# The NEHU Journal

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**From the Desk of the Chief Editor**

The landscape of academic inquiry in the 21st century is defined by an unprecedented merging of disciplines, perspectives, and technologies. Knowledge, once neatly contained within the boundaries of singular fields, now expands through dynamic interactions between diverse domains. It is within this rich and evolving context that *The NEHU Journal* continues to position itself as a space where scholars from across disciplines converge to generate meaningful dialogue, original insights, and new possibilities for collective understanding. As we present this issue *The NEHU Journal, Vol. XXII, No. 1 & 2, 2024 (2025),* I reaffirm our commitment to promoting high-quality research that not only reflects the breadth of contemporary academic engagement but also speaks to the unique social, cultural, environmental, and intellectual realities of our region and beyond. This issue of *The NEHU Journal* reflects that ethos by bringing together contributions from the social sciences, humanities, environmental studies, technology, education, and health sciences, among other domains. Each article undergoes a rigorous peer-review process involving experts from various disciplines, ensuring that research meets the standards of clarity, originality, and methodological soundness.

I wish to recognize the exceptional work of both the Guest Editors, Prof. Nirmalendu Saha, Department of Zoology, NEHU and Dr. S. Majaw, Department of Biotechnology and Bioinformatics, NEHU and our editorial team whose efforts have been instrumental in preserving the publication's high standard of academic rigor and integrity. I remain deeply grateful to the reviewers who dedicate their time and expertise to strengthening the quality of published work. Their thoughtful assessments and constructive critiques uphold the scholarly integrity of *The NEHU Journal* and contribute significantly to its reputation. Likewise, I extend my appreciation to the authors who trust this journal with their research. Their intellectual contributions are at the heart of every issue and help shape the journal's identity as a credible space for multidisciplinary scholarship.

In closing, I extend my gratitude to everyone who has contributed to the making of this issue—the authors, reviewers, editorial board members, production team, and our readers. I hope that the articles presented here will inspire inquiry, stimulate debate, and foster new collaborations. I would like to encourage all the readers to explore the diverse ideas contained within these pages and to join us in celebrating the spirit of academic curiosity, critical reflection, and collaborative knowledge that defines *The NEHU Journal*.

**Prof. Fameline K. Marak**
Chief Editor

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# ***Ex situ*** **conservation strategies for *Spathoglottis plicata* Blume- an orchid of ornamental and medicinal importance**

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**Abstract**

*Spathoglottis plicata Blume is an important orchid having tremendous medicinal and ornamental values. The presence of numerous bioactive compounds such as alkaloids, flavonoids, terpenoids, saponins, phenols, tannins, etc., has been reported. In addition, anti-microbial and anti-inflammatory properties have also been reported in this species. S. plicata is extensively used in traditional medicines for curing various human ailments and diseases. Due to its significant role in traditional medicines and horticulture, it is highly sought after. As such, it has been extensively exploited and its natural population is decreasing at an alarming rate. Therefore, conservation of this remarkable orchid is of great importance. In the recent past, tissue culture techniques such as micropropagation and artificial seed production have been employed for its conservational purposes. The current review aims to provide a concise report on the ex situ conservation strategies employed for the conservation of S. plicata.*

**Keywords:** *Spathoglottis plicata*, micropropagation, artificial seeds, protocorm-like bodies, conservation.

## Introduction

The genus *Spathoglottis*, consisting of 49 terrestrial, sympodial species, spans a geographical range from India through Southeast Asia, reaching as far as Australia and the Pacific Islands, and occurs at altitudes from sea level to 3500 meters (Teoh 2022; Talkah et al. 2024). The generic name is derived from the Greek words: '*spathe*' (broad blade) and '*glotta*' (tongue) referring to the broad midlobe of the lip (Teoh 2016, 2022). The species belonging to this genus have tall, upright inflorescences with multiple flowers that open in succession on a comparatively short rachis and have multiple petiolate, elliptic, plicate, membranous leaves. The plant blooms for several months. *Spathoglottis* grows well under full sunlight among ferns and grasses.

*Spathoglottis plicata* Blume is a highly variable and widely distributed species. It is corm-like, above ground, 3 × 1.5–2 cm pseudobulbs are covered in sheaths. The linear-lanceolate, pleated leaves wrap around the pseudobulb and measure between 30 cm and 80 cm in length and 5-7 cm in breadth. Either inflorescences or new pseudobulbs arise from the pseudobulb's axillary buds (Teoh 2016, 2022). *S. plicata* is valued for both its aesthetic appeal and therapeutic qualities and blooms bright flowers all year long, which makes it a popular ornamental plant (Haque and Ghosh 2017; Bhowmik and Rahman 2020) (Fig.1a, b).

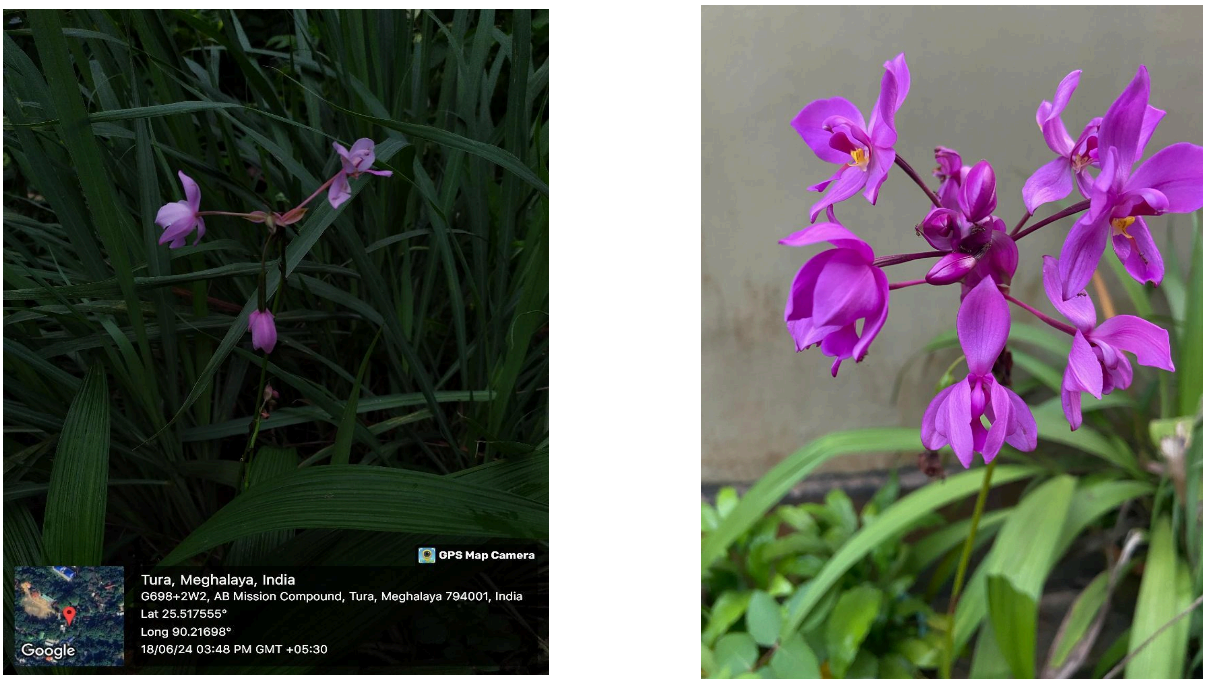


**Fig. 1. a) Spathoglottis plicata in its natural habitat, b) Flowers of S. plicata.**

## Medicinal and economic importance

Numerous bioactive substances, including alkaloids, flavonoids, terpenoids, saponins, phenols and tannins, have been isolated from *S. plicata* through phytochemical screening, suggesting its potential medical properties (Bhowmik and Rahman 2020). Further, the presence of phenolic compounds, terpenoids, steroids and coumarins indicates that *S. plicata* shares a large number of phytochemicals that are frequently found in medicinal plants for their anti-microbial and anti-inflammatory activities (Bhowmik and Rahman 2020). The use of this orchid to treat different human ailments has been reported. In India, the decoction of *S.*

*plicata* is used in the treatment of rheumatism (Mollik *et al.* 2009). In Indonesia, it has been used in treating non-painful limb swelling (Teoh 2016). Dagar and Dagar (2003) have reported its use in alleviating earache. Even its powdered seeds are used in place of *bedak* (jasmine-perfumed rice flower) for lightening the complexion of children (Teoh 2016).

**Declining population of *Spathoglottis plicata***

Several significant anthropogenic, biological and ecological factors influence the populations of *S. plicata*. Even though *S. plicata* is known to be capable of both outcrossing and self-pollination, self-pollination in isolated populations can eventually limit genetic variety (Ginibun *et al.* 2018). *S. plicata* usually multiplies by dividing pseudobulbs, however this mode of multiplication is slow and time taking. Also, habitat degradation such as construction, erosion, extensive collection and adverse environmental changes has made the species naturally fragile, causing its population to shrink in size (Sinha *et al.* 2009). Consequently, there is a need for rapid and reliable technologies to enable mass propagation of this orchid species effectively (Hossain and Dey 2013; Ginibun *et al.* 2018; Bhowmik and Rahman 2020).

**Conservation Strategies**

Conservation of plant resources can be achieved using both *ex situ* and *in situ* methods. While *in-situ* conservation deals with the protection of the plants in their natural habitats, *ex situ* methods of conservation involve the use of *in vitro* technologies for the mass multiplication and sustainable utilization. The *in situ* conservation technique makes it possible to conserve species, genetic and environmental variety in a highly comprehensive and economical way, but it is not achievable in regions with significant environmental and human constraints (Wolf 1999; Zegeye 2017). *Ex situ* conservation aims at preserving seeds and other germplasm materials for as long as possible in order to minimize the likelihood of genetic diversity loss (Dulloo and Borelli 2010). For the *in-vitro* propagation of *S. plicata*, different plant parts and nutrient media have been used. Studies have shown that explants such as nodes, internodes, root tips, leaves and capsules can be used to achieve successful *in vitro* multiplication of *S. plicata*. A variety of media such as Gamborg ($B_5$), Knudson C (KC), Murashige and Skoog (MS), Orchid Seed Sowing Medium (OSSM), and Phytamax (PM) along with the plant growth regulators 6-Benzylaminopurine (BAP), 2,4-Dichlorophenoxyacetic acid (2,4-D), kinetin (Kn), α-Naphthaleneacetic acid (NAA) and indole-3-acetic acid (IAA) have been tried for micropropagation of *S. plicata*.

Murthy *et al.* (2006) demonstrated that MS medium supplemented with 2 mg $l^{-1}$ Kn, 0.5 mg $l^{-1}$ NAA along with 100 mg $l^{-1}$ casein hydrolysate and 10% coconut milk resulted in 85% seed germination in case of seeds from mature capsules of *S. plicata*. However, Thakur and Dongarwar (2012) reported enhanced seed germination in MS medium incorporated with 0.1mg$l^{-1}$ BAP and 1.0 NAA mg $l^{-1}$. Hossain and Dey (2013), on the other hand, observed 95% seed germination of *S. plicata* on PM medium supplemented with 2% (w/v) sucrose and 2.0 g $l^{-1}$ peptone. Sebastinraj and Muhirkuzhali (2014) also reported 90% seed germination on KC basal medium. Stella *et al.* (2015) observed induction of callusing in MS medium supplemented with 10 µM concentrations each of Kn and BAP. Aswathi *et al.* (2017) has reported the best medium for achieving 95% germination rate in *S. plicata* to be Gamborg $B_5$. Haque *et al.* (2017) recorded a total of 82% seed germination on ½ MS basal medium containing 0.5 mg $l^{-1}$ Kn whereas Bhowmik and Rahman (2020) observed an 86.67% germination percentage on PM medium. Shekhawat *et al.* (2021) reported 93% germination rate on MS medium supplemented with 1.0 mg $l^{-1}$ BAP. Using immature capsules of *S. plicata*, Hossain and Dey (2013) have reported around 70% germination in OSSM medium.

Further, nodal, root and leaf segments from the *in vivo* plants have also been utilized as explants for micropropagation of *S. plicata*. Teng *et al.* (1997) reported that ½ MS basal medium supplemented with BAP at 0.44 µM and 5.37 µM NAA resulted in the induction of protocorm-like bodies (PLBs) from nodal sections, leaf explants and root segments with 98.5%, 5-8% and 0.5% PLB induction efficiency respectively. Sinha *et al.* (2009) reported that micro-shoots could be induced in 66.6% explants without the intervening PLBs by culturing nodal segments of *S. plicata* in ½ MS medium supplemented with 2.0 mg $l^{-1}$ BAP, 0.5 mg $l^{-1}$ NAA, 3% sucrose, 10% coconut water, and 2 g $l^{-1}$ peptone. Manokari *et al.* (2021) observed that 93.7% of somatic embryos per explant could be produced in leaf explants grown on MS media supplemented with 1.0 mg $l^{-1}$ 2,4-D.

Also, the use of secondary explants from the *in-vitro* raised seedlings of *S. plicata* has been reported for its multiplication. Bapat and Narayanaswamy (1977) used the stem disc-bearing rhizomatous stock obtained from 6 weeks-old seedlings to generate callus masses on MS medium enriched with 6 mg $l^{-1}$ NAA and 2 mg $l^{-1}$ 2,4-D, along with 2 mg $l^{-1}$ kinetin and 15% coconut milk. Hossain and Dey (2013) employed nodal segments of *in vitro* raised seedlings and found that the optimal combination for inducing PLBs (10.80 ± 0.44 PLBs per explant) was 1.0 mg $l^{-1}$ NAA and 2.5 mg $l^{-1}$ BAP. Sebastinraj and Muhirkuzhali (2014) reported a maximum induction of an average of 12.8 shoots per explant using 5 mm long *in vitro* pseudobulb explants on ½ MS medium supplemented with, 2.0 mg $l^{-1}$ BAP, 0.6

mg $l^{-1}$ NAA and 3% sucrose. Haque *et al.* (2017) reported the induction of callus in root, stem and leaf explants of *in vitro*-raised plantlets of *S. plicata* with a frequency of 30.0%, 43.3%, and 66.7% respectively when cultured in a modified MS medium supplemented with 1.0 mg $l^{-1}$ 2,4-D, 3.0 mg $l^{-1}$ NAA, and 1.0 mg $l^{-1}$ Kn.

*Ex vitro* symbiotic seed propagation is another *ex situ* conservation technique which is advantageous over *in vitro* propagation since the seed germination process does not require severe axenic conditions or laboratory facilities (Aewsakul 2013; Mala and Nontachaiyapoom 2018). Aewsakul (2013) has reported that the seeds of *S. plicata* sown non-axenically on peat moss inoculated with the fungal strain Da-KP-0-1, resulted in enhanced protocorm growth and seed germination were most promoted.

The production of artificial seeds is an approach for conservation of desirable genotypes by encapsulation of suitable explants including somatic embryos in a suitable matrix such as agarose or calcium alginate. It can be a useful tool for large-scale multiplication projects as well as a useful way to re-establish plants in the wild for germplasm preservation (Kumar and Loh, 2012). Stella *et al.* (2015) developed "synseeds" of *S. plicata* by encapsulating the *in vitro* produced somatic embryos and protocorms in 3% sodium alginate matrix, without any hormonal supplementation. Further, Haque *et al.* (2017) reported the development of improved artificial seeds with 3% sodium alginate which had a germination percentage of 66.7% after 3 months of cold storage at 4°C. Manokari *et al.* (2021) reported a maximum of 97.4% conversion frequency of synthetic seeds formed in 3% sodium alginate and 100 mM calcium chloride which could be germinated on MS medium fortified with 2.0 mg $l^{-1}$ BAP and 0.25 mg $l^{-1}$ IAA.

Cryo-seed bank is used as an alternative to the conventional seed-bank for preserving orchid seeds at low liquid nitrogen temperatures while maintaining their high viability (Das *et al.* 2021). Ang *et al*. (2010) have reported successful preservation of seeds of *S. plicata* in liquid nitrogen at Singapore Botanic Gardens, Singapore with 90% viability post-storage.

**Conclusion**

*S. plicata* is a species of significant ornamental and medicinal importance, making its conservation and sustainable utilization a priority. Development of *ex vitro* and *in vitro* micropropagation techniques has yielded successful large-scale propagation strategies, providing a steady supply of desirable genotypes. These techniques have been critical in resolving propagation issues. Further, cryopreservation and artificial seed production offer viable ways to preserve the germplasm, and genetic uniformity of plants for the long term.

These biotechnological methods of conservation and multiplication may ensure the protection and sustainable use of *S. plicata*, an orchid of ornamental and medicinal importance.

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# Meghalaya's traditional dietary plants: natural solutions for hypertension and cardiovascular protection

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**Abstract**
*Hypertension is a serious health concern globally, affecting millions of people worldwide. In Meghalaya, plants have been used for generations to treat various ailments, including hypertension. Although most studies focus on the antihypertensive effect of single medicinal plants in isolation, there appear to be few studies based on the combination of such plants. Among these, Solanum species, Houttuynia cordata, and Allium species not only serve culinary purposes but also demonstrate a significant potential for managing hypertension. Research suggests that these plants contain bioactive compounds such as flavonoids, phenolics and other antioxidants that may exhibit synergistic effects when consumed in combination, enhancing their therapeutic potential against hypertension. Given the complementary interactions of these phytochemicals, specific identification and classification of key antihypertensive plants can inform modern dietary guidelines, facilitating the integration of local knowledge into contemporary hypertension management and potentially leading to new, plant-based interventions tailored to regional practices in Meghalaya.*

**Keywords:** Anti-hypertensive, cardiovascular disease, hypertension, Meghalaya, traditional medicine.

## Introduction

Cardiovascular diseases (CVDs) are the number one cause of death worldwide. In the last 30 years, deaths from CVDs have gone up by 60%. Today, CVDs claim over 20 million lives every year according to the World Heart Federation (WHF) (Heene *et al*. 2023). As of 2017, CVDs accounted for 26.6% (25.3-27.4%) of all mortality and 13.6% (12.5-14.6%) of total Disability-Adjusted Life Years (DALYs) in India, compared to 15.2% (13.7-16.2) and 6.9% (6.3-7.4) in 1990 (Kalra *et al*. 2023), the demographic shift towards an ageing population makes this a bigger public health challenge as people above 60 are more vulnerable to CVDs (Singh *et al*. 2024). In India, the absence of a thorough data collection framework for cardiac morbidity and mortality, notwithstanding the significant incidence of heart disease, impedes effective management and resolution of the problem. The predominance of fatalities occurring at home without a definitive cause of death further intensifies the challenge. Although hospital-based studies provide valuable insights, they may not comprehensively reflect the nation's total burden of heart disease (Ram *et al*. 2023).

Non-communicable diseases (NCDs) contribute significantly to the overall disease burden observed in Meghalaya. Among these, CVDs represent a significant health concern, particularly within the elderly demographic. As individuals advance in age, especially those who are 70 years or older, the likelihood of mortality attributable to CVDs markedly escalates. Indeed, cardiovascular disease (CVD) is responsible for more than 25% of fatalities within this age cohort in Meghalaya, underscoring the imperative for strategic healthcare interventions and preventive measures to tackle this escalating public health issue (Public Health Foundation of India 2018). However, when considering the risk of CVD events like myocardial infarction, stroke, heart failure and end-stage renal disease, it can be significantly reduced by controlling hypertension, the most modifiable risk factor for CVD. Hypertension is a growing global health problem, affecting people in low and middle-income countries more than in high-income countries (Mills *et al*. 2020; Vaduganathan *et al*. 2022). In contrast, according to statistics from the National Family Health Survey (NFHS-5) 2019-2021, hypertension in Meghalaya is greater in urban than rural areas. This disparity could be linked to lifestyle factors. Urban populations face increased stress, inactivity and unhealthy dietary habits. Conversely, rural populations exhibit greater physical activity and healthier eating patterns. The conventional rural way of life, involving manual labour and home-cooked nutrition, likely leads to lower hypertension prevalence.

The antihypertensive drugs used to treat hypertension do reduce the risk of serious CVD events like heart attacks and strokes. Nevertheless, the prolonged administration of these pharmacological agents can incur substantial financial burdens. Of greater concern, such usage elevates the likelihood of experiencing adverse effects, which can manifest as serious conditions such as hypotension, syncope, dysregulation of electrolytes, and acute renal impairment. (Sheppard *et al.* 2018). Consequently, although antihypertensive medications provide significant assistance, alternative and adjunctive treatments may prove exceedingly beneficial, particularly for individuals experiencing mild to moderate hypertension. There is ongoing research into the possibility of plant-based compounds as alternatives to current therapies or components of combination therapy for managing hypertension. Plant-based compounds may improve therapeutic results and safety with lessening adverse effects (Sacks *et al*. 1999).

In Meghalaya, traditional dietary practices are deeply intertwined with the region's rich biodiversity, particularly in utilising specific plants known for their health benefits. Several plants in Meghalaya have potential for their antihypertensive role, among these, some notable antihypertensive plants include *Houttuynia cordata* Thunb. (Pradhan *et al*. 2023), *Solanum lycopersicum* L. (Kumar *et al*. 2021), *Solanum betacea* Cav. (Machado *et al*. 2024), *Solanum gilo* Raddi. (Lalhmingsanga *et al*. 2018), *Sesamum indicum* L. (Elleuch *et al*. 2011), *Centella asiatic* L. Urb (Bunaim *et al*. 2021), *Allium sativum* L. (Al-Qattan *et al*. 2003), *Allium cepa* L. (Galavi *et al*. 2021), *Allium tuberosum* Rotler ex Spreng (Nong *et al*. 2024) and *Clerodendrum colebrookianum* Walp. (Lokesh and Amitsankar 2012). While there have been many studies on the antihypertensive properties of individual plants, there is little research on the synergistic effect of combining these plants. This review aims to explore the medicinal plants used in Meghalaya to treat hypertension and related disorders. By examining the pharmacological properties and synergy of antihypertensive plants like *H. cordata*, *Solanum* species, *Allium* species and others we hypothesise that specific plant combinations may have more therapeutic effects than individual use. What is particularly interesting is that apart from their use as medicinal agents, these plants are also part of the local cuisine. They are very often eaten fresh as salads or added to traditional dishes. The diverse culinary usage of these plants brings interesting questions about how they might synergise, or otherwise, enhance health outcomes when combined. This hypothesis warrants further investigation into the potential of Meghalaya's traditional medicinal flora for developing novel, plant-based interventions for hypertension management.

**Some promising antihypertensive plants of Meghalaya**

Medicinal plants have been a crucial part of the diet and treating various ailments of the tribals of Meghalaya for generations. The therapeutic efficacy of these plants is attributed to their phytochemical constituents. Phytochemicals are naturally occurring plant-derived compounds. They serve as direct medicinal agents and raw materials for the pharmaceutical and aromatic industries. In contrast to synthetic pharmaceuticals, phytochemicals typically exhibit a reduced risk of adverse effects. These compounds, present in various plant parts such as leaves, stems, roots, and fruits, serve crucial roles in plants' growth, development, and defence mechanisms. Their antioxidant properties are gaining increasing recognition.

These compounds are linked to numerous potential benefits, such as antioxidant, anti-inflammatory, antimicrobial and anticancer effects. Additionally, they may contribute positively to cardiovascular, immune, and cognitive health (Balandrin and Klocke 1988; Nanjian 2006; Tyagi *et al.* 2010; Banu and Cathrine 2015). In examining the pharmacological properties of selected plants, it becomes evident that Meghalaya's traditional dietary flora possesses remarkable therapeutic potential. The rich phytochemical composition of these plants, particularly those used in local cuisine, underscores their role in managing hypertension and supporting cardiovascular health. The following paragraphs highlight some of the most effective plants known for their antihypertensive properties.

***Houttuynia cordata* Thunb.**

*H. cordata* is an aromatic medicinal herb with creeping roots, commonly known as fish mint or fish wort. The plant was exclusively found in damp and shady environments (Bhattacharyya and Sarma 2010). In Meghalaya, the entire plant of *H. cordata* is eaten raw as a medical salad or cooked to lower blood sugar levels and is generally known as *Jamyrdoh* (by the Khasis and Jaintias), which is shown in **Table 1** (Kumar *et al*. 2014a). Furthermore, leaf juice is used to treat cholera and dysentery (Laloo and Hemalatha 2011), as well as to cure blood deficiencies and purify the blood. *H. cordata* has several medicinally relevant functions, including anti-leukemic, anti-cancer, adjuvanticity, antioxidant, anti-inflammatory, anti-mutagenic, anti-viral, anti-obesity, anti-bacterial, anti-diabetic and anti-allergic properties (Kumar *et al*. 2014b; Yang and Jiang 2009; Pradhan *et al*. 2023). Many studies have indicated that *H. cordata* is rich in bioactive compounds comprising phenols, essential oils, flavonoids, alkaloid compounds, volatile oil components, natural acids and secondary metabolites comprising fatty acids, sterols, terpenes, saponins, glycosides, tannins, quinines and lactones (Pavan *et al*. 2009). *H. cordata* also improves endothelial function by increasing the availability of nitric oxide (NO). Evidence indicates that NO plays a significant part in controlling blood pressure, and reduced NO function is a key factor in hypertension (Hermann *et al*. 2006).

***Solanum lycopersicum* L.**

The tomato (*S. lycopersicum*; *Lycopersicum esculentum* L.) is the fruit of a perennial herbaceous shrub in the Solanaceae family. In Meghalaya, it is called as *Sohsaw* and it is widely cultivated in the Ri-bhoi District and can be grown both during the kharif and rabi seasons; however, the high-altitude regions of the East Khasi Hills district have recently adopted tomato cultivation on a large scale and it has spread to various areas due to the high return during the off-season (Nongbri and Odyuo 2022). It is consumed as a vegetable or in a raw salad form. Traditionally, the various portions of the tomato have been utilized orally and externally to treat a variety of ailments around the world. For example, fresh juice is given orally to induce vomiting in response to food poisoning and extracted juice is applied externally to reduce excessive bleeding from wounds and cure furuncles and bites from insects. The pulp of the fruit is used fresh as a febrifuge and among pregnant women to reduce water retention. It is also used to cleanse the kidneys and liver, and it acts as a cathartic, promoting normal digestion, which is summarized in **Table 1** (Dawid 2016). *S. lycopersicum* contains antioxidants (Frusciante *et al*. 2007), vitamins E and C, flavonoids (e.g., rutin), phenolic compounds (e.g., chlorogenic acid), carotenoids (β-carotene and lycopene) (Szabo *et al*. 2019), and glycoalkaloids (tomatine) (Friedman and Levin 1995). Furthermore, tomatoes are the primary source of lycopene in human diets (Borguini and Ferraz Da Silva Torres 2009). The aforementioned constituents of tomatoes have demonstrated significant protective properties against cancer (Sathelly *et al.* 2022), cardiovascular diseases (Przybylska and Tokarczyk 2022), and ischemia/reperfusion injury (Tong *et al.* 2016).

***Solanum betaceum*** **Cav.**

Tamarillo, also known as tree tomato, *Sohbaingon dieng*, or S*ohsawdieng* in Meghalaya (*S. betacea* or *Cyphomandra betacea* Cav.), is an exotic fruit belonging to the family Solanaceae, genus Solanum, together with tomato, capsicum and eggplant (Diep *et al*. 2022). *S. betaceum* contains high amounts of phenolics, which are strong anti-oxidants capable of preventing LDL oxidation *in vitro* (Huang and Huang 2024), anthocyanins, carotenoids, vitamins A, B6, C, and E, as well as iron, potassium, fibre, and other vital minerals for human health (Viera *et al*. 2022). It grows naturally and can be found in abundance in the gardens of most people in North Eastern India, especially in Meghalaya, Nagaland and Sikkim (Angami *et al*. 2019). The fruits can be eaten fresh, crushed with milk or water, simmered in soups and sauces, or mixed into desserts and salads. In folk medicine, the fruit with peel is used as an antimicrobial/anti-inflammatory remedy to heal sore throats and irritated gums and decrease cholesterol, which is summarized in Table 1 (Vasco *et al.* 2009). Because of its high antioxidant content, it is thought to be an effective substitute for tomato and cherry tomatoes (Angami *et al*. 2019). Pulp's health benefits include antioxidative, antiproliferative, antinociceptive, anti-inflammatory, allergenicity, anti-obesity and antibacterial properties (Isla *et al*. 2022).

***Solanum gilo* Raddi.**

*Solanum gilo* Raddi. known as bitter brinjal, or *Soh-ngang-heh* in Meghalaya, is a member of the Solanaceae plant family. Characterized by its bitter flavour, the fruit of this plant is not only a culinary ingredient but also holds significant therapeutic value, making it a crucial component in both traditional and modern medicinal practices (Seal *et al*. 2016). Their uses in traditional medicine include the employment of roots and fruits as a carminative and sedative as well as in the treatment of colic and high blood pressure as summarized in **Table 1** including leaf juice as a sedative in the treatment of uterine complaints, anti-emetic as well as in the treatment of tetanus after abortion, weight reduction to the treatment of several ailments that include asthma, allergic rhinitis, nasal catarrh, skin infections, rheumatic disease and swollen joint pains, gastro-oesophageal reflux disease, constipation, dyspepsia (Lalhmingsanga *et al*. 2018). Fruits possess a range of bioactive properties, including anti-oxidant and anti-inflammatory effects (Tchoupang *et al.* 2022), alongside analgesic, anti-asthmatic, anti-glaucoma, hypoglycemic and hypolipidemic attributes (Odetola *et al.* 2004; Ezechukwu *et al.* 2016). Additionally, fruits are rich in compounds such as fibre, ascorbic acid, phenols, flavonoids, saponin, anthocyanin, glycoalkaloids, and α-chaconine, which are integral to their pharmacological benefits (Eze and Kanu 2014).

***Sesamum indicum* L.**

Sesame (*S. indicum*), a member of the Pedaliaceae family, was one of the first oil crops produced by humans, showing its significance and long history in human diets. It prefers hot regions, sandy, well-drained soils, and moderate rainfall (Anilakumar *et al*. 2010). In Meghalaya, it is called as *Nei-iong*, and it is largely used for its edible seeds, which are a less expensive source of fat and protein. The seeds are roasted and processed into powder for subsequent consumption in salads. Sesame seeds have become a staple in many world cuisines due to their mild flavour and rich nutritional value, which includes high levels of protein and fats (Wei *et al*. 2022). With such high protein and fat proportions, sesame seeds bring numerous health benefits to the table, making them an effective addition to any nutritious diet. As summarized in **Table 1**, Sesame has traditionally been used as a folk treatment for a variety of ailments, including intestinal blockage, asthma, allergies and eye diseases, due to its anti-inflammatory, antioxidant, and antibacterial properties (Mohamed *et* *al.* 2021). Sesame seeds also include two unique substances: sesamin and sesamolin, which are known to decrease cholesterol in humans and prevent excessive blood pressure (Wu *et al.* 2019). Aside from these, some therapeutic applications of sesame seeds included anti-cancer activity (Huang *et al*. 2023), as well as neurodegenerative illness, osteoarthritis, liver disease, diabetic eye disease, inflammatory bowel disease, cardiovascular disease and lung disease (Mohamed *et al.* 2021; Huang *et al*. 2023).

***Centella asiatic* (L.) Urb.**

*C. asiatic Urb* (gotu kola), also known as *Bat-Khliang Syiar* or *Bat Moina* in Meghalaya (Laloo and Hemalatha 2011; Bhat *et al.* 2019), is a clonal, perennial herbaceous creeper from the Umbellifere (Apiceae) family that grows in damp areas in India. It grows in swampy places in most tropical and subtropical nations, including India, Pakistan, Sri Lanka, Madagascar, South Africa, the South Pacific and Eastern Europe (Roy and Bharadvaja 2017). The whole plant is eaten raw or in a salad. In northeast India, it is used to treat diarrhoea, liver difficulties, nerve disorders, and stomach problems. It stimulates hunger, can be eaten with milk to improve memory, is beneficial for skin conditions, and acts as a blood purifier. It is also given to mothers after childbirth (De 2016), summarized in **Table 1**. It has been shown to produce a significant amount of alkaloids, tannins, flavonoids and triterpenoids (Quyen *et al*. 2020), including asiatic acid, asiaticoside, madecassic acid and madecacosside. Bioactive compounds found in *C. asiatica* have been proven to have a strong anti-hypertensive effect in a variety of hypertensive rat models (Bunian *et* al. 2021). It also exhibits anti-oxidant, neuroprotective, anti-inflammatory, anti-fungal, anti-bacterial, anti-cancer, hepatoprotective, cognitive function, wound healing, anti-diabetic and antidepressant properties (Haleagrahara and Ponnusamy 2010; Orhan 2012; Islam *et al*. 2020; Riza *et al*. 2024).

***Clerodendrum colebrookianum*** Walp.

*C. colebrookianum*, sometimes known as East-India glory bower, is native to India's north-east area, including West Bengal and Sikkim (Baruah *et al*. 2024). Consuming the water after boiling the leaves is a traditional practice among the Khasi and Jaintia tribes in Meghalaya, where it is commonly referred to as *Sla Jarem*, for the treatment of high blood pressure, malaria, and liver problems and application of the warmed leaf-paste to the affected area is a common traditional practice as outlined in Table 1 (Kayang *et al*. 2003; Das *et al*. 2013). People in India's Northeastern areas utilize the leaves and twigs of this plant as a home treatment for high blood pressure (Kayang *et al*. 2003; Rai and Lalramnghinglova 2010;

Tamang *et al*. 2023). The plant was found to include triacontane, amyrin, clerodin, (24s) ethyl cholesta 5, 22, 25 trien 3-ol, clerodolone, clerodendoside, B-sitosterol, clerosterol, and polyphenols (Kotoky *et al*. 2005). The polyphenols enhance the production of vasorelaxant factors such as nitric oxide (NO), which decreases hypertension (Mohamed *et al.* 2012). *C. colebrookianum* roots have anthelmintic, antibacterial, and anti-fungal qualities (Anitha and Kannan 2006; Yadav and Temjenmongla 2012; Prasad *et al.* 2015) and have been used to treat bronchial asthma, gastrointestinal tract diseases, syphilis and gonorrhea, and a variety of hematological disorders (Kotoky et al. 2005)). Pharmacological studies revealed that it has hypolipidemic, antipyretic, analgesic, anthelmintic, anti-inflammatory, antioxidant, and hepatoprotective properties (Devi and Sharma 2004; Deb *et al.* 2010; Deb *et al*. 2013).

***Allium tuberosum* Rottler ex Spreng**

*A. tuberosum* (Chinese hive) is a perennial herbaceous plant that is native to Central Asia and Europe, however, it may now be cultivated in any region of the world (Sharifi-Rad *et al*. 2016; Jannat *et al*. 2019). In Meghalaya, it is called *Jyllang* and is widely utilized in cuisine and as an edible vegetable (Kayang *et al*. 2003). The plant is not only used as a vegetable and spice, but it is also highly valued in folk medicine for treating nocturnal emissions, abdominal pain, diarrhoea, sexual dysfunction, asthma, gastric ulcer, dyspepsia, and supporting kidney function, which is given in **Table 1** (Tang *et al*. 2017). Recent pharmacological research has shown that *A. tuberosum* and its chemical constituents (organosulfide volatile compound and phenol) have anticancer, antioxidant, aphrodisiac and nematicidal characteristics (Khairan *et al*. 2021; Shahrajabian *et al*. 2021; Nath *et al*. 2022). It also possesses antidiabetic and hepatoprotective properties (Tang *et al*. 2017).

***Allium sativum* L.**

Garlic, *A. sativum*, a member of the Alliaceae family, is well-known as a valuable spice and a popular treatment for a variety of diseases and physiological abnormalities (Londhe *et al*. 2011). Cultivated nearly throughout the world, including India (Batchvarov 1993). In Meghalaya, it is called *Rynsun* and is combined with oil to treat coughs (Meghalaya Forest Department). Garlic's current medical uses include preventing and treating cardiovascular disease by decreasing blood pressure and cholesterol, as an antibacterial, and as a cancer prevention agent, which is brief in **Table 1** (Londhe *et al*. 2011). It includes numerous bioactive components, including organic sulfides, saponins, phenolic compounds and polysaccharides. Organic sulfides such as allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene and S-allyl-cysteine are important bioactive components of garlic (Shang *et al*. 2019). The active ingredients are a group of complex sulfur-containing chemicals that are quickly absorbed, altered and metabolized (Ansari *et al*. 2023). It also contains wound-healing, antifungal, antidiabetic, antimicrobial, anti-inflammatory, antioxidant and hepatoprotective properties (Eidi *et al.* 2006; Ejaz *et al*. 2009; Shin *et al.* 2014; Li *et al*. 2016; Putnik *et al*. 2019).

***Allium cepa* L.**

*A. cepa*, or onion, is a culinary and therapeutic spice from the Amaryllidaceae family of monocotyledon (Alam *et al*. 2023). It has traditionally been utilized for its medicinal properties in treating various illnesses, including blood purification for athletes, scurvy prevention, wound healing, diuretic and pneumonia fighters (**Table 1**) (Teshika *et al*. 2019). It has a high concentration of phenolic compounds, mainly quercetin and its glycosides, phenolic acids, sulfur compounds (allicin), vitamins and minerals. The plant has several pharmacological effects such as anticancer, antidiabetic, antibacterial, cardioprotective and antioxidant properties (Yıkmış *et al*. 2024). It has been used as a diuretic to minimize edema and arteriosclerosis by reducing blood pressure and preventing blood clots (Kumar *et al.* 2010).

**Food synergy of traditional salad ingredients**

Food synergy represents a theoretical framework for comprehending the interactions among various nutrients, their absorption processes and bioavailability within the human organism, which can yield either advantageous or detrimental outcomes. Research has shown that combining different fruits and vegetables like in a salad is more potent in combating several diseases than having it individually. This may be due to the combination of several phytochemicals present in certain foods with their specific targets (Natarajan 2019). Salads often serve as a harmonious blend of flavours and nutrients, with multiple foods coming together to give appropriate nourishment, integrated as a dish. The combination of aromatic chemicals, together with other vegetables and seeds, not only relieves monotony but also improves the health advantages of each component. We will now look at the combinations of basic ingredients in traditional salads of the above-mentioned plants.

'*Sohsaw khleh* bad *Jamyrdoh'* is a known salad of Meghalaya, the juicy, slightly sweet nature of tomatoes contrasts beautifully with the earthy, pungent flavor of fish mint. The synergistic effects of tomatoes' antioxidants and *H. cordata's* anti-inflammatory properties lead to enhanced nitric oxide levels. Sesame seeds that were roasted and ground were added to the boiled bitter brinjal and served as an alternative side dish as they complemented the vegetable's milder bitter taste. *Solanum gilo* fruits have bioactive phytochemicals that are anti-inflammatory and antioxidants (Tchoupang *et al.* 2022). This explains why sesame seeds' fats and oils are of importance nutraceutical. Phytochemicals that are fat-soluble such as glycoalkaloids are made more bioactive by these oils helping in fatty composition and cholesterol reduction where vascular health is improved. A refreshing bitter *'khliang syiar* salad' of gotu kola balanced by the crunch and pungency of onions. The *C. asiatica* triterpenoids and quercetin in onions synergize to enhance blood flow and diminish arterial stiffness when consumed together. Quercetin is believed to promote the bioavailability of active constituents in *C. asiatica*, thereby amplifying their effectiveness in enhancing vascular function and reducing blood pressure. '*Jyllang'* is consumed raw as a single dish or sometimes with roasted tomato, with a mild garlic aroma and crunchy that tandalises the senses, these chives offer a tastier alternative to traditional garlic. The bioactive constituents, such as sulfur compounds present in *A. tuberosum* and lycopene in tomatoes, show synergy in which sulfur compounds provide antioxidant defence and lycopene prevents vascular damage; the result is an increase in endothelial function coupled with blood pressure regulation mostly due to the synergism of antioxidant and vasoprotection.

Yet another salad, *sla-jarem*, is prepared by blanching the *sla-jarem* seasoned with garlic; it is a delicious salad of Meghalaya. *C. colebrookianum* has vasodilatory activity due to an increased synthesis of nitric oxide, which leads to lowering of blood pressure. Garlic, being an allyl sulfide with its rich allicin, is known for its ability to cause vasodilatation by raising nitric oxide levels and thereby reducing vascular resistance. The synergistic effect of both plants markedly enhances antihypertensive activity. '*Sohbaingon dieng* chutney' is a highly famous chutney in Meghalaya; the sour, juicy flavour, when combined with onion, creates a distinct flavour. Tree tomato and onions confer multiple health benefits when consumed together. Such species have been rich in potassium and quercetin to make it cardioprotective; it might even help alleviate hypertension (Vasco *et al.* 2009; Kumar *et al.* 2010). Antioxidants found within these species might potentially control the inflammation and oxidative stress mechanisms, which can be ascribed to the increase of blood pressure (Isla *et al.* 2022; Ykmış *et al.* 2024). Research into traditional dietary practices has unearthed promising avenues for managing hypertension through the synergy of plant-based ingredients native to Meghalaya. Such combinations not only provide enhanced cardiovascular protection but also underline the significance of exploring traditional knowledge for innovative and cost-effective hypertension management strategies. The list of the abovementioned antihypertensive plants, their vernacular names, the parts used for consumption, and their medicinal or culinary benefits are depicted in **Table 1**.

**Table 1:** Common medicinal plants of Meghalaya used in culinary diet.

| | |
|---|---|
|  | Scientific Name: *Houttuynia cordata* Thunb.<br>Vernacular Name: *Jamyrdoh*<br>Edible Parts: Whole plant<br>The entire plant is eaten raw as a salad or cooked to lower blood sugar levels, sores, boils, and for blood purification. |
|  | Scientific Name: *Centella asiatic* L. Urb.<br>Vernacular Name: *Bat-Khliang-Syiar* or *Bat-Moina*<br>Edible Parts: Whole plant<br>It is eaten raw or in a salad and is used to treat diarrhoea, dysentery, liver difficulties, nerve disorders and blood purification. |
|  | Scientific Name: *Solanum betaceum* Cav.<br>Vernacular Name: *Sohbaingon* or *Sohsawdieng*<br>Edible Parts: Fruits<br>It is eaten fresh, crushed with milk or water, simmered in soups and sauces, or mixed into desserts and salads. The fruit with the peel is used as an antimicrobial/anti-inflammatory remedy to heal sore throats and irritated gums and decrease cholesterol. |
|  | Scientific Name: *Allium tuberosum* Rottler ex Spreng<br>Vernacular Name: *Jyllang*<br>Edible Parts: Whole plant<br>It is eaten raw alongside daily meals known to treat blood pressure. It is also used for treating nocturnal emissions, abdominal pain, diarrhoea, sexual dysfunction, asthma, gastric ulcer, dyspepsia, and supporting kidney function. |
|  | Scientific Name: *Clerodendrum colebrookianum* Walp.<br>Vernacular Name: *Sla Jarem*<br>Edible Parts: Leaves<br>Consuming the water after boiling the leaves for the treatment of high blood pressure, malaria, and liver problems, and application of the warmed leaf - paste to the affected area. |
|  | Scientific Name: *Solanum gilo Raddi.*<br>Vernacular Name: *Soh-ngang-heh*<br>Edible Parts: Fruits<br>Fruits are consumed as a vegetable, carminative and sedative, in the treatment of colic and high blood pressure. |

| | |
|---|---|
|  | Scientific Name: *Allium sativum* L.<br>Vernacular Name: *Rynsun*<br>Edible Parts: Bulb<br>It is combined with oil to treat coughs, colds, and respiratory tract infections. It can also be used to treat wound infection and gastrointestinal infections. |
|  | Scientific Name: *Allium cepa* L.<br>Vernacular Name: *Piat*<br>Edible Parts: Whole plant<br>It is a culinary and therapeutic spice eaten raw or added to a salad. It has also been used for blood purification for athletes, scurvy prevention, wound healing, diuretic, and pneumonia. |
|  | Scientific Name: *Solanum lycopersicum* L.<br>Vernacular Name: *Sohsaw*<br>Edible Parts: Fruits<br>It is consumed as a vegetable or in a raw salad form. Fresh juice is used to induce vomiting, reduce bleeding, cure furuncles and bites, act as a febrifuge, and for pregnant women to reduce water retention, cleanse kidneys and liver, and promote digestion. |
|  | Scientific Name: *Sesamum indicum* L.<br>Vernacular Name: *Nei-iong*<br>Edible Parts: Seeds<br>The seeds are roasted and processed into powder for subsequent consumption in salads. Sesame seeds have traditionally been used as a folk treatment for a variety of ailments, including intestinal blockage, asthma, allergies, and eye diseases. |

**Conclusion**

To date, CVDs remain one of the leading causes of death worldwide, it is necessary to look for alternative, more effective treatments. This paper delves into plant-based dietary approaches for reducing the burden of CVDs, with an emphasis on the possible advantages for people with hypertension. Simple salads or chutneys with a combination of tomatoes and fish mint or bitter brinjal and sesame seeds, gotu kola and onion, garlic chives and tomatoes, *Clerodendrum* and garlic, tamarillo and onion can be regarded as simple and natural ways of addressing hypertension. As noted, these plants are deeply rooted in local cuisine, providing a practical approach for cultural integration into dietary practices, which can encourage adherence to health- promoting dietary practices. The consumption of these plants not only aligns with regional dietary practices but also provides a foundation for integrating indigenous knowledge into modern hypertension management strategies. Consequently, exploring these traditional plant combinations could yield novel, plant-based interventions tailored to the specific cardiovascular needs within Meghalaya, paving the way for future research in pharmacological applications. Research on combining phytochemicals from various plants can yield innovative treatment protocols that integrate traditional and modern medicine. This approach honours indigenous knowledge while conforming to modern health standards, creating a comprehensive intervention framework. Additionally, such integration can lead to culturally appropriate dietary guidelines that enhance local adoption, thereby improving health outcomes and acceptance. By bridging the gap between traditional practices and modern research, sustainable solutions for hypertension management and promoting cardiovascular health.

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# Modulatory effect of vicenin-2 in mitigating biochemical and behavioural alteration in swiss albino mice subjected to sub-lethal dose of radiation

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**Abstract**

*The modulatory effect of vicenin-2 (Vcn-2) was studied in mice subjected to sub-lethal X-ray irradiation. The mice were randomly divided into Group I (Normal)- no treatment, Group II (Control)-Vcn-2 administration only (50mg/kg body weight), Group III (IR)- whole-body X-ray irradiation, Group IV (IR+Vcn-2)- administration of Vcn-2 intraperitoneally (50mg/kg b.w.) before and after whole-body irradiation. The survival rate and the body weight of the IR+Vcn-2 group were significantly higher compared to the IR group at 15-30 days following irradiation with statistical significance (*$p<0.001$*). Treatments with Vcn-2 in the irradiated group significantly reduced DNA damage in bone marrow cells. Additionally, oxidative stress analysis indicated that Vcn-2 significantly improves the antioxidant capacity by increasing the level of oxidative enzymes and decreasing the level of malondialdehyde (MDA) in the IR+Vcn-2 group compared to the IR group. These findings suggest that Vcn-2 has a radiomodulatory effect in mice, primarily through the reduction of oxidative damage.*

**Keywords:** Glutathione (GSH), malondialdehyde (MDA), oxidative stress, vicenin-2 (Vcn-2), X-rays.

## Introduction

Exposure to ionising radiation (IR) during radiotherapy or accidents can induce extensive cellular and molecular disruption which poses a significant health risk (Mu *et al.* 2018). Radiation exposure directly alters atomic structures, which trigger a series of events amplified by endogenous signals inducing a range of cellular damage leading to complex biological responses (Soriano *et al.* 2019). Radiation absorption by the tissue generates a considerable amount of highly reactive free radicals which include superoxide anion ($O_2^{\bullet-}$), hydroxyl radical ($OH^{\bullet}$), and hydrogen peroxide ($H_2O_2$) (Srinivasan *et al.* 2007). These reactive oxygen species (ROS) can interact with biomolecules like nucleic acid, proteins, and lipids, inducing damages that alter their structure and function (Reisz *et al.* 2014; Islam 2017). One of the major cellular damage caused by radiation is increased levels of lipid peroxidation (LPO) , a process that can severely compromise cellular membranes and functionality (Kamat *et al.* 2000).

Under physiological conditions, a homeostatic balance exists between the formation of ROS and their removal by endogenous antioxidant scavenging compounds (Victor *et al.* 2004). However, oxidative stress which occurs from an imbalance in ROS production and the cells neutralizing capacity, can lead to a significant change in the redox status. These changes can drive cells to transition from a quiescent to a proliferative state, trigger growth arrest or initiate cell death pathway (Obrador *et al*. 2022). When the harmful effects exceed those of homeostatic biochemical processes, the resulting biological changes can be long lasting and may be transmitted to subsequent generation of cells (Azzam *et al.* 2012; Buonanno *et al.* 2023). Depending on the extent of damage, the cells may initiate a damage repair mechanism or the changes could result in permanent physiological alteration, ultimately resulting in cell death (Szumiel 2015; Buonanno *et al.* 2023).

Studies on natural products especially plant extracts and phytochemicals as modulators of radiation effect are a new area of research. It is necessary to evaluate the modulatory activity of commonly used phytochemicals for exploring their possible application in radiotherapy as a radioprotective agent. Vicenin-2 (Vcn-2) is a bioactive flavonoid present in *Ocimum sanctum*, commonly known as tulsi or holy basil, a herb widely used for centuries in Ayurvedic medicine (Garima *et al.* 2019; Rasheed *et al.* 2022). Reports suggest that Vcn-2 have been shown to possess strong antioxidant properties through mechanisms such as free-radical scavenging, inhibition of inflammation, promotion of repair of damaged DNA and inhibition of cell death pathways (Venuprasad *et al.* 2013; Venuprasad *et al.* 2014; Makni *et al.* 2018; Almatroodi *et al.* 2020;Jit *et al.* 2022; Zhang *et al.* 2023). Previous studies have also shown that Vcn-2 exhibits a potential radiosensitizing activity in non-small cell lung cancer cells by regulating the components of the PI3K/ Akt pathway (Baruah *et al.* 2018; Baruah *et al.* 2019). Therefore, our study aims to investigate the effects of Vcn-2 in mitigating biochemical and behavioural changes in mice subjected to sub-lethal X-ray irradiation.

## Materials and methods

### Experimental animal

The study protocol was approved by the Institutional Animal Ethics Committee (animal model), North-Eastern Hill University, Shillong. Male BALB/c (age, 8 weeks; weight, 20-23 g) procured from an inbred colony Pasteur's Institute, Shillong, Meghalaya. The animals were grouped and housed in polypropylene cages and maintained under standard laboratory conditions (temp 25º-28ºC) with a 12 h light and 12h dark cycle. They were allowed free access to a standard dry pellet diet and water *ad libitum*.

### Experimental Designs

Mice selected from an inbred colony were divided into 4 groups (n=20 per group)

Group I (Normal): the mice of this group received no treatment

Group II (Control): the mice of this group received only Vcn-2 (50mg/kg body weight)

Group III (IR): the mice of this group are whole-body exposed to X-ray

Group IV (IR+Vcn-2): in this group, intraperitoneal administrations of Vcn-2 (50mg/ kg body weight) were made before and after the mice were whole-body exposed to X-ray.

The mice in the irradiated groups were exposed to a sub-lethal radiation dose (6.5 Gy). The control mice were sham irradiated. The mice were fed and observed for 30 days following irradiation.

### Irradiation

The CP160 X-ray irradiation system, Faxitron, USA in the Biochemistry Department, North-Eastern Hill University, Shillong, was used for irradiation. Unanesthetized mice were restrained in a well-ventilated acrylic box and whole-body exposure to ionizing radiation (IR) at a distance of 15 inches approx. delivering a dose rate of 0.42 Gy/min.

### Biochemical analysis

#### *Lipid peroxidation (LPO) assay*

Lipid peroxidation was estimated calorimetrically using thiobarbituric acid reactive substances (TBARS) and was measured using the method described by Silva *et al.* (2011). In brief, 0.5mL of tissue homogenate was treated with 1.5 mL of TBA-TCA-HCI (1:1:1) reagent. The mixture was incubated in a 95ºC water bath for 30 min and then cooled. The absorbance was measured spectrophotometrically at 532 nm. The lipid peroxidation was expressed as Malondialdehyde (MDA) in nM MDA/gm tissue.

***Protein assay***

The total protein concentration was determined by Bradford's method (1976) using bovine serum albumin (BSA) as the standard. The absorbance of standard, as well as test solutions, was read at 595 nm. A standard calibration curve was obtained by plotting the concentration of standard solutions. This curve was used to determine the concentration of protein in test samples.

***Reduced glutathione (GSH) assay***

GSH content of the tissue sample was performed using the method described by Ellman (1959). Briefly, 1.0 ml of tissue homogenate and 1.0 mL phosphate buffer were added followed by 2.0 ml of freshly prepared DTNB (2,2'-dinitro-5,5'-dithiobenzoic acid or Ellman's reagent) solution. The intensity of the yellow colour formed was read at 412 nm in a spectrophotometer after 10 min. The values are expressed as µmoles of GSH/mg protein.

***Superoxide dismutase Enzyme activity* (SOD)**

The activity of SOD was assayed according to the method described by Marklund and Marklund (1974) with some modifications. The reaction mixture of autooxidation consists of 2 ml of Tris HCL buffer (0.1M, pH 8.2), 0.5 ml of 2 mM pyrogallol, and 1.5 ml of water. Initially, the autooxidation rate was noted at an interval of 60 seconds for 3 min at 470 nm. The assay mixture for the enzyme consists of 2 ml of Tris HCL. Buffer (0.05M), 0.5 ml pyrogallol, 0.5 ml of the homogenate, and water to give a final volume of 4 ml. The rate of inhibition of pyrogallol autooxidation after the addition of the enzyme was noted at the same time interval. Iron accelerates pyrogallol oxidation even in trace amounts. DETAPAC acts as a chelator and prevents Fe, $Cu^2$, and $Mn^2$ interference. Enzyme activity is defined as the amount of enzyme required to inhibit 50% pyrogallol auto-oxidation/min (U/mg protein).

***Catalase activity* (CAT)**

CAT activity was determined from the rate of decomposition of $H_2O_2$. Catalase was assayed colorimetrically at 620 nm and expressed as µmoles of $H_2O_2$ consumed/min/mg protein as described by Sinha *et al.* (2016). The reaction mixture (1.5 ml) contained 1.0 ml of (0.01 M pH 7.0) phosphate buffer, 0.1 ml of tissue homogenate (supernatant), and 0.4 ml of 2 M hydrogen peroxide. The reaction was stopped by adding 2.0 ml of dichromate-acetic acid reagent (5% potassium dichromate and glacial acetic acid were mixed in a 1:3 ratio and then the absorbance was measured.

***Bone marrow DNA content***

The bone marrow of the mice was collected immediately after the mice were sacrificed by flushing it out with Phosphate Buffer Saline. The flushed bone marrow was used to extract DNA to assess any damage. The concentration of DNA obtained from the sample was evaluated using a spectrophotometric measurement of absorbance at 260 nm.

**Statistical Analysis**

All the data were expressed as mean ± standard error mean (SEM). Data were analyzed by the one-way analysis of variance (ANOVA) method followed by Tukey's test (multiple comparison tests). All statistical analyses were performed using the GRAPH PAD Prism software, Version 8.0 with a significance value of $P < 0.05$.

**Results**

**General behavioural observation**

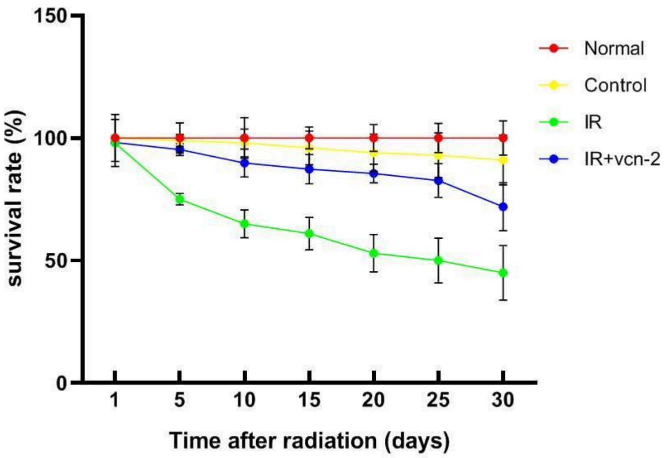
In the present investigation, the mice in the irradiated groups were exposed to 6.5 Gy X-ray radiations. The irradiated mice exhibit signs of radiation sickness within two to three days after irradiation as shown in **Table 1**. The physical observation includes signs of agitation, weight loss, reduction in food and water intake, diarrhoea, profuse perspiration, shivering and extensive grooming or ruffling of hair leading to hair loss, with some mice showing signs of paralysis and curved posture with difficulty in locomotion were also observed.

**Vcn-2 increases the survival rate of mice subjected to ionizing radiation**

Following exposure it was observed that the irradiated mice gradually died the next day, the survival rate was monitored from 0-30 days as shown in **Fig. 1**. However, treatment of Vcn-2 in the irradiated group prolongs the survival time, compared with the IR control group ($p<0.05$). Maximum mortality was observed in the irradiated group at 10-15 days, on the $30^{th}$ day the survival of IR+Vcn-2 was 78% and that of the IR group was 50%. Compared with the control group, the survival time of the mice in the IR+Vcn-2 was also significantly prolonged ($p<0.05$).

**Table 1.** General appearance and behavioural observation of mice in the control, IR and IR+Vcn-2 groups following irradiation.

| Parameters | Control | IR | IR+Vcn-2 |
|---|---|---|---|
| Urination | Normal | Increased | Decreased |
| Food intake | Normal | Increased | Moderate |
| Water intake | Increase | Increased | Moderate |
| Fur condition | Normal | Wet | Wet |
| Posture | Normal | Curved | Normal |
| Movement | Active | Weak/Not active | Not active |
| Body temperature | Normal | High | Moderate |
| Behavior | Normal | Extensive grooming/ruffling of hair | Ruffling of hair observed |
| Clinical sign | Normal | Diarrhea/shivering | Diarrhea |



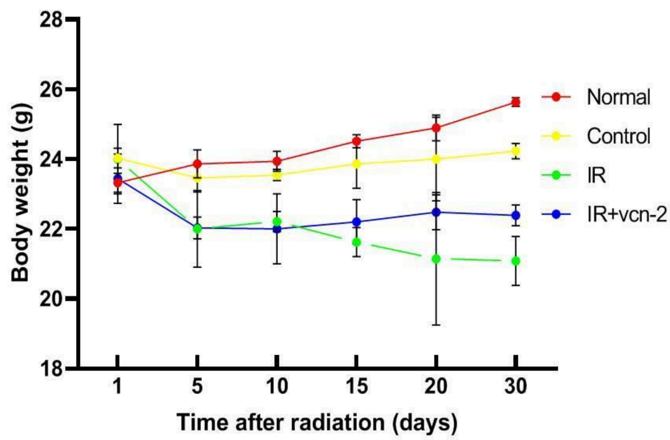




**Fig. 1.** Survival rate and body weight of mice following irradiation. Each vertical bar indicates the standard deviation. Data are represented as the mean ± standard deviation (n=6). IR, irradiated mice; IR+Vcn-2, irradiated mice+ Vcn-2. ($p<0.05$)

**Vcn-2 reduced the IR-induced body weight changes**

The body weight of the mice was measured at various intervals following irradiation, the mean weight was calculated among surviving mice as shown in (**Fig. 1**). Maximum increase in body weight was observed in the normal and control group at 30 days compared to all other groups which showed decreased body weight after exposure to whole-body irradiation. Statistical analysis showed that the body weight was significantly higher in the IR+Vcn-2 group compared to the IR group ($p<0.05$). However, the body weights of the IR+Vcn-2 group on the 20-30 days remained constant with no significant changes compared to the normal and control groups.

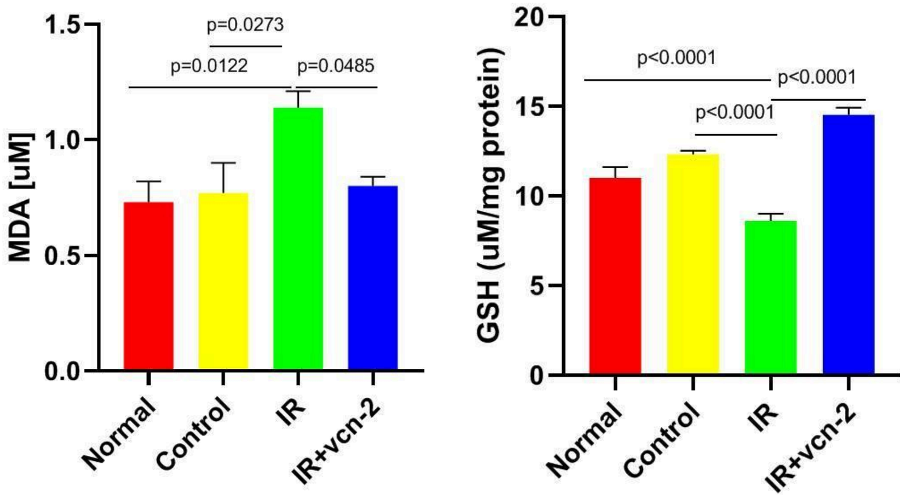



**Fig. 2.** MDA and GSH levels in hepatic tissue following irradiation. Each vertical bar indicates the standard deviation. Data are represented as the mean ± standard deviation (n=6). IR, irradiated mice; IR+Vcn-2, irradiated mice+ Vcn-2. ($p<0.05$).

**Vcn-2 increases antioxidant capacity**

The MDA content, associated with lipid peroxidation (**Fig. 2**), was significantly reduced in the IR+Vcn-2 group compared to the IR group ($p < 0.05$), indicating that Vcn-2 administration helps prevent lipid peroxidation in tissues. The GSH level (**Fig. 2**) significantly decreased in the IR group, whereas it significantly increased in the IR+Vcn2 group ($p < 0.0001$). The activity of SOD and CAT (**Fig. 3**) also significantly decreased in the IR group, while it significantly increased in the IR+Vcn2 group ($p < 0.05$). The increase in activity of SOD, CAT, and GSH indicates the generation of oxidative stress which is prevented by the administration of Vcn-2 in the IR+Vcn-2 group, significantly reducing the oxidative damage caused by radiation.

Protein estimated also showed a statistically significant decrease in the IR group and such a decrease in protein content was noted 30 days post-radiation (**Fig. 4**). However, in the IR+Vcn-2 group, a significant increase in protein content was observed 30 days following radiation compared to the normal and irradiated mice ($p<0.05$).

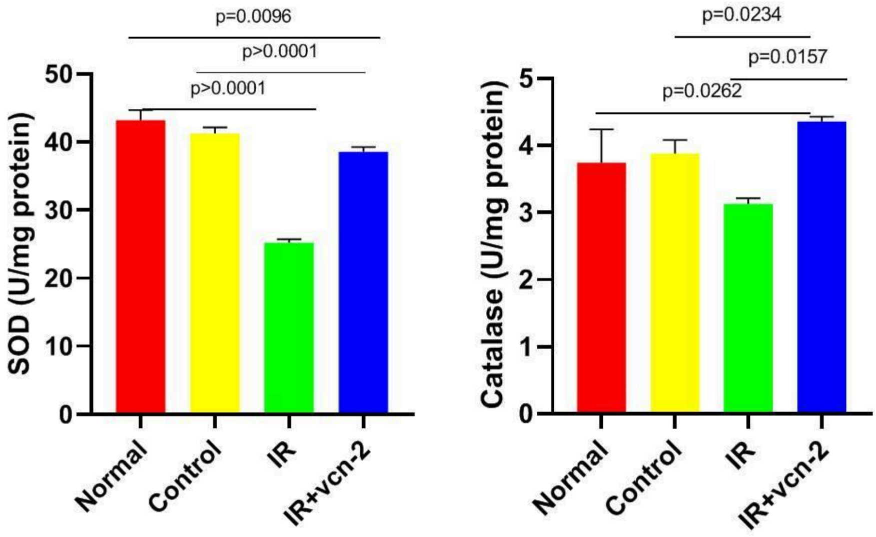



**Fig. 3.** SOD and CAT activity in hepatic tissue following irradiation**.** Each vertical bar indicates the standard deviation. Data are represented as the mean ± standard deviation (n=6). IR, irradiated mice; IR+Vcn-2, irradiated mice+ Vcn-2. (p<0.05).

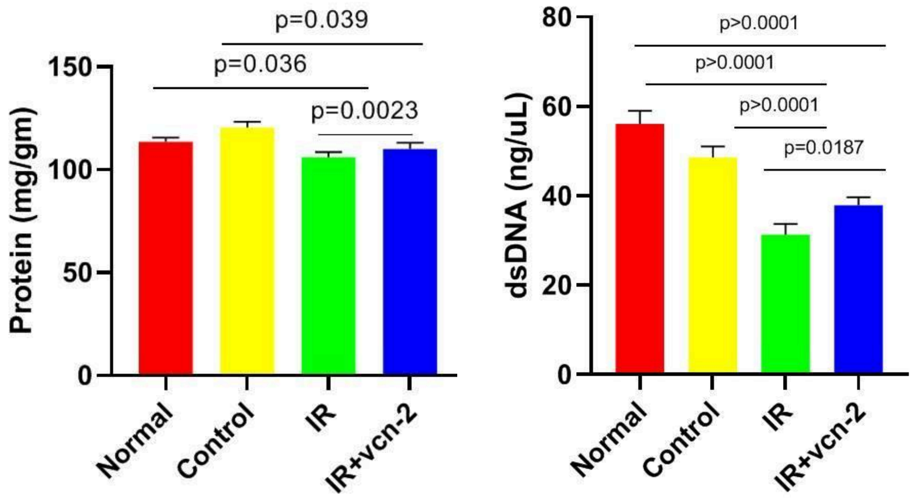



**Fig. 4.** Protein level and bone marrow DNA content following irradiation. Each vertical bar indicates the standard deviation. Data are represented as the mean ± standard deviation (n=6). IR, irradiated mice; IR+Vcn-2, irradiated mice+ Vcn-2. (p<0.05)

**Vcn-2 accelerates the recovery of bone marrow DNA damage in irradiated mice**

DNA content in the bone marrow of mice in the IR+Vcn-2 and control group 30 days post-irradiation (**Fig. 4**) was significantly increased as compared to the IR group (p<0.0001). Compared with the vicenin-2 treated group the bone marrow DNA content of mice in the irradiated group was significantly decreased (p<0.05).

**Discussion**

Flavonoids of *Osmium sanctum* such as orientin and vicenin demonstrate protective effects against radiation by neutralizing free radicals produced by radiation exposure (Uma *et al.* 2000). Additionally, studies have shown that tulsi extract can significantly reduce the production of MMP-9, an enzyme associated with lipid peroxidation that contributes to tissue damages (Ghosh *et al*. 2016; Prasad *et al*. 2021). Tulsi extract has also been found to enhance the levels of antioxidant molecules, including GSH, as well as antioxidant enzymes like SOD, CAT, GPx and GST, which safeguard cell organelles and membranes by eliminating harmful free radicals (Sumran and Aggarwal 2019). The present study was to demonstrate the modulatory effects of Vcn-2 in mitigating biochemical and behavioural alteration in mice subjected to sub-lethal X-ray irradiation. The results demonstrated that the mice in the irradiated group showed signs of radiation sickness within two to three days following irradiation such as agitation, weight loss, decreased intake of food and water, profuse perspiration, shivering and extensive grooming and ruffling of hair leading to hair loss. The time period selected for the study is because the 30-day survival study following whole-body irradiation is the most widely used test (Koch *et al.* 2016). The result of this study showed that the survival rate of the mice in the IR+Vcn-2 group is noticeably higher than that of the IR group, indicating that pre-treatment of Vcn-2 enhances the survival rates of mice exposed to radiation. Radiation exposure can damage the gastrointestinal mucosa leading to an abnormality in absorption (Hauer-Jensen *et al*. 2007); which significantly reduced the body weight of the IR group, whereas, the weight of the mice in the IR+Vcn-2 showed significant recovery. In addition to the behavioural observation the biochemical analysis suggested alteration to a great extent. Free radicals generated from water radiolysis, triggered by ionizing radiation, play a major role in damaging biological molecules (Ahaskar *et al.* 2007). Normally, the natural defence mechanism of the body activates and protects against oxidative damage after exposure to radiation. Oxidative stress is a state of imbalance between the generation of ROS and the levels of the antioxidant defence system (Srinivasan et *al.* 2007). This imbalance leads to lipid peroxidation, protein fragmentation, DNA damage, modulation of genomic expression, calcium influx, inactivation of many metabolic enzymes, mitochondrial swelling and lyses, age-related diseases, genomic instability cell death (Sumran and Aggarwal 2019). Superoxide dismutase (SOD), glutathione reductase (GSH), and catalase (CAT) are key antioxidant enzymes that help mitigate ROS damage (Nuszkiewicz *et al.* 2020; Li *et al.* 2021). In this study, Vcn-2 treatment increased SOD, CAT activity and GSH levels in the liver while significantly reducing the MDA level. MDA is lipid peroxide formed when free radicals interact with polyunsaturated fatty acids in cell membranes, indicating the level of lipid peroxidation (Jadoon and Malik 2017). Exposure to radiation can also cause significant damage to bone marrow, leading to a reduction in bone marrow cells and diminished DNA content (Green and Rubin 2014; Obrador *et al*. 2022). Prolonged resting phase or a delay in DNA synthesis following radiation exposure may be another reason for decreased DNA content (Sisodia and Singh 2009). The results may not be accurate due to contamination from the presence of a small amount of single-stranded DNA. However, studies have shown that Vcn-2, curcumin and related compounds have the potential to protect DNA against oxidative damage induced by free radicals (Srinivasan et *al.* 2007; Sumran and Aggarwal 2019). Vcn-2 treatment provides a significant protection which is indicated by increased DNA concentration together with increased protein concentration. In conclusion, the above result suggests that administration of Vcn-2 prolong the survival time, helps in restoring body weight, improves antioxidant capacity and accelerates bone marrow DNA damage recovery. These synergistic effects lead to better behavioural responses noted in the mice, underscoring the potential advantages of Vcn-2 in alleviating radiation-induced alteration.

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# Cancer Trends in Northeast India: An Overview

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**Abstract**
*Cancer is a growing global concern. India, being a third-world country, raises cancer-related burden significantly. The highest incidence of cancer accompanied by risk factors associated with Northeast India compounds this burden. In 2022, India reported 1.4 million new cases and 0.9 million deaths, with breast and oral cancers being the most common among females and males, respectively. At the same time, the Northeastern region witnessed the highest number of oesophageal cancer and breast cancer among males and females, respectively. When it comes to all types of cancer, Northeastern states are the leaders occupying the top position in the hierarchy of AAR. Similarly, mortality is also highest in these states. This high cancer burden of this region could be due to lifestyle, dietary habits, and genetic makeup. Strengthening treatment facilities, reducing costs, and raising awareness at the community level are crucial to addressing and improving cancer care in the Northeast.*
**Keywords:** Cancer burden, Northeast India, risk factors, tobacco consumption, cancer trends.

## Introduction

Cancer is a notorious disease affecting the global population and ranks second in disease-related mortality (Rahman *et al.* 2020). The incidence of cancer in India is increasing at an alarming rate. In India, As per the reports of IARC-WHO, 1.4 million cases of cancer were reported in 2022 with a mortality of 0.9 million (Sung e*t al.* 2021), making it the leading cause of deaths and morbidity. Among all cancer types, breast cancer is the most prevalent type of cancer in India followed by oral cancer (**Fig. 1**) (Ferlay *et al.* 2024). In the case of gender-dependent incidence, oral and lung cancers had the highest incidence among males, while breast and cervical cancers were the most common among females.

According to the Indian Council of Medical Research (ICMR), North-East has the highest cancer incidence in the country. Due to this, it has been termed the 'Cancer Capital of India' and emerged as a crucial region for cancer research. Considering both the genders in this region, head and neck cancer occupied the top position followed by lung cancer, and stomach cancer (ICMR-NCDIR 2021). The distinct dietary patterns and lifestyles linked to the culture and demographics of the ethnic people in this area are factors that contribute to this cancer trend (Bhattacharjee *et al.* 2006; Shanker *et al.* 2021). In addition to these factors, genetic mutations and epigenetic modifications might also play an important role as a causative factor in cancer cases in the NE region.

Mutations in certain genes have been linked to several cancers in this region (Gauthaman and Moorthy 2020). Mutations in the BRCA1 gene compared to normal were identified in breast cancer patients of the NE region (Hansa *et al.* 2012) In gastric patients of Mizoram, somatic mutations in *TP53*, genes crucial in RTK/RAS/PI3-K signalling pathway and chromatin-remodelling were observed (Chakraborty *et al.* 2023).

Similarly, Epigenetic modifications play a crucial role in cancer development (Shankar and Gupta 2016). DNA methylation is one of the epigenetic changes that has been thoroughly researched in relation to the development of cancer. Several studies from the NE region have shown that tumour suppressors and DNA repair genes like *p16, MGMT, hMLH1, WT1,* and *RASSF1A*, are frequently methylated in head and neck cancer including oesophageal cancer (EC) (Choudhury and Ghosh, 2015; Das *et al.* 2013; Khongsti *et al.* 2018). Though studies on stomach cancer are limited, a study by Lamare et al. has reported novel genes that are differentially methylated in the population of Aizawl district (Lamare *et al.* 2022). Considering the background, this review aims to provide a comprehensive overview of the trends of cancer in Northeast India, risk factors and challenges specific to this region.

**Epidemiology of cancer in North-East India**

The incidence of cancer in NE is increasing at an alarming rate. According to the Indian Council of Medical Research - National Centre for Disease Informatics and Research (ICMR-NCDIR) report 2021, 67,361 cancer cases were reported in the NE states (Sathishkumar *et al.* 2022). Among the Population Based Cancer Registries (PBCR) in the NE states, Tripura PBCR reported the highest number of cancer cases (11,473), followed by Kamrup PBCR with 11,013 cases (Mathur *et al.* 2020). The NE region reported the highest age-adjusted incidence rate (AAR) of cancer compared to the rest of the country. The highest AAR in males was from the Aizawl district (269.4 per 100,000 population) and among females, the Papumpare district in Arunachal Pradesh had the highest AAR of 219.8 for all cancer types (**Fig. 2**) (ICMR-NCDIR 2021). These results imply that the probability associated with cancer development in the NE region for all cancers in a lifetime is the highest in Kamrup urban (1/4 males and 1/6 females) followed by Mizoram state (1/5 males and 1/5 females) and Meghalaya (1/5 males and 1/9 females).

Similarly, mortality associated with cancer in the NE region was also relatively high. As per the 2020-NCRP Report, 27,672 deaths were recorded in NE due to cancer (Report of NCRP 2020). Among males, the age-adjusted mortality rate (AAMR) was the highest in Aizawl district (152.7 per 100000 population), followed by Mizoram state (121.4) and East Khasi Hills district (95). As for females, the same trend was seen with Aizawl district having the highest AAMR of 89.5 followed by Mizoram state (76.4) and East Khasi Hills district (51.5).

**Common Cancer Types in the North-East India**

Out of all the cancer types that are widespread in the Northeast, the most prevalent cancer in both men and women is head and neck cancer (a group of cancers that originates in the mouth, lips, sinuses, nasal cavity, salivary glands, larynx or throat), followed by lung and stomach cancer. As for head and neck cancer, East Khasi Hills District (78.5 per 100,000) and Kamrup Urban (62.4) reported the highest incidence rates in males, and as for females, Papumpare District (21.7) and Kamrup Urban (19.2) had the highest incidence rates (ICMR-NCDIR 2020). Aizawl District occupied the top position for lung cancer in both males (38.8) and females (37.9). In the case of stomach cancer, Aizawl district (44.2) and Papumpare district (27.1) had the highest incidence rate in males and females respectively.

Considering organ-specific cancer types, EC (cancer that originates in the tissue of the oesophagus) (13.6%) was the most prevalent in males followed by lung (10.9%) and stomach (8.7%). In females, cancer of the breast (14.5%), cervix uteri (12.2%), and gallbladder (7.1%) was the most common (**Fig. 3**) (ICMR-NCDIR 2021). The burden of EC in males was the highest in East Khasi Hills (AAR-75.4) and Meghalaya state (54.6). In the case of lung cancer, Aizawl, and Mizoram state had the maximum AAR of 38.8 and 32.1, respectively. As for stomach cancer, Aizawl, and Papumpare districts had the most AAR of 44.2 and 40.3 respectively. In females, Aizawl, and Papumpare district had the highest AAR of 30.7 and 29.6 respectively, for breast cancer. For the second most common cancer in females, i.e., Cervix uteri, Papumpare district (27.7) and Aizawl (27.4) had the maximum AAR. As for gallbladder cancer, which is the third most prevalent cancer, Kamrup urban (7.9) and Cachar district (5.6) occupied the top positions.

**Risk Factors Contributing to Cancer Trends in North-East India**

The risk factors involved in cancer development vary from lifestyle and personal habits to epigenetics, and genetics. In the NE region of India, most of the population is exposed to extensive consumption of tobacco and its related products, alcohol, and betel quid. Apart from these, lifestyle and diet unique to this region also contribute significantly to cancer development.

Consumption of alcohol, betel quid, and tobacco (smoke and smokeless forms) are the major risk factors in the NE region that are associated with cancers of the head and neck (Michaelraj *et al*. 2023; Shanker *et al*. 2021; Shunyu & Syiemlieh, 2013), oesophagus (Harris *et al*. 2024; Phukan *et al*. 2001), lung (Manjunath *et al*. 2022; Shanker *et al*. 2021), stomach and breast cancers (Thapa *et al*. 2016; Zodinpuii *et al*. 2022). 49.3 % of cancers reported from the NE region are related to tobacco use in males, and 22.8% in females (Mathur *et al*. 2020). The top three cancers that are related to tobacco use are the oesophagus, lung, and hypopharynx in males and the oesophagus, lung, and mouth in females (Fig 4). In addition to first-hand smoking of tobacco, second-hand exposure to smoking, and air pollution are also the major causes of lung cancer (Manjunath *et al*. 2022; Shanker *et al*. 2021). Meghalaya occupies the top position in the consumption of betel quid. Almost 63.2% of the adult population in Meghalaya consumes betel quid without tobacco and 70.8% consumes betel quid in any form (Singh *et al*. 2021). Additionally, almost 50% of the population (above 15 years) consumes tobacco (smoke/smokeless form) (ICMR-NCDIR, 2021). In Mizoram, 34.4% of the population (15 years and above) use smoked tobacco which is also the highest in the region (ICMR-NCDIR 2021).

Dietary factors such as low consumption of fruits, high consumption of hot and spicy foods, fermented foods, smoked meat, soda, *H. pylori* infection and hot beverages containing nitrosamines also contribute to EC, stomach cancer and head and neck cancer development in these regions (Dikshit *et al*. 2011; Misra 2014; Phukan *et al*. 2006; Roy *et al*. 2024; Rup Kumar Phukan and Mahanta 2001). The people of Mizoram highly consume ‘Tuibur’ (tobacco water), smoke a local cigarette known as ‘Meiziol’ or ‘Zozial,’ and fermented pork fat called ‘sa-um’ which has been highly associated with the risk of stomach cancer, and breast development in many studies (Lamare *et al*. 2022; Phukan *et al*. 2006; Thapa *et al*. 2016; Zodinpuii *et al*. 2022; Zomawia *et al*. 2023). Aging and reproductive factors, which include late menopause, early menarche, and late age at first pregnancy, are also a risk factor for breast cancer (Sun *et al*. 2017). A study reported delayed marriages, and obesity after menopause as risk factors for breast cancer in the NE region (Biswas *et al*. 2025).

Mutations and family history also play a crucial role in cancer development. For instance, breast cancer, and head and neck cancer have been associated with family history in the NE region (Biswas *et al*. 2025; Pachuau *et al*. 2022; Zodinpuii *et al*. 2022). Family history may be related to genetic factors such as *BRCA1* and *BRCA2* genes (Metcalfe *et al*. 2010; Pourmasoumi *et al*. 2024). A study in the NE region has reported an association of mutations in the *BRCA1* gene with breast cancer (Hansa *et al*. 2012). Epigenetics, which is influenced by lifestyle and personal habits, largely overshadows genetics as a causative factor for cancer (Okugawa *et al*. 2015). Few studies from the NE region have found aberrant methylation of genes crucial in the cell cycle, DNA repair, and tumour suppression to be associated with cancers (Choudhury and Ghosh 2015; Das *et al*. 2013; Khongsti *et al*. 2018).

**Challenges in Cancer Infrastructure and Management**

The prevalence of different types of cancers is very high in the NE region. However, the infrastructure, specialized facilities, and trained professionals are limited in the region. The region has few cancer hospitals and palliative care centres; however, many seek treatment outside the region due to quality and availability factors (Ngaihte *et al*. 2019). A larger number of patients have to travel far distances to avail treatment, which may result in delays in cancer diagnosis and increased costs. Also, the cost of cancer treatment is very high, and therefore significant financial burdens are being faced by patients (Pongener 2024). This may lead to poor prognosis and poorer health outcomes. Though the region has a high incidence of cancer, many are unaware of the disease, especially among the illiterates and rural areas; an indication of low awareness programs and screening among the population.

To reduce the trouble of cancer in the region, resources have to be directed to increase the number of specialized cancer treatment facilities at the primary, secondary and tertiary levels. Reducing the costs of treatment, particularly for low- and middle-income populations will greatly reduce the cancer scenarios in the region. Apart from these, awareness at the grassroots level is of utmost importance to nip the cancer in the bud. Communities can engage in awareness and sensitization programs to increase health literacy among the population. These programs can aim at early screenings, and treatment, ultimately reducing the cancer burden.

**Conclusion**

Comparatively, the NE region of India is leading the chart in the incidence of cancer and its associated mortality. The alarming trend of increasing cancer cases in the region calls for an urgent need to address the issue. Since most cancer is associated with lifestyle, dietary and personal habits, therefore, community awareness is important to mitigate cancer at the grassroots level. Awareness programs and screening involving various stakeholders are pivotal in controlling and preventing the multiple cancers prevalent in the region. Additionally, continued research and intervention to identify key diagnostic and prognostic biomarkers of common cancers specific to this high-risk population will greatly reduce the toll of cancer in the area.

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# Cicada (Cicadoidea: Hemiptera) Research in Meghalaya, Northeast India: Historical Perspectives and Current Status

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**Abstract**

*Meghalaya, a state within the Indo-Burma biodiversity hotspot, harbors a diverse cicada assemblage (superfamily: Cicadoidea); however, its cicada fauna has remained historically underdocumented. Early taxonomic efforts provided foundational classifications but lacked precise locality data, while mid-20th-century surveys largely overlooked cicadas. The late 20th and early 21st centuries witnessed the emergence of targeted studies, including descriptions of new taxa and the application of bioacoustics and molecular taxonomy. Recent discoveries, such as Chremistica ribhoi, Mata meghalayana, and Becquartina bicolor, indicate Meghalaya's significance as a cicada biodiversity hotspot. Despite these advancements, research gaps persist, particularly in underexplored regions like the Jaiñtia Hills, and taxonomic ambiguities remain due to historical misidentifications. Habitat loss and climate change further threaten cicada populations, emphasizing the need for systematic surveys, molecular phylogenetics, and conservation initiatives to ensure comprehensive documentation and biodiversity preservation.*

**Keywords:** Biodiversity, Cicadoidea, conservation, habitat loss, taxonomy, Jaiñtia Hills.

## Introduction

Cicadas (superfamily: *Cicadoidea*) represent a morphologically and behaviorally specialized group of hemipteran insects characterized by their prolonged subterranean nymphal development, species-specific acoustic communication and distinct emergence patterns (Karban 1986). The state of Meghalaya, situated within the Indo-Burma biodiversity hotspot, supports a diverse assemblage of cicadas; however, scientific documentation of this diversity has historically been limited (Lyngdoh *et al.* 2019).

This review synthesizes the progression of cicada research in Meghalaya, spanning early entomological records, mid-20th-century taxonomic ambiguities, late 20th-century developments, and contemporary advances integrating bioacoustics and molecular methodologies

**Early records and initial observations (19$^{th}$ to mid-20$^{th}$ century)**

The documentation of Meghalaya's cicada fauna can be traced indirectly to colonial-era zoological surveys of Northeast India, although specific references to the state remain scarce. Distant (1906) established the genus *Mata* within *Cicadidae* based on morphological characteristics such as wing venation and body structure, describing taxa from broader Asian regions, some of which likely extended into the forests of Meghalaya. However, his taxonomic assessments lacked precise locality data for the state (Distant 1906). Similarly, Boulard (2007) conducted cicada taxonomic research in Southeast Asia, identifying genera such as *Becquartina*, which were later confirmed within Meghalaya, although no direct records from India existed at the time.

Early 20th-century entomological surveys, such as the Zoological Survey of India's 1922 study of the Siju Cave ecosystem in the Garo Hills, predominantly focused on cave fauna, documenting insect orders such as *Coleoptera* and *Diptera*, yet cicadas were not explicitly recorded (Harries *et al.* 2008). Comprehensive taxonomic catalogs, such as Metcalf's (1963) global cicada compendium, incorporated specimens from "British India," which likely included Meghalaya; however, the absence of specific attributions precluded precise geographic documentation. The reliance on morphology-based identification, coupled with a lack of targeted surveys, resulted in significant gaps in the taxonomic resolution of Meghalaya's cicada fauna.

**Mid-20th century: sparse documentation and regional context**

During the mid-20th century, cicada research in Meghalaya remained peripheral within broader entomological surveys. Retrospective analyses by Price *et al.* (2016) emphasized the scarcity of taxonomic studies focused on Northeast India's cicadas during this period, attributing the deficit to logistical challenges and the inherent difficulties of taxonomic delineation within the group.

For instance, Chopra and Kemp's 1922 biospeleological study of the Siju Cave complex, while significant for troglobitic insect research, did not record cicadas, either due to their absence from cave ecosystems or inadvertent omission (Harries *et al.* 2008).

Regional taxonomic checklists, such as Sanborn's (2013) compilation of Indian cicadas, provided species distributions at a national scale but lacked granularity for Meghalaya due to their reliance on historical datasets from British India (Sanborn 2013). Furthermore, although indigenous Khasi and Garo communities likely possessed ecological knowledge of cicadas, the absence of ethnobiological documentation in entomological literature resulted in an incomplete understanding of the state's cicada diversity.

**Late 20th century to early 2000s: Emergence of targeted studies**

The late 20th and early 21st centuries marked the initiation of targeted cicada studies within Meghalaya. Hajong and Yaakop (2013) provided a significant taxonomic breakthrough with the description of *Chremistica ribhoi*, a periodical cicada endemic to the Ri Bhoi district. This species remains the sole known periodical cicada in India exhibiting synchronized emergence cycles. The study employed morphological diagnostics, such as wing venation and tymbal structure, in conjunction with bioacoustics analyses of call patterns, to validate species identity. The discovery of *C. ribhoi* underscored Meghalaya's potential as a cicada biodiversity hotspot and emphasized the importance of acoustic characterization in taxonomic assessments (Hajong and Yaakop 2013).

Subsequently, Price *et al.* (2016) compiled an annotated catalog of cicadas spanning South Asia, recognizing Meghalaya as a region of significant but understudied cicada diversity. The study included *Chremistica ribhoi* and hypothesized the presence of additional genera such as *Mata* and *Salvazana*, based on biogeographic affinities with adjacent regions. However, the assessment was primarily reliant on literature-based analyses and museum collections rather than extensive field-based research within Meghalaya (Price *et al.* 2016). These studies established the foundation for further investigations by highlighting the necessity for detailed regional surveys.

**Modern era: taxonomic refinement and new discoveries (2010s–present)**

The 2010s and early 2020s witnessed a resurgence in cicada research in Meghalaya, facilitated by advancements in molecular phylogenetics, bioacoustic profiling, and targeted field expeditions. Sarkar *et al.* (2021) described three novel species of *Mata*—*Mata meghalayana*, *Mata lenonia*, and *Mata ruffordii*—collected from the Khasi and Garo Hills. The taxonomic delineation was based on morphological characters (e.g., tymbal and wing structural attributes) and detailed acoustic analyses, refining the taxonomic framework for the tribe *Oncotympanini*.

A landmark discovery followed with the documentation of *Becquartina bicolor* by Sarkar *et al.* (2024), marking the first confirmed record of the genus *Becquartina* in India. Specimens were collected from Balpakram National Park (South Garo Hills) in 2017 and the Nongkhrah community forest (Ri Bhoi) in 2020. The species, informally referred to as the "Butterfly Cicada" due to its striking saffron-and-black wing coloration, was characterized through morphological assessments, photographic documentation, and bioacoustics profiling. Notably, its call exhibited geographical variation, with distinct diurnal and crepuscular calling patterns observed across different populations. This discovery extended the known distribution of *Becquartina* from Southeast Asia into Northeast India, increasing the documented species count within the genus to seven (Sarkar *et al.* 2024).

Hajong's extensive fieldwork further contributed to the documentation of Meghalaya's cicada diversity. His research on *Salvazana mirabilis mirabilis*, first reported from Ri Bhoi in 2016, expanded the species' known biogeographic range, which was previously restricted to Southeast Asia. The identification was substantiated through call recordings and morphological analyses (Hajong and Thangkhiew 2018). His long-term studies reinforced Meghalaya's status as a cicada biodiversity hotspot, emphasizing the critical role of its forested landscapes in fostering endemic species (Shillong Times 2024).

**Current understanding and challenges**

Recent documented cicada species in Meghalaya encompass taxa from the genera *Chremistica*, *Mata*, *Becquartina*, and *Salvazana*, with *Chremistica ribhoi* remaining India's only known periodical cicada. The region's cicadas inhabit diverse ecological niches, including primary forests and community-protected landscapes such as Balpakram National Park and the Nongkhrah forest. The application of bioacoustic methodologies has significantly enhanced taxonomic precision, enabling the identification of species-specific call patterns and facilitating behavioral studies (Sarkar *et al.* 2021, 2024).

However, research gaps persist. Incomplete historical records, underexplored habitats (e.g., the Jaiñtia Hills), taxonomic inconsistencies due to misidentifications in early literature (Price *et al.* 2016), and anthropogenic threats such as deforestation and climate change pose significant challenges (Sarkar *et al.* 2024). The reliance on opportunistic discoveries rather than systematic surveys further constrains comprehensive documentation, and molecular phylogenetic studies remain in their nascent stages.

## Conclusion

The trajectory of cicada research in Meghalaya has transitioned from sparse colonial-era records to a dynamic field integrating morphological, bioacoustic and molecular methodologies. While early entomological surveys offered limited insights due to taxonomic ambiguities and geographic omissions, recent advancements have significantly refined species identification and expanded knowledge of regional cicada diversity. The discovery of new taxa, such as *Chremistica ribhoi*, *Mata meghalayana*, and *Becquartina bicolor*, has underscored Meghalaya's importance as a biodiversity hotspot.

Despite these advancements, considerable gaps remain. Several regions, such as the Jaiñtia Hills and lesser-explored forested landscapes, require targeted field studies to uncover undocumented species. Additionally, molecular phylogenetic analyses remain in their early stages, limiting our understanding of evolutionary relationships within the regional cicada assemblage. Bioacoustic profiling has proven instrumental in species delineation, yet further studies on acoustic variations across microhabitats and populations are necessary.

Future research should prioritize systematic surveys to ensure comprehensive species documentation including ecology and molecular phylogenetics to resolve taxonomic uncertainties and evolutionary lineages, and conservation initiatives to mitigate the impact of habitat loss and climate change. Strengthening collaborations between taxonomists, ecologists, and local communities will be essential for long-term preservation of Meghalaya's cicada fauna. As anthropogenic pressures intensify, a proactive research-driven approach will be crucial in safeguarding these ecologically significant yet understudied insects.

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# Mitochondrial Homeostasis as a potential therapeutic target to combat chronic kidney disease

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**Abstract**

*The prevalence of chronic kidney disease (CKD) is rapidly rising worldwide and will become the fifth leading cause of death by 2040. CKD is a complex condition characterized by mitochondrial dysfunction, oxidative stress and inflammation. This review explores the central role of mitochondrial homeostasis in the etiology of CKD, highlighting the complicated relationships between mitochondrial dynamics, biogenesis, cell death, mitophagy and epigenetic changes. We will discuss how mitochondrial dysfunction contributes to renal damage and the advancement of CKD, review existing treatments, examine the capability of natural compounds and neuroendocrine and maintain a healthy lifestyle as an interventional strategy to target mitochondrial dysfunction. Furthermore, we outline future directions for research, emphasizing the need to unravel the molecular pathways driving mitochondrial decline in CKD. By targeting mitochondrial homeostasis, we may uncover novel therapeutic strategies to combat aging and CKD, improving affected individuals' lifespan and quality of life.*

**Keywords**: Chronic kidney disease (CKD), epigenetic, mitochondrial dynamics, mitophagy, natural compounds.

## Introduction

Mitochondrial dysfunction is identified as a key biological hallmark of the aging process (Liu *et al*. 2020), characterized by changes in the mitochondrial network, accumulation of genetic mutations, mitochondrial depolarization and enhanced ROS reactive oxygen species (ROS) generation. These changes can impair energy metabolism, cellular senescence and kidney aging (Choi *et al*. 2024). Mitochondria are pivotal organelles that perform multiple critical functions within cells. These include orchestrating the oxidative phosphorylation pathway and modulating carbon metabolism, generating adenosine triphosphate (ATP) to fuel cellular activities, and regulating key signaling molecules such as calcium ions ($Ca^{2+}$) and ROS. These processes are integral to maintaining cellular homeostasis and influencing cell fate decisions (Boyman *et al*. 2020; Choi *et al*. 2024). Researchers have consistently demonstrated that maintaining optimal mitochondrial dynamics is essential for promoting longevity across various contexts, including conditions mediated by the target of rapamycin complex 1 (TORC1) and adenosine monophosphate-activated protein kinase (AMPK) signaling pathways and caloric restriction (Weir *et al*. 2017; Zhang *et al*. 2019). Studies in mice and *Caenorhabditis elegans* have shown that inhibiting the insulin/IGF-1 Insulin-like growth factor -1 (IIS) signaling pathway can significantly extend lifespan, indicating an evolutionarily conserved mechanism. Furthermore, manipulating IIS pathways has been linked to improved mitochondrial function, increased respiratory capacity and enhanced membrane potential (Akbari *et al*. 2019; Rostamian *et al*. 2021).

As a metabolically active organ, the kidney's energy requirements rely heavily on the efficient functioning of its mitochondria, specifically the process of oxidative phosphorylation, to generate the necessary energy to support its metabolic activities (Guo et al. 2024). Chronic kidney disease (CKD) poses a significant and growing threat to worldwide health, with projections indicating it will become the fifth leading cause of mortality worldwide by 2040. Furthermore, in countries with high life expectancy, CKD is predicted to rank as the second highest cause of mortality by the end of the century (Foreman *et al*. 2018; Ortiz *et al.* 2019). Consequently, mitochondrial stability is essential for maintaining healthy kidney function and preventing premature aging of the kidney. Additionally, research has shown that impaired mitochondrial function and elevated levels of oxidative stress play a significant role in the promotion and progression of numerous prevalent diseases, including metabolic disorders, and neurodegenerative conditions (Alqahtani *et al.* 2023).

Studies have demonstrated that aging is associated with a multi-layered remodeling of the kidney and other organs, leading to changes in their architecture and functional capacity (Miwa *et al.* 2022). Kidney aging is associated with a multifaceted pattern of histological alterations, spanning microscopic and macroscopic changes, which in turn contribute to a steady decline in kidney function, manifesting as a loss of cortical mass, glomerular filtration capacity, arteriosclerosis, tubular integrity and interstitial fibrosis (Hommos *et al.* 2017). Investigations and data have revealed that older adults are at a higher risk of developing renal fibrosis and chronic kidney disease compared to their younger counterparts (Denic *et al.* 2016; Yang *et al.* 2023). A deeper insight into the complex molecular mechanisms underlying mitochondrial homeostatic control in the kidney can facilitate the discovery of novel therapeutic approaches to delay kidney aging and prevent chronic kidney disease.

**Mitochondrial homeostasis in CKD**

Maintaining mitochondrial homeostasis is essential for cellular energy metabolism, redox balance and signaling pathways (Bhargava and Schnellmann 2017). However, in CKD, mitochondrial homeostasis is disrupted, leading to impaired mitochondrial dynamics, increased oxidative stress and altered biogenesis (Forbes 2016; Srivastava *et al*. 2023). Furthermore, CKD is associated with increased cell death, impaired mitophagy and epigenetic changes that affect mitochondrial function (Aranda-Rivera *et al.* 2024). We undertake a comprehensive review of the research on the complex interplay between mitochondrial dysfunction and CKD, exploring the key mechanisms underlying mitochondrial dynamics, oxidative stress, biogenesis, cell death, mitophagy, and epigenetic changes. By elucidating these mechanisms, we hope to identify potential therapeutic targets for the prevention and treatment of CKD.

***Mitochondrial dynamics***

The kidneys are highly energy-demanding organs, utilize 7% of daily ATP and contain numerous mitochondria. These organelles generate ATP via oxidative phosphorylation, varying densities across nephron segments based on energy requirements. Proximal tubular cells, critical for reabsorption and secretion, heavily rely on ATP from mitochondrial oxidative phosphorylation (Blagov *et al*. 2024). Unlike other kidney cells, they primarily use fatty acids, metabolized through β-oxidation in mitochondria (Takemura *et al*. 2020). Effective mitochondrial function is vital for kidney function, especially in proximal tubules where filtration occurs. Mitochondrial dysfunction can severely impair kidney function and contribute to CKD.

Mitochondria change shape via fusion and fission, a balance essential for their health. Too much fission causes fragmentation, while too much fusion causes hypertubulation. Maintaining this balance is crucial for preventing mitochondrial dysfunction and cell damage (Galvan *et al*. 2017). Mitochondrial fission and fusion are controlled by molecular machinery, first found in yeast and later in mammals. Dynamin-related protein 1 (Drp1), a guanosine triphosphatase (GTPase), drives fission by forming rings around mitochondria and constricting them until they divide, with receptors like Mitochondrial fission 1 (FIS1), Mitochondrial dynamics protein of 49 kDa and 51kDa (MiD49/51), and mitochondrial fission factor (MFF) helping Drp1 bind (Galvan *et al*. 2017). Post-translational modifications regulate Drp1 activity. In contrast, mitofusin 1 and mitofusin 2 (Mfn1 and Mfn2) mediate outer membrane fusion (Tubbs and Rieusset 2017), while while Optic atrophy 1 (Opa1) mediates inner membrane fusion (Morigi *et al*. 2015) (**Fig. 1**).

Problems with these processes are linked to diseases like cancer, cardiovascular issues, neurodegeneration and diabetes. Specifically, increased fission is tied to kidney injury (Galvan *et al*. 2017). Studies show that deleting or inhibiting Drp1 in kidney cells protects against diabetic kidney disease (Ayanga *et al*. 2016). Drp1's activity is regulated by phosphorylation, and different kinases have varying effects depending on the cell type and stimulus (Galvan *et al*. 2017). Targeting mitochondrial dynamics could be a therapeutic approach for kidney disease and other conditions involving mitochondrial dysfunction, but further research is needed.

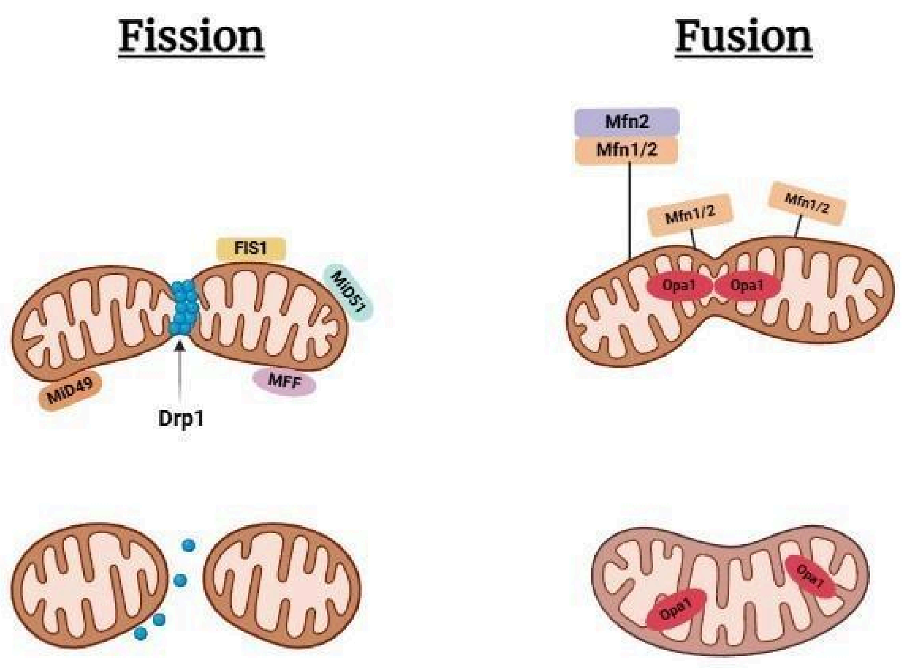


**Fig. 1.** Mitochondrial fission involves Drp1, which uses GTPase activity to oligomerize, form a ring, constrict, and divide the mitochondrion. Mitochondrial fusion requires MFN1 and MFN2, located on the outer membrane, to interact as homo- or heterodimers, while Opa1 mediates the fusion of the inner membrane. *Abbreviations: Drp1, dynamin-related protein 1: FSI1, mitochondrial fission protein 1: MFF, mitochondrial fission factor: MiD49 and MiD51, mitochondrial dynamics proteins of 49 and 51 kDa: Mfn 1/2, mitofusion proteins 1 or 2: Opa1, optic atrophy 1.* Adopted from Galvan *et al*. 2017.

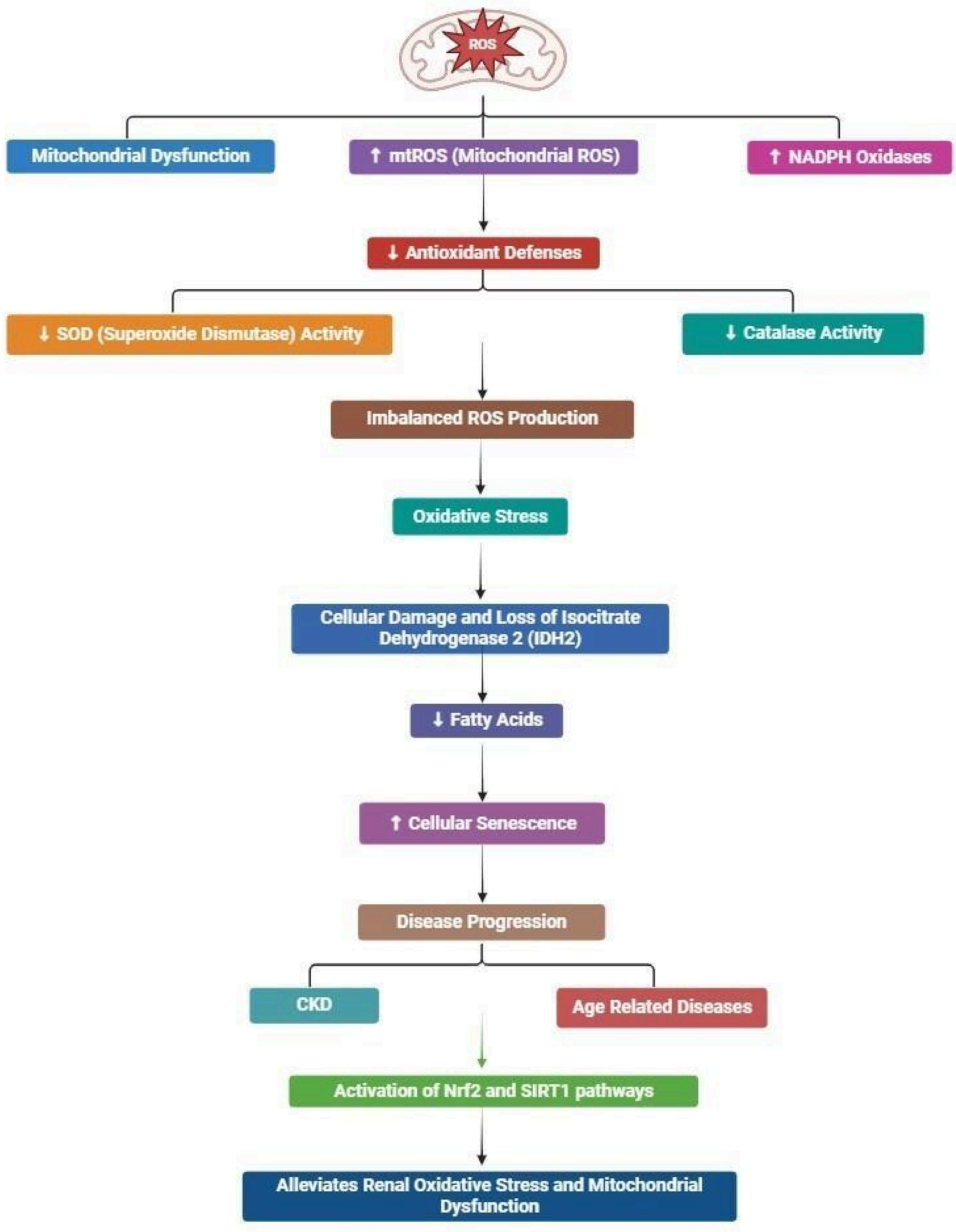


**Fig. 2.** Sources of ROS and oxidative stress in CKD and Aging. This flow chart shows how increased ROS in aging kidneys leads to oxidative stress, damaging cell membranes, and accelerating senescence. Loss of antioxidants and IDH2 worsen this process while activating Nrf2/Sirt1 pathways can offer protection. *Abbreviations: ROS, reactive oxygen species; CKD, chronic kidney disease; Nrf2, Nuclear factor erythroid 2-related factor 2; Sirt1, sirtuins 1; IDH2, isocitrate dehydrogenase 2.*

***Mitochondrial oxidative stress***

ROS are molecules capable of independent existence, containing at least one oxygen atom and one or more unpaired electrons. Different compartments generate ROS in cells, with mitochondria being the primary source, generating about 90% of cellular ROS (Tirichen *et al.* 2021). Studies show that ROS levels increase in aged mammalian kidneys (Davalli *et al*. 2016). The depletion of mitochondrial superoxide dismutase (SOD) and catalase (CAT) elevates oxidative stress (Hajam *et al*. 2022), while increased mitochondrial reactive oxygen species (mtROS) disrupts cell membranes and reduces fatty acids, accelerating cellular senescence (Giorgi *et al*. 2018).

Nicotinamide adenine dinucleotide phosphate (NADPH) oxidases also generate ROS, and elevated NADPH oxidase activity can predict oxidative stress in aging kidneys (Zhang *et al*. 2024). Loss of isocitrate dehydrogenase 2 (IDH2) accelerates kidney aging (Lee *et al*. 2017), while activating Nrf2 and Sirt1 pathways alleviates renal mitochondrial damage and oxidative injury (Naghibi *et al*. 2023) (**Fig. 2**). Mitochondrial oxidative stress is higher in CKD kidneys compared to healthy ones. CKD patients show elevated oxidative stress, linked to mitochondrial respiratory dysfunction (Ho and Shirakawa 2022). A biosensor confirmed increased mitochondrial ROS in CKD kidneys (Zhang *et al*. 2021). Thus, treating mitochondrial-targeted antioxidants like mitochondrially targeted 2,2,6,6-Tetramethylpiperidine-oxyl (mitoTEMPO) alleviate podocyte injury in diabetic nephropathy as reported (Qi *et al*. 2017).

***Mitochondrial biogenesis***

Mitochondrial biogenesis refers to the cellular mechanism responsible for synthesizing new mitochondria and modulating mitochondrial abundance as required. This intricate process involves the harmonized expression of proteins encoded by nuclear and mitochondrial genomes (Selfridge *et al*. 2013). Peroxisome proliferator-activated receptor γ co-activator -1α (PGC-1α) serves as a key orchestrator of mitochondrial biogenesis, directing the transcriptional apparatus to elevate mitochondrial content and enable tissues to adapt to heightened energy requirements (Sun *et al*. 2021). PGC-1α can be activated through post-translational modifications. Various stressors, including starvation, glucose deprivation and exercise, trigger the activation of PGC-1α via AMP-activated protein kinase (AMPK) mediated phosphorylation and increased nicotinamide adenine dinucleotide (NAD) levels. Elevated NAD levels activate Sirtuin-1 (SIRT1), a NAD-dependent deacetylase that deacetylates and activates PGC-1α (Guan *et al.* 2017; Poyan *et al*. 2018). Activated PGC-1α translocates to the nucleus, where it stimulates the expression of Nrf1 and Nrf2, leading to the transcriptional activation of nuclear-encoded mitochondrial genes, mitochondrial transcription factor A (Tfam), and the promotion of mitochondrial biogenesis, protein synthesis, and mitochondrial deoxyribonucleic acid (mtDNA) replication (Uittenbogaard and Chiaramello 2014).

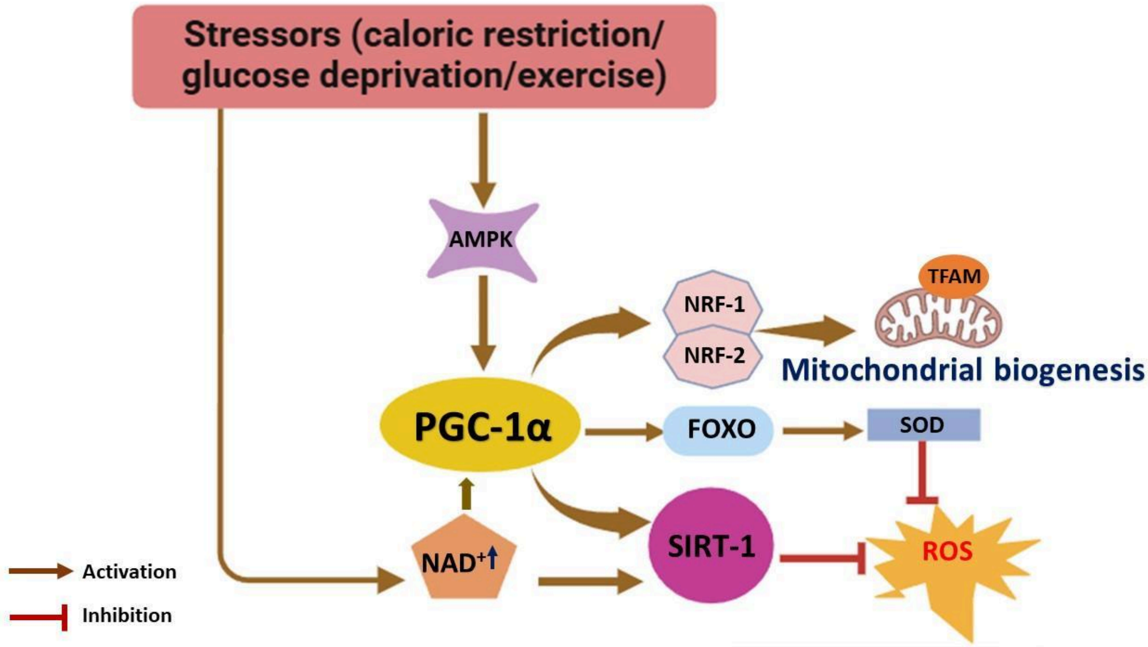


**Fig. 3.** PGC-1α role in regulating mitochondrial biogenesis and mitigating ROS. The activation of PGC-1α is mediated by AMPK-dependent phosphorylation. Once activated, PGC-1α triggers a cascade of events, including the activation of Nrf1 and Nrf2, which upregulate the transcription of Tfam, promoting de novo mitochondrial biogenesis. Furthermore, PGC-1α activation leads to increased $NAD^+$ levels, resulting in the activation of SIRT1 and subsequent inhibition of ROS in CKD. Additionally, PGC-1α stimulates the activation of FOXOs, leading to the enhanced expression of antioxidant genes, such as superoxide dismutase (SOD), which counteract ROS and alleviate renal damage. *Abbreviations: Peroxisome proliferator-activated receptor γ co-activator - 1α (PGC-1α), superoxide dismutase (SOD), sirtuins-1 (SIRT1), nuclear respiratory factors 1 and 2 (Nrf1 and Nrf2), forkhead box O1 (FOXO1), Superoxide dismutase (SOD), AMP-activated protein kinase (AMPK), Nicotinamide adenine dinucleotide (NAD+), Chronic kidney disease (CKD), Reactive oxygen species (ROS).*

Furthermore, PGC-1α interacts with various transcriptional partners, including peroxisome proliferator-activated receptor alpha (PPARα), peroxisome proliferator-activated receptor beta (PPARβ), retinoid receptors (RXR), myocyte enhancer factor-2 (MEF-2), forkhead box O1 (FOXO1) and estrogen-related receptors (ERRs), to regulate multiple energy metabolic pathways within and outside mitochondria (Yuan *et al*. 2023). These pathways are crucial for tissues with high energy demands, such as skeletal muscle, heart, kidney and brain. PGC-1α's transcriptional regulatory network influences genes involved in lipogenesis, mitochondrial fatty acid oxidation, thermogenesis and glucose metabolism, ultimately impacting energy homeostasis and mitochondrial function in metabolically active tissues (Fontecha-Barriuso *et al.* 2020). It has been revealed that PGC-1α acts as a crucial guardian against CKD progression by modulating mitochondrial biogenesis. Studies have demonstrated that decreased PGC-1α expression in CKD patients and animal models is associated with mitochondrial dysfunction, increased oxidative stress and kidney damage (Tran *et al.* 2016). Conversely, enhancing PGC-1α levels in the kidney may offer protective benefits against kidney injury, reducing fibrosis and inflammation (Chambers and Wingert 2020) (**Fig. 3**).

***Mitochondria and cell death***

Cell death refers to the irreversible loss of cellular function and viability. Cell death occurs in two primary forms. One form, necrosis, involves the catastrophic rupture of the cell membrane, releasing cellular contents into the surrounding environment. The second form is apoptosis, a tightly regulated process where cells undergo orderly self-destruction, with neighboring cells rapidly clearing away the dying cells before membrane rupture and content release occur in response to specific signals (**Fig. 4**). Apoptosis can be activated through intrinsic mechanisms, responding to internal cellular stress, or extrinsic mechanisms, triggered by the engagement of death receptors (Medina *et al.* 2020; Sanz *et al*. 2023). B-cell lymphoma 2 protein (Bcl-2) and Bcl-2-associated protein (Bax) play critical roles in regulating cell fate, with their relative expression levels serving as a molecular switch that determines cellular survival or demise (Yang *et al.* 2001).

During kidney development, apoptosis occurs at an exceptionally high rate. Immature kidneys exhibit widespread apoptotic activity, accompanied by elevated expression of genes involved in programmed cell death. In contrast, adult kidneys respond to injury through cell death mechanisms that affect various renal compartments, including tubular and glomerular structures, as well as distinct cell types such as distal tubular, and proximal cells, glomerular, and endothelial cells (Bard 2002). Renal cell death plays a pivotal role in the pathogenesis of kidney diseases including AKI, and CKD (Havasi and Borka 2011; Priante *et al.* 2019). As CKD advances, the gradual loss of renal tubular cells by apoptosis accelerates, leading to the deterioration of tubular structure and the accumulation of scar tissue. This process ultimately contributes to the progression of CKD, characterized by the relentless deterioration of kidney function (Choi *et al.* 2000).

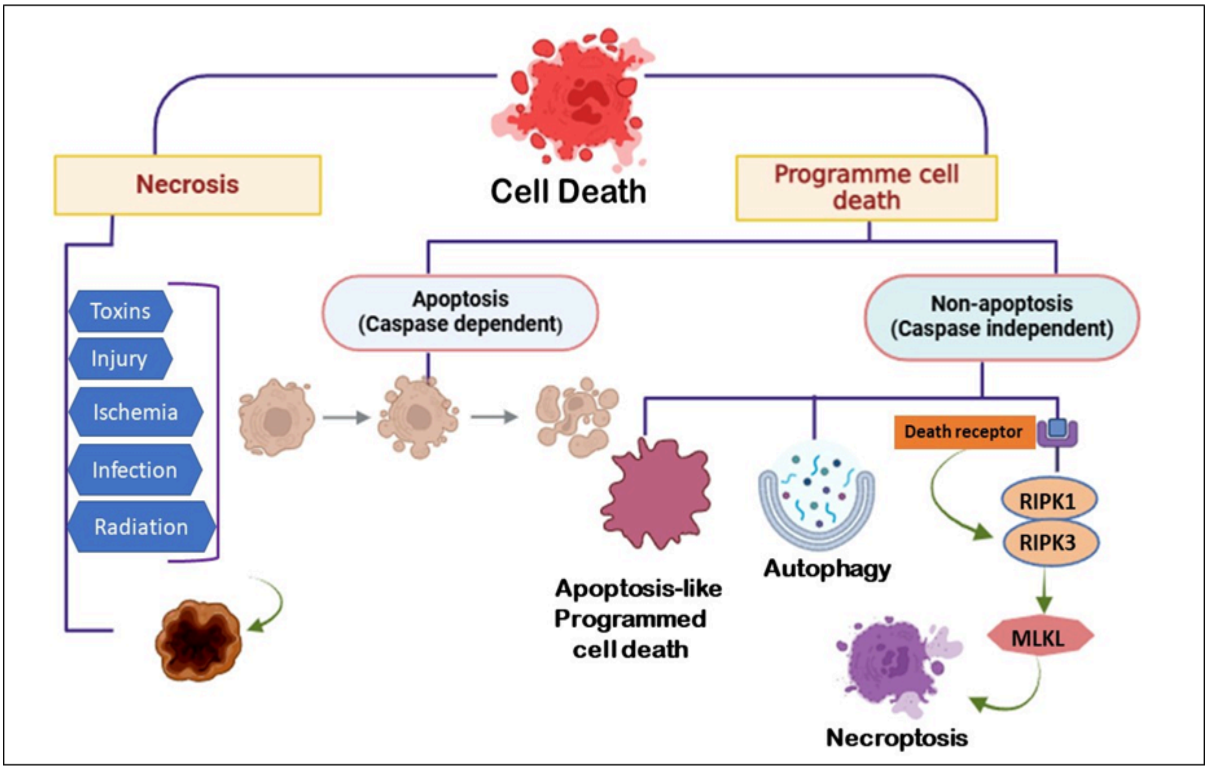


**Fig. 4.** Cell death is broadly classified into two distinct categories: programmed cell death and necrosis. Programmed cell death is a highly regulated process that encompasses various mechanisms, including apoptosis, which is characterized by cellular shrinkage and DNA fragmentation. In addition to apoptosis, programmed cell death also includes non-apoptotic forms, such as autophagy, a process involving cellular self-digestion; necroptosis, a form of programmed necrosis; and apoptosis-like programmed cell death, which shares similarities with apoptosis but lacks certain characteristic features. *Abbreviations: Deoxyribonucleic acid (DNA), receptor-interacting serine threonine kinase 1/3 (RIPK 1), Mixed lineage kinase domain-like (MLKL).* Adopted from Mustafa *et al.* 2024.

Regulated necrosis encompasses multiple forms, each distinguished by unique molecular signatures and responsiveness to inhibitors. Necroptosis, a kinase-driven process, involves the oligomerization and phosphorylation of receptor-interacting serine threonine kinase 1/3 (RIPK 1) and mixed lineage kinase domain-like (MLKL). In contrast, pyroptosis is a pro-inflammatory form characterized by gasdermin-mediated pore formation. Ferroptosis, meanwhile, is marked by iron-dependent lipid peroxidation, leading to plasma membrane disruption (Cao and Kagan 2022; Vandenabeele *et al.* 2023). Research from interventional studies suggests that necroptosis, mitochondrial permeability transition-regulated necrosis (MPT-RN) and ferroptosis may play a role in the development of ischemia-reperfusion injury-associated acute kidney injury (IRI-AKI). Studies using mouse models of IRI-AKI have demonstrated that inhibiting necroptosis, either through pharmacological inhibition with Nec1 or genetic deletion of RIPK3, provides partial protection against tubular damage and reduces serum urea and creatinine levels. Although these findings suggest that necroptosis, MPT-RN, ferroptosis and possibly pyroptosis contribute to the development of IRI-AKI, the precise mechanisms by which these pathways interact with specific cell types, and the upstream factors that trigger their activation, remain to be elucidated (Linkermann *et al*. 2012; Xia *et al*. 2021).

***Mitochondrial mitophagy***

CKD is marked by a gradual decline in renal function and the emergence of kidney scarring (Zhan *et al*. 2015). Studies have shown CKD is accompanied by increased mitochondrial fragmentation and elevated mROS production. Efficient and timely removal of excess or damaged mitochondria in the kidney is essential for preserving cellular homeostasis. Conversely, failure to remove the accumulation of dysfunctional mitochondria exacerbates oxidative stress, leading to tubular apoptosis and kidney damage in CKD (Gamboa *et al*. 2016; Bhatia and Choi 2019). Mitophagy is vital for ensuring mitochondrial function and quality, which facilitates the removal of damaged mitochondria or dysfunctional mitochondria thereby, maintaining mitochondrial balance and ensuring the optimal quality and quantity of these vital organelles (Meng *et al*. 2025). In response to cellular stress, mitophagy is triggered as a protective response to maintain mitochondrial homeostasis. This process can be initiated through two primary mechanisms: the classical ubiquitin-mediated pathway, exemplified by the Phosphatase and TENsin homolog-induced putative kinase 1 PINK1/Parkin Parkinson protein 2, E3 ubiquitin-protein ligase axis, and the receptor-mediated pathway, which encompasses the Bcl2 interacting protein 3, BNIP3/Nix, FUN 14 domain-containing protein 1 (FUNDC1), and cardiolipin pathways (Ashrafi and Schwartz. 2013; Tang *et al*. 2020).

Emerging evidence advocates that mitophagy has a crucial impact on chronic kidney disease mechanisms. Excessive mitophagy may have a self-regulatory effect, suppressing the expression of PINK1 and Parkin, which in turn downregulates these critical genes.

Conversely, a deficiency in PINK1 triggers a compensatory increase in Parkin expression, which significantly inhibits the upregulation of Drp1. This suppression of Drp1, a key regulator of mitochondrial fission and apoptosis, ultimately mitigates excessive mitophagy and renal damage (Zhou *et al.* 2019) (**Fig. 5**). Recent studies propose that augmenting mitophagy could represent a novel therapeutic strategy for CKD (Yang *et al*. 2024).

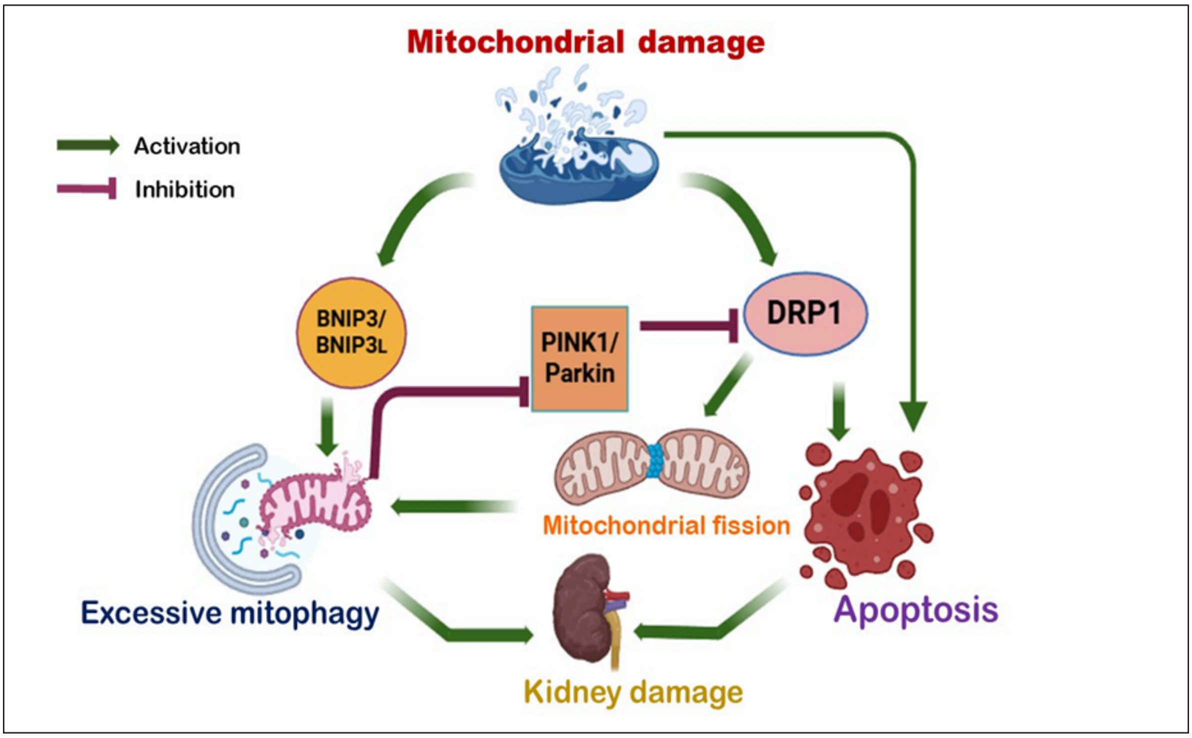


**Fig. 5.** Damage to the mitochondria of renal tubular epithelial cells triggers a cascade of cellular responses, including mitophagy mediated by BNIP3/BNIP3L, mitochondrial fission regulated by DRP1, and programmed cell death, ultimately leading to kidney damage. *Abbreviations: Phosphatase and Tensin homolog-induced putative kinase 1 (PINK1), Parkinson protein 2 (Parkin2), Bcl2 interacting protein 3 (BNIP3/Nix), Dynamic-related protein 1 (DRP1).*

***Mitochondrial epigenetic changes***

Mitochondrial epigenetic modifications contribute significantly to CKD pathophysiology by regulating mitochondrial gene expression, which can lead to impaired mitochondrial function, elevated oxidative stress and accelerated kidney damage. Specifically, alterations in mitochondrial DNA methylation patterns can have far-reaching consequences, disrupt mitochondrial function, affect kidney cell viability and contribute to CKD progression (Galvan *et al.* 2017). Research has revealed that epigenetic modifications within mitochondria can trigger the upregulation of genes involved in fibrogenesis, thereby contributing to the progression of renal fibrosis, a characteristic feature of advanced CKD (Feng *et al.* 2022). This epigenetic reprogramming can lead to the excessive accumulation of extracellular matrix proteins, ultimately disrupting normal kidney architecture and function (Ding *et al.* 2021).

To elucidate the epigenetic alterations that contribute to CKD, researchers are conducting comprehensive analyses of mtDNA methylation patterns in kidney tissue samples from CKD patients (Feng *et al.* 2022; Rysz *et al.* 2022). Studies have also shown that unfavorable conditions during fetal development, including maternal malnutrition or high blood sugar, can predispose individuals to hypertension and kidney disease in adulthood (Lelièvre-Pégorier and Merlet-Bénichou 2000; Ruggenenti *et al.* 2022). By examining how environmental stressors influence mitochondrial epigenetic marks, researchers seek to understand the molecular mechanisms underlying CKD progression better and identify potential therapeutic targets (Yan *et al*. 2024).

**Interventional strategies to target mitochondrial dysfunction in CKD**

The development of novel mitochondria-targeted therapies is a rapidly evolving field, with several promising strategies underway, including certain antidiabetic medications, sodium-glucose linked transporter 2 (SGLT)- inhibitors and glucagon-like peptide 1 (GLP-1) receptor agonists (Tanriover *et al.* 2023), the use of small molecules, nanocarriers (Yu *et al*. 2020), peptides, mitochondrial transplantation and the design of mitochondria-specific compounds and the development of agents that enhance mitochondrial biogenesis, function and overall bioenergetic capacity (Declèves and Sharma 2014; Huang *et al.* 2023). This review endeavors to summarize the key findings and implications of interventional strategies that target mitochondrial dysfunction, including the use of natural compounds, neuroendocrine modulators (melatonin, serotonin, estrogen), healthy lifestyle and dietary interventions. We will explore the current evidence supporting these interventions, their potential mechanisms of action, and their therapeutic potential for improving mitochondrial function and slowing disease progression in aging and CKD.

***Natural compounds***

Bioactive compounds derived from natural sources, including plants, animals, and microorganisms, offer a wealth of opportunities for the unearthing and development of new medications. These natural products, composed of single molecules or complex mixtures, have evolved to produce a wide range of biologically active ingredients (Mu *et al*. 2020; Liang *et al*. 2021; Aranda-Rivera *et al.* 2024). Research has demonstrated that Berberine, a compound extracted from *Coptidis rhizoma* and *Phellodendri Cortex (*Fujii *et al.* 2017) shown to mitigate mitochondrial dysfunction in palmitic acid-induced podocyte, and DKD (diabetic kidney disease) models damaged by the activation of AMPK (Joshi *et al*. 2019), and PGC-1α pathways (Qin *et al.* 2020; Li *et al.* 2021). Furthermore, the salidroside found in *Rhodiola rosea* (Liu *et al.* 2022b; Liang *et al*. 2021), displays a broad spectrum of pharmacological activities, including anti-apoptotic, anti-inflammatory, and mitochondria-protective effects, which contribute to its renal protective properties (Huang *et al.* 2019; Wang *et al.* 2022; Fan *et al.* 2023). Resveratrol, a polyphenol found in Vaccinium species berries (Rimando et. al. 2004), has been found to safely improve renal function and enhance peritoneal ultrafiltration in individuals with kidney disease (Lin *et al*. 2016; Dai *et al.* 2018; Singh *et al*. 2019). Formononetin, a key phytochemical component of *Astragalus membranaceus* (Zhang *et al.* 2018), has also been identified as a potential therapeutic agent, capable of upregulating and activating Sirtuin-1 and mitigating nephrotoxicity in various models of kidney injury (Aladaileh *et al.* 2019; Hao *et al*. 2021; Althunibat *et al.* 2022; Tovar-Palacio *et al.* 2022).

Puerarin, a bioactive compound derived from the root of *Pureraria lobota* (Zhou *et al*. 2014; Tovar-Palacio *et al.* 2022), has been shown to protect mitochondrial damage and inhibit cadmium-induced apoptosis in renal tubular epithelial cells (TECs) (Song *et al.* 2016). Additionally, capsaicin, the most active constituent found in red chili peppers (Lu et al. 2020), has demonstrated therapeutic effects in kidney disease of various animal models including unilateral ureteral obstruction (UUO), DKD (Liu *et al.* 2022a), and nephrotoxicity (Jung *et al.* 2014). Furthermore, sulforaphane, a compound extracted from *Brassica oleracea var. italica* (González *et al*. 2021) has been found to activate the Nrf2 signaling pathway, protecting against mitochondrial oxidative stress and alleviating age-related mitochondrial dysfunction and kidney injury (Briones-Herrera *et al.* 2018; Mohammad *et al.* 2022).

Many studies have verified the therapeutic potential of thymoquinone, a compound derived *Nigella sativa* seeds (Warinhomhoun *et al.* 2023), in enhancing renal mitochondrial function. Thymoquinone enhanced cellular antioxidant defense by increasing the expression of key antioxidant enzymes, notably SOD, catalase, glutathione peroxidase (GPX), and glutathione (GSH), which helps mitigate mitochondrial oxidative stress and restore renal mitochondrial viability through Nrf2 activation (Hannan *et al.* 2021; Hashem *et al.* 2021).

***Endocrine modulators***

Targeting mitochondrial dysfunction with pharmacological endocrine secretions such as melatonin (Agil *et al.* 2013), serotonin (Hurtado *et al*. 2024), and estrogen-related receptors (ERRs) (Wang *et al*. 2023) has become a viable therapeutic strategy to modulate mitochondrial dynamics, bioenergetic deterioration, oxidative stress and improve kidney functions. Melatonin is a neurohormone primarily produced by the pineal gland (Ganguly *et al*. 2002). Recent investigations have confirmed that melatonin indeed protects against kidney damage caused by diabetes and obesity (Stacchiotti *et al.* 2014; Winiarska *et al.* 2016). Melatonin was found to have a dual beneficial effect on mitochondrial dynamics, suppressing Drp1 expression, a protein associated with the fission of mitochondria, while concurrently upregulating the expression of optic atrophy 1 (Opa1) and Mfn2 proteins involved in mitochondrial fusion (Chang *et al.* 2019). This finding is corroborated by a study demonstrating that melatonin increases Mfn2 expression in the renal convoluted tubules of obese mice (Ding *et al.* 2018; Agil *et al*. 2020).

Serotonin or 5-hydroxytryptamine (5 -HT) is best known as a neurotransmitter with a key function in the central nervous system. Still, it exerts widespread influence through its synthesis and activity in organs like the liver, gut, and kidneys (Hurtado *et al.* 2024). The 5-HT receptor family comprises seven established subtypes, ranging from 5-HT1 to 5-HT7. Research has demonstrated that stimulation of 5-HT1F and 5-HT2 receptors confer renoprotective effects in animal models of AKI, including the induction of mitochondrial biogenesis, attenuation of renal injury, and preservation of vascular integrity (Gibbs *et al*. 2018). In contrast, mice deficient in the 5-HT1F receptor exhibited increased renal vascular leakiness (Dupre *et al*. 2019), impaired renal recovery and decreased mitochondrial biogenesis following bilateral I/R injury (Hurtado *et al.* 2023), highlighting the receptor's role in maintaining renal vascular integrity and function.

Beyond its well-known role in reproductive biology, estrogen and estrogen-related receptors (ERRs) exert significant effects on various physiological processes, including kidney function, in mammalian species (El-Gendy *et al.* 2019). Estrogen receptors in the kidney comprise three main subtypes: ERα, ERβ, and G-protein-couple estrogen receptor (GPER) (Chen *et al.* 2004). These receptors are primarily nuclear but also exhibit cytoplasmic and mitochondrial localization (Lee *et al.* 2013). Animal models of kidney disease have revealed a sex-specific difference in disease progression, with females showing slower progression than males (Neugarten 2002). Estrogen therapy or surgical removal of the testes in male rats has been found to slow disease progression. Moreover, estrogen treatment has been shown to reduce proteinuria and glomerular fibrosis and decrease markers of glomerular damage in rats with hypertension or puromycin-induced nephrosis (Wen *et al*. 2009; Lee *et al.* 2013). Although the impact of ERRs on age-related mitochondrial decline and chronic kidney disease is not yet fully understood, a recent study demonstrated that the pan-ERR agonist SLU-PP-332 enhanced mitochondrial function and mitigated inflammation in the kidneys of aging mice (Wang *et al.* 2023), highlighting a potential therapeutic avenue worthy of further investigation.

***Healthy lifestyle and dietary interventions***

Aging is marked by declining tissue and organ function, often paired with chronic inflammation, which can shorten health span and lifespan. Nevertheless, research has identified calorie restriction (CR) as a promising non-genetic intervention capable of preventing age-related diseases and promoting increased longevity, as evidenced by numerous studies conducted in various animal models (Mercken *et al.* 2012; Redman *et al.* 2018). The implementation of CR has been found to profoundly impact various physiological processes. One of the primary benefits of CR is its ability to modulate mitochondrial activity, thereby reducing oxidative damage. This is achieved through the induction of endogenous antioxidant systems, which serve to neutralize harmful reactive oxygen species. Furthermore, CR has decreased metabolic rate, alleviated oxidative stress, and enhanced insulin sensitivity. Additional benefits of CR include improved function of the neuroendocrine and parasympathetic systems, as well as the induction of autophagy and suppression of nuclear factor kappa-light-chain-enhancer of activated B cells (NF-kB). These adaptations ultimately contribute to improved molecular and metabolic function (Kim *et al*. 2017; Di Francesco *et al*. 2018; Hwangbo *et al.* 2020). Recent research has demonstrated that CR can significantly mitigate ischemia/reperfusion (I/R) injury in aged mice, as evidenced by reduced infarct size. Additionally, CR has been shown to enhance glycolytic processes, independent of I/R injury, and restore myocardial glucose uptake in older mice. This is achieved through the upregulation of key proteins, including p-AMPK, p-PGC1α, SIRT1, and SOD2, and the downregulation of PPAR (Guo *et al.* 2023).

Numerous studies have underscored the significance of regular physical activity in preventing muscle atrophy, enhancing exercise capacity and improving quality of life in patients with CKD. Exercise has also been shown to restore mitochondrial turnover and promote a healthy mitochondrial pool, thereby supporting muscle preservation (Roshanravan *et al*. 2013; Tamaki *et al*. 2014; Isoyama *et al*. 2014) Conversely, a sedentary lifestyle and reduced skeletal muscle mass in CKD patients is associated with an increased risk of sarcopenia and premature mortality (Joseph *et al*. 2016). Animal studies have demonstrated that exercise protocols, such as swimming or wheel running, can mitigate the decline in mitochondrial density in rodents with renal failure. Specifically, citrate synthase activity, a proxy for mitochondrial density, was maintained in exercising rodents despite disease progression. This preservation of mitochondrial density appeared to prevent the anticipated deconditioning of skeletal muscle, highlighting the importance of maintaining skeletal muscle health for overall well-being (Davis *et al*. 1983; Adams *et al.* 2005).

Chronic alcohol consumption can lead to kidney damage by disrupting mitochondrial function and antioxidant defenses (Harris *et al.* 2015). Additionally, nicotine, found in tobacco, has been shown to mediate the relationship between smoking and renal damage by inducing oxidative stress, characterized by elevated mitochondrial-derived ROS levels in renal proximal tubular cells (Nguyen *et al.* 2015). Maternal smoking can even increase the risk of kidney disease in offspring (Stangenberg *et al*. 2015). Fortunately, adopting a healthy lifestyle, including dietary restrictions, avoidance of harmful habits, and regular physical exercise, can improve overall health by reducing oxidant production and enhancing antioxidant defenses.

**Future directions for targeting mitochondrial homeostasis in CKD**

Targeting mitochondria may hold significant promise for innovative therapeutic interventions in patients with kidney impairment. By combining mitochondria-targeted interventions with established treatments and lifestyle modifications, it may be possible to prevent or delay the development of CKD and minimize the incidence of severe systemic hitches associated with mitochondrial dysfunction (Granata *et al*. 2015; Jiménez-Uribe and Pedraza-Chaverri 2022). Despite extensive research that has explored various aspects of kidney disease, including mitochondrial metabolism and ROS production, the precise role of mitophagy in CKD remains poorly understood. The mechanisms by which mitophagy modulation influences renal fibrosis, CKD progression, and prognosis require systematic investigation (Yang *et al.* 2024) Elucidating the molecular mechanisms and regulatory pathways of mitophagy in kidney diseases is crucial for developing effective therapeutic interventions.

A new therapeutic strategy, mitochondrial transplantation, has emerged as a potential treatment for kidney disease. However, large-scale clinical trials are necessary to assess the therapeutic potential of mitochondrial transplantation in kidney disease (Tanriover *et al*. 2023). Furthermore, the development of effective therapeutic strategies targeting mitochondrial homeostasis in CKD is hindered by a lack of understanding of the optimal timing, dosage, and duration of treatment. Natural compounds possess unique properties that make them attractive candidates for developing novel therapeutics that regulate energy metabolism. While their therapeutic potential is well recognized, the specific mechanisms by which natural compounds target mitochondrial dysfunction in kidney diseases remain understudied (Aranda-Rivera *et al.* 2024). By addressing these knowledge gaps and exploring these future directions, researchers can develop effective therapeutic strategies targeting mitochondrial homeostasis in aging and CKD, ultimately improving affected individuals' health span and quality of life.

**Conclusion**

This comprehensive review highlights the intricate relationships between mitochondrial dynamics, oxidative stress, mitophagy, biogenesis, and epigenetic changes in the context of aging and chronic kidney disease. The evidence underscores the life-threatening role of mitochondrial dysfunction in the pathogenesis of these conditions, emphasizing the need for effective therapeutic strategies. Natural compounds, such as polyphenols and flavonoids, have emerged as promising agents for targeting mitochondrial dysfunction, offering a potential adjunct to conventional therapies. However, further research is necessary to elucidate the molecular mechanisms underlying mitochondrial dysfunction in aging and CKD, and to develop targeted interventions that can be translated into clinical practice. Future investigations should prioritize exploring novel therapeutic targets, developing biomarkers for mitochondrial function and optimizing treatment strategies to improve outcomes for individuals with aging-related CKD. By advancing our understanding of the complex interplay between mitochondrial homeostasis, aging and CKD, we can unlock new avenues for preventing and treating these debilitating conditions.

**Disclosure**

All the authors declared no competing interests and have consented to the manuscript for submission.

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**Credit authorship contribution statement**

Mildaris Marwein, MM: Conceptualisation, writing original draft, diagram and flow chart preparation.

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# Assessment of bacterial aeroflora in urban settings at different times of a day

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**Abstract**
*Aerobiology explores the origin, dispersion and impact of organisms and materials released into the atmosphere on plant, animal and human life. With this objective in mind, the present study was carried at three different times of the day (morning, afternoon and evening) to investigate the diversity and distribution of airborne bacteria in three major marketplaces of Shillong i.e. Polo Bazar, Police Bazar, and Bara Bazar by petri plate exposure method. The isolates were subjected to biochemical characterisation such as catalase, oxidase, indole, methyl red, citrate, Voges-Proskauer, triple sugar iron tests and gram staining. Bara Bazar exhibited the highest bacterial count in the morning and evening while Police Bazar consistently showed the lowest count. Afternoon samples showed elevated counts in Polo Bazar, correlating with reduced foot traffic. Across all samples, eight bacterial genera were identified, with Bacillus and Staplylococcus present at all sites and time, highlighting their environmental resilience. Morning samples exhibited the highest bacterial diversity, aligning with diurnal patterns. All isolates were Gram-positive, consistent with atmospheric bacterial studies emphasizing their dominance in airborne environments. These findings underscore the dynamic nature of urban microbial communities and emphasize the need for effective monitoring and hygiene practices in public marketplaces, to mitigate potential health risks. This investigation sheds light on the abundance and diversity of airborne bacteria in these marketplaces, raising concern about potential health risk. The findings emphasize the need for effective monitoring and control measures to manage airborne microorganisms in urban environments.*

**Keywords:** Aeroflora, Airborne, Bacteria, Market settings, Risk.

## Introduction

Airborne particles of biological origin are called bioaerosols. Bacteria constitute part of the airborne aerosol and are widely encountered in the lower layer of the troposphere (Fahlgren *et al.* 2010). Bioaerosols can be viable or non-viable, examples include bacteria, fungal spores, pollens, mites, death tissue etc. Air serves as a mode of transport for the dispersal of bioaerosols from one location to another, required for the reproduction and for the colonization of new sites. The presence of bacteria in the air can significantly influence the ecology, climate and public health at both local and global scale (Nowoisky *et al.* 2016). Therefore, without understanding the bacterial aerosol diversity it is difficult to determine their functional importance to atmospheric chemistry and cloud formation, or the risk of infection (Brodie *et al.* 2007; Morris *et al.* 2014; Amato *et al.* 2017). Atmospheric transport of bacteria provides an essential redistribution mechanism for viable microbes and also for genetic potential transfer between distinct regions and essentially different habitats (Polis *et al.* 1997; Säwström *et al.* 2016; Mayol *et al.* 2017) making the bacterial aerosols a critical factor for understanding the connections driving diversity (Prospero *et al.* 2005). Different types of bacteria are present in air which can be pathogenic and non-pathogenic. The pathogenic bacteria can be dispersed in the air from natural events or human activity. Some environments and human-related activities can lead to the generation of large numbers of bioaerosols and numerous airborne pathogenic agents (Nehme *et al.* 2008; Oppliger *et al.* 2008; Lecours *et al.* 2012). They are of important concern as it affects public health, agriculture, ecology, health and international security.

Bioaerosols that consist of fungi, bacteria, plant material (their associated cell wall material and toxins) are capable of causing allergies and respiratory problems. The aerobiological dispersal of pathogens such as species in the *Escherichia, Salmonella, Legionella, Neisseria, Bacillus, Francisella, Burkholderia, Clostridium, Brucella* and *Yersinia* genera pose important health and ecological issues (Kuske *et al.* 2006). Some of the researchers have found that the pathogenic bacteria can be transported in massive dust clouds from one place to another (Sultan *et al.* 2005). Recently atmospheric microbiology studies (Kuske *et al.* 2006) have contributed to our ability to detect bacterial pathogens in air samples; these studies increase our knowledge of the spatial and temporal dispersal of aerosolized bacteria and also increase our understanding of natural bacterial diversity and composition of air. Bacterial community fingerprints have been used to broadly assess the composition of bacteria in urban aerosols (Kuske *et al.* 2006). Thus, there is a need for knowing about the normal abundance, distribution and composition of bacteria in the atmosphere. This type of study poses challenges due to its broad diversity and tremendous variability (both locally and regionally), in terms of microbial load and composition owing to seasonal effects, local climatic conditions, etc. Despite these important aspects, the diversity of bacteria inhabiting atmospheric ecosystems remains poorly constrained in terms of biogeography (Dueker *et al.* 2018). Several studies have also found increased diversity in microbial aerosol samples with low humidity conditions and increased wind speeds (Jones *et al.* 2004; Lee *et al.* 2017).

The study and characterization of these bioaerosols is necessary for several reasons such as to understand the diversity of bacteria in air; increasingly comprehensive taxonomic surveys of bacterial diversity in the outdoor air, helps in explaining the bio geographical distribution of bacteria (Hagstro¨m *et al.* 2000; Kellogg *et al.* 2006; Hervas *et al.* 2009). This further aids in understanding pattern of aerosol dispersal of bacterial pathogens, monitoring aerosol pathogen surveillance, providing clues for the spread of disease (Brown *et al.* 2002) and understand alteration in meteorological processes such as ice nucleation (Mo¨hler *et al.* 2007).

These studies represent a significant effort in understanding the composition, transport, survival and viability of bacteria in the air. However, many questions remain unanswered about patterns and factors affecting the aforementioned components, and the overall abundance, composition and consequences of bacteria in air (Kuske *et al.*2006). Microorganisms can be transported within and between continents on upper air currents(Brown *et al*. 2002). The threat of biological warfare and the need to develop early warning systems also add to the importance of knowing the identity of microorganisms commonly dispersed in the atmosphere (Fahlgren *et al.* 2010). The present-day study was carried out to identify the bacterial forms in three different market places in the Shillong area. Thus, this study will provide more information regarding the microbes present in air and how they vary from location to location.

## Materials and methods

### Study area

Shillong is the capital city of Meghalaya and is situated in the North-eastern part of the country situated at 25.5788° North(N), 91.8933° East(E) at an altitude of 1,491m above sea level. Three markets namely, Polo Bazar, Police Bazar and Bara Bazar were selected for the present study.

Polo Bazar situated at 25.5823° N; 91.8830° E extended to an area of about 3000 sq. m. The different types of stalls in the market are vegetable shops, fish stalls, pork stalls, beef stalls, chicken stalls, tea stalls, grocery, kwai (betelnut) shops, mutton stalls, pharmacies etc.

Police Bazar is another crowded market of Shillong famous for its shopping haunt, which remains on the priority list of locals as well as tourists. It is a modern market that has a number of hotels, shops and eating joints, catering to varied needs of every visitor. It is situated at 25.5779° N, 91.8837° E.

Bara Bazar is a popular market in Shillong for household items like fruits, vegetables, clothes and other items and is situated at 25.5724° N, 91.8745° E.

**Sample Collection**

Airborne microbial sampling was carried out by the petri plate exposure method (passive method) in morning, afternoon and evening. The air samples were collected aseptically from Polo Bazar, Police Bazar and Bara Bazar three times a day i.e. early in the morning from 6:00am-7:00pm, in afternoon from 12:00pm-2:00pm and in evening from 5:30pm-6:30pm. The sample was collected in triplicates using the petri plate exposure method. During the exposure the number of people around was also counted. Nutrient agar served as a culture media for the growth of bacteria. After collecting the sample, the plate was sealed with paraffin and transferred to the laboratory. Thermometric as well as hygrometric readings were also taken during the time of sample collection.

**Isolation of bacteria**

The bacterial samples collected from air were incubated at 37°C for 24 h. After the growth of the microorganism on the plate, colonies that developed were counted and recorded. Based on the colony morphology, representative colonies were picked for further characterization. To isolate the pure colonies of bacteria, streak plate technique was used and incubated at 37°C for 24 h. The pure cultures of bacterial samples were maintained in a 2 ml glycerol stock for further use.

**Characterization of bacterial culture**

***Morphological characterization: Shape, size and colour of bacterial colonies***

Morphological characteristics of the colonies such as shape, size and colour were observed for presumptive identification. The opacity of the bacterial colonies was noted by observing whether the colonies were translucent, transparent or opaque. Their margin and elevation were also observed.

***Gram staining***

For differentiating Gram positive bacteria from Gram negative bacteria Gram's staining was performed. A thin smear of culture on glass slides was made with a loop full of bacteria. The smear was air dried and then heat fixed, and then stained with crystal violet (Himedia, India) for 60 s, Gram's iodine (Himedia, India) for 60 s, followed by Gram's decolourizer (Himedia, India) for 30 s and safranin (Himedia, India) for 60 s. The smear was then washed with distilled water and air dried. The slide was then observed under the microscope in 100x magnification (Aneja *et al*. 2003).

***Biochemical characterization***

To identify the unknown isolates a number of biochemical tests were performed which included catalase test, indole test, methyl red test, Voges-Proskauer test, oxidase test and citrate test.

***Indole test***

A tube of peptone water was inoculated with a small amount of a pure culture. Incubation at 35°C (+/- 2°C) for 24 to 48 h. To test for the indole production, 5 drops of Kovac's reagent was added directly to the tube. A positive indole test was indicated by the formation of a pink to red colour ("cherry-red ring") in the reagent layer on top of the medium within seconds of adding the reagent. The reagent layer remained yellow or slightly cloudy if the culture was indole negative.

***Methyl red test***

MR-VP broth was prepared and 5ml of broth was added in test tubes and was sterilized by autoclaving at 121°C (15psi) for 45 min. The test tubes were inoculated with the bacterial culture and incubated at 37°C for 24-48 h. For the result, test tubes with the isolates were taken and 5 drops of methyl red indicator was added to the tubes. A red colour indicated positive methyl red test and yellow colour indicated a negative methyl red test.

***Voges-Proskauer Test***

MR-VP broth was prepared and 5ml of broth was added in test tubes and were sterilized by autoclaving at 121°C (15psi) for 45 min. The test tubes were inoculated with the bacterial culture and incubated at 37°C for 24-48 h. For the results the test tubes with the isolates were taken and 1-2 drops of Barritt Reagent A and 1-2 drops of Barritt Reagent B were added and kept in the shaker incubator and allowed for the reaction to complete for about 30 min. Pinkish red colour indicated positive test and no change in colour indicated a negative test (Usha *et al.* 2008).

***Citrate utilization test***

A single isolated colony was lightly streaked on the surface of the Simmons Citrate Agar slant. The tubes were incubated at 35°C (+/- 2°C) for 18 to 48 h. A Citrate positive growth was visible on the slant surface and the medium turned intense Prussian blue. Citrate negative culture had minimal trace or no growth visible and colour change had not occurred; the medium remained deep forest green colour of the uninoculated agar.

***Catalase test***

Catalase activity was observed by adding a few drops of 3 % $H_2O_2$ to the broth cultures, kept on the glass slides. Formation of oxygen bubbles confirms the positive result (Singh *et al.* 2012).

***Oxidase test***

The oxidase test was carried out by placing the colony of bacteria onto an oxidase disc which are sterile paper disc impregnated with N N-dimethyl phenylenediamine oxalate, ascorbic acid and a-naphthol (Usha *et al.* 2008). A sterile wooden cotton swab was used to pick a part of the colony of the unknown isolates and touched on the filter paper. If the colour of the disk changes to purple or dark blue within 10 seconds, it indicates a positive result. No colour change indicates a negative result.

***Triple sugar iron agar (TSI) test***

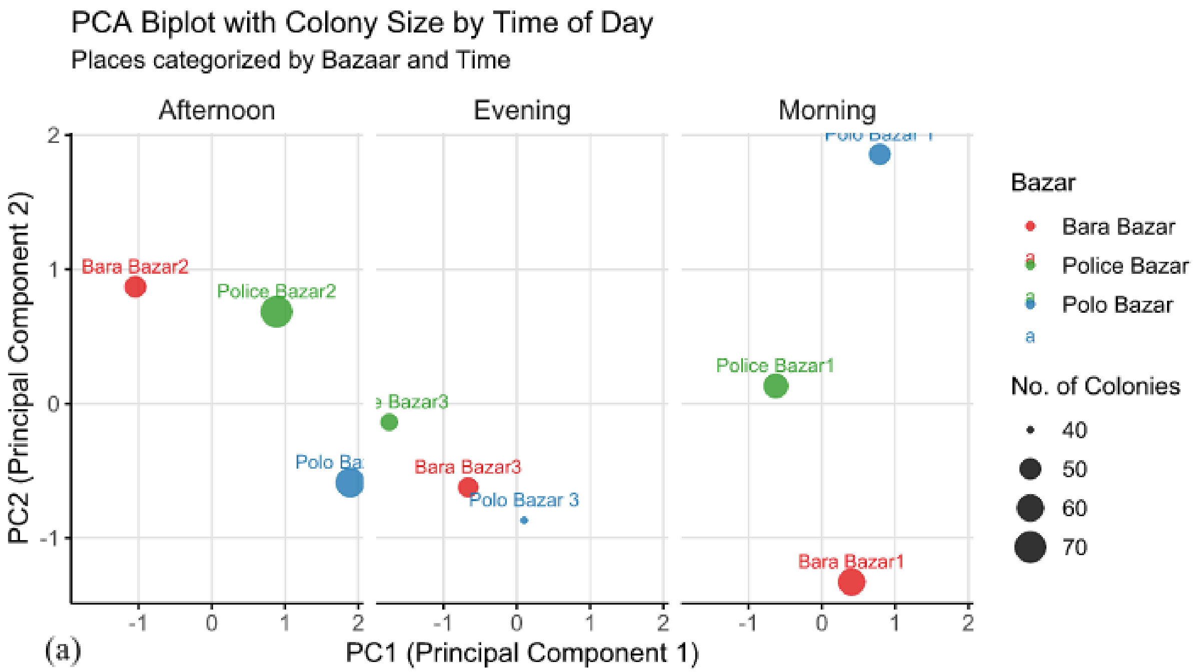
TSI agar was stabbed at the centre of the slant butt and streaked on the slope of the tube with a fresh culture of the test organism. The tubes were incubated at 37°C for 24 to 48 h. The glucose fermentation is shown by a yellow butt and red slant (Usha *et al.* 2008). Yellow slant and red butt indicate lactose/sucrose fermentation while red slant and red butt indicate no fermentation of any of the three sugar sources.

**Results**

Sampling areas show variation in the number of colonies collected in the morning, afternoon and evening (**Table 1**).

**Table 1.** Sampling sites and the bacterial colonies isolated at different times of the day.

| Places | No of colonies | | |
|---|---|---|---|
| | **Morning** | **Afternoon** | **Evening** |
| **Polo Bazar 1** | 4 | 51 | 6 |
| **Polo Bazar 2** | 87 | 67 | 3 |
| **Polo Bazar 3** | 82 | 42 | 17 |
| **Police Bazar1** | 26 | 4 | 10 |
| **Police Bazar2** | 18 | 21 | 4 |
| **Police Bazar3** | 30 | 0 | 14 |
| **Bara Bazar1** | 160 | 6 | 5 |
| **Bara Bazar2** | 10 | 5 | 15 |
| **Bara Bazar3** | 54 | 29 | 29 |




(a)

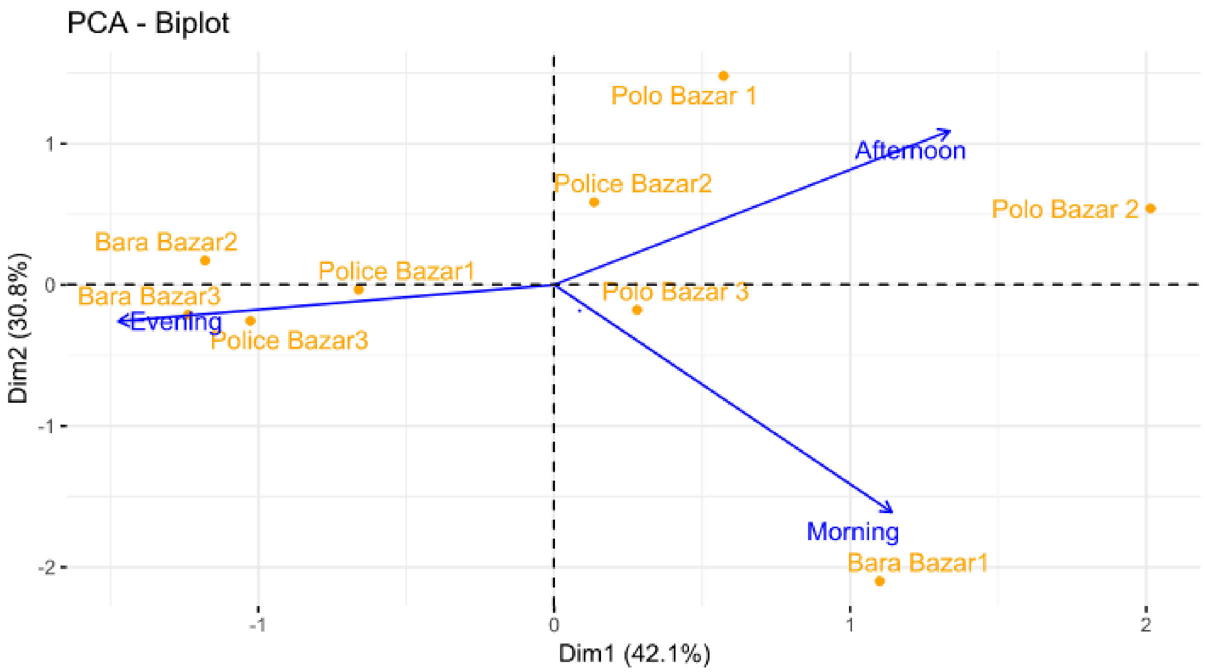
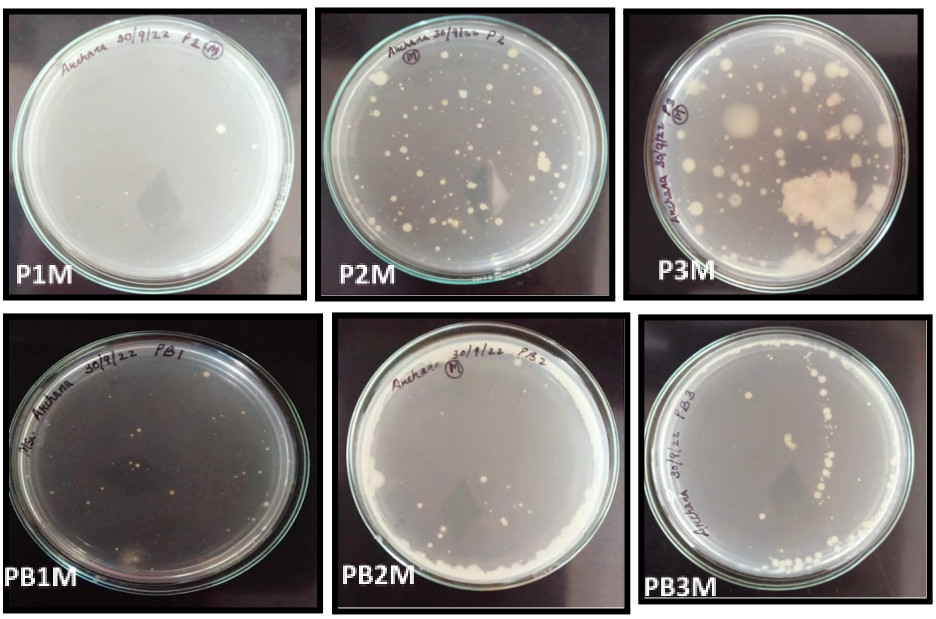



**Fig. 1.** Plot showing distribution of airborne microbes in colony distribution (a) and various locations (b).

The Normality Test (Shapiro-Wilk Test) and ANOVA (Analysis of Variance) showed that the data for morning, afternoon, and evening were normally distributed. There was a significant difference in the number of colonies across different times of the day. The Pearson Correlation coefficient indicated that there was no significant correlation between the sampling times of the day. All correlations were weak and not statistically significant ($p > 0.05$), suggesting no meaningful relationship between the number of colonies observed at different times of the day.



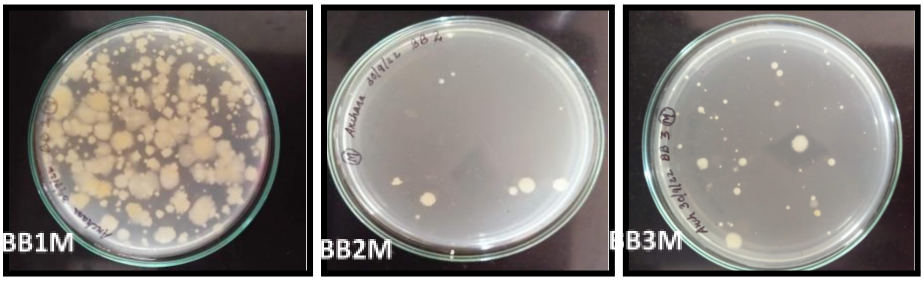



**Fig. 2.** Bacterial growth for morning sampled isolates.

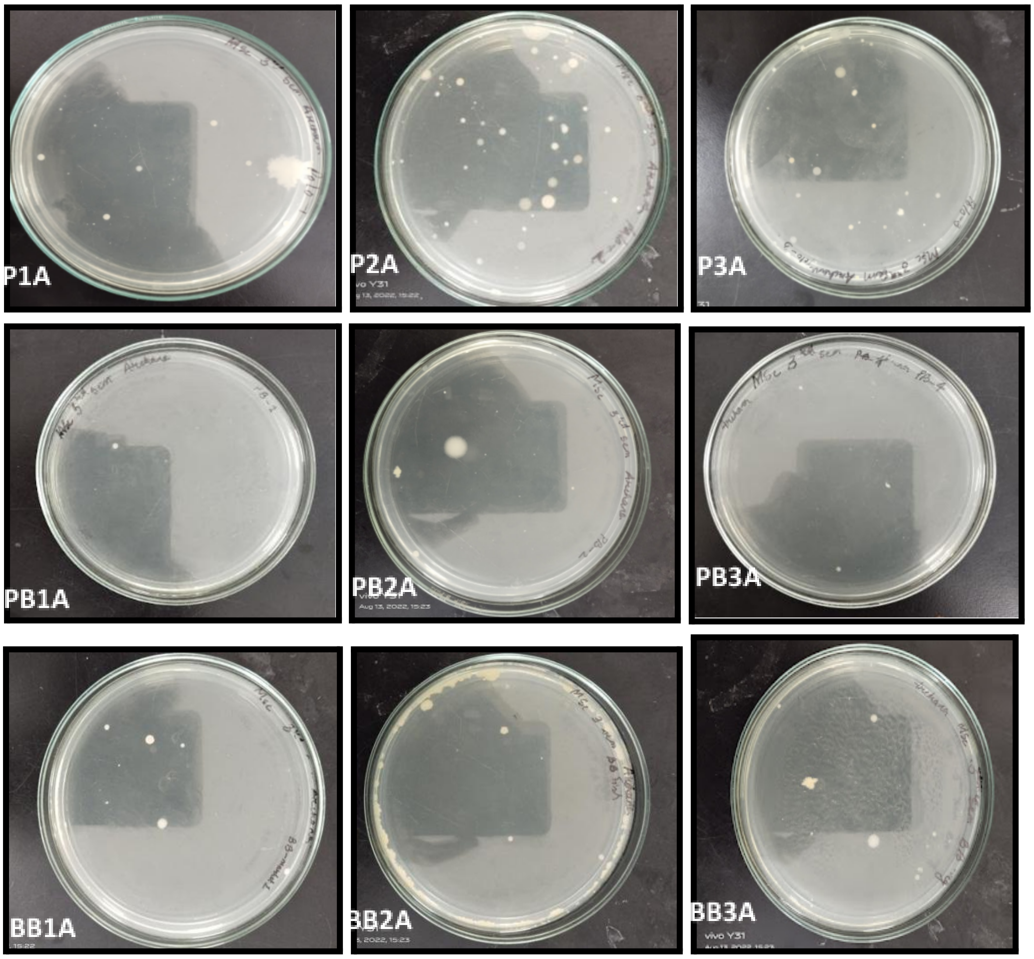



**Fig.3.** Bacterial growth for afternoon sampled isolates.

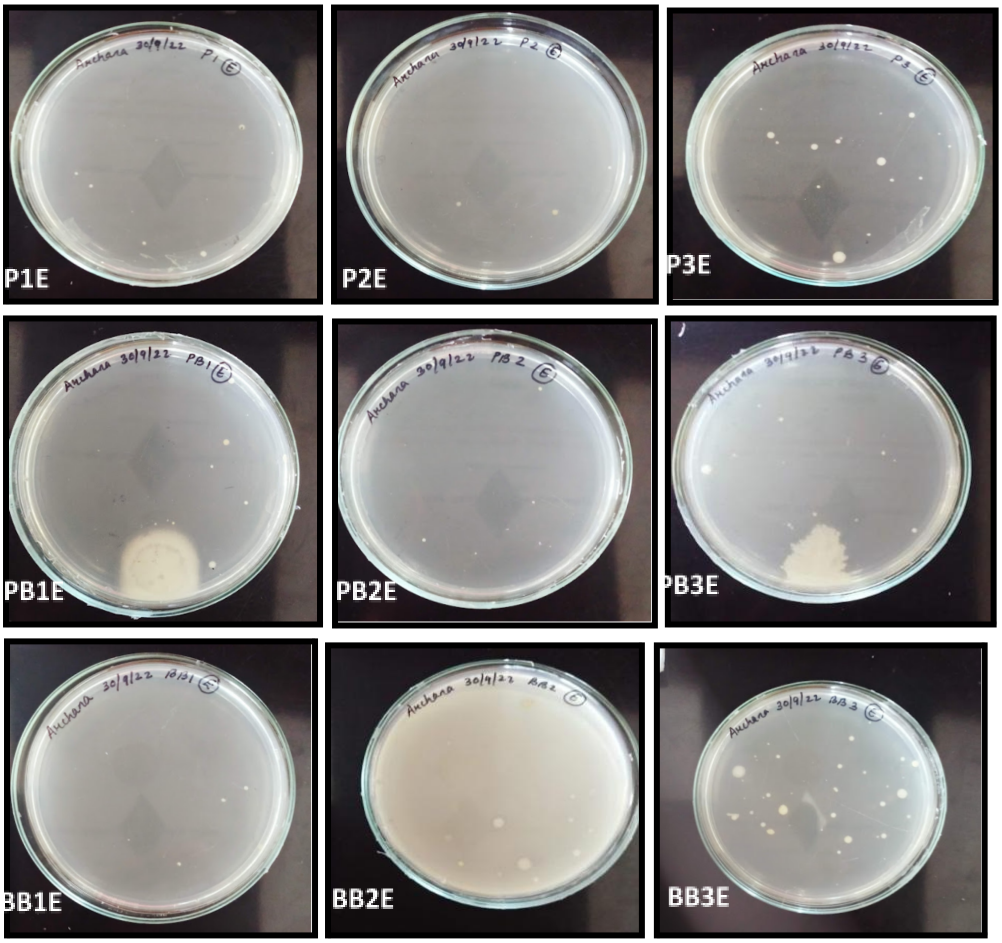


**Fig. 4.** Bacterial growth for evening sampled isolates.

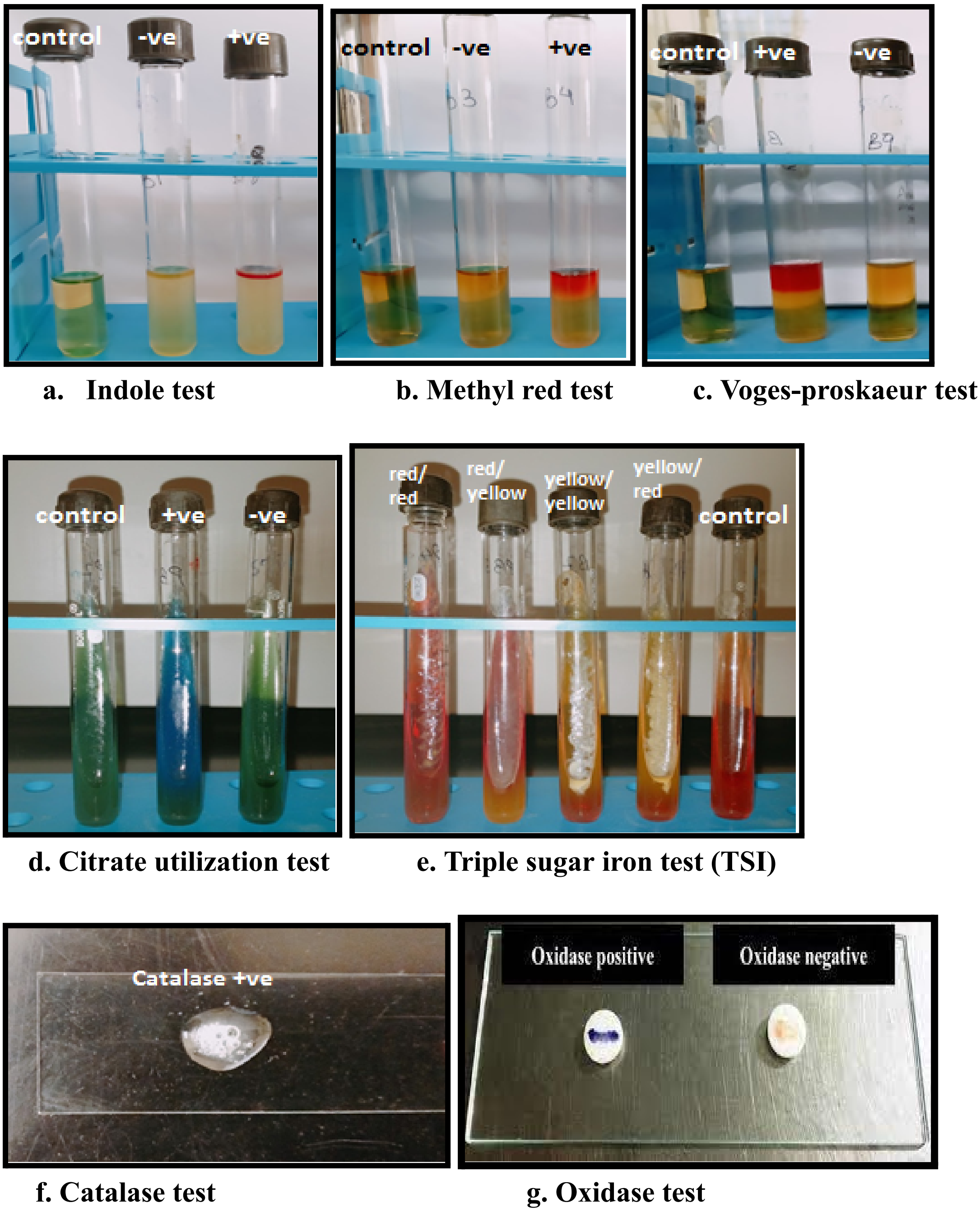



**Fig. 5. (a-g)** Some biochemical tests (a) Indoletest (b) Methyl red test (c) Voges-Proskaeur test (d) Citrate utilization test (e)Triple sugar iron test (TSI) (f) Catalase test (g) Oxidase test.

**Table 2a. Biochemical parameters characterized for the bacterial isolates from different market settings.**

| Isolates (M) | Indole | Methyl red | Voges-Proskaeur test | Citrate utilization test | catalase | oxidase | Triple sugar iron test (TSI) | Gram nature | Presumptive identification |
|---|---|---|---|---|---|---|---|---|---|
| **P2_M** | -ve | -ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Enterococcus* |
| **P4_M** | -ve | -ve | -ve | -ve | +ve | -ve | R/R/- | Gram +ve, cocci | *Gemella* |
| **P6_M** | -ve | +ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Enterococcus* |
| **P7_M** | -ve | +ve | +ve | -ve | +ve | +ve | Y/Y/- | Gram +ve, cocci | *Cellobiosococcus* |
| **P9_M** | -ve | -ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Enterococcus* |
| **P12_M** | -ve | -ve | -ve | +ve | +ve | -ve | R/R/- | Gram +ve, rod | *Bacillus* |
| **P13_M** | -ve | +ve | -ve | -ve | +ve | +ve | Y/Y/- | Gram +ve, rod | *Bacillus* |
| **P14 _M** | -ve | -ve | -ve | -ve | +ve | +ve | Y/Y/- | Gram +ve, cocci | *Micrococcus* |
| **PB1_M** | -ve | -ve | +ve | -ve | +ve | +ve | Y/Y/- | Gram +ve, cocci | *Micrococcus* |
| **PB4_M** | -ve | +ve | -ve | -ve | +ve | +ve | Y/R/- | Gram +ve, cocci | *Saccharococcus* |
| **PB7_M** | -ve | -ve | -ve | -ve | +ve | -ve | Y/R/- | Gram +ve, cocci | *Staphylococcus* |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **PB8_M** | -ve | -ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Enterococcus* |
| **PB9_M** | -ve | +ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Saccharococcus* |
| **PB10_M** | -ve | -ve | -ve | +ve | +ve | -ve | R/R/- | Gram +ve, rod | *Bacillus* |
| **PB11_M** | -ve | +ve | -ve | -ve | +ve | +ve | Y/Y/- | Gram +ve, cocci | *Micrococcus* |
| **PB12_M** | -ve | +ve | +ve | +ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Cellobiosococcus* |
| **BB3_M** | -ve | +ve | -ve | -ve | +ve | +ve | Y/R/- | Gram +ve, cocci | *Saccharoccus* |
| **BB11_M** | -ve | -ve | -ve | +ve | +ve | -ve | Y/Y/- | Gram +ve, cocci | *Trichococcus* |
| **BB12_M** | -ve | -ve | -ve | -ve | +ve | +ve | Y/R/- | Gram +ve, cocci | *Enterococcus* |

**Table 2b. Biochemical parameters characterized for the bacterial isolates from different market settings.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **P1_A** | -ve | -ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, rod | *Bacillus* |
| **P2_A** | -ve | +ve | +ve | -ve | +ve | -ve | Y/Y/- | Gram +ve, rod | *Bacillus* |
| **P4_A** | -ve | -ve | -ve | +ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Staphylococcus* |
| **P22_A** | -ve | -ve | -ve | -ve | +ve | -ve | R/R/- | Gram +ve, cocci | *Gemella* |
| **PB1_A** | -ve | +ve | -ve | -ve | +ve | +ve | Y/R/- | Gram +ve, rod | *Bacillus* |
| **PB2_A** | -ve | +ve | -ve | -ve | +ve | +ve | R/Y/- | Gram +ve, cocci | *Micrococcus* |
| **PB3_A** | -ve | +ve | -ve | -ve | +ve | -ve | Y/R/- | Gram +ve, cocci | *Trichococcus* |
| **PB4_A** | -ve | -ve | -ve | -ve | +ve | -ve | R/R/- | Gram +ve, cocci | *Gemella* |
| **BB3_A** | -ve | -ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Enterococcus* |
| **BB4_A** | -ve | +ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Micrococuus* |
| **BB5_A** | -ve | +ve | -ve | -ve | +ve | -ve | Y/R/- | Gram +ve, cocci | *Trichococcus* |
| **BB11_A** | -ve | +ve | -ve | -ve | +ve | -ve | Y/R/- | Gram +ve, cocci | *Trichococcus* |
| **BB12_A** | -ve | -ve | -ve | -ve | +ve | -ve | Y/R/- | Gram +ve, cocci | *Staphylococcus* |
| **BB13_A** | -ve | -ve | +ve | -ve | +ve | +ve | R/Y/- | Gram +ve, rod | *Bacillus* |

**Table 2c.** Biochemical parameters characterized for the bacterial isolates from different market settings.

| Isolates (E) | Indole | Methyl red test | Voges-Proskaeur test | Citrate utilization test | Catalase test | Oxidase | Triple sugar iron test | Gram nature | Presumptive identification |
|---|---|---|---|---|---|---|---|---|---|
| **P1_E** | -ve | -ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, rod | *Bacillus* |
| **P2_E** | -ve | +ve | -ve | -ve | +ve | +ve | Y/R/- | Gram +ve, cocci | *Saccharococcus* |
| **P4_E** | -ve | -ve | -ve | -ve | +ve | -ve | R/R/- | Gram +ve, cocci | *Gemella* |
| **P5_E** | -ve | -ve | -ve | -ve | +ve | +ve | Y/R/- | Gram +ve, rod | *Bacillus* |
| **P7_E** | -ve | +ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Staphylococcus* |
| **PB1_E** | -ve | -ve | -ve | +ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Staphylococcus* |
| **PB3_E** | +ve | +ve | -ve | -ve | +ve | +ve | R/Y/- | Gram +ve, rod | *Bacillus* |
| **PB6_E** | -ve | -ve | -ve | -ve | +ve | -ve | R/R/- | Gram +ve, cocci | *Gemella* |
| **PB8_E** | -ve | -ve | -ve | -ve | +ve | -ve | Y/R/- | Gram +ve, cocci | *Staphylococcus* |
| **PB11_E** | -ve | -ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Enterococcus* |
| **BB3_E** | -ve | -ve | -ve | -ve | +ve | -ve | Y/R/- | Gram +ve, cocci | *Staphylococcus* |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **BB4_E** | -ve | +ve | -ve | -ve | +ve | -ve | Y/Y/- | Gram +ve, cocci | *Trichococcus* |
| **BB7_E** | -ve | +ve | -ve | -ve | +ve | -ve | Y/R/- | Gram +ve, cocci | *Trichococcus* |
| **BB13_E** | -ve | +ve | -ve | -ve | +ve | +ve | Y/R/- | Gram +ve, rod | *Bacillus* |
| **BB14_E** | -ve | -ve | -ve | -ve | +ve | +ve | R/R/- | Gram +ve, cocci | *Enterococcus* |

**Biochemical characterization of isolates collected in morning, afternoon and evening**

The majority of the isolates showed negative results for methyl red, citrate, Voges-Proskauer test and indole test (except PB3_E). Additionally, all the isolates were tested positive for catalase activity. Most of the isolates exhibited a positive reaction for the oxidase test (**Table 2a-c**).

**Discussion**

This study highlights the variation in airborne bacterial diversity across three marketplaces in Shillong-Polo Bazar, Police Bazar, and Bara Bazar based on time of day and market conditions. Bara Bazar showed the highest bacterial count due to dense crowds and perishable goods, while Police Bazar had the lowest which could be attributed to its focus on non-perishable items like clothing and accessories and better hygiene conditions. The observation of higher morning bacterial count aligns with findings by Chmiel and Lenart-Boroń (2021), indicating a diurnal pattern where bacterial presence peaks in the morning and diminishes in the evening. Eight bacterial genera were identified, with *Bacillus* and *Staphylococcus* consistently present across all locations and times. All isolates were gram-positive, consistent with findings by Fengxiang (1990), indicating resilience in airborne environments. The dominance of Gram-positive cocci and rods aligns with previous atmospheric bacterial studies, where Gram-negative bacteria are a minority. *Staphylococcus,* commonly found on human skin and respiratory tracts, is abundant in the atmosphere due to shedding and coughing, as well as from organic waste. *Bacillus*, widely distributed in soil, is also prevalent in the air. Other significant bacteria include *Micrococcus*, *Enterococcus*, and *Gemella*, found in diverse environments such as soil, water, and the human body which align with the findings by Yongyi *et al.* (1993). These findings underscore the need for regular monitoring and improved hygiene practices in urban marketplaces to reduce potential health risks. The composition of airborne microbes in urban marketplaces like Polo Bazar, Police Bazar, and Bara Bazar in Shillong is influenced by various factors such as local sources of microbes from soil, human activity, and the presence of organic matter like garbage.

Furthermore, this study emphasizes the importance of understanding the microbial community in urban areas, as these environments host a large number of people who may inadvertently spread diseases as well as antibiotic and heavy metal resistance genes carried by these microbes. Monitoring microbial presence helps detect potential pathogenic strains and supports efforts to control their spread.

## Conclusion

The present study revealed a wide microbial diversity present in the air in the bustling areas of Shillong. This study further emphasizes the microbial risks prevailing in the air around Shillong as well as necessitates adequate air quality monitoring and appropriate measures to improve the air quality such as establishment of green belt in and around the busy areas of Shillong. However, further studies are needed to assess and characterize the risk posed by the aerial microflora present in Shillong.

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Review of the book:

# Trees and Shrubs of Amritsar: a pictorial field guide

### *INFORMATION ABOUT THE BOOK*

| Sl. | Item | Detail |
|---|---|---|
| 1. | Title of the Book | Trees and Shrubs of Amritsar: a pictorial field guide |
| 2, | Authors | Avinash Kaur Nagpal, Akanksha Bakshi, Nitika Sharma, Gurveen Kaur, Jaskirat Kaur Rooprai |
| 3. | First copyright date | 2024 (BSMPS) |
| 4. | Type of book | A Pictorial Field Guide |
| 5. | General subject matter | Identification of trees and shrubs grown everywhere |
| 6. | Publisher | Bishen Singh Mahendra Pal Singh, Dehra Dun, India. |
| 7. | Number of pages | Pp. viii+240 |
| 8. | Binding type | Flexi bound |
| 9. | Special features | The book contains adequate botanical characteristics of bark, leaves, flowers, fruits, seeds, and spines can truly resolve the correct identity of many plants even without comprehensive knowledge of botany. |
| 10. | Colour plates | Laced with multiple high quality colour photos for every species included in the book. |
| 11. | Price | ₹ 1200 (MRP) |
| 12. | ISBN 13 | 978-93-6028-319-3 |
| 13. | Summary and background | Please the write up below |
| 14. | Critical analysis (such as strength and weaknesses | <u>Strengths:</u><br>● Each plant has its verified botanical name, popular name, habit, economic importance, and description of stem, leaves, inflorescence, flower, fruits, and seeds.<br>● All the photographs are of the authors.<br><u>Weaknesses:</u><br>● Missing an index of the families of plants. |
| 15. | Conclusion | The authors aim to inspire people to plant more trees and shrubs to enrich urban greenspaces in Amritsar and other cities. |

*Review of the book*

**Trees and Shrubs of Amritsar: a pictorial field guide**

Review by

Uma Shankar*

Department of Botany, North-Eastern Hill University, Shillong 793 022, India

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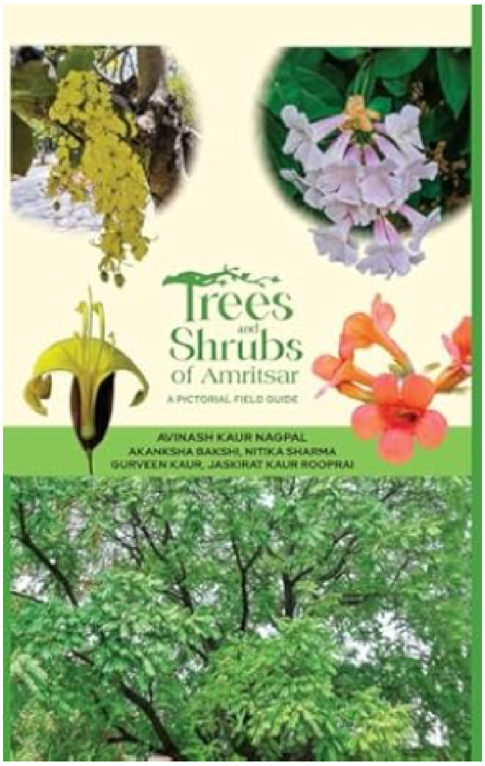


## Introduction

"*Be like a tree. The tree gives shade even to those who cut off its boughs*," said Sri Chaitanya. Soaked with such learning, the lead author, Prof. (Mrs.) Avinash Kaur Nagpal, along with her enthusiastic research scholars, has crafted a delightful pictorial field guide of trees and shrubs that adorn the Golden Temple city of Amritsar in the plains of Punjab. The authors aim to inspire people to plant more trees and shrubs to enrich urban greenspaces in Amritsar and other cities anywhere in the tropics.

**Background**

The book unlocks a brief history of the founding of Amritsar in 1577 by Sri Guru Ramdas ji, the fourth Sikh Guru. This section of the introduction encompasses beautiful pictures of the complex of the Golden Temple, Guru Nanak Dev University, Khalsa College, Jallianwala Bagh, Wagah Border, and others. The second section apprises the reader about trees and shrubs, highlighting their importance in the biosphere and their role in the culture and livelihoods. The authors draw attention to bio-aesthetic planning along roads and rail tracks, in public gardens and parks, and in open spaces of institutional compounds. The third section of the introduction is enriched with a glimpse of the heritage trees in Amritsar. The depictions include Lachi Ber, Ber Baba Buda ji, Dukh Bhanjani Ber (all of these belonging to the genus *Zizyphus*), mulberry tree at Gurdwara Toot Sahib (*Morus* sp.), Karir tree at Gurudwara Bibeksar Sahib (*Capparis decidua*), Vat Vriksha in Bada Hanuman Mandir (*Ficus benghalensis*), a more than 400 years old Pipal tree at Gurdwara Pipli Sahib (*Ficus religiosa*) and Simbal (*Bombax ceiba*), Arjun (*Terminalia arjuna*), Samudraphala (*Barringtonia acutangula*), Pilkhan (*Ficus tsjakela*) and a maidenhair tree (*Ginkgo biloba*) growing in Ram Bagh. The fourth section apprises the readers of the morphological features of trees and shrubs that are useful in identification. The idea is that the features of bark, leaves, flowers, fruits, seeds and spines can truly resolve the correct identity of many plants even without comprehensive knowledge of botany. Arrangement of leaves on the stem, type of leaves, types and colours of flowers and their parts are the traits of maximum taxonomic value for identification. For those who are curious about botanical names of plants, an introductory account of plant nomenclature is included in the fifth and final section of the introduction.

**Critical analysis**

The main body of the book describes 100 trees and shrubs. Arranged in alphabetical order of the botanical names and starting with *Abrus precatorius* and ending with *Yucca gloriosa*, each plant is dedicated a two-page space for description. Although there seems to be no bias or any preference to include a plant in the book, the authors have successfully packed in a great diversity of native as well as non-native plants suited for planting in a variety of spaces. These include gymnosperms (*Cycas circinalis, C. revoluta, Pinus roxburghii, Platycladus orientalis*), palms (*Caryota urens, Livistona chinensis, Phoenix dactylifera*), climbers

(*Bougainvillea glabra, Campis grandiflora, Clerodendrum splendens, Jasminum sambac, Masona alliacea, Passiflora coccinea, Phanera vahlii*), edible fruit trees (*Aegle marmelos, Citrus x limon, Dillenia indica, Grewia asiatica, Mangifera indica, Prunus persica, Psidium guajava, Punica granatum, Pyrus communis, Syzygium cumini*), and medicinal plants (*Azadirachta indica, Calotropis procera, Cordia dichotoma, Justicia adhatoda, Moringa oleifera, Oroxylum indicum, Phyllanthus emblica, Putranjiva roxburghii, Sapindus mukorossi, Terminalia arjuna, T. bellirica*).

Each plant has its verified botanical name, popular name, habit, economic importance, and description of stem, leaves, inflorescence, flower, fruits, and seeds. A glossary of botanical terms makes it easy for a layman to understand botanical terms used in the book. Indices of binomials and common names of plants at the end of the book facilitate spotting a species inside. The authors highlight the conservation status of all plants according to the worldwide accepted IUCN Red List. While most of the plants are of least concern or not yet assessed, two of all the species are endangered (*Cycas circinalis, Tectona grandis*), two are vulnerable (*Eucalyptus longifolia, Jacaranda mimosifolia*), and two are near-threatened (*Platycladus orientalis, Swietenia mahogoni*). A tree of Malvaceae, *Dombeya acutangular*, is actually of least concern and not critically endangered as mentioned.

Understandably, a book of this precision would see the light of day only after the meticulous efforts of the authors and their associates. The novelty of the book lies in the fact that all the photographs depicted in the book are the primary work of the authors themselves or of their commissioned photographers. The authors have deeply devoted themselves to the exactness of the botanical identification of the trees and shrubs. Besides, they have successfully captured many identifying traits in photographs, making it easier for a student of botany to identify them in the field conditions without the help of a mentor. The authors aptly believe that the information in the book is, although mainly a collection from Amritsar, equally applicable to any other city in the country and many others abroad. One thing I would surely demand from the authors is an index of the families of plants.

**Conclusion**

The book is highly commendable for arousing the interest of all and particularly of students of “not-so-preferred” classical botany. The book will prove a very handy compendium for the foresters, plantation managers, horticulturists, conservation biologists, ecologists, plant taxonomists, environmental scientists, policy planners and all those who realise the importance of trees and shrubs. I feel honoured to wholeheartedly recommend the book to all plant lovers across the globe. We must remember what Franklin D. Roosevelt advised*, "A nation that destroys its soils destroys itself. Forests are the lungs of our land, purifying the air and giving fresh strength to our people."* And, also the words of Everett Mamor, "*We can learn a lot from trees: they're always grounded but never stop reaching heavenward*." Stocks last quickly, and therefore, grab a copy, folks; it only costs you a pizza!

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