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Review

Drugs from poisonous plants: Ethnopharmacological relevance to modern perspectives

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ABSTRACT

The world of plant diversity is endlessly fascinating and essential for life on Earth. Since the inception of early civilization, humans have utilized plants for several purposes, particularly for their medicinal value. While some plants are known for their toxicity, they also contain beneficial phytochemicals that are important for both plants and humans, indicating their dual nature. This study aims to explore and synthesize the existing knowledge on various poisonous plant species found worldwide. It primarily focuses on the therapeutic potential of specific types of phytochemicals responsible for treating multiple diseases. This review includes a list of 70 poisonous plants with medicinal properties for treating various ailments, as well as some of their traditional uses. A few of these plants are emphasized, which have been tremendously explored and studied, hold significant potential to contribute to modern drug discovery. Furthermore, it addresses the possible prospects and challenges of using poisonous plants and their phytochemicals as therapeutic agents. Although the therapeutic potential of poisonous plants is substantial, many toxins remain unexplored. This review accentuates the need for rigorous scientific investigations, prior to clinical trials to validate their traditional uses, which would reveal the pharmacological interventions that will eventually advance human health and well-being.

1. Introduction

Plants have been integral to ethnopharmacology, rooted in cultural and religious traditions worldwide for centuries, highlighting the significance of traditional knowledge in healing practices and providing valuable alternatives to conventional healthcare (Yasin et al., 2019). This includes plants with therapeutic capabilities, referred to as "medicinal plants," which possess active chemicals that function synergistically or mitigate potential adverse effects. They are often used as raw materials to extract active chemicals utilized in drug production (Zahoor et al., 2021; Baksh and Ansari, 2022). Nevertheless, in addition to advantageous flora, our forebears also met toxic plant species, acquiring the ability to differentiate between dangerous and non-harmful varieties via experimentation. A chemical is deemed dangerous when it reaches the bloodstream or poses a potential threat after oral intake. Plants with poisonous secondary metabolites have been used historically for assassination, suicide, execution, and murder. It could be deadly even a tiny amount of these plants' stems, leaves, seeds, fruits, or roots are consumed (Gupta and Sharma, 2017; Gotefode et al., 2022).

Interestingly, in earlier days, poisonous plants helped many people in various ways to develop a tribe or society. For instance, Socrates' demise by hemlock (*Conium maculatum* L.) poisoning exemplifies their role in serving justice (Qasem et al., 2022). Africa uniquely employed poison ordeals to determine innocence or guilt, where suspects would ingest poison, proving their innocence by vomiting (Philippe and Angenot, 2005). Indigenous peoples employed poisoned arrows for hunting and combat, a tradition that persists in certain regions globally. They utilized toxic flora-containing chemicals such as quinine (Fig. 1 xxvi) and ouabain (Fig. 1 xxvii), classified as alkaloids and cardiac glycosides. Consequently, these chemicals induce muscular paralysis, convulsions, and cardiac arrest (Tulp and Bohlin, 2004; Chaboo et al., 2019). Certain toxic plant extracts, comprising chemicals such as saponins, rotenoids, and diterpene esters, have been utilized for fishing and pest management and are esteemed for their insecticidal and therapeutic properties (Dutta et al., 2019).

Researchers have recently explored poisonous plants and their phytochemicals to promote environmental protection and sustainable development methods to support the agricultural sector. For instance, a study focused on improving the solubility and application of tropane

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List of abbreviations

ALOX5	Arachidonate 5-lipoxygenase
ALT	Alanine Transaminase
AMPK	Adenosine Monophosphate-Activated Protein Kinase
AKT	Protein kinase B
BDNF	Brain-derived neurotrophic factor
CAT	Catalase
CB1/CB2	Cannabinoid 1/2
CDKs	Cyclin-dependent kinases
COX	Cyclooxygenase
EI	Electron Ionization
ERK 1/2	Extracellular signal-regulated kinase 1/2
GC-MS	Gas Chromatography- Mass Spectroscopy
GDNF	Glial cell line-derived neurotrophic factor
GPx	Glutathione peroxidase
GSH	Glutathione
GST	Glutathione S-transferases
H_2O_2	Hydrogen Peroxide
HDAC	Histone Deacetylase
HETES	Hydroxyeicosatetraenoic acids
HMC3	Human Microglial Clone 3
^{1}HNMR	Proton Nuclear Magnetic Resonance
HPLC	High-performance Liquid Chromatography
IκBα	Inhibitor of nuclear factor-κBα
IKK	Inhibitory-κB kinase
IR	Infrared
JAK/STAT	Janus kinase/signal transducers and activators of transcription
JNK	c-Jun N-terminal kinase
LC_{50}	Lethal Concentration 50
LOX	Lipooxygenase
MDA	Malondialdehyde
MPO	Myeloperoxidase
NF-κB	Nuclear Factor kappa B
NIH-3T3	Mouse Embryonic Fibroblast Cell line
NMDA	N-methyl-D-aspartate
NO	Nitric oxide
Nrf 2	Nuclear factor erythroid 2-related factor 2
6-OHDA	6-hydroxydopamine
p38 MAPK	p38 mitogen-activated protein kinase
pAkt	Protein kinase B
PLA_2	Phospholipase A_2
PKA	Protein kinase A
SOD	Superoxide dismutase
PTGS2	Prostaglandin-Endoperoxide Synthase 2
THP-1	Human Leukemia Monocyte Cell line
TNF-α	Tumor Necrosis Factor alpha
TRB3	Tribbles homolog 3
UV	Ultraviolet

alkaloids (TAs) from *Datura stramonium* L., which exhibited insecticidal properties but had poor water solubility. To overcome this limitation, cyclodextrins (CDs), cyclic oligosaccharides with hydrophilic exteriors and hydrophobic cavities were utilized to form inclusion complexes with TAs that significantly enhanced their solubility and stability (Butnariu et al., 2021). Likewise, the allelopathic potential of aqueous extracts of *D. stramonium* L. revealed that its toxic alkaloids inhibit the growth of surrounding plants. Thus, different concentrations of TAs showed the same effects on the root development of *Sorghum halepense* without affecting germination. However, exposure to higher concentrations caused toxicity symptoms in *S. halepense* seedlings, like chlorosis and necrosis (Butnariu, 2012).

Additionally, *D. stramonium* L. extracts were microencapsulated using interfacial cross-linking to protect active compounds such as TAs and maintain their activity over time, reducing application frequency. The encapsulated TAs retained their efficacy and were released gradually. This approach supports sustainable agriculture by promoting using natural products for pest control (Barbat et al., 2013).

One challenging fact is that it is difficult to distinguish between edible, medicinal, and toxic plants due to their overlapping properties. For example, while *Abrus precatorius* L. seeds are poisonous, their leaves are edible and used medicinally. Similarly, *Malus* spp. (apple) seeds contain cyanogenic glycoside amygdalin, while Cassava roots detoxify cyanogenic glucosides when sun-dried. Understanding plant toxicity ensures food safety (Anywar, 2020). Poisonous plants have also been utilized as biopesticides, especially rotenone (Fig. 1 xxviii) (3–10%) found in the roots or rhizomes of Derris, Lonchocarpus, and other species, exhibiting insecticidal properties (Bidyarani & Kumar, 2019). Additionally, various cultures throughout history have utilized toxic plants containing psychoactive substances for medicinal, recreational, or ceremonial purposes, including *Atropa belladonna* L. (belladonna), *Cannabis* spp. (marijuana), *Datura* spp., and *Papaver somniferum* L. (opium poppy) (Alrashedy and Molina, 2016).

Poisoning can happen through various means, including contact, which can lead to skin irritation ingestion, causing internal toxicity, absorption, or inhalation through the respiratory tract (Tamilselvan et al., 2014). Most people worldwide are unfamiliar with the phytochemical toxins in the plants around them, with which they sometimes come in direct contact or even ingest. One primary concern is that animals and livestock might inadvertently consume these plants, leading to poisoning (Botha and Penrith, 2008). It is expected that local elderly individuals pass down their limited knowledge of poisonous plants from one generation to the next, increasing the risk of misinformation. Hence, it is crucial to raise public awareness regarding plant toxicological profiles. Over the past few decades, continuous research and development in plant knowledge have significantly enhanced awareness and utilization of plants for medicinal purposes (Jamloki et al., 2022), alongside a deeper understanding of their toxicological profiles. A list of medically important poisonous plants found worldwide is shown in Table 1.

According to the World Health Organization (WHO), the historical uses of poisonous plants in traditional medicine have been acknowledged. It emphasizes the need for caution and their usage with proper scientific validation. WHO also recognizes the diversity of traditional and complementary medicine (T&CM) practices across countries, noting that approximately 80% of the global population relies on traditional medicines (Painuli et al., 2022). After conducting an extensive literature survey, we found that review articles focusing on poisonous medicinal plant species worldwide have needed to be improved in recent years. Therefore, this review aims to bridge the gap by providing a comprehensive overview of such plant species, emphasizing their potential therapeutic activities for treating numerous diseases. A few of them are shown in Fig. 2. Additionally, this review proposes plausible mechanisms underlying the effects of such plants. Moreover, it highlights the current research landscape and serves as a valuable resource for understanding the broader significance of these plants in therapeutic applications.

To fulfill this study, we have comprehensively reviewed the literature from public databases such as Google Scholar, Scopus, PubMed, and Web of Science. A flowchart depicting our review process is illustrated in Fig. 3. The keywords used in the search included terms such as “Poisonous plants of all countries,” “toxic compounds of poisonous plants,” “medicinal properties of poisonous plants,” “drugs from poisonous plants,” or “pharmacological activities of the poisonous plant

species."

2. The chemical nature of toxic metabolites: a brief overview of its dual nature

Poisonous plants contain toxic substances such as vegetal-alkaloids, glycosides, oxalates, saponins, minerals, amines or resins, photosensitizing compounds, tannins, and volatile oils. Interestingly, these poisons (phytochemicals) can also serve as drugs to treat various diseases at an appropriate concentration (Dubey, 2018; Riet-Correa et al., 2023). In terms of toxicity, alkaloids, characterized by their nitrogen content and bitter taste, exhibit alkaline properties and form salts upon reacting with acids (Dey et al., 2020). Glycosides are carbohydrates that yield one or more sugars, such as digoxin (Fig. 4 xxi) and oleandrin (Fig. 4 xxii), in contrast, the non-sugar part of the molecule holds the toxic substance (Dhara and Nayak, 2022). Oxalates are oxalic acid salts

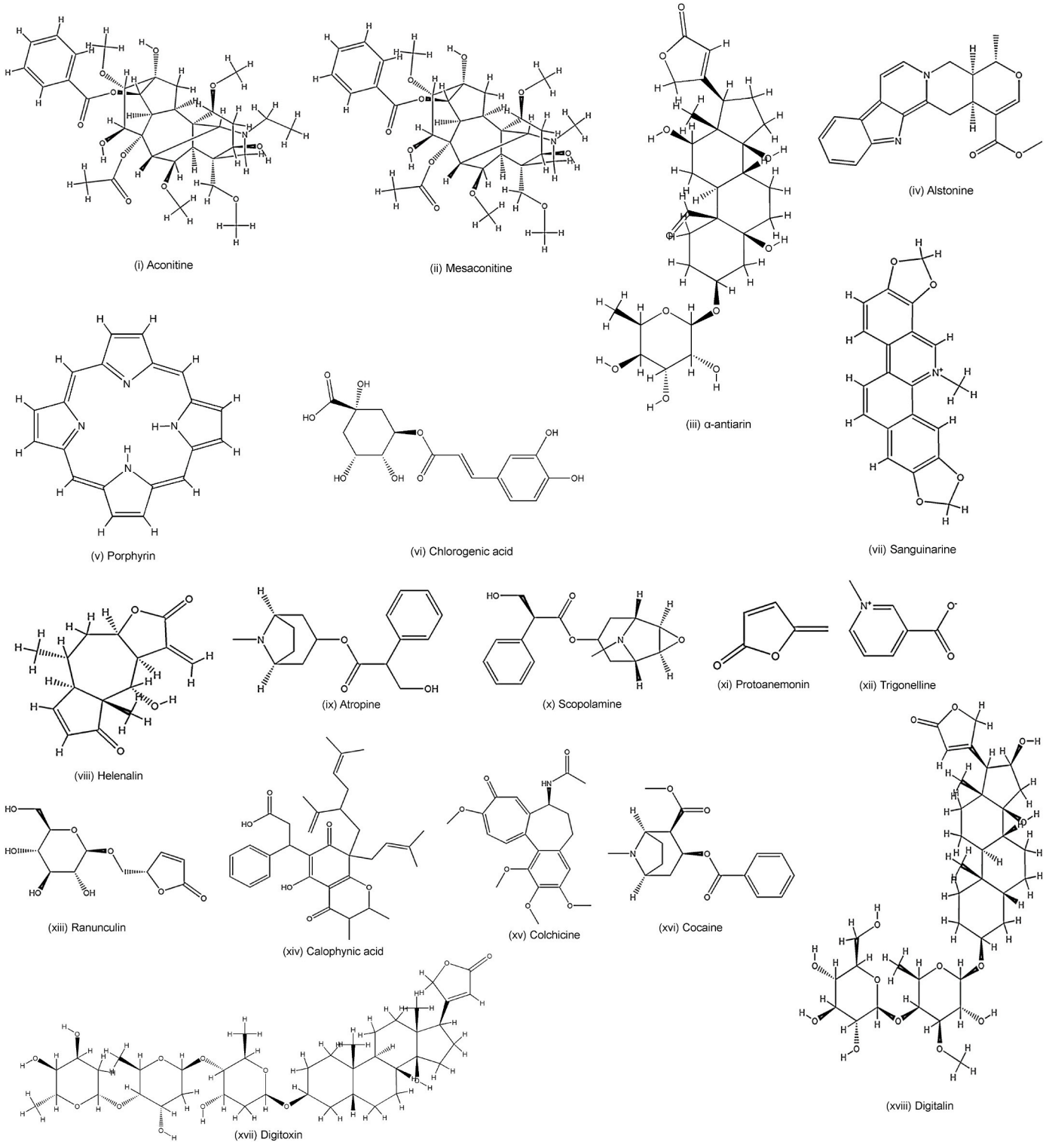

Fig. 1. Chemical structures of some toxic metabolites derived from poisonous plants. The structures were drawn using ChemDraw software.

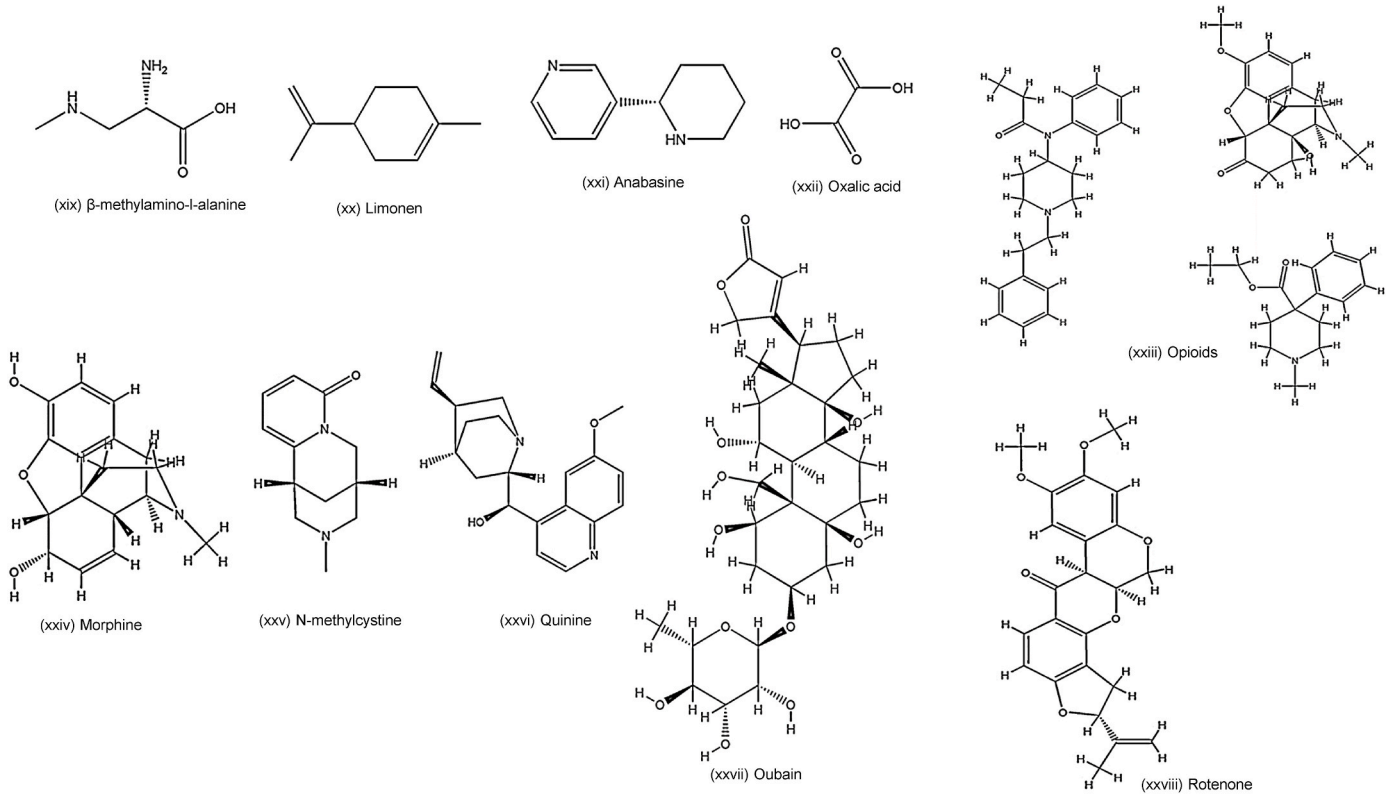

Fig. 1. (*continued*).

(Fig. 1 xxii), that exerts toxicity through their ions (Salgado et al., 2023). Saponins are large molecules that create soap-like froth when agitated with water (Rai et al., 2021), while minerals accumulate within plants after being taken up from the soil or atmosphere and turning harmful. Some examples of such toxic minerals are lead, arsenic, and copper (Angulo-Bejarano et al., 2021). Resins are complex hydrocarbons soluble in organic solvents but poorly soluble in water (Woods et al., 2007). Volatile oils are non-greasy and aromatic hydrocarbons that contain various classes of substances like ketones, alcohols, aldehydes, esters, ethers, oxides, phenols, terpenes, etc. (Dhifi et al., 2016).

Based on the nature of poison, poisonous plants can be divided into three main groups such as systemic toxins that affect the cardiovascular, nervous, and respiratory systems; corrosive substances encompassing weak organic acids and alkalis; and irritants, which can be metallic, non-metallic, or inorganic, causing various degrees of irritation and harm (Yadav and Verma, 2018). Recent progress in phytochemistry has facilitated screening numerous plants, including poisonous plants, to identify their active components and pharmacological activity or toxicity mechanism.

3. Clinical symptoms and mechanism of toxicity of poisonous phytochemicals

Specific toxicological principles dictate whether these metabolites are harmful or non-toxic based on their efficacy. In addition, many factors influence toxicity, such as the concentration and potency of the toxic substance, the part of the plant affected, the exposure route, the dose taken, the amount absorbed, the toxicity mechanism, and the organ or system affected (Tchounwou et al., 2012). Variation in phytochemical concentrations is expected between different parts of the plant, and these concentrations may also be affected by varying environmental conditions (Alsop and Karlik, 2016). Therefore, toxicity is also influenced by the part of the plant consumed and may vary depending on the season and geographical origin of the plant.

Poisonous plants can induce various effects, including allergies, irritations, skin sensitivity to light, skin rashes, dermatitis, and internal poisonings (Khan et al., 2018). In cases of internal poisoning, the toxic substances within these plants can impact organs such as the brain, heart, spinal cord, liver, and lungs. Plant toxins are organic chemicals that plants naturally synthesize through their cellular processes, aided by enzymes. Symptoms of plant-induced poisoning encompass vomiting, stomach cramps, irregular heartbeat, burning sensations in the mouth, lips, or tongue, and convulsions. They can lead to mild irritation or severe illness and, in extreme cases, even death (Rasool et al., 2024).

Poisonous secondary metabolites exhibit two distinct modes of action. The first type involves non-specific toxicants that induce a state of narcosis. Prolonged exposure to these narcotic toxicants can lead to death, but the effects are reversible once the toxicant exposure is discontinued. On the other hand, specific toxicants are non-narcotic and exert their toxic effects by targeting particular sites within the body (Boelsterli, 2007).

There are various mechanisms involved during toxication. One such mechanism involves uncouplers of oxidative phosphorylation, which inhibits the coupling of electron transfer and the production of adenosine triphosphate (ATP) in the process (Song and Villeneuve, 2021). Another mechanism involves inhibiting acetylcholinesterase (AChE), an enzyme crucial for regulating nerve impulses at synapses. Toxins binding to AChE hinder the breakdown of acetylcholine, leading to continuous nerve impulses and subsequent damage to the nervous system. Examples of AChE inhibitors include carbamates and organophosphates (Colović et al., 2013).

Irritants represent another mode of specific toxicants, exerting their effects through chemical interactions at the contact site, resulting in inflammation within living tissues. The concepts of hypertrophy, where cells enlarge due to various stimuli, and hyperplasia, involving an increase in cell numbers, are also relevant here. Common irritants are acrolein, benzaldehyde, and chlorine, as shown in Fig. 5 (Jo et al., 2009). Agents that cause seizures in the central nervous system (CNS)

Table 1
List of some of the selected poisonous plants, their botanical name, common name, family, plant parts, drugs, and medicinal properties.

Sl No	Botanical Name	Common name	Family	Plant parts	Drugs	Medicinal properties	Reference
1	*Abrus precatorius* L.	Indian liquiorice, Gunchi, Kainch, Jequirity bean, Crab's Eyes	*Fabaceae*	Seeds	Albrin, flavonoids, triterpene glycosides and alkaloids	Used as an antidiabetic, neuroprotective, anti-abortifacient, anti-viral, anti-malarial, anti-cancer, anti-oxidant, etc. Some of the traditional uses are: It cures tumors, fever, cold, leucoderma, jaundice, and tetanus; it prevents rabies.	Garaniya and Bapodra (2014)
2	*Aconitum* sp.	Indian aconite, Monkshood, Mithazahar, Wolfsbane, Gobari	*Ranunculaceae*	Whole plants, especially roots	Diterpenoid alkaloids (Mesaconine, hypaconine, higenamine, mesaconitine, hyaconitine)	It exhibits effects on the cardiovascular and nervous system and has antioxidant activity.	Mi et al. (2021)
3	*Adonis vernalis* Asso, *A. amurensis* Regel & Radde, *A. cupaniana* Guss. and related species	Bird's eye, Phesant's eye, False Hellebore	*Ranunculaceae*	Aerial parts of the plant	Cardiac glycosides (cymarin) and other glycosides	Pharmacological properties include cardiovascular, antibacterial, anti-angiogenic, anti-inflammatory, etc. Some traditional uses are that it cures oedema, epilepsy, and heart diseases.	Shang et al. (2019)
4	*Aesculus hippocastanum* L., *A. indica* (Wall. Ex Cambess.) Hook.	Horse chestnut	*Sapindaceae*	Seeds	Saponin (Aescin), glucoside (esculin), flavonoid (rutin), mandelic acid	Anti-edematous, antiobesity, anti-inflammatory, anti-proliferative, anticancer, immunomodulator, antinociceptive effect, and antioxidant	Yadav et al. (2022)
5	*Allamanda cathartica* Schrad.	Golden trumpet, Yellow allamanda, Araba	*Apocynaceae*	Stem barks (juice), leaves and sap	Iridoid, plumieride, flavonoids such as rutin and sugars	Anti-inflammatory, antioxidant, antifertility, anti-dermatophytic effects, wound-healing activity, hepatoprotective activity, thrombolytic activity, antibacterial and antifungal activity	Matignon et al., 2023
6	*Aleurites molucanna* (L.) Willd.	Indian walnut, Country walnut, Akhoda	*Euphorbiaceae*	All parts especially seeds and leaves	C-glycosyl-flavone derivatives (Swertisin, 2″-O-rhamnosylswertisin)	Anti-inflammatory, antibacterial, antinociceptive effects, etc. It is also used as a remedy for dysentery, stab wound dressing, tumors, ulcers, etc.	Hakim et al. (2022)
7	*Alocasia macrorrhiza* (L.) G. Don	Giant taro	*Araceae*	Rhizome	Hyrtiosin, hyrtiosulawesine	Acts as anti-phlogistic medicine. Additionally, it exhibited anticancer, anti-inflammatory, antinociceptive, and antifebrile activities, commonly used in treating joint disorders and flu-related complications, including headache, bleeding hemorrhoids, pulmonary tuberculosis.	Arbain et al. (2022)
8	*Alstonia scholaris* (L. R.Br.)	Chatiani daru, Dita-bark tree	*Apocynaceae*	Latex	Indole alkaloids	Treats respiratory disorders such as asthma, respiratory infections, acute lung injury, tuberculosis, lung cancer, and pulmonary fibrosis	Mitra et al. (2021)
9	*Anagallis arvensis* L.	Scarlet pimpernel, Krishnaneel	*Primulaceae*	Aerial parts	Cucurbitacin, triterpenoid, kaempferol, querticin, rutin, spinasterol, sterol, β-sitosterol, and stigasterol. bronchicum, pectosol, simpret and tussipect	Exhibits anti-inflammatory, antimicrobial, antiviral, antioxidant, anti-leishmania, antimycotic, antimutagenic, anticancer, cytotoxic and spermatogenic effects, lung problems, dermatological activities, etc.	Saleem et al. (2022)
10	*Anamirta cocculus* (L.) Wight & Arn.	Crow killer, kakphal	*Menespermaceae*	Fruit and seeds	Beriberine, columbamine, magnoflorine, oxypalmine, palmatine, stepharine and major tertiary alkaloids (1,8-oxotetrahydropalmatine)	Exhibits antimicrobial, antibacterial, sympatholytical, and antifertility properties.	Jijith et al. (2016)
11	*Anemone nemrosa* L. , *A. occidentalis* S. Watson, *A.*	Wood anemone, Wood wind flower	*Ranunculaceae*	All parts	Anemonin and ranunculin, Raddeanin A	Exhibits anti-inflammatory and anticancer activities. It also	Hao et al. (2017)

(*continued on next page*)

Table 1 (*continued*)

Sl No	Botanical Name	Common name	Family	Plant parts	Drugs	Medicinal properties	Reference
	coronaria L. and related species					inhibits the expression of gastric cancer cells.	
12	*Antiaris toxicaria* (J. F.Gmel.) Lesch.	Upas tree, Karwat, Ajjanapatte, Valkala	*Moraceae*	Latex and sap	Cardiac glycosides (antiarotoxinin A, antiarosides A-I)	Anticancer activity	Shi et al. (2010)
13	*Argemone Mexicana* (L.)	Mexican pricklypoppy, Bakul, Bukla kata	*Papaveraceae*	All parts, especially seeds (seed oil)	Dehydrocorydalmine, oxyberberine, benzo[*c*] phenanthridine, -6-acetonyl dihydrochelerythrine	Antifungal, anti-HIV, anti-inflammatory, etc. Traditional uses include- jaundice, skin diseases, leprosy, etc.	Brahmachari et al., 2013
14	*Arisaema tortuosum* (Wall.) Schott, *A. triphyllum* (L.) and related species	Jack-in-the-pulpit, Huring chakkad	*Araceae*	Whole plant, especially corms	Campesterol, cholesterol, choline chloride, *n*-alkanes, *n*-alkanols, stigmasterols, sitosterols, staychydrine hydrochloride, lutin,l uteolin, quercetin	Anticancer activity	Ali and Yaqoob (2021)
15	*Arisaema helleborifolium* Schott	Jack in Pulpit, Cobra lilies	*Araceae*	Rhizomes or tubers	Lectins	Exhibits insecticidal activity and inhibits *in-vitro* proliferation	Ali and Yaqoob (2021)
16	*Arisaema flavum* (Forssk.) Schott	Jack in Pulpit, Cobra lilies	*Araceae*	Rhizomes or tubers	Lectins,13-phenyltridecanoic acid, asparagine, cysteine, glycine, norvaline, β-sitosteryl, ornithine galactoside, α- and β-amyrin	Anti-proliferation activity	Ali and Yaqoob (2021)
17	*Arisaema vulgare* (L.)	Jack in Pulpit, Cobra lilies	*Araceae*	Rhizomes or tubers	2-alkyl pyrrolidine and 2-alkyl piperidine alkaloids	Antitumor activity	Ali and Yaqoob (2021)
18	*Arnica montana* (L.)	Mountain tobacco, Leopard's bane, Mountain arnica	*Asteraceae*	All parts, especially flowers and roots	Terpenoids and essential oils	Antioxidant, anti-inflammation, antifungal and antibacterial activities	Sugier et al., 2020
19	*Artemisia maritma* (L.), *A. nilagirica* (C. B.Clarke) Pamp.	Wormseed, Jangli ibhang, Kermani	*Asteraceae*	All parts, especially the flower head and leaves	Essential oils	Antibacterial and antifungal activity	Stappen et al. (2014)
20	*Atropa belladonna* L.	Deadly nightshade, Banewort	*Solanaceae*	All parts, especially roots	Atropine, hyoscyamine, scopolamine, tiotropium bromide	Hypertension and other diseases, gastrointestinal disorders, chronic obstructive pulmonary disease	Kasali et al. (2020)
21	*Brugmansia* spp.	Angel's trumpet	*Solanaceae*	Flowers, leaves, seeds	Tropane alkaloids	Exhibits anticancer activity. Some traditional uses include treating rheumatism, dermatitis, infections, snakebites, etc.	Petricevich et al. (2020)
22	*Calotropis gigantean* (L.) Dryand, *C. procera* (Aiton) Dryand.	Giant milkweed, Mudar plant, Akuan, Akon	*Asclepiadaceae*	Latex and leaves	Calotropin and uscharin,a nhydrosophoradiol-3-acetate, frugoside, and rutin	It can be used for the treatment of neural tumors and exhibits anticancer activity	Khosravi & Kumar (2021)
23	*Cannabis sativa* L.	Indian hemp, Ganja, Marijuana	*Cannabinaceae*	Dry flowers, fruiting tops of female plants	Cannabinoid (anticancer agents)	Inhibits cell proliferation, includes breast cancer, neuroblastoma, lymphomas, thyroid epithelioma, and colorectal carcinoma.	Kasali et al. (2020)
24	*Casearia elliptica* Willd.	Biri, Churchu daru	*Flacourtiaceae*	Fruit juice	Clerodane diterpenoids	Exhibits anti-ulcer, antiviral, anti-snake venom, antitumor, hypoglycemic, anti-malarial activity, and other activities	Xia et al. (2014)
25	*Catharanthus roseus* (L.) G.Don	Annual venica, Baro-masiya	*Apocynaceae*	All parts (Amorphous alkaloids)	Vinblastine, vincristine	Exhibits anticancer, antidiabetic, antimicrobial, antioxidant, antihelminthic, and antitumor activity	Kasali et al. (2020); Aftab et al. (2017)
26	*Cerbera manghas* L., *C. tanghin* Hook., *C. odollam* Gaertn.	Ordeal tree, Suicide tree, Dabur, Garji, Kalachedi	*Apocynaceae*	Seed kernels, fruit, and latex	Cerberin, deacetyltanghin, dehydrocerberin, neriifolin, tanghinigenin, tagninin	Exhibits anticancer properties	Chan (2016)
27	*Citrullus colocynthis* (L.)	Indrayan colocynth	*Cucurbitaceae*	Root and fruit	Cucurbitacin and cucurbic acid	Exhibits antioxidant and anticancer property. It also has anti-microbial, antifungal, anti-hyperglycemic, anti-obesity, neuroprotective, and cardioprotective activity.	Li et al. (2022)
28	*Colchicum autumnale* L.	Autumn crocus	*Colchicaeae*	Bulb-like corms	Colchicine	Gout	Kasali et al. (2020)
29	*Conium maculatum* L.	Hemlock, Poison snakeweed	*Apiaceae*	All parts, especially seeds	Conium	Can cure prostate gland and testis swelling, breast cancer, and cervix uterus cancer	Mondal et al. (2014)

(*continued on next page*)

Table 1 (*continued*)

Sl No	Botanical Name	Common name	Family	Plant parts	Drugs	Medicinal properties	Reference
30	*Crocus sativus* L.	Saffron crocus, Common saffron plant	*Iridaceae*	All parts	Crocetin, saffron, safranal, crocin	Exhibits anti-inflammatory, antioxidant, anti-depressant, anti-convulsant, neuro-protective and relaxant activity	Butnariu et al. (2022)
31	*Croton tiglium* L.	Purging croton, Jamalgota	*Euphorbiaceae*	Seeds and oils	12-O-tetradecanoylphorbol-13-acetate (TPA)	Exhibits antitumor, antioxidant, anti-dermatophytic, anti-HIV, anti-inflammatory, anti-microbial, anti-leukemia, anti-convulsant, and gastrointestinal activity	Sinsinwar et al. (2016)
32	*Cytisus scoparius* (L.) Link	Broom	*Fabaceae*	All parts	Carotenoid and flavonoid	Antioxidant and anti-inflammatory activity	González et al. (2013)
33	*Datura metel* L., *D. stramonium* L. and other related species	Thorn apple and Dhatura	*Solanaceae*	All parts, especially seeds, fruits, and dried leaves	Scopolamine, hyoscyamine, physostigmine	Exhibits anti-microbial, anti-fungal, antiasthmatic, and vibriocidal activities. It treats gastrointestinal disorders, motion sickness, nausea, and vomiting. It has anti-cholinergic properties. Oil extract from seed cures baldness and stimulates hair growth.	Kasali et al. (2020); Gotefode et al., 2022
34	*Delphinium staphisagria* L.	Larkspur, Nirvishi	*Ranunculaceae*	All parts of young plants and seeds	Flavonoid	Parasiticidal activity	Lotfaliani et al. (2021)
35	*Digitalis purpurea* L., *D. lutea* L., *D. grandiflora* Mill. *and D. lanata* Ehrh.	Common fox-glove, Yellow broom	*Scrophulariaceae*	All parts, especially seeds, leaves, and twigs	Digoxin	Used for congestive heart failure (CHF) effect, atrial fibrillation, etc.	Gašić et al. (2023)
36	*Dioncea muscipula* J. Ellis	Venus fly trap	*Droseraceae*	Whole plant	Plumbagin, 8,8′-biplumbagin (maritinone)	Exhibits antifungal, antibacterial, anti-parasitical agent, apoptotic agent, anti-microbial activity	Gaascht et al. (2013)
37	*Dioscorea pentaphylla* L., *D. hispida* Dennst.	Hasa, Kandu	*Dioscoreaceae*	Tubers	Allantoin, cyanidin, dioscorin, diosgenin, flavonoids, sapogenin, saponin	Used for ammonia detoxification, trypsin inhibitors, birth control, steroid drug synthesis, and skin infections and has anti-inflammatory activity	Kumar et al. (2017)
38	*Eranthis hyemalis* Salisb.	Winter aconite	*Ranunculaceae*	All parts, especially tubers	Lectin	Anticancer activity	McConnell et al. (2015)
39	*Ephedra sinica* Stapf.	Yellow hemp, Chinese ephedra, Ma Huang	*Ephedraceae*	All parts	Ephedrine and pseudoephedrine	Used for nasal congestion. It treats allergies and common cold and exhibits anti-asthmatic, anti-inflammatory, and immunosuppressive properties	Alsaeed et al. (2019)
40	*Eupatorium adenophorum* Spreng.	Crofton weed	*Eupatorieae*	Leaves and aerial parts	Chlorogenic acid, neochlorogenic acid, cryptochlorogenic acid, 5-o-trans-o-coumaroylquinic acid methyl ester, macranthoin F, macranthoin G, euptox A (9-oxo10,11-dehydroageraphorone), Cadinan-3-ene-2,7-dione	Exhibits anti-inflammatory, antibacterial, antiobesity, antioxidant, antitumor, anticancer and anti-fungi activity	Tripathi et al. (2018)
41	*Gloriosa superba* Linn.	Flame lilly, Jhagrahi, Chukuru	*Colchicaceae*	All parts, especially tuberous rhizome	Colchicine	Has the ability to treat AIDs, FMF (Hereditary inflammatory disorder)	Maroyi and Maesen (2011)
42	*Heracleum canescens* Lindl.	Hogweed	*Apiaceae*	All parts especially essential oils	Coumarins (pimpinellin, imperatorin, and phellopterin)	Antimicrobial activity	Bahadori et al. (2016)
43	*Hypericum perforatum* L.	Common St. Johnswort	*Hypericaceae*	Aerial parts	Hypericin and hyperforin	Natural anti-depressants and anti-inflammatory activities	Mahmoudi et al. (2022)
44	*Ipomoea hederacea* Jacq.	Indian jalap, Kala Daana	*Convolvulaceae*	Seeds	Pharbitisin	Anti-helminthic, blood purifiers, promotes menstruation, treats cataracts and eye inflammation. Beneficial for skin diseases, gout, fevers, headache, etc.	Zia-Ul-Haq et al. (2012)
45	*Jatropha curcas* L.	Physic Nut, Danti	*Euphorbiaceae*	Seeds	Jatropha factor C1, jatropholones A, caniojane, curcusone E, spirocurcasone,	Exhibits anti-microbial, antitumor, anti-plasmodial, anti-proliferative, antibacterial,	Abdelgadir and Van Staden (2013);

(*continued on next page*)

Table 1 (*continued*)

Sl No	Botanical Name	Common name	Family	Plant parts	Drugs	Medicinal properties	Reference
					palmarumycin JC1-JC2, jatrophalactam, caffeoylaldehyde	anticancer and anti-inflammatory activity	Oskoueian et al. (2011)
46	*Mandragora autumnalis* Bertol.	Autumn mandrake	*Solanaceae*	Roots and leaves	Atropine, scopolamine, hyoscyamine	Treatment for hypertension, motion-sickness, vomiting, gastrointestinal disorders, and other diseases	Tamilselvan et al. (2014)
47	*Melia azedarach* L.	Bead Tree, Pride of India, Chinaberry	*Meliaceae*	All parts, especially fruits, and leaves	Vincristine, etoposide, camptothecin, homoharringtonine, and other compounds	Cures Hodgkin's disease, testicular cancer and has anticancer property	Ervina and Sukardiman (2018)
48	*Mercurialis perennis* L.	Dog's Mercury, Wild spinach	*Euphorbiaceae*	All parts	Rutin, narcissin, mequinol, kaempferol, squalene, scopoletin, cycloartenol	It exhibits antidiabetic, anti-hypertensive, and anti-inflammatory activity and also is a remedy for dark spots occurring on the skin	Blanco-Salas et al. (2019)
49	*Mucuna pruriens* (L.) DC.	Velvet bean, Alkusa, Wakmi	*Fabaceae*	Hairs on fruits	Proteins (gpMuc), tannins, alkaloids, L-Dopa, isoquinolines, cyclitols, oligosaccharides, phenol	Exhibits anti-venom, anti-microbial, neuroprotective, antidiabetic, and antioxidant activity	Lampariello et al. (2012)
50	*Nerium indicum* Mill.	Rajbaka, Kamili ba	*Apocynaceae*	Roots, barks, and seeds	Beutulinic acid, oleanolic acid, 4-hydroxyacetophenone, kaempferol, β-sitosterol, and α-amyrin	Exhibits anticancer, antimalarial, anti-inflammatory, antioxidant, antidiabetic, anti-osteoporotic, and anti-allergic activities. It is also used in treating hypercholesterolemia and has analgesic properties.	Kuete, 2014
51	*Nerium oleander* L.	White oleander, Kaner	*Apocynaceae*	All parts	Oleandrin, cardenolides, kaneric acid	Exhibits anticancer, anti-inflammatory, cardiotonic, and antibacterial properties. It also has cytotoxic activity.	Tamilselvan et al. (2014)
52	*Nicotiana glauca* Graham	Tobacco	*Solanaceae*	All parts	Scopoletin	Inhibits human tumor	Tabana et al. (2016)
53	*Nicotiana tabacum* L. and related species	Tobacco	*Solanaceae*	All parts	Nicotine	Exhibits antioxidant, anti-microbial, anti-Alzheimer, anti-Parkinson, antidiabetic, antifertility, analgesic, peripheral nervous system and cardiovascular system activity	Ali (2022); Alhowail (2021)
54	*Nothapodytes foetida* (Wight) Sleumer	Wight, Kalgur, Arali	*Icacinaceae*	Stems	Camptothecin and 9-methoxycamptothecin	Exhibits anticancer and anti-AID activity	Fulzele and Satdive (2005)
55	*Oenanthe aquatic* (L.) Poir., *O. crocata* L., *O. sarmentosa* Presl ex DC.	Water dropwort	*Apiaceae*	All parts	Caffeic acid, chlorogenic acid, neochlorogenic acid	Possesses anti-viral, anti-herpetic (HSV-1, HSV-2), anti-adenovirus and anti-SARS-CoV-2 activity	S'wiątek et al. (2022)
56	*Papaver somniferum* L.	Opium poppy, Afin	*Papaveraceae*	Fruit and seed	Morphine, codeine, rhoeadine, thebaine, and papaverine	Possesses antioxidant, antimicrobial, anticancer, analgesic, and antidiabetic activities	Butnariu et al. (2022)
57	*Parthenium hysterophorus* L.	Bish-gach	*Asteraceae*	Whole plant	Parthenin	Anticancer and antitumor activity	Patel (2011)
58	*Phytolacca americana* L.	Indian polk	*Phytolaccaceae*	Leaves and roots	Sapogenin	Antifungal, anticancer, antioxidant, anti-inflammatory activities are reported.	Bailly (2021)
59	*Punica granatum* L.	Pomegranate	*Puniaceae*	Fruit and seed oil	Ellagic acid	Antioxidant activity	Shaygannia et al., 2016
60	*Ranunculus ternatus* Thunb, *R. acris* L., *R. sceleratus* L., *R. multifidu* Pursh, *R. bulbosus* L., and related species	Buttercup	*Ranunculaceae*	Leaves	Ternatolide	Anti-tuberculosis activity	Tamilselvan et al. (2014)
61	*Rauvolfia serpentine* Benth. Ex Kurz	Indian snakeroot	*Apocyanaceae*	Roots	Reserpine	Hypertension	Tamilselvan et al. (2014)
62	*Ricinus communis* L.	Castor bean	*Euphorbiaceae*	Seeds	Ricin	Anticancer activity	Franke et al. (2019)
63	*Rhododendron* spp	Azaleas	*Ericaceae*	Leaves	Chomene, chromane, flavonoid, orcinol derivatives, coumarin	Exhibits anti-HIV, antioxidant, smooth vascular muscle cell proliferation, antiviral, cytotoxic, anti-inflammatory and anticancer activity	Popescu and Kopp (2013)
64	*Scopolia carniolica* Jacq. and related species	Hanbane bell	*Solanaceae*	All parts	Hyoscyamine/atropine and scopolamine	Treatment for hypertension, motion-sickness, vomiting,	Fatur et al. (2021)

(*continued on next page*)

Table 1 (*continued*)

Sl No	Botanical Name	Common name	Family	Plant parts	Drugs	Medicinal properties	Reference
						gastrointestinal disorders, and other diseases	
65	*Sedum acre* L.	Biting Stonecrop, Gold-moss	*Crassulaceae*	All parts	Semadine	Possesses healing, laxative, astringent, hypotensive, and anti-helminthic properties	Stankovic et al. (2012)
66	*Strychnos nux-vomica* L.	Kuchila, Poison nut	*Loganiaceae*	Barks, seeds, leaves and woods	Strychnine and brucine	Act as a stimulant drug. It exhibits stimulant effects on the respiratory, circulatory, and nervous systems. The drug is also used in the digestive tract and paralytic conditions (due to the dysfunction of the motor nerve)	Guo et al. (2018)
67	*Taxus baccata* Thunb. and related species	Graveyard Tree, Taleespatra	*Taxaceae*	All parts, especially seeds and fruits	Paclitaxel, docetaxel	Anticancer activity	Tamilselvan et al. (2014)
68	*Thevetia peruviana* (Pers.) K.Schum	Yellow oleander, Pila Kaner	*Apocynaceae*	All parts, especially fruits, and leaves	Thevetin (Mixture of thevetin A and thevetin B)	It has the ability to treat chronic sores, ulcers, malarial fever, snakebites amenorrhoea, jaundice, rheumatism, and dropsy	Ahmad et al. (2017)
69	*Thlaspi arvense* L.	Pennycress	*Brassicaceae*	All parts	Isovitexin	Antioxidant activity	Pedras et al. (2003)
70	*Tragia involucrate* L.	Indian stinging nettle	*Euphorbiaceae*	Roots	Quercetin	It reduces aggregation of erythrocytes and treats capillary fragility. Exhibits anti-ulcer and antioxidant activity	Reddy et al. (2017)

can also function as receptor antagonists, interfering with cellular signaling and preventing biological reactions, for example, organochlorine insecticides (Jayaraj et al., 2016). Furthermore, a class of toxicants called respiratory blockers disrupt the mitochondrial Electron Transport Chain (ETC), which impacts multiple biological systems. Among them are cyanide and rotenone (Zhou and Huang, 2018).

The mechanism of toxicity follows events as shown in Fig. 6, typically begins with delivering a toxicant from its exposure site to its target site while maintaining its active form. During the transfer, the toxicant may either be absorbed, i.e., systemic circulation, or eliminated, i.e., pre-systemic elimination. Subsequently, the toxicants progress into the distribution phase, where they exit the bloodstream and reach the target site facilitated via the porosity of the capillary endothelium, transport across the plasma, and accumulation in cellular organelles (Gupta, 2016). Conversely, distribution away from the target site may also happen via specialized barriers, binding to plasma proteins, export from cells, etc. The delivery pathway also encompasses a physical mechanism for eliminating toxicants known as excretion. It removes xenobiotics from the bloodstream and returns them to the external environment (Pawlaczyk and Szynkowska, 2024).

Furthermore, toxicants may be reabsorbed through diffusion across the intestinal mucosa, which depends entirely on lipid solubility. This route can lead to either toxicity or detoxification. Certain xenobiotics can become hazardous in some situations due to metabolic activation, affecting the internal environment of biological structures or processes, ultimately leading to toxicology. In contrast, detoxication prevents or eliminates (Boelsterli, 2007; Timbrell, 2009; Curry, 2011; Gregus, 2013).

4. An overview of poisonous plants and their phytochemicals used to treat various diseases

4.1. Poisonous plants as anticancer agents

4.1.1. Taxus spp

Taxus brevifolia Nutt, also known as Pacific Yew, belongs to a member of the *Taxaceae* family and is found all along the Pacific Coast of South-eastern Alaska to central California. *T. baccata* Thunb. and *T. cuspidate* Siebold & Zucc. are two related species found in Russia, Canada, Europe, and the Himalayas (Lange and Conner, 2021). *Taxus* spp, widely recognized in traditional medicine systems like Ayurveda, Unani, and Traditional Chinese Medicine, has been used for various health conditions. Herbal teas or juices from *Taxus* spp alleviate cold symptoms, epilepsy, and indigestion (Purohit et al., 2001). Its bark and leaves, when used in steam baths, are known to provide relief from rheumatism, and applying its paste can help treat fractures and headaches. In Ayurveda, the young shoots of this plant are also used as a tincture to address issues such as diarrhoea, headaches, severe colds, and digestive distress (Nisar et al., 2008; Juyal et al., 2014). Taxol, a diterpene found in *Taxus* species (Gallego-Jara et al., 2020), has emerged as highly effective in treating ovarian and breast cancer. The well-known anticancer drug Paclitaxel (PTX) (Fig. 4 i) is extracted from the bark of *T. brevifolia* Nutt. Taxol has demonstrated a distinct mechanism of action. It targets the microtubules and prevents their dissociation by promoting the tubulin assembly into microtubules, which then blocks the cell cycle, thus inhibiting further proliferation of cancer cells. PTX is also used for the treatment of oesophagal cancer, cervical cancer, Kaposi's sarcoma, lung cancer, and pancreatic cancer (Pienta, 2001).

Docetaxel (DTX) (Fig. 4 ii), a semi-synthetic taxane that is one of the Paclitaxel analogues, has shown better efficacy than Paclitaxel in terms of the degree of polymerization, higher affinity for tubulin, and potent inducer of microtubule assembly (Sousa-Pimenta et al., 2023). Docetaxel exhibits a 2-fold mechanism of antineoplastic activity, inhibiting the microtubular depolymerization and mitigating the effects of bcl-2 and bcl-XL gene expression. It induces bcl-2 phosphorylation during the G2/M phase of the cell cycle, initiating a series of events that ultimately lead to apoptotic cell death (Obasaju and Hudes, 2001; Imran et al., 2020). Studies have reported that paclitaxel and docetaxel drugs are both critical in the chemotherapy of Hormone Refractory Prostate Cancer (HRPC), with DTX targeting a range of cancers, including head and neck, breast, stomach, prostate, and non-small-cell lung cancer (Buchler and Harland, 2007; Petrylak, 2003; Sousa-Pimenta et al., 2023).

4.1.2. Catharanthus roseus (L.) G.Don

Catharanthus roseus (L.) G.Don is also known as Madagascar

Fig. 2. List of some of the common poisonous plants that have been used for medicinal purposes. (A) *Taxus baccata* (https://commons.wikimedia.org/wiki/File:Yew_Berries.jpg) (B) *Catharanthus roseus* (https://commons.wikimedia.org/wiki/File:Flowers_of_Catharanthus_roseus_at_the_campus_of_Ramakrishna_Mission_Shikshanamandira.jpg) (C) *Cannabis sativa* (https://commons.wikimedia.org/wiki/File:Cannabis_sativa_plant_(3).JPG) (D) *Croton tiglium* (https://commons.wikimedia.org/wiki/File:Croton_tiglium_03.JPG) (E) *Abrus precatorius* (https://commons.wikimedia.org/wiki/File:Jequirity_habit_and_pods.jpg) (F) *Nicotiana tabacum* (https://commons.wikimedia.org/wiki/File:P1000484_Nicotiana_tabacum_(tobacco)_(Solanaceae)_Flower.JPG) (G) *Crocus sativus* (https://commons.wikimedia.org/wiki/File:Crocus_sativus_Y03.jpg) (H) *Mucuna pruriens* (https://commons.wikimedia.org/wiki/File:Mucuna_pruriens_flowers.jpg) (I) *Strychnos nux vomica* (https://commons.wikimedia.org/wiki/File:Strychnos_nux-vomica_L.jpg) (J) *Atropa belladonna* (https://commons.wikimedia.org/wiki/File:Atropa_belladonna_Pokrzyk_wilcza_jagoda_2017-08-06_01.jpg) (K) *Aleurites moluccana* (https://commons.wikimedia.org/wiki/File:Aleurites_moluccana_tuitui.jpg) (L) *Alocasia indica* (https://commons.wikimedia.org/wiki/File:Alocasia_indica.jpg) (M) *Arnica montana* (https://commons.wikimedia.org/wiki/File:Arnica_montana_Arnika_g%C3%B3rska_2023-06-08_01.jpg) (N) *Jatropha curcas* (https://commons.wikimedia.org/wiki/File:Jatropha_curcas,_AJT_Johnsingh._.P1020719.jpg) (O) *Nerium oleander* (https://pin.ithttps://pin.it/3EN5DcNx5) (P) *Citrullus colocynthis* (https://commons.wikimedia.org/wiki/File:Citrullus_colocynthis_004.JPG) (Q) *Datura metel* (https://commons.wikimedia.org/wiki/File:Datura_metel_(11984121745).jpg) (R) *Anamirta cocculus* (https://commons.wikimedia.org/wiki/File:Anamirta_cocculus_%E0%B4%AA%E0%B5%8A%E0%B4%B3%E0%B5%8D%E0%B4%B3.jpg) (S) *Aconitum napellus* (https://commons.wikimedia.org/wiki/File:Aconitum_napellus_inflorescence_(28).jpg) (T) *Conium maculatum* (https://commons.wikimedia.org/wiki/File:Conium_maculatum._Mexac%C3%A1n.jpg
The pictures were sourced from Wikimedia Commons.

periwinkle, belonging to a member of the *Apocynaceae* family and is native to the Indian Ocean Island of Madagascar and found in many tropical and subtropical regions of Australia, Africa, China, Europe, and the USA (Lee et al., 2020). *C. roseus* L. has been used in traditional medicine systems such as Ayurveda, Unani, Siddha, and Traditional Chinese Medicine to treat conditions such as cancer, genitourinary issues, kidney problems, cardiovascular diseases, and liver ailments. In Ayurveda, stem, leaves, and roots are used for treating parasitic infections, digestive problems, hypotension, constipation, sedation, toothache, stomachache, and diabetes (Kumar et al., 2022). The regions of North-east India, Australia, England, the Philippines, Northern Europe, Vietnam, and Thailand have employed desiccated leaves or whole plants for diabetes management. Kenya employs it to treat several forms of cancer, whereas South Africa uses it to manage urogenital infections (Pham et al., 2020).

It has been reported that alkaloids like vinblastine (Fig. 4 iii) and vincristine (Fig. 4 iv) are the most essential drugs in cancer chemotherapy. Vinblastine is cell cycle phase-specific; it binds to the tubulin protein, inhibiting the microtubule formation, which then disrupts the assembly of the mitotic spindle, leading to the arrest of the tumour cells in the M-phase. Also, it interferes with cyclic AMP and glutathione metabolism, amino acid metabolism, cellular respiration, nucleic acid, and lipid biosynthesis (Chun et al., 2007; Castle et al., 2017; Zhuang et al., 2019).

On the other hand, vincristine prevents the binding of free tubulin to the microtubule fibre by binding to the β-subunit of tubulin dimers that

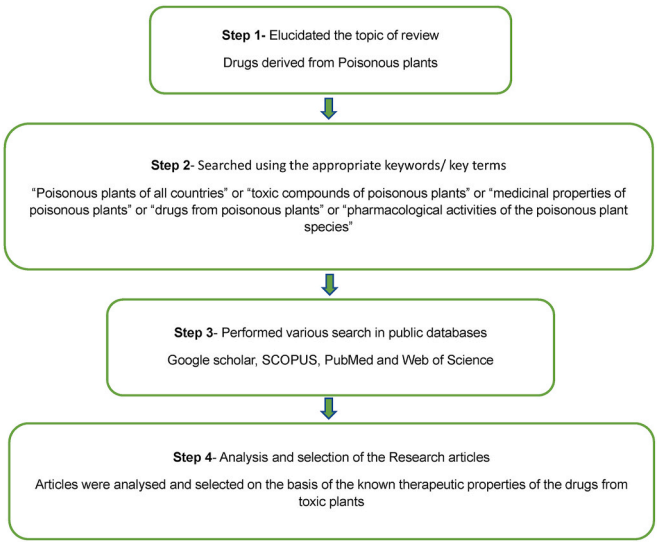

Fig. 3. Schematic flow diagram showing the search process and databases used for this study.

lies between the boundaries of two heterodimers (Škubník et al., 2021). Vincristine has been used clinically to treat childhood leukemia, and vinblastine has medicinal properties to cure Hodgkin's disease. Both vincristine and vinblastine exhibit neurotoxic activity in higher concentrations, though lower concentrations have been used therapeutically (Aniszewski, 2007).

4.1.3. *Cannabis sativa L*

Cannabis sativa L. is commonly known as Indian Hemp Marijuana or Ganja (local language). It belongs to a member of the *Cannabaceae* family and is native to Central and South Asia, Siberia, the Himalayas, and South Africa (Odieka et al., 2022). *C. sativa* L. has been traditionally used for a variety of health conditions. Its different parts, such as seeds, leaves, stems, bark, and roots, have wide medicinal applications. Seeds relieve pain, seizures, nausea, and anxiety and prevent hair loss (Hourfane et al., 2023). Foliage has therapeutic properties for several ailments, including central nervous system depressants, gout, mental illnesses resembling schizophrenia, stomach disorders, malaria, scorpion stings, hair loss, and greying hair. The stem or bark is employed to treat urinary problems and injuries. Roots have therapeutic characteristics for fever, cancer, inflammation, haemorrhage, skin burns, physical injuries, placental retention, vaginal discharge, and delivery difficulties. Additionally, they have anti-dote capabilities against toxins (Odieka et al., 2022). It is reported that cannabinoids are a class of terpene phenolic compounds, and the mainly focused cannabinoids are Cannabidiol (CBD) (Fig. 4 v), delta-9 tetrahydrocannabinol (THC) (Fig. 4 vi), and Cannabinol (CBN) (Fig. 4 vii) (Pugazhendhi et al., 2021).

Cannabinoids function as agonists for CB1 and CB2 receptors, and research indicates that they provide antiproliferative effects in breast and skin cancer through activating cyclin-dependent kinase (CDK) inhibitors. Furthermore, they influence melanoma cells by inhibiting the prosurvival protein Akt and inducing hypophosphorylation of the retinoblastoma protein (pRb), thus disrupting the cell cycle and triggering apoptosis-mediated cell death (Velasco et al., 2016). The anti-tumor effects on head and neck squamous cell carcinoma (HNSCC) were demonstrated by diminishing cell migration, invasion, and viability in a dose- and time-dependent way. CBD diminishes tumor size and weight in a mouse xenograft model. When used in conjunction with chemotherapeutic agents, it has a synergistic effect that necessitates lower dosages to attain equivalent efficacy (Go et al., 2020).

The antitumor effects of cannabinoids on cancers such as human gastric, non-small cell lung, and hepatocellular carcinoma (HCC) cells are mediated via inactivation of the Akt pathway (Pugazhendhi et al., 2021; Hinz and Ramer, 2022). The use of drugs containing cannabinoids treats anxiety, nausea, schizophrenia, stroke, epilepsy, multiple sclerosis, etc (Zou & Kumar, 2018).

Compounds such as β-Caryophyllene (BCP) (Fig. 4 viii) and β-Caryophyllene oxide (BCPO) (Fig. 4 ix) are naturally occurring bicyclic sesquiterpenes present in essential oils of many plants, including *C. sativa* L., have been studied for their effects on cancer cells (Fidyt et al., 2016). BCP acts as a cannabinoid receptor 2 (CB2) agonist, significantly inhibiting the antiproliferative activity of human glioblastoma (U-373 and U-87) and human glioma stem-like cells. It reduced the expression of anti-apoptotic markers (Bcl-2) while increasing the pro-apoptotic markers (BAX), activating caspase-3 and caspase-9, leading to apoptosis. Additionally, BCP decreased the pro-inflammatory cytokines (NF-κB and TNF-α), resulting in its anti-inflammatory effects (Irrera et al., 2020).

In contrast, BCPO does not bind to CB1/2 receptors but influences other key pathways that could alter cancer development (Fidyt et al., 2016). Studies have reported that BCPO inhibits the growth of prostate cancer cells (PC-3) and breast cancer cells (MCF-7), promoting ROS generation and the activation of MAPK. It also hinders several pathways, such as PI3K/AKT/mTOR/S6K1, essential for the tumour cell's proliferation, survival, and angiogenesis (Park et al., 2011). Furthermore, BCPO effectively inhibits ATP-binding cassette (ABC) transporters, such as multidrug resistance (MDR1) and multi-drug associated proteins (MRP1, and MRP2) at non-toxic doses in HCC cells, responsible for drug efflux. By enhancing the intracellular accumulation of sorafenib, BCPO, in combination, increases the sensitivity of HCC cells to sorafenib without causing significant adverse effects (Di Giacomo et al., 2019).

The plausible mechanism of action of anticancer drugs such as taxoids, alkaloids or cannabinoids is summarized in Fig. 7.

4.2. *Neuroprotective drugs*

4.2.1. *Croton tiglium L*

Croton tiglium L, also known as Purging Croton or Jamalgota, belongs to the *Euphorbiaceae* family. It is native to India and across Tropical Asia, including China, the Philippines, Indonesia, and New Guinea (Dey et al., 2015). In Ayurveda, seeds are commonly used to treat constipation after detoxification (Sodhana) with cow milk (godugdha). Additionally, the oil of *C. tiglium* L. is utilized for treating gastrointestinal disorders (Pal et al., 2014; Pucker et al., 2020).

A study highlighted the preparation of a crude extract of *C. tiglium* L., where the resulting residue was mixed with water and partitioned with hexane and diethyl ether, repeating the process thrice for each solvent. The combined diethyl ether fraction was collected and quantified using the HPLC method (Pal et al., 2014). *C. tiglium* L. seeds contain croton oil, a source of many phorbol derivatives, particularly 12-O-tetradecanoylphorbol-13-acetate (TPA) (Fig. 4 x) (Choe et al., 2002). In 1983, Kinghorn et al. filed a patent on the extraction process of TPA from croton oil. This process involved an initial extraction with aqueous methanol, followed by purification using Droplet Counter-Current Chromatography (DCCC) with a stationary and mobile phase mixture of hexane-diethylether-n-propanol-ethanol-water (1:2:1:1:1). Subsequent refinement was done through liquid column chromatography using octylsilyl phase-bonded silica gel and eluting solvents of decreasing polarity (water-acetonitrile-methanol). Finally, preparative thin-layer chromatography with chloroform-ethyl acetate was utilized to achieve high-purity TPA (Kinghorn and Marshall, 1983).

Pre-treatment with TPA induced neurite outgrowth and growth cone formation, which was blocked by the selective inhibitors, suggesting the selective involvement of Protein kinase C alpha (PKCα) (Choe et al., 2002). Furthermore, *C. tiglium* L. extract (CTE) significantly inhibited neurotoxic inflammatory factors like NO and TNF-α, while increasing the production of neurotrophic factor BDNF. This resulted in the suppression of pro-inflammatory responses and promotion of

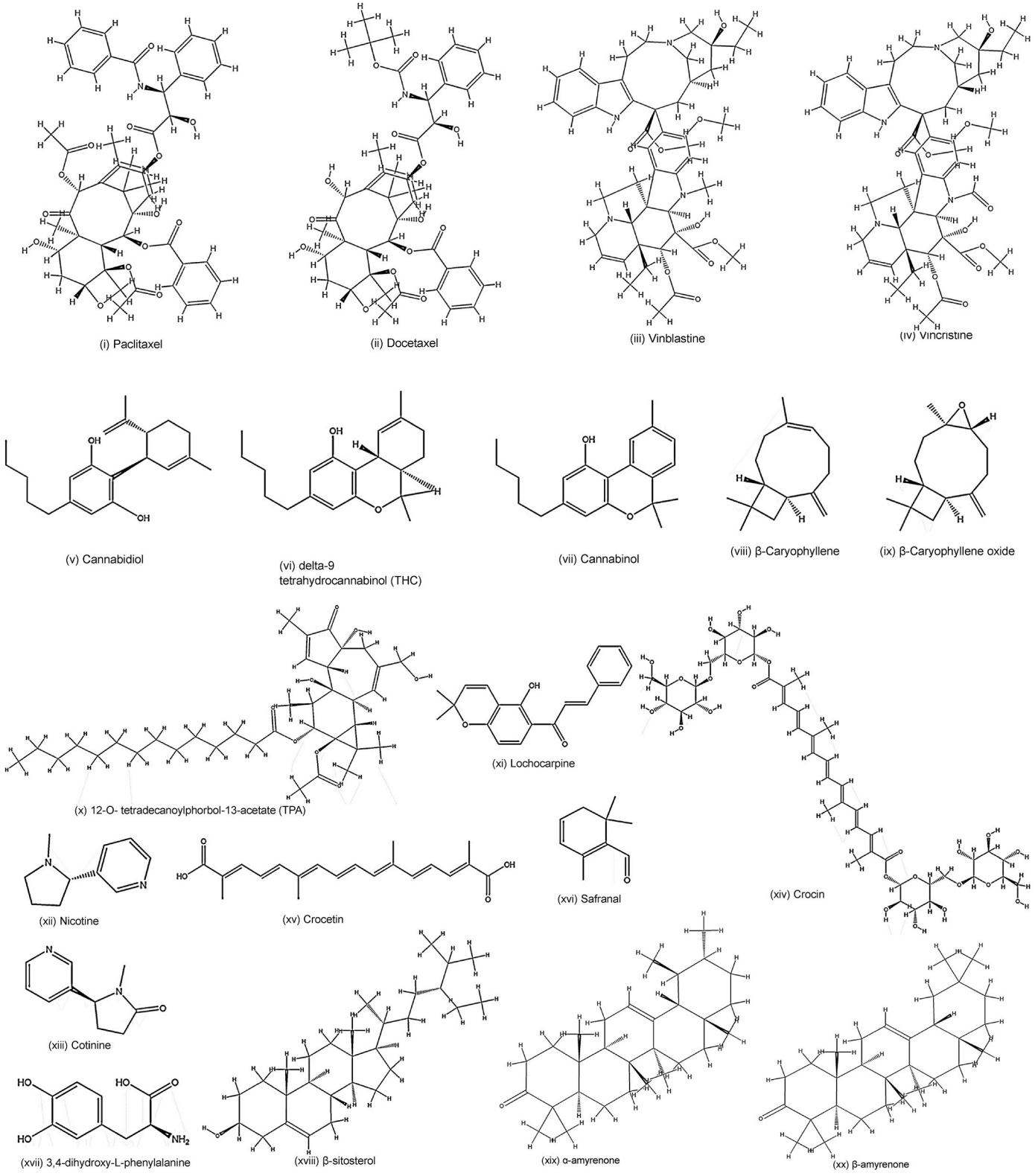

Fig. 4. Chemical structures of some bioactive compounds derived from poisonous plants. The structures were drawn using ChemDraw software.

anti-inflammatory and neuroprotective activation of microglia. It is proposed that CTE may have exerted its effects by modulating MAPK and HDAC/NF-κB pathways, which are involved in neuroinflammation and neuronal survival (Gupta et al., 2020; Franco and Fernández-Suárez, 2015).

4.2.2. *Abrus precatorius L*

Abrus precatorius L. (AP), also known as "Jequirity bean" or "Rosary pea," is a perennial herbaceous plant belonging to the *Fabaceae* family. It is abundant in India, the Himalayas, and tropical regions, including South Africa, China, the West Indies, the Islands, and more. In India, it is

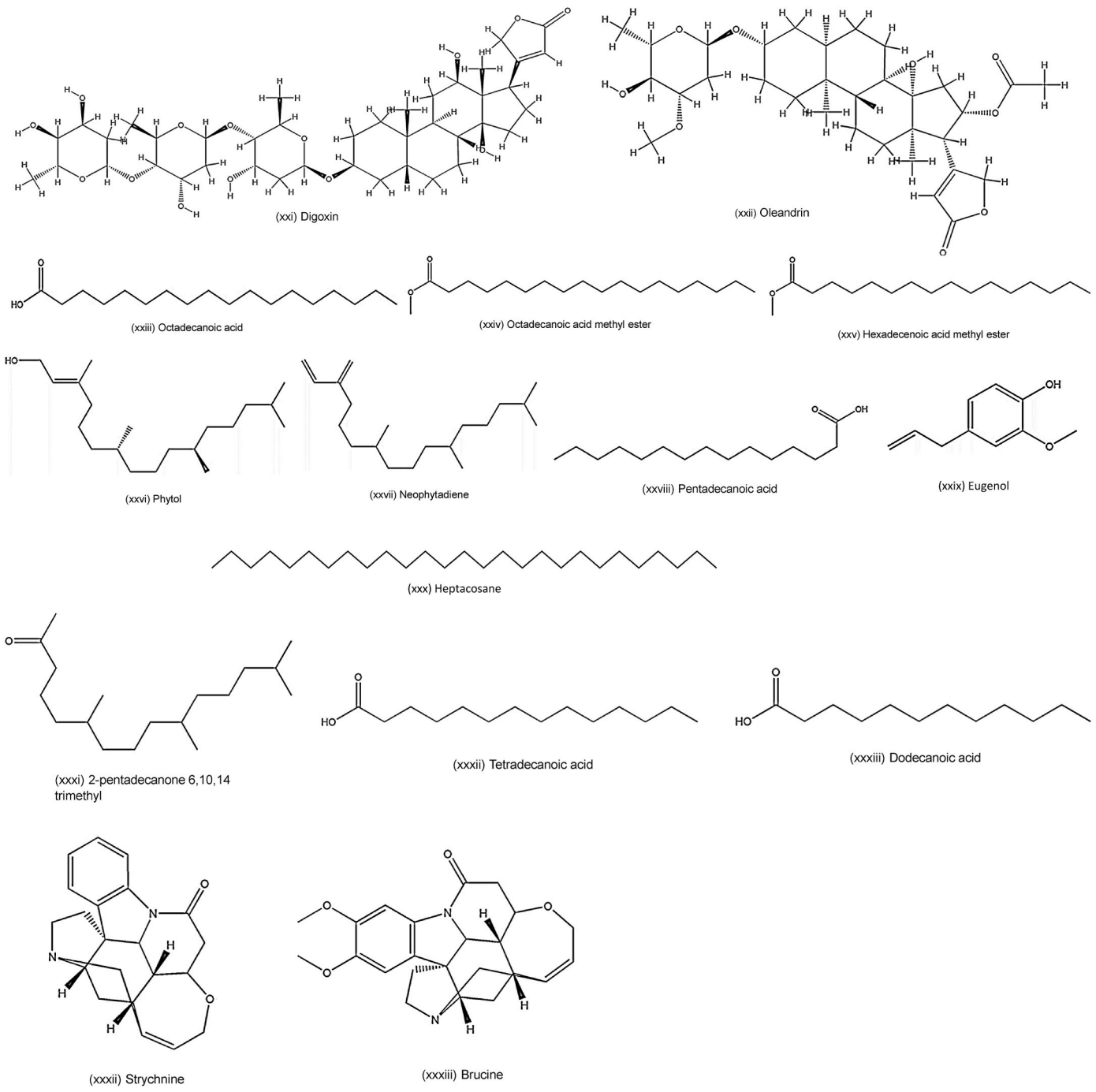

Fig. 4. (*continued*).

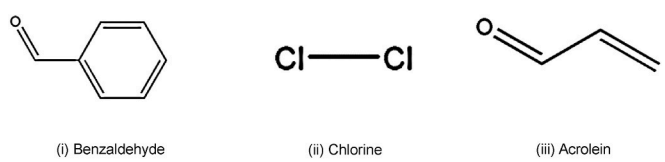

Fig. 5. Chemical structures of some irritants. The structures were drawn using ChemDraw software.

locally known as "Ratti" or "Gunja" (Garaniya and Bapodra, 2014). The stems, leaves, and roots of *A. precatorius* L. are employed in traditional Chinese medicine (TCM) for cleansing and diuretic therapeutic purposes. It is commonly used in Africa for treating diarrhoea, gonorrhoea, and skin inflammations. The powdered seeds are utilized as oral contraceptives. In Ayurveda, leaves are recommended for treating colds, coughs, fever, migraine, constipation, and conjunctivitis. Root paste has therapeutic properties for alleviating stomach discomfort and tumors and is also employed as an oral contraceptive. When masticated, roots serve as a treatment for snakebites. Additionally, it is used to treat malaria, jaundice, bronchitis, and hepatitis (Qian et al., 2022; Kaula et al., 2022).

Studies have reported that lonchocarpine (Fig. 4 xi), a phenylpropanoid compound isolated from AP, can protect brain astrocytes by inhibiting reactive oxygen species (ROS) generation and H_2O_2-induced cell death. It has augmented antioxidant enzyme expression via the Nrf2/antioxidant response enzyme (ARE) signaling pathway, facilitating

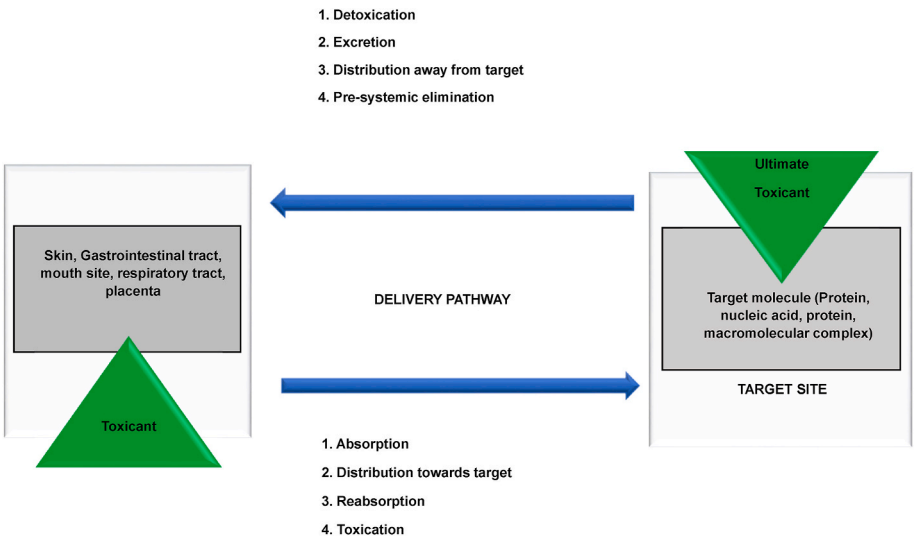

Fig. 6. Mechanism of toxicity inflicted by poisonous plants and their toxic compounds. Created with Microsoft PowerPoint 365.

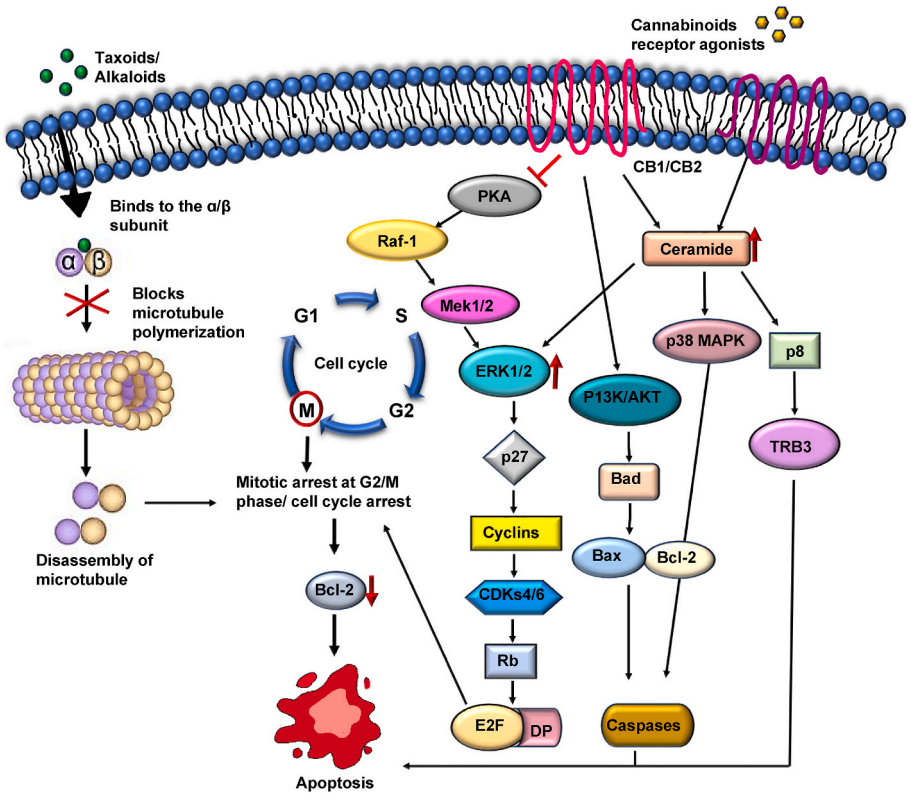

Fig. 7. The most plausible schematic representation of signaling pathways associated with activating taxoids, alkaloids or cannabinoid receptors induced by its agonists. The hypothesized mechanisms are based on the existing literatures and created with Microsoft PowerPoint 365.

nuclear translocation and DNA binding of Nrf2 to ARE, which has increased transcriptional activities (Jeong et al., 2016).

Furthermore, lonchocarpine's modulation of AMPK and MAPK signaling pathways suggested its therapeutic potential for oxidative stress-related neurodegenerative conditions (de Vries et al., 2008). It has also exhibited significant anti-inflammatory effects in neuro-inflammatory conditions triggered by LPS or poly, inhibiting iNOS and proinflammatory cytokine expression in stimulated microglial cells. It has also reduced activated microglia in mice brains, and hampered NF-κB activity by inhibiting IκBα phosphorylation and degradation (Jeong et al., 2017).

In silico analysis has demonstrated that the terpenoid drimenin extracted from AP seeds, when docked with α-synuclein protein, showed the lowest binding energy and stability during molecular dynamic (MD) simulation, may have inhibitory potential against the Parkinson's disease (PD) (Omoboyowa et al., 2021). Additionally, seeds collected from AP such as red-black and white seeds, were extracted using methanol. Chromatography and numerous spectroscopic techniques (EI-mass, UV, IR, ^{1}HNMR) have been employed to detect and identify levodopa (L-DOPA). Upon quantitative analysis, red-black seeds showed higher concentration of L-DOPA than in white seeds, and chemical tests have confirmed the presence of an aromatic amino acid, validating the

presence of L-DOPA (Gupta and Gupta, 2018).

4.2.3. *Nicotiana tabacum L. and related species*

Nicotiana and its related species, which belong to the *Solanaceae* family, are commonly known as tobacco. These plants are found abundantly in India and other countries. Aztec or Indian tobacco is widely cultivated in North America, Mexico, Russia, Vietnam, and Turkey (Sierro et al., 2018; Mehmood et al., 2020). Traditionally, the leaves of *N. tabacum* L. and its related species are used to treat various conditions, including bronchitis, tonsillitis, arthritis, sore throat, wounds, skin illness, and stomach infection. Meanwhile, the extract is applied to help relieve toothache and respiratory tract diseases (Zou et al., 2021).

Nicotine (Fig. 4 xii) and its derivatives, like cotinine (Fig. 4 xiii), have shown neuroprotective effects by reducing brain oxidative stress and neuroinflammation linked to Parkinson's disease (Barreto et al., 2015). Moreover, these compounds were also found to enhance synaptic plasticity and dopaminergic neuronal survival, which is crucial for motor and memory functions (Parain et al., 2003). Nicotine has been reported to protect hippocampal neurons against apoptosis induced by β-amyloid peptide (Aβ), which is associated with AD by inhibiting $A\beta_{25–35}$ or $A\beta_{1–40}$-induced apoptosis and decreases the caspase activity. It also helps mitigate the Aβ-induced accumulation of free radicals and the increase of intracellular free calcium (Ca^{2+}) (Liu and Zhao, 2004). Pre-treatment with nicotine followed by H_2O_2-induced neurotoxicity significantly reduces oxidative damage, restores the cell cycle arrest at the G2/M phase, and prevents mitochondria dysfunction. Its neuroprotection and antioxidative mechanisms are mediated by activating the Erk1/2 signaling pathway, highlighting the role of 7-nicotinic acetylcholine receptors (7-nAChRs) (Dong et al., 2020). It also enhanced neuronal survival by inhibiting Sirtuin 6 (SIRT 6), reducing neuronal apoptosis, and potentially protecting against PD (Nicholatos et al., 2018).

Another study investigated the beneficial effects of nicotine on PD phenotypes using Synphilin-1 (Sph-1) overexpression in *Drosophila melanogaster*. It was observed that nicotine improved neuronal survival and motor functions, resulting in an increase of tyrosine hydroxylase and dopamine levels, indicating its potential for cholinergic agonists in supporting neuronal metabolic functions (Carvajal-Oliveros et al., 2021). Similarly, using MPTP-induced mice as a PD model, nicotine pre-treatment notably enhanced motor function. It also exhibited anxiolytic effect, possibly modulating the JNK and ERK signaling pathways within the nigrostriatal regions (Ruan et al., 2023).

4.2.4. *Crocus sativus L*

Crocus sativus L. is commonly known as saffron or kesar, belonging to the family of *Iridaceae*, and is widely distributed in Northern Africa, Western Asia, and Southern and Central Europe. It is also cultivated widely in countries such as Iran, India, and Greece (Srivastava et al., 2010; Matraszek-Gawron et al., 2022). In Persian traditional medicine, *C. sativa* L. is valued as a tonic to boost strength, especially for vascular and nervous systems. It is also used to treat melancholy, sleeplessness, diarrhoea, and measles. Ancient Egypt and Greece employed it as a medicinal remedy to combat skin ulcers and alleviate ocular problems resulting from acute pain and infections. Furthermore, it treats symptoms of urinary and menstrual problems. Within the Unani tradition, it is a therapeutic intervention for urinary and renal disorders. When it is administered in conjunction with honey, it functions as a diuretic. In Ayurveda, the mixture of powdered *C. sativa* L. with ghee is advised for treating diabetes, external wounds, digestive problems, asthma, arthritis, and oedema (Butnariu et al., 2022; Yang et al., 2023). Most importantly, *C. sativa* contains active compounds like crocin (Fig. 4 xiv), crocetin (Fig. 4 xv), and safranal (Fig. 4 xvi), exhibits various pharmacological activities as mentioned in Table 1.

The hydroalcoholic extract of *C. sativus* L. (IIIM-141) has shown promising effects by inhibiting NLRP3 (NOD-like receptor pyrin domain-containing protein 3), a cytoplasmic protein and an inflammasome sensor, protecting against Aβ- and glutamate-induced neurotoxicities in human neuroblastoma (SH-SY5Y) cells, as well as improving the memory impairment in rats and mice AD models (Bharate et al., 2018). Pre-treatment with *C. sativus* L. extract (CSE) reduced Aβ accumulation in the hippocampus of 5XFAD mice, increased Aβ-degrading enzymes (IDE, NEP), activated ApoE clearance proteins, improved synaptic proteins (PSD-95, SNAP-25), reduced neuroinflammation, and promoted astrocyte activation. It also maintained blood brain barrier (BBB) integrity against Aβ damage proving its potential Alzheimer's therapy (Batarseh et al., 2017).

Crocin, a bioactive compound found in saffron (Cerdá-Bernad et al., 2022), prevents cell death triggered by tumour necrosis factor (TNF)-α in neuronally differentiated rat pheochromocytoma (PC-12) cells by blocking the TNF-induced apoptotic alterations and DNA fragmentations. It has influenced the Bcl-2 family proteins' expression and decreased cytochrome c release from mitochondria (Soeda et al., 2001). In addition, it has shown protection against apoptosis in PC-12 cells triggered by serum/glucose deprivation that causes a rise in cellular ceramide levels, activating c-jun kinase JNK pathway by preventing sphingomyelinase activation, ceramide production and JNK phosphorylation (Ochiai et al., 2004a). Furthermore, it was also found to be more potent than α-tocopherol in protecting against H_2O_2-induced oxidative stress-related cell death in PC-12 cells (Ochiai et al., 2004b).

Moreover, a repetitive mild traumatic brain injury (rmTBI) in a mouse model was established, where CSE and crocin exhibited a significant reduction of oxidative stress markers like malondialdehyde (MDA) and increased glutathione (GSH) levels. They also suppressed proinflammatory cytokines (TNF-α and IFN-γ), alleviating inflammatory responses, and found no signs of neuronal loss or abnormal histological features in injured groups (Salem et al., 2022). Additionally, both CSE and crocin prevented chronic stress-induced oxidative stress in *in vivo* rat models (Bandegi et al., 2014).

4.2.5. *Mucuna pruriens (L.) DC*

Mucuna pruriens (L.) DC. is commonly known as velvet bean, belonging to the family of *Fabaceae*, widely distributed in tropical regions, especially Asia, Africa, tropical America, the West Indies, the USA, and the Pacific Islands (Pathania et al., 2020; Ezegbe et al., 2023). Countries like India, Thailand, China, and tropical countries use different plant parts-seeds, leaves and roots to treat various conditions. In Ayurveda, *M. pruriens* (L.) DC. is traditionally used to treat PD, psychological stress and low sexual desire disorder. The roots are used for treating sexual dysfunction and brain-related issues. In Nigeria and Brazil, seeds are used as oral prophylactics against snakebites and to treat conditions like oedema, impotence, and worm infections. They are even considered a diuretic, an aphrodisiac, and nerve tonic (Rachsee et al., 2021; Tangsrisakda et al., 2022; Tan et al., 2009). It contains proteins (gpMuc), tannins, alkaloids, isoquinolines, cyclitols, oligosaccharides, phenol, and most importantly, a non-protein amino acid 3, 4-dihydroxy-L-phenylalanine or L-Dopa, a natural precursor used for the treatment of PD (Fig. 4 xvii) (Lampariello et al., 2012).

Studies have shown that the aqueous extracts of *M. pruriens* (L.) DC. (MPE) seed showed significant cell viability in P19-derived neurons, including serum deprivation and H_2O_2 assays, indicating its potential to protect neurons from premature cell death. Notably, it demonstrated inhibitory activity against acetylcholinesterase, highlighting potential advantages in treating PDs over synthetic L-Dopa (Kamkaen et al., 2022). Another study demonstrated that L-dopa-reduced MPE showed a significant reduction of cytotoxicity and oxidative stress against H_2O_2-induced toxicity in murine microglia (BV-2) cells. It also mitigated cell apoptosis in SH-SY5Y cells, maximized survivability of *C. elegans* when exposed to neurotoxins (6-OHDA and rotenone), and ameliorated negative geotaxis behaviour in *D. melanogaster* (Johnson et al., 2018).

Additionally, the effects of methanolic MPE on $PINK1^{B9}$ *D. melanogaster* genetic model of PD significantly increased $PINK1^{B9}$ mutants' lifespan. It has restored olfactory response and climbing

behaviour, reversed mitochondrial dysfunction, restored T-bars density, and normalized brain proteins such as bruchpilot (BRP) and tyrosine hydroxylase (TH) expression, unlike L-Dopa (Poddighe et al., 2014). In the *in vivo* Swiss albino mice model, MPE mitigated the neurotoxic effects induced by MPTP through the activation of NF-KB and promotion of pAkt pathway, indicating its potential in preventing apoptosis of dopaminergic neurons, ameliorating neuroinflammation, and exhibiting antioxidant properties (Rai et al., 2017).

Furthermore, MPE attenuated sodium arsenite-induced neurotoxicity in the *in vivo* rat model and showed significant improvement in memory impairment, neurodegeneration reduction, and decreased serum ALT levels (Concessao et al., 2020). Recently, a study explored the effects of methanolic MPE of seeds and its active compound β-sitosterol (Fig. 4 xviii) on gene expression linked to NMDA receptors and tau protein in male Wistar rat models of cerebral ischemia. Upon pre-treatment with β-sitosterol and MPE of seeds, it showed a reduction in ischemic brain injury and neurological deficit scores compared to the untreated group, indicating its potential protection against ischemic damage (Parvatikar et al., 2023).

4.2.6. *Strychnos nux-vomica L*

Strychnos nux-vomica L., also known as Poison fruit, belongs to the family of *Loganiaceae*, and is widely distributed and grown in India, Sri Lanka, and Australia (Guo et al., 2018). In Chinese folk medicine, the dried seeds of *N. vomica* L. are used to improve blood circulation and are valued to cure cancer rheumatic pain and reduce swelling (Chen et al., 2012). In Ayurveda and other traditional Asian medicine, it is used to treat a range of conditions such as arthritis, cancer, constipation, gastritis, heart disease, influenza, and musculoskeletal disorders. It is also believed to help manage diabetes, asthma, and aphrodisiac while improving appetite (Bhati et al., 2012).

Studies have reported that the processed *N. vomica* L. seeds at a dose of 250 mg/kg enhanced the recovery rate of both sensory and motor functions, reduced total oxidant levels, restored muscle mass, and boosted antioxidant capacity in a mouse model of sciatic nerve lesion (Razzaq et al., 2020). Additionally, homeopathic medicinal preparations (HMPs) of *N. vomica* L. were evaluated for their effect against pentylenetetrazole (PTZ)-induced acute seizures in mice. The study revealed that HMPs reduced seizure severity, delayed kindling, ameliorated cognitive impairment, enhanced motor coordination, and significantly decreased MDA levels by inhibiting lipid peroxidation while boosting antioxidant mechanisms (Mishra et al., 2021). A plausible neuroprotective mechanism of phytochemicals derived from poisonous plants is summarized in Fig. 8.

4.3. *Poisonous plants used in anti-inflammatory activity*

4.3.1. *Aleurites moluccana (L.) Willd*

Aleurites moluccana (L.) Willd., also known as Indian walnut or Candlenut tree, is a member of the *Euphorbiaceae* family that grows around the world, including India, the southeast and east areas of Brazil, Sri Lanka, Madagascar, the West Indies, and the United States (Hakim et al., 2022). *A. moluccana* (L.) Willd. is widely used in traditional folk medicine by various tribes worldwide to treat various conditions, including diarrhoea, asthma, stomach, swollen womb, and stomach problems. The plant's bark is used to cure dysentery and typhoid fever. Meanwhile, leaves are commonly used for treating asthma, fever, headache, gastric ulcers, and hepatitis (Quintão et al., 2011).

The anti-inflammatory effects of methanolic extract from dried leaves of *A. moluccana* (L.) Willd. were conducted in carrageenan-induced paw oedema in Wistar rats, a widely used model for anti-inflammatory activity. The oedema formation comprises two phases: the initial phase involves the release of histamine and serotonin in the first 4 h, and delayed oedema releases bradykinin and prostaglandins. Meanwhile, the second phase is sensitive to steroidal and anti-steroidal anti-inflammatory events. Upon treatment, *A. moluccana* (L.) Willd. prevented the increase in carrageenan-induced paw oedema, with the most significant impact observed at the dose of 300 mg/kg (Niazi et al., 2010).

Moreover, triterpenes such as *α*-amyrenone (Fig. 4 xix) and *β*-amyrenone (Fig. 4 xx), isolated from the dichloromethane fraction of the *A. moluccana* (L.) Willd. leaf methanol extract, exhibited anti-inflammatory effects in both chronic and acute conditions by alleviating mechanical hypersensitivity in mouse models induced by carrageenan-induced hyperalgesia and paw oedema. Notably, the hypersensitivity induced by carrageenan injection is closely associated with the production of cytokines such as IL-1β and the CXC chemokine CINC-1, which has contributed to the inflammatory process. Thereby, *α*- and *β*-amyrenone demonstrated the ability to reduce neutrophil migration, highlighting its significance in pain processing mechanisms (Quintão et al., 2014). A similar study was carried out by using semisolid containing *A. moluccana* (L.) Willd. dried extract, where it significantly

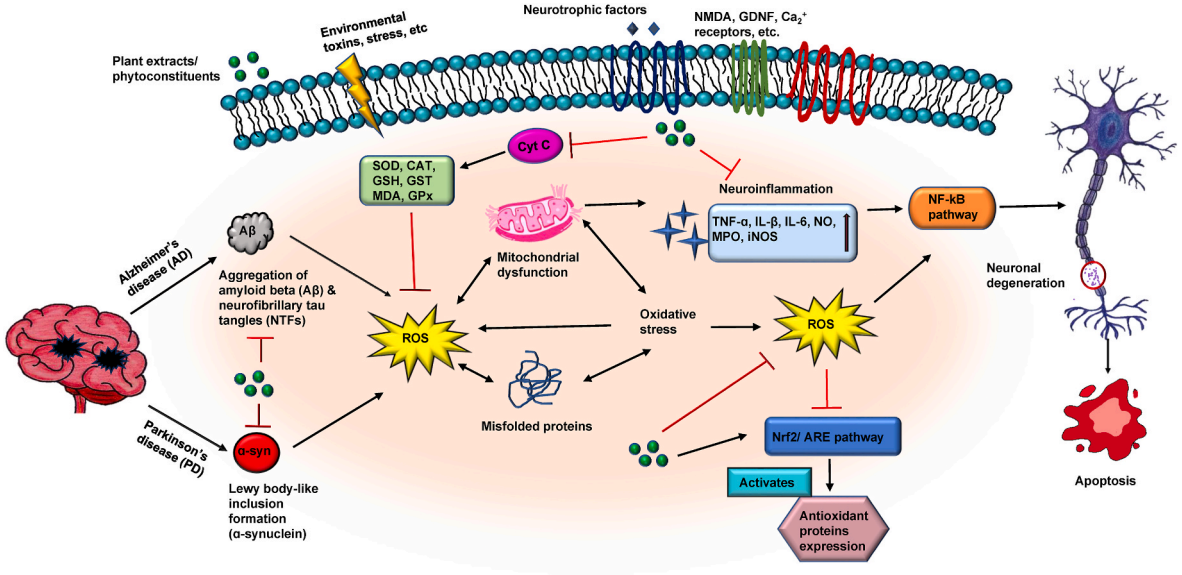

Fig. 8. The most plausible mechanism of action of neuroprotective agents against the molecular pathways involved in the pathophysiology of Alzheimer's disease (AD) and Parkinson's disease (PD) are illustrated. The hypothesized mechanisms are based on the existing literature and created with Microsoft PowerPoint 365.

reduced ear oedema, leukocyte migration, and the levels of inflammatory mediators in mice, proving it to be the natural anti-inflammatory remedy for skin inflammatory conditions (Mendes Hoepers et al., 2015).

4.3.2. *Alocasia sp.*

Alocasia sp. (Giant taro) belongs to the family *Araceae,* which is widely distributed throughout Asia, Australia, and Southeast Asia. Consumption of this plant can be dangerous due to the presence of oxalate crystals, which can cause oral pain, vomiting, nausea, and dysentery. Different species of *Alocasia* are used in traditional medicine to treat sexual diseases, diarrhoea, diabetes, constipation, and even cancer (Nauheimer et al., 2012). *A. indica* Schott is commonly used to treat rheumatoid arthritis, snakebites, and hives. Meanwhile, *A. maccorhiza* (L.) G.Don treats ear infections and jaundice. In Malaysia, it is traditionally used in wound healing and inflammation (Arbain et al., 2022). Lignanamides and monoindoles, isolated from the rhizomes of *A. macrorrhiza* (L.) G.Don showed notable inhibitory effects on lipopolysaccharide (LPS)-induced nitric-oxide production in RAW 264.7 cells (macrophage-like cell line derived from BALB/c mice) (Huang et al., 2017).

The ethanolic extract of *A. indica* Schott leaves demonstrated dose-dependent antinociceptive and anti-inflammatory properties in female Wistar albino rats. It decreased acetic acid-induced writhing, prolonged response time in hot plate and tail flick assays, and markedly suppressed carrageenan-induced paw oedema, arachidonic acid-induced ear oedema, and xylene-induced ear oedema. The observed effects were analogous to those of the medicine diclofenac sodium and are likely ascribed to the antioxidant characteristics of the examined plant, which were shown to be equivalent to the standard ascorbic acid (Mulla et al., 2010).

A comparable investigation was undertaken utilizing ethanolic crude extract of *A. indica's* dried rhizome which was tested in a carrageenan-induced paw oedema model in Wistar rats. The extract significantly inhibited oedema formation in treated rats. A comparative analysis found that its anti-inflammatory properties are similar to a typical medicine (aspirin). These findings support the traditional medicinal use of *A. indica* Schott for pain and inflammation control (Rahman et al., 2011).

4.3.3. *Arnica montana L*

Arnica montana L., commonly known as Leopard's bane or Mountain tobacco, belongs to the member of the *Asteraceae* family and is mainly found in the mountainous regions of central and eastern Europe, as well as southern Scandinavia and some former Soviet Union states. It can be harmful if ingested in large quantities (Macêdo et al., 2004; Kriplani et al., 2017). In traditional practices, the flowers, roots, and rhizomes of *A. montana* L. are used to treat various tropical ailments. They are commonly used in treating bruises, backaches, rheumatoid arthritis, sprains, etc. (Gyawali et al., 2022; Schimdt, 2023).

Inflammation is primarily triggered by the NF-κB signaling pathway, which regulates proinflammatory genes such as ALOX5 and PTGS2, responsible for encoding enzymes like 5-lipoxygenase (5-LOX) and cyclooxygenase-2 (COX-2). This process synthesizes eicosanoids like leukotrienes and prostaglandins, leading to early inflammatory symptoms such as redness, swelling (oedema), and pain (Tak and Firestein, 2001). Studies found that whole *Arnica* ethanolic plant extracts have shown superior anti-inflammatory effects compared to ethanolic flower extracts. The plant extracts significantly inhibited NF-κB signaling more effectively and reduced the activity of inflammation-causing enzymes like 5-LOX and COX-2. The mouse oedema model effectively reduced paw oedema, indicating the potential for improved acute inflammation treatment (Röhrl et al., 2023).

In an acute carrageenin-induced rat paw oedema model, *A. montana* L. 6 cH showed 30% inhibition, indicating its potential as an anti-inflammatory agent. Conversely, the chronic model of nystatin-induced oedema reduced inflammation when administered before the inflammatory agent. Furthermore, pre-treatment with *A. montana* L. 6 cH decreased vascular permeability by blocking histamine's action, suggesting a protective effect against histamine-induced reactions (Macêdo et al., 2004). It is also reported that *A. montana* L. (mother tincture and 1C homoeopathic dilution) showed significant anti-inflammatory effects, reducing proinflammatory cytokines (TNFα and IL-6) and adhesion molecules in human (THP-1 and HMC3) and murine (NIH-3T3) cell lines. Furthermore, it showed antioxidant properties by decreasing ROS in the endothelial and microglial cells. Interestingly, the mother tincture hindered the migration, while the 9C dilution enhanced the fibroblast cell migration, possibly aiding wound healing through inhibition of NF-κB signaling pathway (Verre et al., 2024).

4.3.4. *Jatropha spp.*

Jatropha curcas L., also known as Poison nut, is a member of the *Euphorbiaceae* family, widely distributed throughout Asian and African countries and some sub-tropical regions of Central and South America. Though each component of the plant is dangerous, seeds have the most significant proportion of toxalbumin, such as ricin, cyanic acid, and curcin, and are incredibly toxic. The side effects of eating seeds include diarrhoea, vomiting, abdominal pain, and a burning sensation in the throat (Oskoueian et al., 2011; Singh et al., 2010). Traditional folklore medicine uses different plant parts to treat various health conditions. The seeds and fruits treat leprosy, piles, and digestive issues and alleviate vomiting and burning sensation. The leaves and latex are applied to direct wounds to stop bleeding, while the whole plant cures snakebites, scorpion stings, sores, and swelling. Stems and barks are used as anti-parasitic remedies. In Tanzania, the traditional healers use different plant parts to combat fungal infections, and in Europe, it is commonly used to treat malaria (Sabandar et al., 2013).

The anti-inflammatory potential of *J. curcas* L. root powder, traditionally utilized by the Bhil tribes in India, was validated in TPA-induced ear inflammation in Swiss albino mice. The methanolic extract of *J. curcas* L. exhibited a significant reduction in acute carrageenan-induced rat paw oedema, formalin-induced oedema, and turpentine oil-induced granuloma in rats, and these potential effects might be due to the inhibition of prostaglandin biosynthesis and other mediators involved in inflammation (Mujumdar and Misar, 2004).

However, methanolic extract at a concentration of 0.1 μg/mL is non-toxic to the primary cultures of glial cells that are derived from the cerebral cortex of neonate Wistar rats. It showed the inhibition of morphological changes and expression of ionized calcium-binding adaptor molecule 1 (Iba1), glial fibrillary acidic protein (GFAP) and the upregulation of transcription factor NF-kB induced by lipopolysaccharide (LPS) of *Escherichia coli* (Muniz Santana Bastos et al., 2021). Studies have also reported that the hexane fraction of the root extract elevated anti-inflammatory activity in the RAW 264.7 cell line, with GC-MS analysis revealing the presence of octadecanoic acid (Fig. 4 xxiii), octadecanoic acid methyl ester (Fig. 4 xxiv), and hexadecenoic acid methyl ester (Fig. 4 xxv) (Othman et al., 2015). Similarly, investigations of the essential oil from *J. curcas* L. leaves demonstrated notable anti-inflammatory effects in Wistar rats, with a steady increase in inhibition over 4 h when tested with egg albumin. Compounds such as phytol (Fig. 4 xxvi) and neophytadiene (Fig. 4 xxvii) identified through GC-MS analysis are believed to contribute to its anti-inflammatory potential (Adeosun et al., 2017).

Another study formulated a herbal gel with a hydroethanolic extract from *Jatropha mollissima* (Pohl) Baill. (Jm) leaves, demonstrated significant efficacy in reducing inflammation in Swiss albino mice (Passos et al., 2024). This gel effectively inhibited paw and ear oedema induced by carrageenan. It exhibited notable wound-healing properties and effectively inhibited activities induced by *Bothrops jaracaca* snake venom, including edematogenic, hemorrhagic, and dermonecrotic effects. Furthermore, when combined with commercial snake antivenom, the herbal gel enhanced the antivenom's effectiveness in mitigating

venom-induced oedema (Passos et al., 2024). The plausible anti-inflammatory mechanism of poisonous plant-derived phytochemicals is depicted in Fig. 9.

4.4. Poisonous plants or their phytochemicals showing cardioprotective activity

4.4.1. Nerium oleander L

Nerium oleander L. (NO), often known as oleander or rosebay, is a shrub or small tree grown as an ornamental and aesthetic plant worldwide in tropical and subtropical regions. This plant is exceedingly dangerous, and consumption of its leaf may kill an adult (Zhai et al., 2022). *N. oleander* L. has been traditionally used worldwide for its various medicinal properties. Leaves of the plant have been used to treat cardiac disease, high blood pressure, cancer, diabetes, skin infection, gastrointestinal problems, reproductive health, wound healing, inflammatory infections, swelling, paralysis, acute pains, and the common cold. In Ayurveda, oleander leaves are particularly valued for treating fever, leprosy, wounds, and swelling, while the stem and bark are used to alleviate ear pain. (Sharma et al., 2023).

The cardioprotective effects of NO distillate in male Wistar albino rats revealed an increase in the expression of MnSOD and CAT, indicating the involvement of hypoxia-inducible factor 2A (HIF2A) mRNA in oxidative stress defense by modulating these antioxidant enzymes. The increased expression of HIF2A mRNA, alongside changes in MnSOD and CAT mRNA levels, supported NO distillate's potential cardioprotection via the oxidative stress pathway (Hitit et al., 2018).

Additionally, the effect of the hydroethanolic extract of NO flower in Wistar rats examined its efficacy against isoproterenol-induced myocardial toxicity and compared its impact to propranolol, the standard. Pretreatment with both NO extract and propranolol before isoproterenol administration prevented the increase in marker enzymes, suggesting its potential cardioprotective activity (Gayathri et al., 2011; Shah et al., 2019).

4.4.2. Citrullus colocynthis L

Citrullus colocynthis, commonly known as Colocynth or Bitter apple, is a member of *Cucurbitaceae* family and is widely distributed in Southern Asia, such as India, Pakistan, Sudan, and some parts of the Sahara and Arabian deserts (Cheng et al., 2023). *C. colocynthis* (L.) has been used traditionally worldwide to treat a range of conditions, including asthma, constipation, diabetes, leprosy, jaundice, bronchitis, joint pain, and cancer (Mughal et al., 2020). Countries like India, China, Africa, Asia, and Pakistan use this plant to treat gut disorders such as cough, cold, diabetes, toothache, and wounds (Hussain et al., 2014).

The ethyl acetate fraction (EAF) from *C. colocynthis* (L.) led to a notable reduction in mean arterial pressure (MAP), systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse pressure (PP) in a spontaneous hypertensive rat (SHR) model. These results are likely attributed to dietary polyphenols, which have alleviated hypertension by enhancing nitric oxide production and modulating vascular smooth muscle contractility, thereby enhancing cardiovascular health through decreased blood pressure (Iftikhar et al., 2023).

Another study investigated the hydroalcoholic peel extract from *C. colocynthis* (L.) on adrenaline-induced myocardial ischemia in male rabbits, which exhibited a reduction in cardiac biomarkers compared to the adrenaline group when administered 100, 200, and 300 mg/kg. The extract also correlated with reduced necrosis and disintegration of cardiac tissues, suggesting its potential as a therapeutic intervention for cardiovascular disorders (Li et al., 2022).

4.5. Poisonous plants or their phytochemicals as antimicrobial agents

The process of antibacterial activity is very complex, involving microscopic organisms whose vital functions can be disrupted by various harmful substances. The zone of inhibition (IZ) refers to the region where bacteria are unable to proliferate due to the presence of a substance impeding their growth, and the minimum inhibitory concentration (MIC) represents the lowest medication dose at which

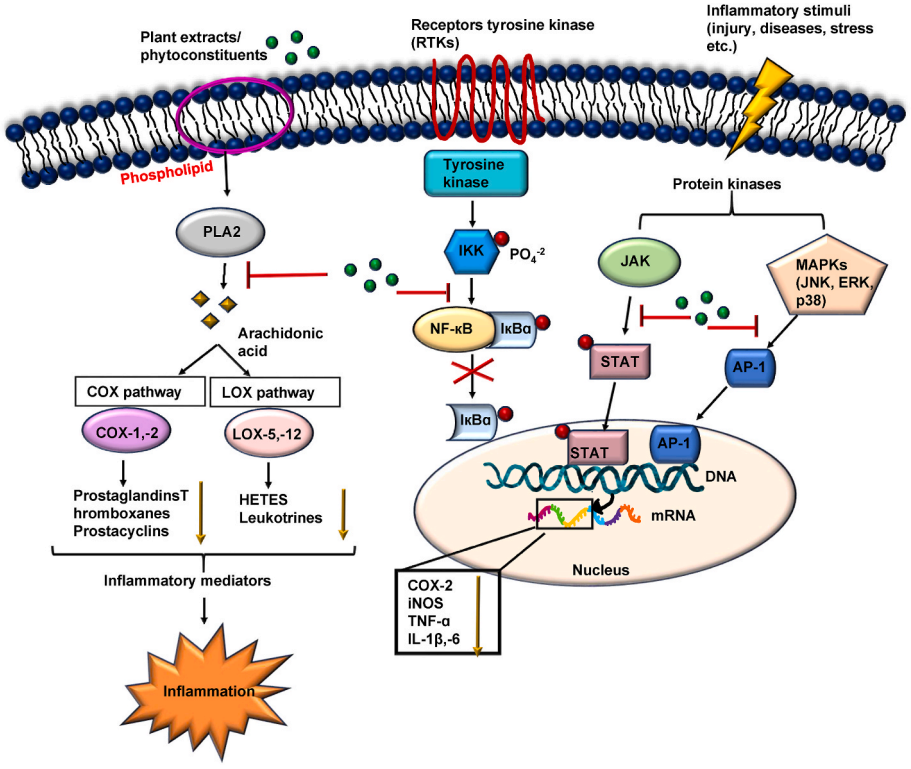

Fig. 9. The most plausible mechanism of action of anti-inflammatory agents has been associated with inhibiting various signaling pathways involved during inflammation. The hypothesized mechanisms are based on the literature survey. Created with Microsoft PowerPoint 365.

bacterial growth halts after overnight incubation (Islam et al., 2023).

4.5.1. Croton spp.

This poisonous plant is known to induce contact dermatitis and blistering. Upon oral ingestion of this plant, the patient exhibits diarrhoea, vomiting, and abdominal cramps. A study reported a 50 kDa protein called *Croton tiglium*-50 (Ct-50), successfully isolated from *C. tiglium* L., showed potent antimicrobial activity against, both fungal (*Aspergillus niger* and *Mucor mucedo*) and bacterial (*Bacillus subtilis* and *Pasteurella multocida*) strains (Shahid et al., 2008).

It is reported that the n-hexane fraction of *C. macrostachyus* Hochst. Ex Delile seeds were used to obtain a maximum oil yield of 45.89% under specific reaction conditions (reaction temperature of 70 °C, particle size of 0.5 mm, reaction time of 5 h, and solute-to-solvent ratio of 0.6 g/mL). The oil of *C. macrostachyus* Hochst. Ex Delile seeds exhibited antimicrobial activity against *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *A. niger*, and *Candida albicans*, with MIC ranging from 31.25 to 500 mg/mL (Bayisa and Bullo, 2021).

4.5.2. Datura spp.

Datura, commonly known as Dhatura or Thorn apple, belongs to the *Solanaceae* family, and it is toxic as it contains tropane alkaloids. Therefore, this plant is avoided. However, this plant is used in several traditional medicines (Sharma et al., 2021). The Drug and Cosmetic Act 1940 & Rule 1995 of India banned the use of *D. metel* L. except for its use in Ayurvedic medicine. Since ancient times, different species of *Datura* have been used traditionally for their medicinal properties, such as epilepsy, skin ailments, fever, heart issues, and diarrhoea, with the leaves offering pain relief. In China and Vietnam, *Datura* is used for asthma, while in India, *D. metel* L. is used for psychological disorders, brain conditions, catarrhal infections, skin diseases, elephantiasis, and digestive problems. Chinese Traditional Medicine also employs it for psoriasis and skin inflammation (Islam et al., 2023; Soni et al., 2012).

The ethanolic and aqueous extracts from both flowers and leaves of *D. metel* L. exhibited quorum-sensing activity against *Chromobacterium violaceum* and *Agrobacterium tumefaciens*, while also displaying antimicrobial effects, suggesting the involvement of additional inhibition mechanisms (Adonizio et al., 2006). Similarly, the chloroform fraction of *D. metel* L. leaf extract effectively suppressed the growth of *Rhizoctonia solani*. This detrimental pathogen causes damping-off disease in tomatoes by 21% to 27%. GC-MS analysis revealed the presence of phytochemicals, including pentadecanoic acid (Fig. 4 xxviii), eugenol (Fig. 4 xxix), phytol, heptacosane (Fig. 4 xxx), 2-pentadecanone 6,10,14 trimethyl (Fig. 4 xxxi) tetradecanoic acid (Fig. 4 xxxii), and dodecanoic acids (Fig. 4 xxxii) (Hanif et al., 2022).

Another study investigated the methanolic extracts of *D. fastuosa* L., which was found to inhibit effectively the pathogenic bacteria viz. *E. coli*, *S. aureus*, *B. subtilis*, *C. albicans,* and *A. niger* (Ibrahim et al., 2018). Additionally, the methanolic leaf extract of *D. stramonium* exhibited significant antimicrobial activity against *E. coli* (IZ = 19.8 mm), *Pseudomonas aeruginosa* (IZ = 22.2 mm), *S. aureus* (IZ = 18.2 mm), *A. niger* (IZ = 12.1 mm), and *Aspergillus flavus* (IZ = 12.8 mm) (Sharma and Sharma, 2013).

4.5.3. Anamirta cocculus (L.) Wight & Arn

Anamirta cocculus (L.) Wight & Arn. is commonly known as Crow killer, belonging to *Menespermaceae* family and native to Southeast Asian countries, including India, and its fruits possess a poisonous compound known as picrotoxin. However, this plant has been used for its medicinal properties (Agarwal et al., 1999). *A. cocculus* (L.) Wight & Arn. has been used by many traditional healers throughout Asia. Its seeds are used in treating different types of cancer. They are widely used as a natural remedy for conditions like scald-head itch, barber's itch, and skin diseases caused by microbial infections, indicating its potential anti-microbial properties (Jijith et al., 2016). The methanolic extract of the seeds of *A. cocullus* (L.) Wight & Arn. exhibited significant levels of antibacterial activity against pathogenic bacteria such as *S. aureus*, *E. coli*, *Salmonella typhi*, *Proteus vulgaris*, and *Klebsiella pneumoniae*, with the lowest MIC observed against E. coli at 3 μg/mL (Qadir et al., 2015).

4.5.4. Jatropha curcas L

Jatropha is a poisonous plant and contains several toxic compounds. Notably, due to a high concentration of a toxic phytochemical called ricin, the seeds are the most poisonous part of this plant. *J. curcas* L. seeds contain toxic lectin dimers and carcinogenic phorbol esters, and consumption of seeds causes diarrhoea and vomiting in patients (Shah and Sanmukhani, 2010). However, the crude ethyl acetate of *Jatropha curcas* L. exhibited pronounced efficacy against Gram-positive bacteria (*Bacillus algicola*, *Bacillus cereus*, *Listeria innocua*, *S. aureus*, *S. epidermis*, and *Viridibacillus arenosi*). In contrast, the ethyl acetate and methanol extracts were effective against Gram-negative bacteria (*Klebsiella oxytoca*, *Proteus mirabilis*, *P. aeruginosa*, and *S. typhi*), demonstrating their antimicrobial properties against various microorganisms (Rampadarath et al., 2016).

Furthermore, the 20% ethanolic stem extract of *J. curcas* L. showed significant antibacterial activity (IZ = 40 mm) against *K. pneumoniae,* and water extract of the root was effective against *E. coli* (IZ = 35.25 mm) (Rahu et al., 2021). Another study focused on the aqueous and diluted acetone extracts of *Citrullus colocynthis* (L.), where all the extracts showed antibacterial activity against Gram-negative, Gram--positive bacteria and various *Candida* spp, with the highest activity observed in fruit aqueous extracts of MIC 0.10 mg/mL against *C. glabrata* and *C. albicans* and 0.20 mg/mL against *P. aeruginosa* and *E. coli* (Marzouk et al., 2009).

4.6. Poisonous plants and their phytochemicals used in antimalarial activity

Malaria has been one of the most important vector-borne diseases since immemorial, transmitted to humans by certain mosquitoes. The *Nerium* plant species is exceedingly toxic; even a single leaf may harm an adult. The study investigated the larvicidal potential of ethanolic and acetone extracts of *Nerium indicum* Mill. and found that the ethanolic extract was more effective against *Anopheles* mosquito larvae than the acetone extract, with LC_{50} values of 185.99 ppm and 148.05 ppm after 24 and 48 h, respectively. For culicine larvae, the acetone extract was more effective (Sharma et al., 2005; Dey and Chaudhuri, 2014). The benzene extract of flowers and the chloroform extract of leaves of *N. oleander* L. showed the most notable mortality rate on *Anopheles stephensi* mosquito larvae (Fakoorziba et al., 2015).

Another study explored the larvicidal activity of *Thevetia peruviana* (Pers.) K.Schum leaf extracts against *A. stephensi* and *Aedes aegypti* larvae, vectors of malaria and dengue. Among the extracts tested, acetone extract was the most effective, with LC_{50} values of 234 μg/mL for *A.stephensi* and 197.1 μg/mL for *Aedes aegypti*, further offers an environmentally friendly alternative to synthetic insecticides (Yadav et al., 2013).

The pentane extract of *Abrus precatorius* L. against FcM29-Cameroon strain (known for its resistance to chloroquine) and a Nigerian chloroquine-sensitive strain of *Plasmodium falciparum* demonstrated IC_{50} value below 20 μg/mL, suggesting its anti-malarial effects (Bagavan et al., 2011).

4.7. Use of poisonous plants in traditional medicines

In contemporary society, the adoption of homoeopathy as an alternative healthcare option has surged significantly. Homeopathy harnesses the healing potential of diverse medicinal plants, including those with toxic properties, to address a range of mental and physical ailments (Nekratova and Kosmodemyanskiy, 2019). Some poisonous plants, such as *Strychnos nux-vomica* L., *Strychnos ignatii* P.J.Bergius, *Atropa belladonna* L., *Aconitum napellus* L., *Arnica montana* L., etc., have been used

tremendously for various therapeutic advantages.

4.7.1. Nux vomica

Strychnos nux-vomica L. extract, though it is highly poisonous, yet has diverse therapeutic and clinical applications in the AYUSH (Ayurveda, Unani, Naturopathy, Siddha, and Homeopathy), Indian and Chinese medicines. The phytochemicals of *N. vomica* are alkaloids, flavonoids, tannins, saponins, and glycosides. In homeopathy, it is mainly helpful in the treatment of erectile dysfunction, gastrointestinal distress, alcoholism, anger issues, tobacco habits, dyspepsia, hemorrhoids, insomnia, constipation, and many more diseases (Rehman, 2021; Downs et al., 2021).

N. vomica's dried, processed seeds have been utilized in Ayurveda and traditional Asian medicine for treating various diseases, such as constipation, gastritis, arthritis, musculoskeletal disorders, influenza, heart diseases, and cancer (Mitra et al., 2011). For instance, studies investigated detoxification methods for nux-vomica seeds, including using aloe and ginger juices, frying them in cow ghee, and boiling them in cow milk. All methods reduced motor activity and inhibited morphine-induced catalepsy (Fig. 1 xxiv). Milk-processed seeds showed least strychnine, strong convulsion suppression, potent hypnosis enhancement, safest LD_{50}, and improved pharmacological effects (Katiyar et al., 2010).

Studies have assessed the impact of homoeopathic *N. vomica* L. on sleep quality using polysomnography (PSG), revealing a significant increase in total sleep time (TST) and non-rapid eye movement (NREM) sleep, with notable changes in awakenings and sleep stage transitions. Further investigations on Electroencephalographic (EEG) studies were conducted to differentiate fibromyalgia responders treated with *N. Vomica* L., and actigraphy's role in assessing sleep and sleep disorders was also underscored (Bell et al., 2011). Strychnine (Fig. 4 xxxiv) and brucine (Fig. 4 xxxv) are two indole-alkaloids derived from *N. Vomica* L. that are utilized in lower doses for treating stomach ailments and regulating high blood pressure and other mild cardiac conditions, respectively (Rathi et al., 2008).

An alkaloid, namely brucine, derived from *N. vomica* L., revealed that it could inhibit the SMMC-7721 and HepG2 hepatocellular carcinoma (HCC) cell migration and inhibit Hypoxia-inducible factor 1 (HIF-1)-dependent luciferase activity in HepG2 cells and attenuated target genes such as fibronectin, lysyl oxidase, matrix metallopeptidase 2, and cathepsin D that are linked to hmetastasis. Moreover, brucine reduced H22 ascitic hepatoma cells with minimal toxicity at 15 mg/kg, correlating with downregulated HIF-1 responsive genes (Shu et al., 2013).

Another study explored the reduced effects of strychnine content in the total alkaloid fraction (TAF) from *N. vomica* L. seeds. The modified TAF (MTAF), with a brucine-to-strychnine ratio of 2.7:1, exhibited significant analgesic effects in chemical-, physical-, and thermal-induced nociception models. MTAF also showed anti-inflammatory effects against xylene-induced ear oedema and enhanced brucine absorption, enhancing therapeutic potential (Chen et al., 2012).

4.7.2. Strychnos ignatii P.J.Bergius

Strychnos ignatii P.J.Bergius is a tree of the *Loganiaceae* family and native to the Philippines. In 1818, Pelletier and Caventou identified the deadly alkaloid strychnine (Fig. 5) from *S. ignatii* P.J.Bergius beans. The dried blooms of the seeds contain about 1.5% and 1% strychnine, respectively. Some evidence proved the efficacy of homoeopathic *Ignatia amara,* a remedy derived from *S. ignatii* P.J.Bergius, in alleviating emotional disturbances such as depression, anxiety, and gastrointestinal symptoms (Dombrowski et al., 2018).

4.7.3. Mixture of poisonous plants

Canova, a homoeopathic blend, composed of the extracts of 19X *Thuja occidentals* L., 19X *Arsenicum album*, 11X *Aconitum napellus* L., 18X *Bryonia alba* L., and 18X *Lachesis muta* (Viperidae) venom in equal proportions diluted in 70% alcohol, is suggested to boosts immunity by stimulating macrophages. *Traumeel S*, another remedy, contains *Arnica montana* L. and various plant extracts (*C. officinalis*, *A. belladonna, A. napellum*, *A. millefolium*, *H. sulfuris*, *B. perennis*, etc.) contain low potencies (4X to 12X), commonly used to relieve trauma, inflammation, and degenerative conditions in humans (Bellavite et al., 2006).

4.8. Prospectives and challenges of using poisonous plants and their phytochemicals as therapeutic agents

In recent decades, the tremendous need for poisonous medicinal plants in pharmaceutical industries and research sectors has resulted in the overexploitation of their natural habitat, increasing the likelihood of extinction. Consequently, it is imperative to foster their conservation to acquire additional information regarding these plants and their phytochemicals for drug development, which can be accomplished by encouraging farmers to cultivate them. This approach would strengthen local economies by fostering sustainable agricultural practices, generating income, and creating employment opportunities in the regions where these plants are naturally abundant.

Nevertheless, the cultivation and commercialization of these poisonous plants are challenging due to the necessity of procuring licenses, which necessitates the development of comprehensive cultivation plans that address issues such as waste management and harvesting methods to reduce potential toxicity risks. Therefore, it is necessary to address specific regulatory considerations based on safety concerns. These considerations frequently involve government regulatory bodies and agencies that oversee aspects such as agriculture, environmental protection, food safety, and pharmaceuticals, such as the U.S. Department of Agriculture (USDA), National Institutes of Health (NIH), and the Environmental Protection Agency (EPA). Grants and investments are provided by these regulatory bodies and a few other public and private partnerships to support these initiatives. These organizations and authorities may work together to mitigate the risks of poisonous plants globally while simultaneously advocating for their safe and sustainable utilization.

Public perception and education may also present challenges when cultivating poisonous plants. Communities may inherently harbour apprehensions regarding environmental consequences and safety. Consequently, trust and comprehension can be cultivated through transparent communication regarding the cultivation of these plants, the safety protocols in place, and the objectives behind their cultivation. This transparency mitigates potential concerns and guarantees that all parties are apprised of the implemented procedures. Additionally, addressing these challenges ensures the safety of cultivators and encourages responsible management practices that protect the environment and human health.

5. Conclusion

Poisonous plants has an extensive human history, fulfilling functions that span from instruments of justice and warfare to significant elements of traditional medicine and cultural ceremonies. Their ethnopharmacological importance is in the intricate equilibrium between the toxic and non-toxic properties of these plants. In modern research, apart from therapeutic approach, poisonous plants are also utilized as a part of a sustainable approach towards the societal development, particularly enhancing the agricultural systems globally. Further, this research highlights the dual nature of toxic metabolites from harmful plants, stressing their toxicological profiles to clarify the chemical characteristics of the poison, so facilitating a comprehensive understanding of the many effects of these plants. The review provides a comprehensive scientific elucidation of the mechanisms by which these plant toxins inflict damage, while examining the delivery system (Fig. 6) that can be effectively harnessed for therapeutic applications.

Moreover, the medicinal potential of phytochemicals obtained from poisonous plants has been a promising avenue for modern medicine.

Despite their toxicity in their natural state, these compounds may be isolated, modified, and utilized in controlled dosages to benefit human health. From cancer treatment to pain management and beyond, these phytochemicals have many potential applications, supported by rising scientific evidence and pre-clinical investigations, and some of which are discussed in this paper. However, the journey from plant to pharmaceutical consideration is challenging. Therefore, managing toxicity remains a primary concern, requiring exact dosage calculations, thorough investigations, and careful assessment of any possible adverse effects.

Further research efforts should focus on optimizing extraction techniques, elucidating specific mechanisms of action, and carrying out meticulous clinical studies to completely harness their therapeutic possibilities while ensuring patient safety and well-being. Integrating these natural compounds into conventional medicine is essential to developing more comprehensive and holistic treatments for various diseases.

Finally, as previously mentioned, it is imperative to implement various commercial and cultivation strategies to guarantee the sustainable production and utilization of specific poisonous medicinal plants, thereby facilitating ongoing research in the years ahead.

CRediT authorship contribution statement

Bhagya Lakhmi Rajbongshi: Writing – original draft, Methodology, Formal analysis. **Ashis K. Mukherjee:** Writing – review & editing, Supervision, Project administration, Conceptualization.

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Data availability statement

Data derived from public domain resources.

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