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ETHNOMEDICINAL PLANTS OF THE GARO HILLS AS POTENTIAL SOURCES OF ANTICANCER AGENTS

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ABSTRACT

Cancer caused roughly 20 million new cases and 9.7 million deaths worldwide in 2022, and Meghalaya carries one of the heaviest oesophageal cancer burdens in India. Conventional treatment remains constrained by systemic toxicity and acquired drug resistance, which has renewed interest in plant-derived cytotoxic agents. The Garo Hills of Meghalaya fall within the Indo-Burma biodiversity hotspot and support a body of traditional plant knowledge held by Garo healers and passed on orally.This review examines 23 species from 20 families used in Garo ethnomedicine, drawing together ethnobotanical records, phytochemical profiles and published pharmacological data. Species were selected on documented traditional use among the Garo, available phytochemical characterisation and reported biological activity. Recorded constituents include alkaloids, flavonoids, terpenoids and phenolic acids, several of which act by inducing apoptosis, arresting the cell cycle and modulating NF-kB and related signalling pathways.The species separate into three groups by strength of evidence. Eight, among them *Citrus macroptera* and *Oroxylum indicum*, have measured cytotoxicity against cancer cell lines including HeLa, MCF-7 and HCT116. Five show antioxidant and anti-inflammatory activity consistent with chemopreventive potential but have not been tested directly against cancer cells. The remaining ten rest mainly on ethnobotanical record and genus-level evidence. Most data come from in vitro assays; in vivo work is sparse and clinical data absent. Bioassay-guided fractionation, selectivity indexing against normal cell lines and animal studies are the immediate priorities for this flora.

KEYWORDS: Garo Hills; ethnomedicine; anticancer; phytochemicals; apoptosis; Meghalaya.

1. INTRODUCTION

1.1 Global burden of cancer

Cancer ranks second among causes of death in many countries and is expected to overtake all others as cardiovascular treatment continues to improve.[1] GLOBOCAN recorded approximately 20 million new cancer cases and 9.7 million cancer deaths in 2022, with lung cancer both the most frequent diagnosis and the leading cause of cancer death; about one person in five develops the disease at some point.[2] Demographic change alone is projected to push global incidence to 35 million cases by 2050.[3]

India recorded an estimated 1,461,427 new cases in 2022, or 100.4 per 100,000 residents. Lung cancer predominates in men and breast cancer in women, and incidence is projected to rise 12.8% between 2020 and 2025.[4] Case numbers quadrupled between 1964 and 2012 as diagnostic methods and registry coverage improved, with wide variation between regions.[5] Hypopharyngeal and stomach cancers are common in Indian men, cervical and oral cancers in women.[6]

Meghalaya presents a sharper picture. Both men and women in the state face the highest oesophageal cancer risk in the country. Tobacco use accounts for much of it, with a smoking history in 67% of affected men and 43% of affected women.[7] Screening coverage is negligible, reaching roughly 0.2% of women and less among men, and low household income compounds late presentation.[8–10]

1.2 Cancer biology in brief

Cancer covers more than 200 genetically related diseases in which cells accumulate DNA damage and divide without normal restraint. The resulting tumours may be benign or malignant; malignant tumours invade surrounding tissue, seed distant sites through blood and lymph, and recur after treatment. Benign tumours do not metastasise but can still cause harm by compression or hormone secretion. With the exception of the leukaemias, most cancers form solid masses.[11–12]

The genetic and epigenetic changes behind this behaviour converge on a familiar set of capabilities: sustained proliferation, evasion of apoptosis, immune escape, angiogenesis and

metastatic spread. Each depends on signalling between the tumour and its surrounding microenvironment, which is why therapeutic strategies increasingly target that interface rather than the dividing cell alone.[13]

1.3 Limitations of conventional therapy

Surgery, radiotherapy, chemotherapy and hormone therapy have all improved survival, and all carry limits that shape the search for alternatives.[14] Radiotherapy damages surrounding tissue and suppresses immune function. Cytotoxic chemotherapy lacks selectivity between malignant and normal dividing cells, producing myelosuppression, mucositis and neuropathy. Surgical resection rarely removes every malignant cell, so local recurrence remains common. Hormone therapy improves quality of life in responsive tumours but loses effect as resistance develops.[1,15–17] Agents with wider therapeutic windows and lower systemic toxicity would address a real gap.

1.4 Ethnomedicine as a route to drug discovery

Ethnomedicine refers to medical knowledge developed and transmitted within an ethnic community.[18]It has fed modern pharmacology directly: Ayurveda, Siddha, Unani and traditional Chinese medicine have all yielded therapeutically useful compounds, though quality control and standardisation continue to limit their wider adoption.[18–23]

Plant secondary metabolites remain a productive source of new drugs. Ethnopharmacological leads narrow the search space, modern analytical methods identify the active constituents, and heterologous biosynthesis and genomic approaches address supply. Vincristine, vinblastine, paclitaxel and the podophyllotoxin and camptothecin derivatives all reached the clinic through systematic screening of plants already in traditional use, and all remain in oncology practice.[24]

1.5 Medicinal plants in cancer treatment

Plants supply flavonoids, alkaloids and other classes of compound with demonstrated antiproliferative activity, several of which are in clinical evaluation.[25–27] Cost matters here as much as pharmacology. Plant-derived agents are comparatively cheap to source and often better tolerated than cytotoxic chemotherapy, which is relevant in settings where treatment access is limited by income.[28–29] The World Health Organization has supported the integration of traditional medicine into primary healthcare on similar grounds.

2. ETHNOMEDICINAL PRACTICE AND PLANT DIVERSITY OF THE GARO HILLS

Northeast India occupies 7.7% of the country's land area and holds close to half of its endemic plant species. Varied terrain, soil and climate across short distances explain much of this concentration, and continued traditional land use has helped maintain it.[30–31]

Meghalaya carries tropical moist evergreen, semi-evergreen and moist deciduous forest across rolling hills, deep valleys and limestone country. Elevation ranges from 100 to 1,500 m, rising to Nokrek Peak at 1,418 m.[32] The Garo make heavier use of wild plants than the other communities of the state, and over 105 species are recorded in local use for food and medicine.[33–34]

The Garo Hills sit within the Indo-Myanmar biodiversity hotspot and combine high species richness with substantial endemism. Wild edible plants supply food, medicine and cash income to households across the district. The *Citrus* Gene Sanctuary within the Nokrek Biosphere Reserve protects the wild *Citrus* germplasm of the region and is the principal source of *Citrus indica*.[35]

Garo medical knowledge is transmitted orally and remains thinly documented. Traditional practitioners, known locally as Ojhas, treat a substantial share of primary complaints, and women in East Garo Hills in particular rely on Achik medicine where modern facilities are distant or poorly equipped.[36–37] Reluctance among practitioners to record their knowledge, often on personal or religious grounds, has limited systematic documentation, and the WHO Traditional Medicine Strategy identifies this as a general obstacle across the region.[38–39]

A survey of Garo healers in the Nokrek Biosphere Reserve conducted between 2007 and 2011 recorded 157 medicinal species used against 67 distinct complaints. Leaves, roots, rhizomes and tubers were the parts most often collected, and decoction was the commonest preparation. Respiratory complaints, cough and colds accounted for the largest share of treatments.[40]

Very few of these species have been screened for anticancer activity, and the gap between recorded local use and laboratory evidence is wide. Deforestation and changing livelihoods now threaten both the flora and the knowledge attached to it. Documenting and testing this material serves two purposes at once: it opens a route to new drug leads, and it preserves a

record of Garo botanical practice before it is lost. This review compiles the published ethnobotanical, phytochemical and pharmacological data for Garo ethnomedicinal plants and assesses their potential as sources of anticancer compounds.

2.1 Ethnomedicinal plants of the Garo Hills with anticancer potential

Twenty-three species from 20 families are treated here. All are used by Garo communities of the Garo Hills, and all have either published phytochemical characterisation, reported biological activity, or both. The set covers trees (*Oroxylum indicum*, *Baccaurea ramiflora*, *Elaeocarpus floribundus*), shrubs (*Clerodendrum glandulosum*, *Hibiscus sabdariffa*, *Phlogacanthus thyrsiformis*), climbers and rattans (*Haematocarpus validus*, *Calamus erectus*), herbs (*Amorphophallus paeoniifolius*, *Colocasia esculenta*), a fern (*Diplazium esculentum*) and a wild banana (*Musa flaviflora*). Families represented include Menispermaceae, Rutaceae, Acanthaceae, Myrtaceae, Dilleniaceae, Lamiaceae, Musaceae and Araceae. *Citrus indica* is of particular conservation interest, restricted to the Nokrek Biosphere Reserve. Species are ordered below from those with the strongest pharmacological record to those with least, and summarised in Table 1.

Citrus macroptera Montrouz

Citrus macroptera (Rutaceae) is known to the Garo as Chambal and grows mainly on the southern hill slopes of Meghalaya. Garo households use the juice and peel in meat dishes, pulses and pickles, and in treating gastrointestinal complaints, fever and food poisoning; the juice also serves as a wound antiseptic.[41] The fruit is boiled and bottled to keep through the year, and it holds a place in the Wangala harvest festival.[41–42]

Reported constituents include limonene, beta-caryophyllene, beta-pinene, geranial, edulinine, ribalinine and isoplatydesmine, with antioxidant, antimicrobial, hypoglycaemic, hepatoprotective, cardioprotective, anxiolytic, antidepressant and thrombolytic activity described across plant parts.[43–47]

Fruit pulp juice suppressed Ehrlich ascites carcinoma growth in mice by 19.5%, 49.2% and 68.9% at 25, 50 and 100 mg/kg respectively, acting through caspase-8, caspase-9, cytochrome c and caspase-3.[48] Fruit peel extract triggered apoptosis in human non-small cell lung cancer cells through both death receptor and mitochondrial routes. Methanolic leaf extracts were cytotoxic to SH-SY5Y neuroblastoma cells with IC50 values of 167.71 and 216.39 micrograms/ml at 24 hours.[49–50] Dichloromethane and n-hexane extracts were the

most active against MCF-7 breast adenocarcinoma, with additional activity against A549 lung and PC-3 prostate lines.[51]

Leaf extract reduced carrageenan-induced paw oedema in Wistar rats by 71% and lowered reactive oxygen species in HepG2 cells at 200 micrograms/ml, with stronger antibacterial effect against *Klebsiella* than Staphylococcus.[52] Docking placed proximadiol and menthone at NF-kB with binding affinities of -5.6 and -5.7 kcal/mol. Silver nanoparticles synthesised using fruit peel extract as reducing and capping agent measured 11 nm, were spherical and face-centred cubic, and catalysed reduction of 4-nitrophenol, methyl orange and methylene blue.[53–54] The combination of in vitro, animal and docking evidence makes this the best-supported species in the set.[47, 55–57]

Oroxylum indicum (L.) Kurz

The Indian trumpet tree (Bignoniaceae) is known to the Garo as Khering and is distributed across the Indian subcontinent and much of South and Southeast Asia, with a long record in Chinese, Indian, Burmese and Malay medical systems.[58–60] Garo households cook the young leaves as a vegetable and use them for liver complaints, particularly jaundice.[34]

Phytochemical work has identified baicalein, baicalin, chrysin, oroxylin A, and a range of flavonoids, xanthones, coumarins and phenolics.[61] Leaf extracts and isolated baicalein inhibited proliferation of glioblastoma multiforme cells in vitro. A systematic review attributed most of the reported anticancer, anti-inflammatory, cardioprotective, antibacterial, anti-hyperglycaemic, neurogenic and wound healing activity to baicalein specifically.[62]

Bark extract and its flavonoids inhibited lipid accumulation and pancreatic lipase activity in preadipocyte models.[63] Root preparations reduced amyloid burden, oxidative damage, apoptosis and tau pathology in Alzheimer models.[64] Leaf and pod extracts acted on inflammation and oxidative stress, while stem bark extracts increased collagen deposition and suppressed NF-kB and COX-II signalling, accelerating wound closure.[65–67] Clinical trials, standardised preparations and a conservation plan are the outstanding requirements.[68–72]

Flacourtia indica (Burm. f.) Merr.

Indian plum or governor's plum (Salicaceae) is a thorny deciduous shrub native to Africa and widespread across tropical and temperate Asia.[73] The Garo call it Ponial, eat the fully

ripened fruit, and use it as a digestive aid and diuretic and in treating jaundice and splenomegaly.[34,74]

Roots contain tannins, flavonoids, saponins, terpenoids, alkaloids, anthraquinones, phenols and reducing sugars. Ethanolic fruit extracts yielded 24 identified constituents, with N-hexadecanoic acid at 18.03%, and the leaves contain the phenolic glucosides flacourside, flacourtiosides A-F and xylosmin.[75–76]

Methanolic extract of the aerial parts induced apoptosis in HCT116 colon cancer cells at 500 micrograms/ml through reactive oxygen species generation, caspase-3 activation, PARP cleavage and cytochrome c release, with downregulation of Bcl-2, Bcl-xL and survivin. Anti-inflammatory activity was measured at 70% inhibition of protein denaturation and 64.23% HRBC membrane stabilisation, alongside hepatoprotective, antimalarial, antiasthmatic, antidiabetic and antimicrobial effects.[77–82] Bioassay-guided isolation of the active constituents is the logical next step.

Phlogacanthus thyrsiformis Nees

An evergreen shrub of the Acanthaceae bearing orange-red tubular flowers in upright spikes, distributed through the subtropical Himalaya and adjoining regions from Garhwal to Bhutan, including Northeast India.[83–84] The Garo know it as Allot, boil the flowers as a vegetable, and use the fruit against diabetes. Consumption of the flowers addresses seasonal food scarcity as well as the plant's reputed antidiabetic effect.[33, 85–87]

Water, ethanol and methanol leaf extracts contain alkaloids, saponins, phytosterols, phenols, tannins, flavonoids, coumarins and diterpenes. The aqueous extract gave the broadest profile, ethanol was richest in saponins, phenols, tannins and coumarins, and methanol in saponins, phenols and diterpenes.[88–89]

Methanolic leaf extract induced apoptosis in HeLa and MCF-7 cells, confirmed by nuclear fragmentation, DNA laddering, annexin V/PI staining with secondary necrosis, caspase-3 activation, mitochondrial swelling on TEM and membrane blebbing on SEM.[90] The same extract showed DPPH scavenging across 25-800 micrograms/ml, central and peripheral analgesia (55.73-72.81% hot plate inhibition and 42.17-56.63% reduction in writhing at 250-500 mg/kg) and inhibition of carrageenan-induced paw oedema.[87,89]

Houttuynia cordata Thunb.

Fish mint or chameleon plant (Saururaceae) is a perennial herb of damp shaded ground, widespread in Asia and particularly common in China and Japan.[91] It is eaten as a vegetable in several Asian countries and used against pneumonia, lung abscess, diarrhoea, colds, fever and mumps.[92] Garo speakers call it Matcha-duri and use young shoots and leaves for respiratory, diarrhoeal and inflammatory complaints.[93–94] Within Meghalaya it is eaten as an everyday food rather than reserved for medicinal use. A recent review of the state's traditional dietary plants places it among the species with antihypertensive and cardioprotective effect, and attributes that to flavonoid and phenolic constituents acting in combination with those of other plants eaten in the same meals.[95]

The plant contains flavonoids, alkaloids, volatile oils and organic acids. Quercetin, quercitrin, hyperoside, afzelin, sodium houttuyfonate and 2-undecanone reduce TNF-alpha, IL-1beta and IL-6 through NF-kB, MAPK, AMPK and cAMP signalling. Antiviral activity has been reported against HIV-1, H1N1, dengue virus and SARS-CoV.

Anticancer and immunostimulatory activity has been confirmed in vitro and in vivo, with extracts inducing apoptosis in cancer cells at low host toxicity. Activity against MRSA and other resistant organisms has also been documented, with organ-protective effects in the same models.[92,96–99]

Hibiscus sabdariffa L.

Roselle (Malvaceae) grows across tropical and subtropical Asia, Africa, Central America and the Caribbean and is used widely in beverages, food and traditional medicine.[100–102] The Garo call it Gal.da, eat the leaves, fruit and flowers as vegetables, pickles and jams, and use the plant for fever and physical weakness on account of its cooling and restorative reputation.[86,103–104]

The calyces are rich in anthocyanins, flavonoids, phenolic acids and organic acids.[105–106] Protocatechuic acid, hibiscus acid, hydroxycitric acid, delphinidin-3-sambubioside, cyanidin-3-sambubioside, quercetin and myricetin account for much of the measured activity.[107]

Extracts inhibited *Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis*, and showed antiproliferative activity against breast, ovarian, cervical and liver cancer lines.[108–111] Constituents inhibit mitosis and scavenge free radicals.[112–113] Alpha-glucosidase, alpha-

amylase and angiotensin-converting enzyme inhibition, together with vasorelaxant and calcium channel activity, underlie the antihypertensive and antidiabetic effects.[114–115] No significant toxicity has been reported at the doses tested,[116] though standardised in vivo and clinical work is still needed.

Ziziphus mauritiana Lam.

Indian jujube (Rhamnaceae) occurs in scrubland, tropical dry deciduous forest and urban settings across India, Asia and Africa.[117–118] The Garo call the mature fruit Kangkil and eat it raw or pickled. Seeds and other parts are used against inflammatory conditions, for wound healing and for digestive complaints.[86, 119]

Flavonoids, glycosides, phenols, lignin, saponins, sterols and tannins are the principal secondary metabolites, and are used in treating liver disease through cytotoxic, radical scavenging and antimicrobial activity.[120–121] Methanolic bark and leaf extracts showed antibacterial, antioxidant and enzyme-inhibitory activity, with bark preparations effective against *Staphylococcus aureus*.[122–123]

The dichloromethane bark fraction gave IC50 values of 3.8 micrograms/ml against NCI-H460 lung cancer and 5.0 micrograms/ml against MCF-7, with dose-dependent apoptosis, cell cycle arrest and modulation of p53, STAT and MMP pathways.[124–126] These results come from cell line and mechanistic models only; in vivo confirmation is outstanding.

Amorphophallus paeoniifolius (Dennst.) Nicolson

Elephant foot yam (Araceae) is known to the Garo as Songru. The species is cultivated commercially in India, Indonesia, China, the Philippines, Bangladesh, Malaysia and Sri Lanka and occurs across parts of Africa, the Pacific and South America.[86,127–128] Garo households boil the leaves, stems and corms thoroughly to destroy calcium oxalate crystals before eating them as a staple vegetable.[34]

The plant appears in Ayurvedic and tribal practice for chronic complaints, supported by a documented phytochemical profile and safety record.[129–130] Reported activities include analgesia from methanolic extract at 250-500 mg/kg, anti-inflammatory effect at 200-400 mg/kg, antibacterial and anthelmintic activity, and hepatoprotection from a quercetin-rich fraction.

Tuber extract produced dose- and time-dependent cytotoxicity in MCF-7 and MDA-MB-231 breast cancer cells and reduced migration, adhesion and invasion, most markedly in MDA-MB-231. Apoptosis proceeded through Bcl-2 downregulation, Bax and caspase-7 upregulation and PARP cleavage.[131] Ethyl acetate and butanol fractions carried most of the activity, with further work extending the findings to colorectal and cervical models.[132–133]

Elaeocarpus floribundus Blume

A member of the Elaeocarpaceae distributed from India and Myanmar through Indo-China to Java and Borneo, occurring wild and cultivated in humid semi-evergreen forest between 1,000 and 1,500 m in the Garo Hills.[134] The Garo know it as Jolpai, eat the mature fruit raw for its antioxidant properties, and use immature fruit in meals, chips and pickles.[135]

Ethanolic leaf extracts contain phenols, flavonoids, sterols and triterpenoids, with high total phenolic content.[134] Dibutyl succinate was the principal active constituent of the ethanolic extract and ethyl acetate fraction, inhibiting *Shigella dysenteriae*, *Candida albicans* and *Bacillus subtilis* at 60-90 micrograms/ml. Gallic acid was the most active single compound tested, effective against *B. subtilis* at 30 micrograms/ml.[136]

Myricitrin, eustifoline B and 3-n-nonadecanoyl-beta-sitosterol occur in the leaves at lower antibacterial potency; myricitrin is a strong alpha-amylase inhibitor with an IC50 of 2.32 plus or minus 0.6 micrograms/ml.[136–137] Methanolic leaf extract contained 149.28 mg quercetin equivalents per gram of flavonoids and gave an SPF of 45.47 at 1,000 mg/ml. Loliolide, cis-3-hydroxy-alpha-ionone and (3R)-3-hydroxy-beta-ionone showed phytotoxicity across 1.06-8.53 micromolar.[138] In vivo confirmation of anticancer activity has not yet been carried out.

Colocasia esculenta (L.) Schott

Taro (Araceae) is a perennial herb of tropical Southeast Asian origin, cultivated across the warmer parts of India and the tropics generally. The Garo call it Matchitagong.[139] Corms and leaves are boiled or steamed to remove calcium oxalate before eating,[140–141] and Garo practice applies a leaf paste to open wounds to stop bleeding.[142]

The corm supplies over 135 kcal per 100 g and more than twice the carbohydrate of potato, with roughly 11% protein on a dry weight basis, 85-87% starch, vitamin C, thiamine, riboflavin and niacin, calcium, phosphorus, iron, zinc and potassium, and high dietary

fibre.[143–145] Arabinogalactan mucilage from the tubers lowered serum and tissue cholesterol and triacylglycerols in rats by reducing hepatic VLDL synthesis and secretion.[146]

Flavonoids, phenolics, alkaloids, beta-sitosterol, steroids, glycosides, terpenoid saponins and the cystatin CeCPI have all been recorded.[147–150] Recombinant CeCPI completely inhibited mycelial growth of *Sclerotium rolfsii* at 150-200 micrograms/ml.[151] Daucosterol, thermopsoside, chrysoeriol 7-O-beta-D-neohesperidoside and orientin from methanolic leaf extract showed neuroprotective binding in excitotoxicity models.[152–154]

A 25 kDa protein inhibited breast cancer metastasis in vitro and in animal models. Ethanol extract gave 78.92% DPPH scavenging, and the plant showed inhibition of carrageenan-induced paw oedema and hypoglycaemic activity attributed to the cyanoglucoside linamarin.[155–157] In streptozotocin-diabetic mice, dasheen extract lowered blood glucose and improved intestinal disaccharidase and Na+/K+ ATPase activity.[158]

Baccaurea ramiflora Lour.

Burmese grape (Euphorbiaceae) is native to South and Southeast Asia, from southern China and Hainan through India, Nepal, Bhutan, Bangladesh and Myanmar to Thailand, Cambodia, Laos and Vietnam.[159–160] The Garo call it Gasampe. Communities of the Garo Hills and the Nokrek Biosphere Reserve eat the ripe fruit raw with salt or pickled, and use bark and leaves for skin complaints, diarrhoea and ulcers.[34,40,160]

Tannins, alkaloids, saponins, proanthocyanidins, phenolics, flavonoids and flavonols occur across rind, seed, leaf and bark.[139,161] Rosmarinic acid and related phenolics in the leaves account for measured antioxidant activity in both chemical and cell-based assays.[162–163]

Reported activities include antioxidant, cytotoxic, anti-inflammatory, analgesic, antidiarrhoeal, CNS-depressant, antidiabetic and antihyperglycaemic effects.[164–165] Leaf extract reduced carrageenan-induced paw oedema, and fruit fractions gave high DPPH scavenging.[166] Pulp and seed extracts were active in animal models of pain, inflammation and diarrhoea.[167–170]

Clerodendrum glandulosum Lindl.

East Indian glory bower (Lamiaceae, sometimes placed in Verbenaceae) is a perennial shrub of tropical and subtropical Asia, in India restricted to the northeast.[171–172] The Garo call it

Dongam and eat the cooked leaves with pork, beef and dal, using them to control hypertension.[34,173–175]

Verbascoside is the principal active constituent, with caffeic acid and a range of flavonoids also present. Leaf extracts scavenge free radicals and inhibit angiotensin-converting enzyme, xanthine oxidase, pancreatic lipase, alpha-amylase and alpha-glucosidase, which is consistent with long use against metabolic syndrome, diabetes, hypertension and obesity.[176–179]

The plant has a wide safety margin, with an LD50 above 5,000 mg/kg body weight and no cytotoxicity in HepG2 or L6 cell lines.[180] Aqueous preparations protected against carbon tetrachloride-induced liver damage, and silver nanoparticles biofunctionalised with leaf extract were active against pathogenic bacteria.[181] Direct anticancer testing has not been done.

Bauhinia purpurea Linn.

The purple orchid tree (Fabaceae) is native to the Indian subcontinent and Myanmar and introduced widely across the tropics.[182] The Garo call it Bol-Megong and use it against hypertension.[34,183–184]

Flavonoids, steroidal saponins, phenolic compounds, tannins and triterpenes support the recorded use in wound, respiratory, hepatic and inflammatory conditions.[182,185–187] Ethyl acetate extract gave the strongest hydroxyl radical scavenging, with an IC50 of 230 micrograms/ml against 1,050 micrograms/ml for petroleum ether. GC-MS identified stigmasterol at 34.48% and lupeol at 15.63% as the major constituents.[188]

The ethyl acetate partition of the methanol extract, rich in flavonoids, condensed tannins and triterpenes, lowered ALT and AST and restored hepatocyte histology in paracetamol-induced liver injury in rats.[189] Methanol and chloroform leaf extracts at 2.5% and 5% produced 50% wound contraction and increased breaking strength across excision, burn and incision models. Polyphenol- and flavonoid-enriched fractions FBP8, FBP9 and FBP10 at 25 mg/kg were active against carrageenan-induced paw oedema and adjuvant-induced arthritis.[190–191] Ethyl acetate leaf extract attenuated hyperoxia-induced acute lung injury by suppressing IL-1beta, TNF-alpha, IL-6 and COX-2, restoring SOD1, NRF2 and NQO1 expression and upregulating PPAR-gamma.[192]Anticancer potential is inferred rather than demonstrated.

Haematocarpus validus (Miers) Bakh. f. ex Forman

Blood fruit (Menispermaceae) occurs in Thailand, Bangladesh, Indonesia, Singapore, India and Pakistan.[193] Within India it grows in Tripura, Assam, Arunachal Pradesh, Sikkim, West Bengal and the Andaman and Nicobar Islands, with West Garo Hills a major centre of concentration.[194] The Garo call it Te.pattang or Tipatang. The sweet-sour blood-red pulp is eaten raw and used as a blood purifier.[34,195–196]

Methanol extracts of leaves and fruit are rich in phenolics, flavonoids and alkaloids including sinomenine, and showed DPPH scavenging and DNA protective activity consistent with the recorded hepatoprotective and anti-inflammatory uses.[197] HP-TLC spectrodensitometry measured choline at 197.81 mg per 100 g dry weight in fruit extract and above 500 mg per 100 g in leaf extract, which supports the hepatoprotective application since choline limits hepatic fat accumulation.[197]

Antioxidant, hepatoprotective, anti-inflammatory, anti-arthritic, antibacterial and cytotoxic activities have all been reported, and the alkaloid content makes the species a reasonable candidate for anticancer screening.[198–200]

Elaeagnus conferta Roxb.

Bastard oleaster or silver berry (Elaeagnaceae) is a dense prickly shrub of temperate Vietnam, Malaysia, southern China and India, occurring in lower temperate zones up to 2,100 m.[201] The Garo call the fruit Sokkua, Sukhwa or Chhokhua, eat it raw, use it in pickles and sell it locally, valuing it for antioxidant properties.[34,40,86]

The fruit contains flavonoids, carotenoids, phenolics and ascorbic acid, and is comparatively high in protein, carbohydrate and minerals, particularly potassium and magnesium, relative to other wild fruits of the region.[34,40,202] Measured DPPH activity and phenolic content indicate chemopreventive potential, and reported effects extend to anti-inflammatory, antifungal, antiviral, antibacterial, analgesic and hepatoprotective activity.[203–206] Dedicated cytotoxicity testing has not been reported.

Solanum kurzii L.

A perennial shrub of the Solanaceae occupying humid or partly shaded ground across tropical Asia, including Bhutan, India, Sri Lanka, Thailand and parts of China.[207] The Garo call it Kimka, cook the fruit as a vegetable and use it against diabetes.[35,183–184, 208]

The berry contains 14.60 mg gallic acid equivalents per gram of phenolics and 89.00 micromolar rutin equivalents per gram of flavonoids, with antioxidant activity of 30.75 micromolar per gram by ABTS and 257.74 micromolar per gram by DPPH.[209] The fruit is bitter, rich in sodium, potassium and calcium, and contains 14.95% protein. A separate assessment recorded total phenolic content of 26.38 mg gallic acid equivalents per gram of dry extract with correspondingly high DPPH scavenging.[210–211] Cytotoxicity data are absent.

Zanthoxylum oxyphyllum Edgew.

Prickly ash (Rutaceae) is a shrub of the Eastern Himalaya and Indo-Burma region, distributed through subtropical to temperate forest in Meghalaya, Arunachal Pradesh, Sikkim, Manipur and West Bengal, and into Bhutan, Nepal, China and Myanmar.[212] The Garo call it Me.Cheng, cook the leaves as a vegetable and use the seeds as an aromatic spice. Pastes and decoctions treat rheumatic pain, gastrointestinal complaints and toothache.[85–86,213–214]

Leaf extracts showed high antioxidant activity across DPPH, FRAP, ABTS, phosphomolybdate, reducing power and metal chelation assays, with the methanolic extract most active. Gallic acid was identified as the principal antioxidant on the basis of high radical stabilisation energy and low bond dissociation energy.[215] Ethanolic leaf extract was active in adjuvant-induced arthritis and carrageenan-induced paw oedema in rats. Stem bark alkaloids include zanthophylline, corydine, rhetsinine and zanoxyline.[212,216–217] Direct cytotoxicity testing is outstanding.

Dillenia scabrella Roxb. ex Wall.

A medium-sized tropical tree of the Dilleniaceae native to Northeast India, Bangladesh, Cambodia, Laos and Myanmar, with Assam and the Garo Hills at the western edge of its range.[218] The Garo of North Garo Hills call it Agatchi, use the bark to treat snakebite and prepare the fruit as a vegetable.[34,135,174]

Methanolic, ethyl acetate, ethanol and aqueous extracts of leaf and bark contain alkaloids, saponins, phenolic compounds, tannins, gums, flavonoids, steroids and carbohydrates, with phenolics present in every extract. Methanolic leaf and bark extracts gave 93% and 93.48% DPPH inhibition at 500 micrograms/ml, exceeding ascorbic acid at 92.5%. GC-MS identified 16 constituents including cyclotrisiloxane hexamethyl, 2,4,6-cycloheptatrien-1,3,5-bis-trimethylsilyl and trisiloxane-1,1,1,5,5,5-hexamethyl-3,3-bis-trimethylsilyl, which account

for the antioxidant and antimicrobial activity observed.[219–220] No anticancer bioactivity work has been published.

Eugenia claviflora Roxb.

Now accepted as *Syzygium claviflorum* (Roxb.) Wall. ex Steud. (Myrtaceae), distributed from northeast India and southern China to New Guinea and Australia in mixed dipterocarp, coastal, kerangas and peat-swamp forest up to 1,500 m.[221–222] The Garo call it Chambu and eat the mature fruit, using it to control blood glucose in diabetes.[34, 223]

Direct pharmacological data on this species are limited. Related Myrtaceae are better characterised: ethanolic leaf extracts of *Eugenia pyriformis*, *Myrcia laruotteana* and *Myrcia obtecta* showed high phenolic content and strong antioxidant activity in DPPH and ORAC assays,[224] and essential oils from *Eucalyptus* and related genera showed antioxidant and antifungal activity attributable to 1,8-cineole, alpha-pinene, beta-pinene and other oxygenated monoterpenes.[225] Whether *S. claviflorum* shares this profile has not been tested.

Citrus indica Tanaka

The Indian wild orange (Rutaceae) is an endangered species of northeastern India, concentrated in the Nokrek Biosphere Reserve in the Garo Hills and extending into Assam and adjoining Bangladesh.[226] It is a valuable wild genetic resource for cultivated *Citrus*.[227] The Garo call it Memang Narang and eat the ripe sour fruit raw with salt. The fruit carries cultural and spiritual significance and is used against smallpox, stomach ache and jaundice in people and cattle.[34,174]

The fruit contains flavonoids and related constituents with measurable antioxidant activity.[228] Micropropagated plantlets treated with sodium nitroprusside accumulated higher phytochemical content, showed improved scavenging of DPPH, hydrogen peroxide and superoxide radicals, and maintained membrane stability, which suggests a route to producing standardised antioxidant material without harvesting wild stock.[229] Genomic analysis has identified extensive shared gene content between *C. aurantifolia* and *C. indica*. Its endangered status makes ex situ propagation a precondition for any pharmaceutical development.[45,230–231]

Musa flaviflora N.W. Simmonds

The yellow-flower banana (Musaceae) is a wild species of the Himalayan foothills, common in Assam, Arunachal Pradesh, Meghalaya and parts of Nagaland, and particularly abundant in the Patkai and Garo Hills across a range of elevations.[232–234] The Garo call the fruit Te.rik and the inflorescence Sobok. Both are eaten, and the stem pith is processed into kalchi, a local alkaline food additive.[34–35] The species is also an important genetic resource within the genus (Čížková et al., 2015).

M. flaviflora itself has not been studied pharmacologically. Work on *M. acuminata*, *M. paradisiaca*, *M. sapientum* and *M. balbisiana* has identified phenolic acids, alkaloids, anthocyanins, catecholamines, carotenoids and glycosides.[235–239] Extracts of fruit, peel, flowers, bracts, leaves, pseudostem and unripe fruit have shown antioxidant, antimicrobial, anti-inflammatory, antidiabetic, antiulcer, immunomodulatory, antiallergic, anticancer and gastroprotective activity.[240–241] Pulp and peel extracts of *M. acuminata* inhibited Gram-positive bacteria, unripe plantain preparations were antiulcerogenic, and anthocyanin content supports food, pharmaceutical, nutraceutical and cosmetic application.[242–246] The wild species remain comparatively unexamined.[247]

Calamus erectus Roxb.

A self-supporting upright rattan of the Arecaceae reaching 3-4 m, found in subtropical and temperate hill ecosystems of the Eastern Himalaya and distributed across Sikkim, Arunachal Pradesh, Meghalaya, Assam, Tripura, Mizoram and Nagaland.[248]The Garo call the fruit Sokmil and use it in preserves and juice.[34, 183] Tender shoots are eaten raw in Ayurvedic practice for fever, haemorrhoids, dyspepsia and biliousness, and the fruit is taken as a functional food for its antiseptic and antibacterial reputation.[249–250]

C. erectus itself has not been tested against cancer cells. Related *Calamus* species contain alkaloids, tannins, flavonoids and steroids in the fruit. Methanol, petroleum ether and ethyl acetate extracts of *C. tenuis* fruit gave brine shrimp LC50 values of 25.53, 28.07 and 47.79 micrograms/ml, with the methanol extract showing antioxidant activity equivalent to 95 mg/g ascorbic acid by DPPH.[251] Antidiabetic, anthelmintic, antitumour and anti-inflammatory activity has been reported across the genus.

Diplazium esculentum (Retz.) Sw.

The vegetable fern (Athyriaceae) is native to tropical and subtropical Asia and the southwest Pacific, including the Himalayan and sub-Himalayan belt, where it is collected as a wild vegetable.[252] The Garo call it Me.Konchek or Gonginjak and cook the young fronds as a leafy vegetable. Leaf preparations and decoctions are used for body pain, musculoskeletal complaints and blood pressure regulation, consistent with reports from other Himalayan and Northeast Indian communities.[34,135,253]

Recorded constituents include alkaloids, flavonoids, saponins, tannins, phenolics, triterpenoids, steroids, glycosides and flavones.[254–255] Ethanol extract inhibited *Staphylococcus aureus* with zones of 6.52 and 5.55 mm and *Escherichia coli* at 5.11 and 4.37 mm, with weaker activity against *Pseudomonas aeruginosa* and *Staphylococcus epidermidis*. Brine shrimp assay gave an LC50 of 9,817.48 ppm, indicating low toxicity, and DPPH scavenging gave an IC50 of 131.03 ppm. Anti-inflammatory, analgesic, antifungal, antidiabetic, immunomodulatory, hepatoprotective and anti-leishmanial activity has been reported; dedicated anticancer studies are absent.

2.2 Summary of evidence

Table 1 sets out the local name, parts used, recorded traditional application, reported constituents and published pharmacological evidence for each of the 23 species. Figure 1 shows the species in the field.

Table 1: Garo Hills ethnomedicinal plants with anticancer potential: Garo names, traditional uses, reported bioactive compounds and pharmacological evidence.

SI No	Scientific Name	Garo Name	Parts Used	Traditional Uses	Reported Bioactive Compounds	Pharmacological Evidences
1	*Citrus macroptera* Montrouz.	Chambil/Chambal	Fruit pulp, Peel, Leaves	Consumed as food and medicine; used for stomach disorders, fever, food poisoning, wounds, antiseptic. Cultural significance in Wangala harvest festival.	Limonene, beta-caryophyllene, beta-pinene, geranial, edulinine, ribalinine, isoplatydesmine, proximadiol, menthone, flavonoids, phenolics	Fruit pulp juice: ~68.9% tumour inhibition at 100 mg/kg in EAC mouse model via caspase-8/-9/-3 mediated apoptosis. Peel extract: apoptosis induction in NSCLC via death-receptor and mitochondrial pathways. Leaf extract: IC50 ~167-216 µg/mL (neuroblastoma SH-SY5Y). Active against MCF-7, A549, PC-3 cells. Molecular docking: proximadiol and menthone bind NF-kB (-5.6 to -5.7 kcal/mol).
2	*Oroxylum indicum* (L.) Kurz	Khering	Leaves, Bark, Roots, Pods	Young leaves consumed as cooked vegetable; used for liver-related conditions (jaundice). Part of traditional pharmacopeias in India,China, Myanmar and Malay regions.	Baicalein, baicalin, chrysin, oroxylinA,flavonoids,xanthones, coumarins, phenolics	Leaf extracts and baicalein inhibit glioblastoma multiforme cells in vitro. Baicalein has anticancer, anti-inflammatory, cardioprotective, antibacterial, anti-hyperglycemic, neurogenic, and wound healing properties. Bark extract suppresses NF-kB and COX-II pathways. Root extracts neuroprotective against Alzheimer's disease.
3	*Flacourtia indica* (Burm. f.) Merr.	Ponial	Fruits, Roots, Leaves,	Ripened fruits consumed as digestive aid, diuretic; used to treat jaundice and	Tannins, flavonoids, saponins, terpenoids, alkaloids, anthraquinones, phenols,N-	Methanolic extract of aerial parts induces apoptosis in HCT116 colon cancer cells at

			Aerial parts	splenomegaly by Garo people.	hexadecanoic acid, phenolic glucosides (flacourside, flacourtiosides A-F, xylosmin)	500 µg/mL via ROS generation, caspase-3 activation, PARP cleavage, cytochrome c release, and downregulation of Bcl-2, Bcl-xL, and survivin. Anti-inflammatory, hepatoprotective, antimicrobial, and antidiabetic activities also reported.
4	*Phlogacanthus thyrsiformis* Nees	Allot	Leaves, Flowers	Flowers boiled and consumed as vegetable by Garo tribes. Fruits used to treat diabetes.	Alkaloids, saponins, phytosterols, phenols, tannins, flavonoids, coumarins, diterpenes	Methanolic leaf extract induces apoptosis in HeLa and MCF-7 cells via nuclear fragmentation, DNA laddering, annexin V/PI staining, caspase-3 activation, and ultrastructural alterations. Anti-inflammatory, analgesic (55.73-72.81% inhibition at 250-500 mg/kg), and antioxidant activities documented.
5	*Houttuynia cordata* Thunb.	Matcha-duri	Young shoots, Leaves	Used in traditional medicine for respiratory ailments, diarrhoea, inflammatory conditions, antiviral, antibacterial, and anti-leukemic properties.	Quercetin, quercitrin, hyperoside, afzelin, sodium houttuyfonate, 2-undecanone, flavonoids, alkaloids, volatile oils, organic acids	Anticancer and immunostimulatory activities confirmed in vitro and in vivo. Extract induced apoptosis in cancer cells. Reduces TNF-alpha, IL-1beta, IL-6 via NF-kB, MAPK, AMPK, and cAMP pathway modulation. Antiviral, antibacterial, and immunomodulatory effects with low toxicity documented.
6	*Hibiscus sabdariffa* L.	Gal.da	Leaves, Fruits,	Leaves, fruits, and flowers consumed as vegetables,	Anthocyanins (delphinidin-3-sambubioside, cyanidin-3-	Antiproliferative and cytotoxic effects against breast, ovarian,

			Flowers	pickles, and jams. Used by Garo people for body weakness and fever.	sambubioside), flavonoids (quercetin, myricetin), phenolic acids (protocatechuic acid),hibiscus acid, hydroxycitric acid	cervical, liver and other cancer cell lines. Antimitotic and antioxidant properties confirmed. Inhibition of alpha-glucosidase, alpha-amylase, and ACE. No significant toxicity. Further standardised in vivo and clinical trials needed.
7	*Ziziphus mauritiana* Lam.	Kangkil	Fruits, Bark, Roots, Seeds	Mature fruits consumed raw, used for pickles. Bark, fruits, roots and seeds used for inflammatory conditions, wound healing, and digestive disorders.	Flavonoids, glycosides, phenols, lignin, saponins, sterols, tannins, secondary metabolites with antioxidant, antibacterial, and cytotoxic properties	Dichloromethane bark fraction: IC50 3.8 µg/mL (NCI-H460 lung) and 5.0 µg/mL (MCF-7 breast cancer). Dose-dependent apoptosis induction, cell-cycle arrest, cytotoxicity via modulation of p53, STAT, and MMPs pathways reported. In vivo and clinical validation needed.
8	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Songru	Corms, Leaves, Stems	Leaves, stems, and corms consumed as vegetable after extensive boiling to remove calcium oxalate. Used in Ayurvedic and tribal medicine for tumours, liver ailments, and digestive disorders.	Quercetin-rich fraction, flavonoids, alkaloids, phenolics, saponins, tannins, terpenoids, steroids	Significant anticancer efficacy against colorectal, breast, and cervical cancer models via cytotoxic effects, apoptosis induction, and cancer cell migration inhibition. Petroleum ether extract non-toxic at 2500 mg/kg (mice). Hepatoprotective, analgesic, anti-inflammatory, antimicrobial, and antioxidant effects validated.
9	*Elaeocarpus floribundus* Blume	Jolpai	Fruits, Leaves, Seeds	Mature fruits eaten raw; immature fruits used for pickling, chips. Garo people	Phenols, flavonoids, sterols, triterpenoids (friedelin, epifriedelanol), myricitrin,	Strong in vitro cytotoxic effects against human cancer cell lines. Bioactive triterpenoids

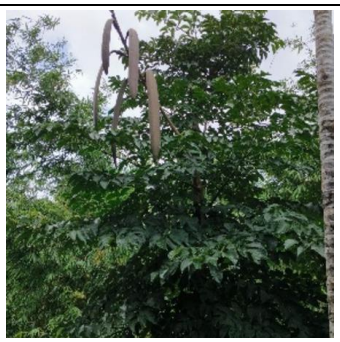
				consume mature fruits for antioxidant properties against cancer.	eustifoline B, 3-n-nonadecanoyl-beta-sitosterol, gallic acid, loliolide	identified as anticancer candidates. Gallic acid active against *B. subtilis* (MIC 30 µg/mL). Myricitrin: potent alpha-amylase inhibitor (IC50 2.32 µg/mL). In vivo validation of anticancer effects needed.
10	*Colocasia esculenta* (L.) Schott	Matchitagong	Corms, Leaves	Leaves used as paste/plaster on wounds. Corms and leaves boiled/steamed and consumed as staple food.	Flavonoids, phenolic compounds, alkaloids, beta-sitosterol, steroids, cystatin (CeCPI), daucosterol, thermopsoside, chrysoeriol 7-O-beta-D-neohesperidoside, orientin, cyanoglucoside (linamarin)	25 kDa protein inhibits breast cancer metastasis. Antioxidant: DPPH scavenging 78.92%. Anti-inflammatory: inhibition of carrageenan-induced paw oedema. Antidiabetic: hypoglycemic activity in STZ-diabetic mice. Antifungal: CeCPI fully inhibited *Sclerotium rolfsii*. Hypolipidaemic effects also documented.
11	*Baccaurea ramiflora* Lour.	Gasampe	Fruits, Leaves	Fruits eaten raw/pickled; skin disorders, diarrhoea	Phenolics, flavonoids, flavonols, proanthocyanidins, tannins, alkaloids, saponins, rosmarinic acid, anthocyanins	Antioxidant, anti-inflammatory, analgesic, antidiarrheal, CNS-depressant, antidiabetic and antihyperglycemic effects reported. Cytotoxic activity evaluated. Good DPPH scavenging activity and rich phenolic profile support chemopreventive potential.
12	*Clerodendrum glandulosum* Lindl.	Dongam	Leaves	Leaves consumed as vegetables with pork, beef and dal. Conventionally used by Garo communities	Verbascoside, caffeic acid, flavonoids; rich antioxidant polyphenols	Non-cytotoxic in HepG2 and L6 cell lines; LD50 >5000 mg/kg. Significant antioxidant, antidiabetic, antihypertensive

				as traditional remedy for blood pressure and hypertension.		(ACE inhibition), and hepatoprotective effects. Antibacterial silver nanoparticles synthesised using leaf extract. Direct anticancer studies limited.
13	*Bauhinia purpurea* Linn.	Bol-Megong	Leaves, Bark, Flowers	Ethnomedically used to manage hypertension by Garo communities. Antioxidant flavonoids and phenolic compounds assist in regulating blood pressure.	Lupeol,stigmasterol, flavonoids, condensed tannins, triterpenes, polyphenols, steroidal saponins	Ethyl acetate extract: antioxidant (hydroxyl radical scavenging IC50 = 230 µg/mL). Hepatoprotective against paracetamol-induced liver injury. Anti-inflammatory and anti-arthritis fractions. Leaf extract protects against hyperoxia-induced acute lung injury. Anticancer potential inferred; direct cancer cell studies needed.
14	*Haematocarpus validus* Bakh. f. ex Forman	Te.pattang/Tipatang	Fruits, Leaves	Used by Garo tribe as anti-inflammatory, liver protectant, and blood purifier. Raw fruits used for heart problems, infections, liver diseases, and anaemia.	Alkaloids, phenolics, flavonoids, anthocyanins (pelargonidin, cyanidin, peonidin), choline, anthraquinones	Methanolic leaf/fruit extracts show significant DPPH scavenging and DNA-protective activity. High choline content validated by HP-TLC spectrodensitometry. Alkaloids with documented anticancer and antioxidant activity. Chemopreventive potential indicated.
15	*Elaeagnus conferta* Roxb.	Sokkua, Sukhwa, Chhokhua	Fruits	Fruits consumed fresh and pickled	Carotenoids, flavonoids, ascorbic acid, phenolics, vitamins C and E, potassium, magnesium	Potent DPPH radical scavenging activity demonstrated. Anti-inflammatory, antifungal, antiviral, antibacterial,

						analgesic, hepatoprotective, and anti-tumour/anticancer potential reported. Further dedicated anticancer studies warranted.
16	*Solanum kurzii* L.	Kimka	Fruits	Fruits used medicinally to treat diabetes; also prepared as vegetables. Used in Garo Hills for nutritional and medicinal value.	Phenolic compounds, flavonoids, proteins, minerals (Na, K, Ca), alkaloids	Significant DPPH radical scavenging activity (257.74 µM/g) and ABTS activity (30.75 µM/g). High total phenolic and flavonoid content indicate antioxidant and nutraceutical potential. Dedicated cytotoxicity studies lacking.
17	*Zanthoxylum oxyphyllum* Edgew.	Me.Cheng	Leaves, Seeds, Stem bark	Leaves used as culinary vegetable; seeds used as spice. Decoctions/pastes used for rheumatic pain, toothaches, and gastrointestinal disorders.	Gallic acid, zanthophylline, corydine, rhetsinine, zanoxyline, flavonoids, tannins, terpenoids	Methanolic leaf extract exhibited high antioxidant activity across DPPH, FRAP, ABTS and related assays; gallic acid identified as principal bioactive. Ethanolic extract showed anti-inflammatory activity in rat models. Direct cytotoxicity studies needed.
18	*Dillenia scabrella* Roxb. ex Wall.	Agatchi	Fruits, Leaves, Bark	Bark traditionally used by Garo tribe in North Garo Hills for snake bite treatment. Fruits prepared as a vegetable.	Alkaloids, saponins, phenolic compounds,tannis, flavonoids, steroids, carbohydrates; GC-MS identified 16 compounds including cyclotrisiloxane hexamethyl and related silylated terpenoids	Methanolic leaf and bark extracts showed 93% and 93.48% DPPH inhibition at 500 µg/mL, exceeding ascorbic acid. Antibacterial and antimicrobial properties demonstrated. Dedicated anticancer bioactivity studies absent.
19	*Eugenia claviflora* Roxb.	Chambu	Leaves, Fruits	Ripe fruits consumed as food; used to control blood	Phenolic compounds, flavonoids, 1,8-cineole, alpha-	Direct pharmacological data limited. Related Myrtaceae

				glucose levels in diabetic patients by Garo communities of the Garo Hills.	pinene, beta-pinene, oxygenated monoterpenes	species exhibit strong antioxidant, phenolic, and antifungal properties. Further phytochemical and anticancer studies on this species are needed.
20	*Citrus indica* Tanaka	Memang Narang	Fruits, Peel	Ripe fruits eaten raw with salt. Used to heal smallpox, stomach problems, and jaundice. Cultural and spiritual significance among Garo people. Endangered species in Nokrek Biosphere Reserve.	Flavonoids, limonoids, flavanones, phenolics, antioxidant bioactive compounds	In vitro studies on micropropagated plantlets with SNP treatment showed enhanced phytochemical accumulation, increased antioxidant capacity and membrane stability. Specific anticancer studies absent; conservation and pharmaceutical interest high.
21	*Musa flaviflora* N.W. Simmonds	Te.rik (fruits)/Sobok (inflorescence)	Fruits, Leaves, Flowers	Edible fruits and inflorescence consumed as nutritional food sources. Stem-pith used to make the local alkaline food additive (kalchi). Supports food and nutritional security.	Phenolic compounds, flavonoids, antioxidant constituents, minerals, vitamins, nutritional compounds; alkaloids, tannins, saponins, terpenoids	Species-specific pharmacological studies remain limited. Wild *Musa* species assessments reveal significant nutritional and nutraceutical value. Related *Musa* species demonstrate antioxidant, antimicrobial, anti-inflammatory, antidiabetic, antiulcer, immunomodulatory, anticancer and cardioprotective properties.
22	*Calamus erectus* Roxb.	Sokmil	Fruits, Shoots	Fruits and shoots consumed as food	Alkaloids, tannins, flavonoids, steroids, phenolics, vitamin C, cytotoxic compounds	Specific *C. erectus* anticancer studies are limited. Related species *Calamus* tenuis fruit methanol extract showed strong

						cytotoxicity (LC50 25.53 µg/mL, brine shrimp assay) and strong antioxidant activity. Anti-tumor and chemopreventive potential reported.
23	*Diplazium esculentum* (Retz.) Sw.	Me.konchek/Gonginjak	Young fronds	Young fronds cooked and consumed as leafy vegetable. Leaf decoctions used for musculoskeletal pain, body aches, and blood pressure regulation.	Alkaloids, flavonoids, saponins, tannins, phenolics, triterpenoids, steroids, glycosides, flavones; high protein content	Brine shrimp assay: non-toxic (LC50 9817.48 ppm). DPPH antioxidant: IC50131.03 ppm. Bacteriostatic against S. aureus and E. coli.Antiinflammatory, analgesic,antifungal, antidiabetic,immunomodulatory, hepatoprotective and anti-leishmanial potential reported. Dedicated anticancer studies absent.

 (a) *Citrus macroptera* Montrouz.	 (b) *Oroxylum indicum* (L.) Kurz	 (c) *Flacourtia indica* (Burm. f.) Merr.
 (d) *Phlogacanthus thyrsiformis* Nees	 (e) *Houttuynia cordata* Thunb.	 (f) *Hibiscus sabdariffa* L.
 (g) *Ziziphus mauritiana* Lam.	 (h) *Amorphophallus paeoniifolius* (Dennst.) Nicolson	 (i) *Elaeocarpus floribundus* Blume
 (j) *Colocasia esculenta* (L.) Schott	 (k) *Baccaurea ramiflora* Lour.	 (l) *Clerodendrum glandulosum* Lindl.
 (m) *Bauhinia purpurea*	 (n) *Haematocarpus validus*	 (o) *Elaeagnus conferta*

Linn.	(Miers) Bakh. f. ex Forman	Roxb.
 (p) *Solanum kurzii* L.	 (q) *Zanthoxylum oxyphyllum* Edgew.	 (r) *Dillenia scabrella* Roxb. ex Wall.
 (s) *Eugenia claviflora* Roxb.	 (t) *Citrus indica* Tanaka	 (u) *Musa flaviflora* N.W. Simmonds
 (v) *Calamus erectus* Roxb.	 (w) *Diplazium esculentum* (Retz.) Sw.	

Figure 1: Ethnomedicinal plants of Garo Hills with reported anticancer potential.

Figure 1: Ethnomedicinal plants of the Garo Hills with reported anticancer potential. (a) *Citrus macroptera* Montrouz., (b) *Oroxylum indicum* (L.) Kurz, (c) *Flacourtia indica* (Burm. f.) Merr., (d) *Phlogacanthus thyrsiformis* Nees, (e) *Houttuynia cordata* Thunb., (f) *Hibiscus sabdariffa* L., (g) *Ziziphus mauritiana* Lam., (h) *Amorphophallus paeoniifolius* (Dennst.) Nicolson, (i) *Elaeocarpus floribundus* Blume, (j) *Colocasia esculenta* (L.) Schott, (k) *Baccaurea ramiflora* Lour., (l) *Clerodendrum glandulosum* Lindl., (m) *Bauhinia purpurea* Linn., (n) *Haematocarpus validus* (Miers) Bakh. f. ex Forman, (o) *Elaeagnus conferta* Roxb., (p) *Solanum kurzii* L., (q) *Zanthoxylum oxyphyllum* Edgew., (r) *Dillenia scabrella* Roxb. ex Wall., (s) *Eugenia claviflora* Roxb., (t) *Citrus indica* Tanaka, (u) *Musa flaviflora* N.W. Simmonds, (v) *Calamus erectus* Roxb., (w) *Diplazium esculentum* (Retz.) Sw.

3. DISTRIBUTION AND TRENDS

Rutaceae is the best-represented family in the set, with *Citrus macroptera*, *Citrus indica* and *Zanthoxylum oxyphyllum*, followed by Araceae with *Amorphophallus paeoniifolius* and *Colocasia esculenta*. Fruits and leaves are the parts most often used, which follows from a pattern of collecting wild and semi-cultivated fruit as food that carries a medicinal reputation alongside it. Roots and bark appear less often but attach to more serious indications: jaundice, tumours and chronic illness in *Ziziphus mauritiana* and *Flacourtia indica*.

Decoction, raw consumption, boiling and paste application account for nearly all Garo preparation methods. These map reasonably well onto the aqueous and alcoholic fractions used in laboratory screening, which means published extract data are broadly relevant to the traditional preparation rather than testing a different material altogether. Species with recorded use against tumours, for blood purification or to check abnormal growth tend to show high antioxidant activity and phenolic content in vitro, so the biochemical evidence supports at least part of the ethnomedicinal classification.

3.1 Phytochemical patterns

Flavonoids, phenolics, alkaloids, terpenoids, tannins, saponins, glycosides, coumarins, carotenoids and essential oils recur throughout the set. Flavonoids are the most widely distributed class, present in *Citrus macroptera*, *Houttuynia cordata*, *Phlogacanthus thyrsiformis*, *Hibiscus sabdariffa*, *Oroxylum indicum*, *Bauhinia purpurea*, *Elaeagnus conferta* and *Flacourtia indica*, and are associated with apoptosis induction, anti-inflammatory and antiproliferative effects.

Phenolic compounds occur at comparable levels in *Haematocarpus validus*, *Solanum kurzii*, *Zanthoxylum oxyphyllum*, *Dillenia scabrella* and *Clerodendrum glandulosum*, where they act mainly by lowering oxidative stress. Alkaloid content is highest in *Phlogacanthus thyrsiformis*, *Houttuynia cordata*, *Zanthoxylum oxyphyllum* and *Calamus erectus*. This matters more than the raw distribution suggests, since a large share of clinically approved plant-derived anticancer drugs are alkaloids. Terpenoids in *Flacourtia indica*, *Phlogacanthus thyrsiformis*, *Bauhinia purpurea* and *Citrus macroptera* act on proliferation, cell death and metastasis.

Several species carry specific compounds with established anticancer activity: baicalein, baicalin, chrysin and oroxylin A in *Oroxylum indicum*; quercetin and hyperoside in

Houttuynia cordata; anthocyanins and protocatechuic acid in *Hibiscus sabdariffa*; gallic acid in *Zanthoxylum oxyphyllum*; and limonene and beta-caryophyllene in *Citrus macroptera*. The overall weighting toward flavonoids and phenolics points to antioxidant-mediated mechanisms as the dominant route in this flora.

3.2 Strength of the anticancer evidence

The 23 species fall into three groups. Eight have been tested directly against cancer cells with measured IC50 values: *Citrus macroptera*, *Oroxylum indicum*, *Flacourtia indica*, *Phlogacanthus thyrsiformis*, *Houttuynia cordata*, *Hibiscus sabdariffa*, *Ziziphus mauritiana* and *Amorphophallus paeoniifolius*. These are the candidates worth advancing first.

Five more show antioxidant, anti-inflammatory and antimicrobial activity together with a bioactive profile consistent with chemoprevention, but have not been assayed against cancer cells: *Elaeocarpus floribundus*, *Colocasia esculenta*, *Baccaurea ramiflora*, *Clerodendrum glandulosum* and *Bauhinia purpurea*. Screening these would be inexpensive relative to the information gained.

The remaining ten rest on ethnobotanical record, genus-level evidence or antioxidant data alone: *Solanum kurzii*, *Zanthoxylum oxyphyllum*, *Dillenia scabrella*, *Eugenia claviflora*, *Citrus indica*, *Musa flaviflora*, *Calamus erectus* and *Diplazium esculentum* among them. Chemically the Garo Hills flora compares well with ethnomedicinal plants documented elsewhere in Northeast India and Southeast Asia. What separates it is the near-absence of cell line and animal work, which is a gap in the literature rather than a judgement on the plants.

3.3 Correspondence between traditional use and laboratory findings

Ethnobotanical leads have produced vincristine, vinblastine, paclitaxel and the camptothecin derivatives, so testing recorded traditional use against laboratory assay is a reasonable discovery strategy rather than a retrospective exercise. Within this set the correspondence holds up in several cases. *Citrus macroptera*, used for wound healing and gastrointestinal complaints, shows anti-inflammatory, antioxidant and apoptosis-inducing activity. *Oroxylum indicum*, used against liver disorders, yields baicalein and oroxylin A with measured anticancer effect. *Flacourtia indica*, used for jaundice and digestive complaints, induces apoptosis in colon cancer cells. *Houttuynia cordata* and *Phlogacanthus thyrsiformis* both show cytotoxic and apoptosis-inducing activity across several cancer cell lines.

The correspondence is partial, though. Most available data stop at phytochemical screening, antioxidant assays, in vitro cytotoxicity and preliminary animal work. Clinical validation in human subjects is absent across the whole set, and for most species the compound responsible for a given effect has not been isolated and characterised.

3.4 Limitations

This review draws only on published scientific literature, which underrepresents Garo ethnomedical knowledge held by Ojhas and transmitted orally. Comparison between studies is complicated by inconsistent plant identification, varied solvent systems, different cancer cell lines and non-standard assay methods. For several taxa known only from ethnobotanical survey, the anticancer evidence is inferred from related species rather than measured on the plant itself, and that inference should not be read as efficacy.

Two further gaps matter for anyone planning follow-up work. Selectivity indices comparing cytotoxicity in cancer versus normal cells are rarely reported, so therapeutic windows cannot be estimated from the published data. And Garo healers commonly use polyherbal preparations, whereas almost all the laboratory work tests single species, leaving possible synergistic effects unexamined.

4. CONCLUSION AND FUTURE PROSPECTS

Twenty-three species used in Garo ethnomedicine carry phytochemical profiles and pharmacological activity relevant to cancer treatment and prevention. Flavonoids, phenolics, alkaloids, terpenoids, tannins, coumarins, carotenoids and glycosides occur throughout. *Citrus macroptera*, *Oroxylum indicum*, *Houttuynia cordata*, *Hibiscus sabdariffa*, *Phlogacanthus thyrsiformis* and *Flacourtia indica* showed antioxidant, anti-inflammatory, cytotoxic, antiproliferative and apoptosis-inducing effects under experimental conditions. For these species the laboratory evidence supports some of the therapeutic applications recorded in Garo practice.

The Garo Hills flora is worth attention for a specific reason rather than a general one: it combines high endemism with documented traditional use and almost no pharmacological screening. *Citrus indica*, confined to the Nokrek Biosphere Reserve, is endangered and narrowly distributed, which puts a time limit on the work.

Four lines of work would advance the field. Bioassay-guided fractionation should isolate the active constituents from the eight species with confirmed cytotoxicity and establish their mechanisms, including apoptosis, cell cycle arrest, angiogenesis inhibition and metastasis suppression. In vivo studies should establish efficacy, pharmacokinetics and safety, with selectivity indices against normal cell lines reported as standard. Omics methods and nanoparticle delivery systems can address the bioavailability problems that limit most plant-derived cytotoxics. And documentation of Garo botanical knowledge should proceed alongside the laboratory work, since habitat loss and changing livelihoods are eroding both the flora and the knowledge attached to it. Research designed jointly with Garo communities, with benefit-sharing agreed at the outset, is the appropriate framework for that.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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