alpha, reducing inflammation via IκB inhibition [25, 26]. It mitigates oxidative stress, reduces atherosclerosis severity, prevents hypercholesterolemic atherosclerosis, and lowers coronary heart disease risk factors [27]. Dandelion also helps manage metabolic syndrome, prevents diabetic complications, and improves lipid metabolism [28]. Additionally, it also shows anti-angiogenic, anti-inflammatory, anti-nociceptive, and anti-cancer properties [29]. However, dandelion may cause allergic reactions, mouth sores, exacerbate heartburn, and increase stomach acid in some individuals.

4. Amaranthus viridis Linn

Known as green amaranth, this weed is widely found in tropical and subtropical regions, with local names like chengkruk in Manipur and kuppacheera in South India. It is rich in unsaturated fatty acids (arachidonic, linoleic, oleic, linolenic) and saturated fatty acids (arachidic, stearic, palmitic), along with proteins, fats, fibers, and minerals like selenium, zinc, and iron [30, 31]. The plant contains phytochemicals such as tannins, phenolics, alkaloids, steroids, flavonoids, and saponins, with notable polyphenol, flavonoid, and tannin contents [32]. It is used to treat microbial infections, diabetes, inflammation, ulcers, asthma, and respiratory problems, exhibiting diuretic, anti-rheumatic, and anti-inflammatory properties [33]. Its leaf extract shows antibacterial effects against

gram-positive bacteria [34] and anthelminthic activity [35]. The methanolic extract also reduces blood glucose levels in diabetic rats [36].

5. Achyranthes aspera var. indica L.

Achyranthes aspera Linn, commonly known as chaff-flower or devil's horsewhip, belongs to the Amaranthaceae family and is widely found in India. The plant, known as Apamarga in Sanskrit, is consumed in various forms like cooked leaves, juice, or powder. It is rich in carbohydrates, proteins, and contains secondary metabolites such as alkaloids, flavonoids, saponins, triterpenoids, phenolic compounds, sterols, and lignans [37]. Key alkaloids like betaine and ecdysterone have analgesic and anti-inflammatory properties, while flavonoids (quercetin, rutin, kaempferol, apigenin) offer antioxidant and antimicrobial benefits. Phenolic compounds protect cells from oxidative stress, and beta-sitosterol and stigmasterol have immunomodulatory effects [37]. The plant is used for treating dysentery, asthma, hypertension, and diabetes, and has hypoglycemic, hepatoprotective, analgesic, and antipyretic properties. Methanolic leaf extract has shown wound-healing potential [38]. A study by Nadeem Alvi et al. (2010) reported that chloroform extract exhibited antibacterial activity against *Micrococcus luteus* and *Salmonella choleraesuis* [39], and methanolic extract demonstrated anticancer effects [40]. The plant may also aid in combating antibiotic resistance [41] and has diuretic effects, suggesting potential in treating hypertension and cardiovascular diseases [42]. However, it should not be used by pregnant women and can cause allergic reactions or gastrointestinal issues like nausea, vomiting, and diarrhea if consumed excessively.

6. Trigonella foenum-graecum

Fenugreek, an annual plant from the Fabaceae family, is widely grown and used across the world, especially in the Indian subcontinent as a vegetable, herb, and spice. Its leaves and seeds are rich in protein, fat, minerals, fiber, carbohydrates, vitamins (C, riboflavin), and carotene. Fresh leaves contain about 220.97 mg of ascorbic acid and 19 mg of β-carotene per 100g [43]. The plant also contains secondary metabolites like alkaloids (betaine, trimethylamine), flavonoids (quercetin, rutin), amino acids (isoleucine, lysine), and saponins (fenugrin B, graecunin) [43]. Fenugreek improves glycemic control and lipid profiles by lowering total cholesterol, triglycerides, and HDL cholesterol [44]. It also has anticancer properties due to phytoestrogens and saponins, which induce apoptosis and inhibit cancer cell division [44]. Its defatted seeds show cholesterol-lowering effects and anti-obesity activity [44]. However, fenugreek can cause allergic reactions, even at small doses (about 2 mg), with identified allergens in proteins at 50, 52, and 74 kDa, so caution is advised for sensitive individuals.

7. Eclipta prostrata Linn

This weed, found in moist areas across India, belongs to the Asteraceae family and is known as false daisy, bhringaraja, bheemraja, or mayweed. Its leaves and shoots are consumed as vegetables. It contains phytochemicals like thiopenes, cardiac glycosides, flavonoids, alkaloids, triterpenes, phenolic compounds, coumestans, steroids, and saponins. Saponins, such as ursolic acid and eclalbasaponin, are effective for treating skin diseases. Coumestans, like wedelolactone, have antimicrobial, antioxidant, UV-protective, and neuroprotective properties, and may help with cancer, diabetes, obesity, and aging [45]. Studies by Woranan Nakbanpote (2019) identified coumestans and flavonoids [46], while Azza S. Helmy (2019) demonstrated improved lipid profiles and liver function in a fatty liver rat model [47]. Ananthi (2003) reported anti-hyperglycemic effects in rats, showing improved enzyme activity and reduced blood glucose levels [48]. However, side effects include severe allergic reactions, liver issues, metal toxicity, and arsenic poisoning.

8. Senna tora Linn

This annual weed, found throughout India and in the central Himalayas, belongs to the Fabaceae family and is known as cassia tora, fetid cassia, ringworm plant, pavand, and sickle senna. The edible parts are the leaves and seeds, with seeds roasted as a coffee substitute and leaves cooked as vegetables. The plant contains 11.63% protein, 27.0% crude fiber, 9.86% ash, and minerals such as 0.86 g magnesium, 0.10 g sodium, and 0.76 g potassium per 100g. Amino acids include lysine, valine, glutamic acid, serine, and aspartic acid [49]. Phytochemicals in the leaves include emodin, kaempferol-2-diglucoside, and beta-sitosterol, while seeds contain phenolic glycosides like rubrofusarin. The roots have naphtho-alpha-pyrone and torlactone. Traditionally, the plant is used for anti-inflammatory, anti-genotoxic, and anti-mutagenic activities [50]. An ethanolic seed extract study in rats showed hypolipidemic effects by lowering triglycerides [51]. Manjusha Choudhary (2012) reported its anti-ulcer action in rats, reducing gastric juice production and ulcer formation [52]. The plant also exhibits bronchodilator activity, as shown in an in vitro anti-asthmatic study [53]. However, it may cause stomach discomfort, diarrhea, and long-term liver damage.

9. Centella asiatica Linn

It is a perennial herb and commonly found as weed in crop fields throughout India. It belongs to the family of apiaceae and is recognized by various common names like Indian pennywort, gotu kola, brahmi and brahma manduki etc. The minerals and vitamins iron, zinc, calcium, potassium, magnesium, and vitamins K, C, E, and B are abundant in these plants [54]. Some other nutritional contents are carbohydrates (43.11-44.51%), protein (7.07-9.63%), lipid (1.101.30%), fiber (15.13-18.87%), ash (16.1-17%) [55].

This plant also possesses several secondary metabolites like sesquiterpenes, saponins, pentacyclic triterpenoids, caffeoylquinic acids [56], sitosterol, stigmasterol. Some free amino acids *viz* alanine, serine, aminobutyrate, aspartate, glutamate, and treonin and fatty acids *viz* linoleic, linolenic, oleic, palmitic, and stearic. Some of the traditional uses are antioxidant, wound healing, cytotoxic, antitumor, neuroprotective, cardioprotective, antiviral, and antileprotic etc [57]. Yao Chen (2003) studied the effects of triterpenes on immobility duration in swimming mice and amino acid levels in brain tissue. Both triterpenes and iripramine reduced immobility and balanced amino acids, showing antidepressant effects. M.G. Jayathirtha reported that oral administration of Centella-containing Brahma Rasayana to gamma-irradiated mice increased white blood cell count, bone marrow cellularity, and antibodydependent activity, reducing liver peroxidation, imunomodulatory effects. Potential side effects include skin allergy, burning sensation, and stomach upset.

10. Acalypha indica Linn

This herbaceous plant has small flowers surrounded by cup-shaped bracts in ament-like inflorescences and is valued for its roots and therapeutic applications. Found across tropical India and Africa, it belongs to the Euphorbiaceae family and is known by names like Indian mercury and Indian nettle. Nutritionally, it contains 17.5% crude protein, 16.1% ash, 70.5%–92.3% moisture, 0.65 mg/g reducing sugar, 37.5 mg/g non-reducing sugar, and 50 mg/g fat. Key elements include potassium (26797.91 ppm), sodium (599.91 ppm), magnesium (3949.94 ppm), zinc (19.04 ppm), copper (10.08 ppm), and iron (597.51 ppm) [58].

The main phytochemicals in this plant include retusoquinone (1.694%), antimycin A (1.324%), quinone (1.152%), ramipril glucuronide (1.563%), bumetanide (0.847%), propionylglycine methyl ester (1.18%), choline (0.847%), octadecanoic acid (2.053%), piperidine-2,5-dione (3.73%), phenols (70.92 mg/g), and flavonoids (16.01 mg/g) [59]. Traditionally, it is known for anti-inflammatory, anticancer, antihyperlipidemic, and anti-obesity properties. In 2017, Sudhakar Chekur demonstrated its anticancer potential using the MTT assay. Methanolic extracts tested on cancer cell lines (MCF-7, KB, and human prostate) showed inhibitory effects above 50 µg/mL, confirming anticancer activity [60]. In 2009, B. Chengaiah reported dose-dependent anthelmintic activity. The alcoholic extract (50 mg/mL) caused paralysis in 20 minutes and death in 30 minutes in *Pheretima posthuma*, surpassing the efficacy of albendazole (10 mg/mL). However, this plant may cause toxic effects like acute hemolysis and methemoglobinemia [61].

11. Alternanthera sessilis Linn

This perennial herb, belonging to the Amaranthaceae family, is commonly found near ponds, reservoirs, and canals in the warmer regions of India. Known by various names such as sessile joy weed, dwarf copperleaf, Brazilian spinach, and matikanduri. The leaves and shoots are consumed raw, cooked, or as ingredients in traditional recipes. This plant contains vital nutrients, including vitamin B1, vitamin B2, protein (16.1 g per 100 g), lipids (0.74 g per 100 g), carbohydrates (73.2 g per 100 g), saturated fatty acids (70.2%), monounsaturated fatty acids (8.23–11.8%), and polyunsaturated fatty acids (15.1%) [62].

The phytoconstituents include phenolic content (503.04–500.22 mg CEQ/g), alkaloids (34.22–31.56 mg/g), flavonoids (42.11–39.97 mg/g), tannins (376.11–374.05 mg/g), saponins (81.13–78.85 mg/g), stigmasterol, campesterol, betasitosterol, and palmitate [63]. This plant is traditionally used to treat fever, wounds, diarrhea, gonorrhea, and ulcers. Methanolic extracts of the whole plant significantly altered lipid profiles in rats after 36 hours of carbon tetrachloride (CCl_4) induction, showing its potential for managing liver diseases [64]. In 2014, Mondal et al revealed that ethanolic extract of the plant decreased sleep duration and hastened sleep onset in mice during sleeping time tests. It also increased mouse movements in open field and hole cross tests and significantly suppressed the writhing response in the writhing test, indicating notable analgesic activity [65].

12. Amaranthus spinosus Linn

This plant, widely distributed in tropical and subtropical regions, is commonly known as Chaulai, spiny pigweed, spiny amaranth, and thorny amaranth. Belonging to the Amaranthaceae family, it has been used in Ayurvedic and traditional medicine to treat digestive, respiratory, and skin ailments. It is nutritionally rich, containing vitamin A, vitamin C, and minerals such as sodium (28.48–31.52 mg), potassium (2499.5–2500.5 mg), calcium (4499.07–4500.93 mg), iron (12.47–14.09 mg), protein (8.81–9.19 g), and carbohydrates (19.66–22.92 g) [66].

The plant is abundant in phytochemicals like rutin, beta-sitosterol, phenolic acids, lipids, steroids, linoleic acid, carotenoids, saponins, and amino acids. It is traditionally known for its anti-inflammatory, anti-diabetic, antiulcer, and anthelmintic properties. Bi-Fong Lin (2005) reported its water extract activated spleen cells in mice, indicating potent immunostimulant properties that could aid in immunology and pharmacology. In 2011, Jamaluddin Abu Taiab demonstrated its methanolic extract's antinociceptive effects in mice, reducing pain in thermal and chemical nociception models. In 2017, Shravani Potllapalli found its aqueous extract at 250–500 mg/kg increased sodium, potassium, and chlorine levels in rat urine and significantly enhanced urine volume, showing diuretic activity [67].

13. Cardiospermum halicacabum Linn

It is a weed that is widely distributed across the tropical and sub-tropical regions. It is growing up to 1200 m in the northwest Himalayas. It belongs to the sapindaceae family and is commonly recognized by various names such as ballon vine, heart's plea, Jyotishmati and Kaan Phuti etc. These are strongly overgrown annual herbaceous climbing plants and can even become rigid at the base. This plant also contains various phytochemical constituents like alkaloid, quinine, terpenoids, flavonoids, flavonoid glucuronides, flavonoid glycosides, and phenolic acids. Some of the fatty acids found in the seed of this plant are palmitic acid, arachidic acid, linolenic acid, stearic acid, eicosanoid acid, and oleic acid and some of the phytochemicals found in the different part of this plant are caffeic acid, luteolin-7-oglucuronide and coumaric acid etc. [68] This plant treats rheumatism, snake bites, skin diseases, and neurological disorders and offers therapeutic properties like antifungal, antibacterial, anticonvulsant, anticancer, anxiolytic, and antipyretic effects.[69]. M. Huang (2011) reported its ethanolic extract shows anti-inflammatory activity by suppressing TNF-alpha and nitric oxide. It also has antihyperglycemic effects, improving body weight and reducing blood glucose in diabetic rats. Its methanolic extract demonstrated neuroprotective activity by reversing scopolamine-induced amnesia in mice and reducing brain acetylcholinesterase activity, restoring learning and memory [70]. Additionally, its alcoholic extract showed anti-diarrheal properties by reducing fecal output in rats with castor oil-induced diarrhea.

14. Senna auriculata (L.) Roxb

This herb from the Fabaceae family, found in arid regions of India and Sri Lanka. Its nutritional content includes protein (9.54%), fiber (1.89%), moisture (11.73%), ash (5.51%), zinc (17.53 mg/kg), and iron (189.95 mg/kg)[71]. The plant is rich in phytochemicals such as alkaloids, flavonoids, phenolics, tannins, steroids, and saponins. Key contents include alkaloids (90.26–90.56 mg AE/g), flavonoids (155.67–157.61 mg quercetin/g), phenolics (153.79–157.09 mg GAE/g), and tannins (118.97–123.65 mg GAE/g). It exhibits therapeutic properties like antimicrobial, antiviral, antifungal, anti-inflammatory, and antibacterial effects.[72]. This plant also has the potential of providing various therapeutic effects such as antimicrobial, antiviral, antifungal, anti inflammatory, antibacterial effects etc. The extract induces apoptosis in A549 human lung cancer cells, demonstrating anti-cancer activity [73]. Rajendran Vijayakumar (2017) reported its ethanolic flower extract reduces LDL cholesterol in hyperlipidemic rats, showing anti-hyperlipidemic effects [74]. Gayathri Nambirajan (2022) highlighted its buds and blooms possess anti-diabetic properties, tested using a diabetic rat model [75].

15. Boerhaavia diffusa Linn

This herb, found throughout the Indian plains, belongs to the Nyctaginaceae family and is known as hogweed, gadapurna, red spider ling, and tarvine. The plant is rich in nutrients and phytochemicals, aiding in the treatment of inflammation, anemia, nephrological disorders, asthma, and jaundice. Its nutritional content includes protein (2.24–2.28%), moisture (78.06–86.38%), fiber (2.37–2.43%), vitamin C (39.02–50.58 mg/100g), vitamin B2 (17.75–26.25 mg/100g), and minerals like iron (0.011–0.013 mg/100g) and calcium (171.36–176.82 mg/100g).

Phytochemicals include flavonoids (14.11–14.17%), alkaloids (6.98–7.02%), tannins (20.13–20.27 mg/100g), phenols (225.59–225.69 mg/100g), saponins (13.97–14.035%), and oxalates(3.48–3.54 mg/g) [76]. Therapeutic properties include antioxidant, antiviral, anticonvulsant, hepatoprotective, and anticancer effects. The ethanolic

extract showed antidiabetic activity in hyperglycemic rats by reducing blood glucose and regenerating beta cells. Leaf juice demonstrated antinociceptive effects, and the methanolic extract exhibited antiproliferative activity, suppressing the growth of MCF-7 breast cancer cells.

16. Euphorbia hirta Linn

It is an herb that is abundantly distributed throughout India. It belongs to the Euphorbiaceae family and is recognized by various names such as asthma herb, snake weed, hairy spurge etc. This herb has long been used medicinally as an infusion or decoction to treat a variety of illness, such as coughs, diarrhea, asthma, kidney stones, peptic ulcers, and vomiting. This plant consists a rich source of phytochemicals and nutrients. The nutrient content reported were protein (1.1644 mg/g), carbohydrates (96.7 mg/g), ascorbic acid (25.15 mg/g), reducing sugar (0.00422 mg/g), moisture content (10.7%), and lipids (41.6 mg/g) etc [77].

The phytoconstituents found in this plant are phenols, flavonoids, sterol, terpenoid, tannins, volatile oils, carotenoids etc. [78] The total phenolic content reported in the leaves (204.22-208.12 mg GAE/g), flower (113.98-120.18 mg GAE/g), roots (81.96-84.34 mg GAE/g), and stem extract (63.98-67.42 mg GAE/g), and total flavonoid content reported in leaves (37.967-37.973 mg CEQ/g), flower (35.198-35.202 mg CEQ/g), roots (24.344-24.356 mg CEQ/g) and stem extract (24.116-24.124 mg CEQ/g) respectively [79], sterol compound reported were beta-sitosterol (1.203.56 mg/100g), cholesterol (0.41-3.36 mg/100g), campesterol (0.33-0.51 mg/100g) and stigmasterol (11.69-19.66 mg/100g) respectively [80]. This plant has the potential of providing various therapeutic uses such as antibacterial, anti-inflammatory, antiasthmatic, antioxidant, and antifungal activity etc. Rashmi in 2010 reported that ethanolic and petroleum ether extract of the plant possesses anti-diabetic activity by oral administration to alloxan induced diabetic and normal mice which resulted in decreasing the blood glucose level [81]. The ethanolic extract also possesses immunosupportive effect by administering it in T lymphocytes and Th1 cytokines which resulted in decreasing dose related primary antibody reaction and delayed hypersensitivity response [82]. Johnson in 1999 investigated the diuretic effects of leaf extract in rats given the diuretic drug acetazolamide.

17. Ageratum conyzoides Linn

This annual herb, belonging to the Asteraceae family, is widely distributed across India and other parts of the world, thriving in diverse environments from hills to plains. Known as goatweed, billygoat weed, whiteweed, and chickweed. It is used to treat ailments such as stomach ache, wound healing, leprosy, chest congestion, and anthelmintic issues.

Nutritional content includes protein (24.426–24.634%), ash (11.75–11.81%), fiber (18.867–18.913%), carbohydrate (36.804–36.816%), and minerals like sodium (88.154–88.846 mg/100g), magnesium (110.015–110.245 mg/100g), iron (22.441–23.019 mg/100g), calcium (220.427–220.773 mg/100g), and zinc (43.327–43.673 mg/100g) [98]. Phytochemicals include alkaloids (e.g., caffeic acid, pyrrolizidine alkaloids), flavonoids (e.g., quercetin, kaempferol), sterols (e.g., beta-sitosterol, stigmasterol), terpenes (e.g., alpha-pinene, beta-pinene), coumarins, and benzofurans (e.g., precocene I, precocene II) [83]. Therapeutic effects include analgesic, antipyretic, anticonvulsant, antioxidant, antiprotozoal, antihelminthic, gastroprotective, and hepatoprotective activities. Ethyl acetate extracts show anticancer potential against cell lines such as A-549 and P-388. Aqueous extracts reduce blood glucose levels in alloxaninduced diabetic rats, while ethanolic extracts exhibit hepatoprotective effects by mitigating oxidative stress in the liver. However, its use is limited due to toxicity that can adversely affect the kidneys and liver.

18. Phyllanthus niruri Linn

This plant, native to tropical coastal regions of India (Maharashtra, Kerala, Tamil Nadu, Andhra Pradesh), belongs to the Phyllanthaceae family and is known by names like gale of wind, chance pierre, and shatter stone. Its nutritional content includes 16.90% fiber, 14.74% protein, 7.33% ash, and minerals such as sodium (1.947mg/g), calcium (2.911mg/g), potassium (18.252mg/g), along with vitamins E (57.18mg/g), K (19.83mg/g), and B6 (0.234mg/g) [103]. Phytochemicals in the leaves include phenolics (11.85 mg GAE/100g), tannins (0.001g/100g), saponins (0.20g/100g), alkaloids (3.67g/100g), flavonoids (1.40g/100g), phytates (5.40g/100g), and oxalates (22.69mg/g) [84]. The plant is known for its medicinal properties, including the treatment of ulcers, diabetes, skin disorders, jaundice, chest pain, and wound healing. It exhibits hepatoprotective, antiviral, wound-healing, and antidiabetic activities. Studies have shown that the extract improves blood glucose and lipid metabolism in streptozotocin-induced diabetic mice [85], and Kumar S (2023) reported its antibacterial activity against

drug-resistant pathogens [86]. Okoli (2010) found that the extract inhibited ulcer formation induced by ethanol and indomethacin .

19. Bidens pilosa Linn

It is an annual herb in the Asteraceae family, and also known as black jack, Spanish needle, cobblers peg, and hitch hikers. It grows in warm, tropical and subtropical regions, including the Western Ghats, North-eastern India, Himalayan Foothills, Central India, and Southern India. The It is rich in nutrients, with crude fiber (18.13g/100g), crude protein (15.86g/100g), ash content (12.31g/100g), crude fat (7.49g/100g), and minerals like sodium (0.54mg/100g), calcium (0.39mg/100g), potassium (1.21mg/100g), and zinc (45.3mg/kg) [87].

Phytochemicals in the plant include alkaloids (1.29mg/100g), saponins (0.896mg/100g), glycosides (0.383mg/100g), tannins (0.085mg/100g), and phenols (0.206mg/100g) . Due to its nutrient and phytochemical content, it is used to treat inflammation, diabetes, ulcers, and hypertension. The plant shows potential therapeutic properties, including antifungal, anti-hyperglycemic, hepatoprotective, anti-inflammatory, antibacterial, anti-malarial, and antioxidant effects. Deba F. (2008) found that oils exhibited strong antibacterial and antifungal activity against several pathogens. Chien S.C. (2009) reported that methanol extract showed anti-diabetic effects in mice, lowering blood glucose levels and promoting insulin release.

20. Cleome viscose Linn

It is an annual herb from the Cleomaceae family, grows up to one-meter-tall and is known as Tick weed or Asian spider flower. It is found across India. The plant has glandular hairs, with 3-5 leaflets that are oval or elliptic in shape. Its nutritional content includes ash (5%), fiber (35%), carbohydrates (15.73%), lipids (35%), protein (2.77%), and minerals such as calcium (0.74 µg/ml), potassium (1.32 µg/ml), sodium (1.95 µg/ml), zinc (0.0513 µg/ml), and iron (2.592 µg/ml) [88]. Phytochemicals include alkaloids (3.92mg/g), phenols (15.23mg/g), saponins (4.72mg/g), tannins (7.38mg/g), triterpenoids (5.28mg/g), glycosides (3.65mg/g), anthraquinones (3.82mg/g), fatty acids (5.06mg/g), and flavonoids (14.52mg/g) [89]. It is used for treating rheumatoid arthritis, malaria, wounds, and hypertension, with therapeutic properties like anthelmintic, antiseptic, carminative, and cardiac stimulant effects. Bose (2011) reported its antibacterial activity against *Salmonella typhi*, *Streptococcus epidermidis*, and *Staphylococcus aureus* [90]. Singh H (2017) found that the petroleum ether extract ointment has strong wound-healing properties [91], and Devi B.P. (2002) confirmed its anti-diarrheal effects in rats.

21. Crotalaria verrucosa Linn

It is commonly known as blue rattlepod, belongs to the Fabaceae family. It is found across various regions of India, including the Eastern Ghats, Southern Ghats, Gangetic Plains and the North-eastern region. The plant is rich in nutrients, including protein (22.03-22.27%), carbohydrates (52.09-52.23%), crude fiber (4.39-4.77%), and crude lipid (1.25-1.31%), along with minerals like calcium (219.81-220.19mg/g), copper (11.77-12.23mg/g), iron (3.173.83mg/g), potassium (869.63-870.37mg/g), and sodium (633.68-634.32mg/g). Phytochemicals reported include flavonoids, glycosides, steroids, tannins, and saponins [92].

It is used to treat rheumatism, inflammation, skin allergies, and tetanus, and has therapeutic properties such as hepatoprotective, antidiabetic, antioxidant, anticancer, antibacterial, and wound-healing activities. Kumari M (2010) found that the aqueous extract promoted faster wound contraction and epithelial growth in rats, indicating woundhealing effects. Billah M (2020) reported its anti-inflammatory effects in rat paw edema and mouse ear edema models [93].

Discussion and conclusion

Edible weeds such as *Chenopodium album*, *Portulaca oleracea*, and *Amaranthus viridis* are rich in essential vitamins, minerals, and phytochemicals, offering cost-effective alternatives to expensive nutraceuticals. These plants are also beneficial in preventing and managing chronic diseases like cancer, diabetes, heart disease, and hypertension due to their antioxidant, anti-inflammatory, anticancer, and antidiabetic properties. Furthermore, these weeds grow abundantly in rural areas, providing a sustainable and easily accessible source of nutrition, thus reducing dependence on commercially grown crops and addressing food insecurity [94]. Many of these plants, such as *Trigonella foenumgraecum* and *Eclipta prostrata*, have demonstrated significant medicinal properties, offering an alternative to conventional treatments. Including edible weeds in traditional diets not only provides nutritional benefits but also revives healthy, locally rooted food practices. Additionally, these weeds present a sustainable food source that can reduce reliance on expensive or processed foods, benefiting low-income and rural populations [95].

However, managing weeds on small farms presents challenges, especially in India, where labor is scarce. Weeding is typically done by hand, and the National Rural Employment Guarantee scheme exacerbates labor shortages, leading to increased costs[96] . Identifying weeds accurately is also a critical challenge, as different plant species or parts may have varying chemical profiles and therapeutic properties. Integrated Weed Management (IWM) offers a sustainable approach by combining various control strategies to prevent resistance to any single method. Climate change further complicates weed management, as rising temperatures, CO_2 levels, and extreme weather events like droughts and floods may influence weed growth and herbicide effectiveness. Finally, understanding the biology and ecology of weeds is crucial for developing effective control strategies, particularly regarding seed germination, which can be suppressed or manipulated to improve weed management outcomes[97] .

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