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A Systematic Review on Molluscicidal Activity of Plants Worldwide Against Intermediate Snail Host of Schistosomes

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ABSTRACT

Objective: Schistosomiasis affects more than 230 million people worldwide each year. Aquatic snails, which serve as the intermediate hosts, play a key role in transmitting the disease. The present systematic review compiles data on the molluscicidal activity of plants and their phytochemicals to help minimize the incidence of schistosomiasis.
Methodology: Online databases such as Google Scholar, PubMed, and ScienceDirect were searched for articles published between 2000 and 2022. In total, 290 articles were identified, of which 193 were included; studies involving snail species not associated with schistosomiasis were excluded. Data such as snail species, plant species and family name, plant parts used, assessment type, and phytoconstituents were analyzed.
Results: This review identified 279 plant species with molluscicidal activity, most belonging to the families Euphorbiaceae (9.31%), Solanaceae (7.16%), Asteraceae (6.09%), Leguminosae (5.73%), and Lamiaceae (4.3%). The most frequently used plant parts were leaves (48.74%), followed by seeds (12.9%), fruits (15.05%), roots (14.69%), stems (12.54%), and bark (10%).
Conclusion: Moreover, the review highlights the major plant phytochemicals and mechanisms of molluscicidal activity. Plants and their phytochemicals are promising resources for controlling snail species associated with schistosomiasis. Future studies should focus on identifying and isolating active phytochemicals and clarifying their mechanisms of molluscicidal action. **Keywords:** Schistosomiasis Control, Phytochemicals, Molluscicidal Plants, Biomphalaria, Oncomelania, Intermediate Host

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Introduction

Schistosomiasis, commonly known as snail fever, is caused by trematodes belonging to the genus Schistosoma [1]. The main Schistosoma species that cause schistosomiasis include S. japonicum, S. mansoni, S. haematobium, S. mekongi, and S. intercalatum [2]. Chistosomiasis is a parasitic disease caused by Schistosoma worms, with clinical manifestations varying depending on the species, immune response, and infection duration. Symptoms include fever, fatigue, eosinophilia, abdominal pain, rashes, cough, respiratory issues, muscle and joint pain, nausea, vomiting, and gastrointestinal disturbances. Chronic symptoms include hepatosplenomegaly, intestinal complications, urinary symptoms, neurological symptoms, immunoreconstitution inflammatory syndrome, and cognitive impairments. Understanding these symptoms can aid in early detection and management, reducing the burden of schistosomiasis on affected individuals and communities [3].

Globally, over 230 million people are infected, with Africa accounting for 95% of cases, highlighting significant regional disparities in disease burden[4]. The regional breakdown of the numbers shows that Africa has the highest prevalence due to a combination of environmental and socioeconomic factors that favour parasite survival. In Uganda, [5] even after treatment, individuals in high-endemic areas continue to become infected. Schistosomiasis in Asia varies by region, but rural populations in China show a high prevalence [6].

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The life cycle of schistosomes is completed in two hosts. Snails, mainly freshwater snails, serve as an intermediate host in which schistosomes undergo asexual reproduction, including the development of miracidia and formation of cercariae (a tailed structure), which upon contact with human skin enter the tissue and develop into adults [1]. The snail species acting as an intermediate host of schistosomes [7] mainly belong to the genera Biomphalaria, Bulinus and Oncomelania (Gastropoda: Pulmonata: Planorbidae) [8,9].

Biomphalaria glabrata, host of S. mansoni, is widely found in Africa and South America and sustains transmission in both urban and rural settings. In East and Southeast Asia, Oncomelania hupensis is closely linked with S. japonicum, particularly in rice paddies where irrigation practices increase exposure risks. Bulinus truncatus, the main host of S. haematobium, thrives in freshwater habitats across the Middle East and North Africa, playing a central role in urinary schistosomiasis. In contrast, Austropeplea species have a more restricted distribution in Sub-Saharan Africa and mainly facilitate livestock-associated S. bovis infections. Together, these host–parasite associations underline the ecological diversity of transmission and can help novice readers appreciate regional variations in schistosomiasis epidemiology [10].

In different regions of the world, various control strategies are used to prevent the transmission and outbreak of schistosomiasis [11] and eliminate the disease by disrupting the life cycle of snail species (intermediate host) [12]. Egypt was the first country to control schistosomiasis by using chemical agents against the schistosome-transmitting snail species [13]. The chemicals commonly used as molluscicides include pyrethroids, carbamates, metaldehyde, organophosphates, and niclosamide [14]. Metaldehyde is a widely used, stable molluscicide belonging to the aldehyde group; its application causes snails to secrete an excessive amount of mucus from the body, leading to dehydration and death [15]. Niclosamide is another preferred synthetic molluscicide that restricts the transmission of schistosomes by killing snails or making them inactive [16]. However, these synthetic molluscicides cause environmental pollution.

Recently, the focus has shifted from synthetic molluscicides to plant-based molluscicides because they are economical, easily degradable in the environment and less likely to produce resistance in snails [17]. Phytolacca dedecandra (family Phytolaccaceae) is the first plant reported to exhibit molluscicidal activity [18], but its use is now restricted owing to its toxicity to non-target species [11].

An ideal molluscicidal plant must have certain key characteristics. For example, the plant extract should be toxic at extremely low concentrations and non-toxic to non-target species and it needs to remain viable after a period of storage. It is also preferred that the plant species is endemic. Another characteristic of an ideal plant-based molluscicide is that it has a stable structure against environmental fluctuations [19].

This review aims to present worldwide data on plants and their phytochemicals that exhibit molluscicidal activity against intermediate host snail species of schistosomes.

Materials and Methods

Studies regarding the molluscicidal activity of plants against the intermediate host of schistosomes were identified and screened on the basis of certain inclusion and exclusion criteria described later here (Fig 2). Articles were searched using online databases such as Google Scholar, PubMed, and ScienceDirect using keywords such as "plant molluscicide," "phytolacca, natural products against schistosome snail hosts.phytochemicals," "molluscicidal activity of plants," "snail sp. causing schistosomiasis" and "plant extracts against snail species." Only articles available as full texts (n = 290) were downloaded and further screened; of these, duplicates (n = 6), irrelevant studies (n = 4), and studies that did not mention snail species associated with the transmission of schistosomiasis (n = 83) were excluded. The remaining 193 articles were included in this review. Subsequently, data were extracted from 173 articles (Table 1), including information on plant species and family, plant parts used, screened phytochemicals, and their efficacy against snail species.

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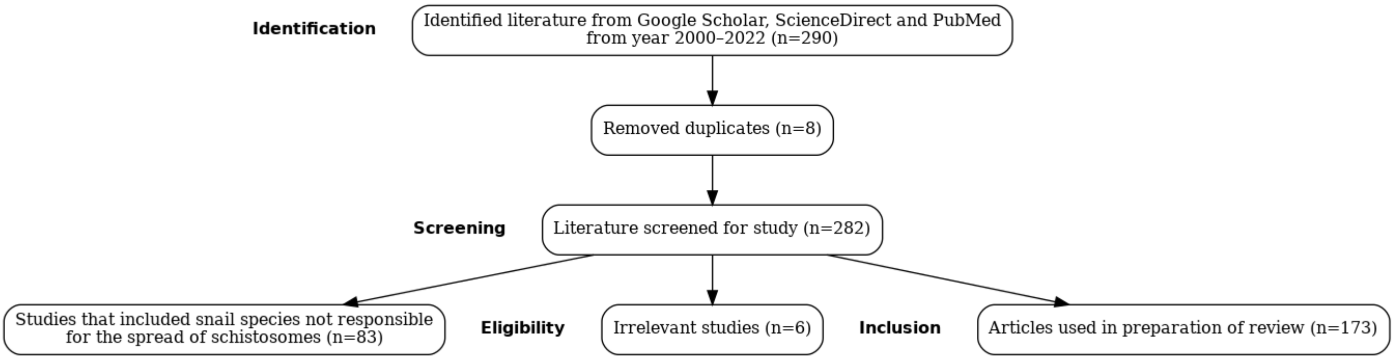

Figure 1: Study design for the review process.

Results

A total of 193 articles were found eligible to be included in the review, and data from 173 articles related to plant molluscicidal activity against schistosome-transmitting snails were extracted (Table 1).

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Table 1: List of plants exhibiting molluscicidal activity against snail species that acts as intermediate hosts of schistosomes (data extracted from articles published between 2000 and 2022)

Snail species	Country	Plant species	Plant Family	Part used	Extraction method	Phytoconstituent	Assessment type	Lethal concentration	Findings	Ref.
Biomophalaria alexandrina	Egypt	Moringa oleifera	Moringaceae	Seed	Cerium oxide nano-composite	-----------	In-vitro	LC50= 314.5 mg/L, LC90= 386.5 mg/L	Reduced reproductive rate, significant disappearance of cilia and structural deformation in tubular glands	[20]
	Egypt	Colchicum ritchii	Colchicaceae	Flower	Methanolic extract	Tannins, flavonoids, saponins, terpenoids, steroids, anthraquinones and alkaloids	In-vitro, In-vivo	LC50 = 35.1 mg/L	Significant increase in micronuclei and 55 % miracidia mortality rate	[21]
	Egypt	Ziziphus spina-christi	Rhamnaceae	Seed	Methanolic extract	Tannins, saponins, alkaloids, flavonoids, phenols and glycosides	In-vitro	LC50 = 108 mg/L	Reduced catalase activity, Increased total antioxidant activity and caused mortality in Daphnia magna	[22]

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	Egypt	Carica papaya	Caricaceae	Seed	Methanolic extract	Tannin and saponin	In-vitro	LC50= 138.5 mg/L	Increased catalase activity, Slight increase in total antioxidant activity and caused mortality in Daphnia magna	
	Egypt	Origanum majorana	Lamiaceae	Leaves	Aqueous extract	Zingiberene, nerolidol, cubenol, eudesmenol, cedren, butanone, capsaicin, gingerol, stigmasterol and nonivamide	In-vitro	LC50= 42 mg/ml	Swelling of a cephalopodal mass and hemorrhagic blisters on the foot sole	[23]
	Egypt	Ziziphus spina-christi	Rhamnaceae	Leaves	Aqueous extract	Cyclooctasiloxane, hydrochinon, morphinan, tricycloundecan, spathulenol, imidazole, megastigmatrieno	In-vitro	LC50= 43 mg/ml	Reduced miracidial activity and 100 % cercarial activity at 6.25 mg/ml	[23][22][22][22][22][22][22][22]

						ne, guanosine, desulphosinigrin, phenanthrenemethanol and thienopyridine				
	Egypt	Salvia fruticosa	Lamiaceae	Leaves	Aqueous extract	Quinolinol, tetrasiloxane, androstadienol, purinol, spirosten, tetradecanoic acid, benzene methanol and cystathionineand terphenyl	In-vitro	LC50= 69 mg/ml	Less effective against miracidial activity and 100 % cercarial activity at 100 mg/ml	
	Egypt	Ziziphus spina christi	Rhamnaceae	Leaves	Ethanolic extract	-----------	In-vitro	LC50=	Increased apoptosis and condensed zygotene	[24]

								108.7 mg/l		
	Egypt	Moringa oleifera	Moringaceae	Leaves	Ethanolic extract	-----------	In-vitro	LC50= 209.4 mg/l	Increased apoptosis and condensed zygotene	
	Egypt	Tecoma stans	Bignoniaceae	Leaves	Ethanolic extract	-----------	In-vitro	LC50= 256 mg/l	Increased apoptosis and condensed zygotene	
	Egypt	Carica papaya	Caricaceae	Leaves	Methanol, ethanol and butanol extract	------------	In-vitro	LC50 (mg/L) against cercariae For methanol= 2; For ethanol= 20 and for butanol= 4	65-86 % mortality rate	[25]
	Egypt	Anagalis arvensis	Primulaceae	Whole plant	Ethanolic extract	-------------	In-vitro	LC50= 1.76 ppm ; LC90= 3.16 ppm	Reduction in protein content, denatured hermaphrodite gland, decreased amount of connective tissues and 100 % mortality rate in case of LC90 after 4 hr	[26]
	Egypt	Anagallis arvensis	Agavacae	Whole plant	Methanolic extract	--------------	In-vitro	LC50= 45 ppm LC90= 60 ppm	Extensive vacuolation in cells of digestive system and 100 % mortality at 70 ppm	[27]
	Egypt	Viburnum tinus	Caprifoliaceae	Whole plant	Methanolic extract	--------------	In-vitro	LC50= 38 ppm	90 % mortality at 60 ppm, deformed gonadal cells, reduced	

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								LC90= 59 ppm	number of sperms and degenerated cercariae	
	Egypt	Anagallis arvensis	Primulaceae	Leaves	Aqeous extract	------------	In-vitro	LC50= 37.9 mg/l LC90= 48.3 mg/l	Decreased reproductive rate, deformation in hermaphrodite gland cells and loss of connective tissues in gonadal cells	[28]
	Egypt	Albizia anthelmintica	Leguminosae	Leaves	--------	Saponin	In-vitro	LC50 = 17.6 ppm LC90 = 25.3 ppm	Decrease in granulocytes and hyalinocytes while increased amoebocytes	[29]
	Egypt	Callistemon citrinus	Myrtaceae	Leaves	Methanol extract	------------	In-vitro	LC90= 37.8 ppm	Loss of hyaline substance, loss of connective tissues and formation of vacuoles	[30]
	Egypt	Callistemon citrinus	Myrtaceae	Leaves	Methanolic extract	------------	In-vitro	LC50= 22.3 ppm LC90 = 37.8 ppm	54.2 % reduction in reproductive rate, crumpling of young oocytes and 56% reduction of testosterone	[31]
	Egypt	Zingiber officinale	Zingiberaceae	Root	Methanolic extract	------------	In-vitro	LC50= 43.8 ppm LC90 = 74.9 ppm	60 % reduction in reproductive rate, atrophy of nuclei and degeneration of necrotic cells	

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	Egypt	Asparagus densiflorus	Asparagaeae	Leaves	Aqeous extract	------------	In-vivo	LC50 = 75 ppm LC90 = 102 ppm	Caused atrophy in gonadal cells, reduced reproductive rate and 100% mortality	[32]
	Egypt	Oreopanax guatemalensis	Araliaceae	Leaves	Aqeous extract	------------	In-vivo	LC50 = 160 ppm LC90 = 188 ppm	100 % motality rate at 1000 mg/L within 24 h	
	Egypt	Juniperus horizontalis	Cupressaceae	Aerial parts	Methanolic extract	Thujone, D-limonene, β-myrcene, sabinene and methyl citronellate	In-vitro	LC50 = 38.9 ppm	Proved toxic against snail sp.	[33]
	Egypt	Juniperus communis	Cupressaceae	Aerial parts	Methanolic extract	Sabinene, β-myrcene, D-limonene,	In-vitro	LC50 = 22.9 ppm	Proved toxic against snail sp.	

						thujone and terpinen-4-ol				
	Egypt	Cestrum purpureum	Solanaceae	Whole plant	Methanolic extract	ursolic acid and 3-O-β-D-glucopyranosyl-(1→4)-α-L-rhamnopyranosyl-2 and 19-dihydroxy-epihederagenin-28-O-1-[26-(3-acetyl-4-methox-ycinnamoyloxyhexacosanoyl)] glycerol	In-vivo	LC50= 72 ppm LC90 = 120 ppm	90 % mortality rate after 24h	[34]
	Egypt	Agave angustifolia	Agavaceae	Whole plant	Aqeous suspension	------------	In-vivo, In-vitro	LC90= 120 ppm	Decreased egg laying capacity and survival rate	[35]

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	Egypt	Pittosporum tobira	Pittosporaceae	Whole plant	Aqeous suspension	------------	In-vivo, In-vitro	LC90= 120 ppm	Decrease in cercaricidal mortality by 81% and miracidia by 87 %	
	Egypt	Euphorbia peploides	Euphorbiaceae	Aerial parts	Methanolic extract	Quercetin, luteolin, gallic acid, β-amyrin, P-hydroxybenzoic acid, quercetin-3-O-β-D-glucopyranoside and kampferol-3-O-β-D-glucopyranoside	In-vivo	LC90= 30 ppm	Strong molluscicidal activity	[36]
	Egypt	Callistemon viminalis	Myrtaceae	Leaves, fruit and bark	Methanolic extract	------------	In-vivo	LC50 (ppm): Fruit=6.2, Bark=32, Leaves =40	63.3 % mortality rate due to leaves extract, 66.7% due to bark and 100% due to leaves	[37]
	Egypt	Eucalyptus globulus, Melaleuca styphelioides	Myrtaceae	Leaves	Methanolic extract	Eucalbanin B, tellimagrandin I, pentagall	In-vitro	LC50= 165.6 ppm	25 % reduction in protein content, 100 % cercaricidal mortality, 21 % increase in acid	[38]

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						oyl glucose, casuarinin and 1,2,3,4,6-Penta-O-galloyl-b-D-glucopyranose		LC90= 245.5 ppm	phosphatase and 113 % increase in aspartate aminotransferase	
	Egypt	Citrus limon	Rutaceae	Peel	Aqeous extract	-------------	In-vitro	LC50 =744.17 ppm LC90= 1821.25 ppm	58 % reduction in hatchability rate, necrosis in digestive glands and significant increase in protein content	[39]
	Egypt	Origanum syriacum	Lamiaceae	Seed	Ethanolic extract	-------------	In-vitro	B. alexandrina LC50= 226.8 ppm LC90= 422.9 ppm	Chromosomal aberrations	[40]
	Egypt	Yucca desmettiana	Asparagaceae	Leaves	Methanolic extract	Saponin	In-vivo	LC50 = 68 mg/L LC90 = 96 mg/L	Significant molluscicidal activity	[41]

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	Egypt	Haptophyllum tuberculatum	Rutaceae	Aerial parts	Chloroform and methanolic extracts	Steroids	In-vitro	LC50 = 16 ppm	100 % mortality rate at 25 ppm with excessive mucous production, increased hemolysis and decreased progesterone level	[42]
	Egypt	Datura stramonium	Solanaceae	Leaves	Dry powder	------------	In-vitro	LC50= 25.8 ppm LC90= 40.4 ppm	60 % mortality rate, increased alanine transaminase and alkaline phosphatase in haemolymph	[43]
	Egypt	Sesbania sesban	Leguminosae	Leaves	Dry powder	------------	In-vitro	LC50= 51.0 ppm LC90= 62.4 ppm	80 % mortality rate and decreased total protein content	
	Egypt	Solanum siniacum	Solanaceae	Leaves	Ethanolic, aqueous, methanolic and chloroform extract	------------	In-vitro	LC50 = 14.8 ppm	88 % reduction in reproductive rate, 100 % increase in glucose and 80 % in lactate and significant decrease in glycogen, pyruvate and total protein amount	[44]
	Egypt	Artemisia judaica L	Asteraceae	Leaves	Ethanolic, aqueous, methanolic and chloroform extract	------------	In-vitro	LC50 = 38 ppm	Increase in protease quantity but decreased lactic dehydrogenase and cytochrome oxidase	
	Egypt	Dalbergia sissoo	Leguminosae	Fruits, leaves, root and stem bark	Ethanolic extracts	------------	In-vivo	LC50= 10.8 ppm LC90= 20.4 ppm	Mainly toxic at pre-hatch stage and 100 % mortality rate	[45]

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	Egypt	Furcraea selloa marginata	Agavaceae	Leaves	Aqueous suspension	------------	In-vitro	LC50 =53.66 ppm LC90 =84.35 ppm	30 % mortality rate after 24 hr and 100 % miracidial mortality rate	[46]
	Egypt	Euphorbia milii	Euphorbiaceae	Latex	Aqueous solution	------------	In-vitro	LC50= 19 ppm LC90= 38 ppm	Proved toxic against snail sp.	[47]
	Egypt	Meryta denhamii	Araliaceae	Flower	Methanolic extract	Oleonolic acid-3-O-α-arabinopyranoside, oleonoic acid-3-O-β-glucopyranoside and hedragenin-3-O-α rhamnopyranoside	In-vivo	LC50=85 mg/L	Increased glucose level and decreased glycogen and protein level in tissues	[48]
	Egypt	Guayacum officinalis	Zygophyllaceae	Whole plant	Methanolic, aqeous and ethanolic extract	------------	In-vitro	LC50= 120 ppm LC90= 210 ppm	Decreased acetylcholinesterase and Succinate dehydrogenase	[49]

	Egypt	Atriplex stylosa	Chenopediaceae	Whole plant	Methanolic, aqeous and ethanolic extract	------------	In-vitro	LC50= 94 ppm LC90= 180 ppm	36 % decreased glycogen content and 53 % increased glucose level	
	Egypt	Euphorbia splendens	Euphorbiacae	Whole plant	Methanolic, aqeous and ethanolic extract	-----------	In-vitro	LC50= 40 ppm LC90= 73 ppm	Effectively decreased the number of juveniles and adult	
	Egypt	Citrus reticulata	Rutaceae	Fruit	Peel extract	-----------	In-vivo	LC50= 163.79 ppm	95 % mortality rate	[50]
	Egypt	Euphorbia paralias	Euphorbiaceae	Aerial parts	Methanolic extract	Diterpene (Paralianes, segetanes and jatrophenes)	In-vivo	---------	100 % mortality rate	[51]
	Egypt	Commiphora molmol	Bruseraceae	Stem (Gum resin)	Aqeous solution	Terpenes and eugenol	In-vivo	---------	67 % mortality rate	[52]
	Egypt	Commiphora molmol	Bruseraceae	Whole plant	Oil extract	------------	In-vivo	LD50= 155 ppm LD90= 195 ppm	100 % mortality rate	[53]

	Egypt	Yucca elephantipes	Agavaceae	Leaves	Methanolic extract	saponin	In-vivo	LC90= 4 ppm	Strong molluscicidal activity	[54]
	Egypt	Ambrosia Maritima	Asteraceae	Whole plant	Dry powder	--------------	In-vivo	--------------	95 % decrease number of snails in first month	[55]
	Egypt	Azolla pinnata	Salviniaceae	Whole plant	Dry powder	--------------	In-vivo	--------------	94 % decrease number of snails in first month	
	Egypt	Commiphora molmol	Burseraceae	Whole plant	Oil and resin extract	--------------	In-vivo	LC50= 4 ppm	100 % mortality rate of both snail sp.	[56]
	Saudi Arabia	Rosmarinus officinalis	Lamiaceae	Whole plant	Pet-ether and ethanolic extracts	------------	In-vivo	LC50= 236.81 ppm	85 % mortality rate	[57]
	Italy	Vitex trifola	Verbenaceae	Leaves, stem and seed	chloroform, n-hexane and ethanolic extract	Platanic acid , β-sitosterol, ursolic acid acetate and ursolic acid acetate	In-vivo	LC50= 26.42 mg/l	92 % mortality rate at 32.01 mg/l	[58]
Biomphalaria pfeifferi	Zimbabwe	Cucurbita maxima	Cucurbitaceae	Seed	Aqeous and crude ethanolic extracts	------------	In-vivo	LC50 (mg/ml) for:	100 % mortality rate at 2 mg/mL in both snails	[59]

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								Aqeous extract = 0.002, Ethanolic extract = 0.002		
	Nigeria	Balanites aegyptiaca	Balanitaceae	Leaves and fruit	Aqeous extract	Alkaloids, saponins, flavonoids, tannins, phenols and steroids	In-vitro	--------------	90 % mortality rate at 50 µg/ml	[60]
	Sudan	Combretum glutinosum Perr. ex DC	Combretaceae	leaves	Ethanolic extract	Cumarins, tannins, flavonoids, saponins and triterpenes	In-vivo	LC50 at 24 hr: 117.57 LC90 at 24 hr: 220.84	Possess strong molluscicidal ability	[61]
	Sudan	Hyphaene thebaica (L.) Mart	Arecaceae	Male	Ethanolic extract	Cumarins,	In-vivo	LC50 at 24 hr:	Caused mortality at low concentration	

				Inflorescences		tannins and saponins		158 LC90 at 24 hr: 228		
	Sudan	Indigofera oblongifolia Forssk	Leguminosae	Aerial parts	Ethanolic extract	Cumarins, tannins, saponins, triterpenes and steroids	In-vivo	LC50 at 24 hr: 158.11 LC90 at 24 hr: 228.11	Mortality rate was more than 90 %	
	Sudan	Rhynchosia minima (L.) DC	Leguminosae	Aerial parts	Ethanolic extract	Cumarins, tannins, flavonoids and saponins	In-vivo	LC50 at 24 hr: 158.11 LC90 at 24 hr: 228.11	Caused mortality at low concentration	
	Sudan	Solanum dubium L.	Solanaceae	Fruit	Ethanolic extract	Cumarins, tannins, flavonoids,	In-vivo	LC50 at 24 hr: 153.02 LC90 at 24 hr:	90 % mortality at low concentration	

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						saponins, alkaloids and steroids		226.62		
	Sudan	Pulicaria crispa	Asteraceae	Leaves, stem and root	Powder	------------	In-vivo	LC50(ppm): Leaves= 616.6 Stem=616.6 Root= 645.65 LC90(ppm): Leaves= 776.25 Stem= 812.83 Root= 812.83	Sluggish and disoriented behavior	[62]
	Ethiopia	Achyranthes aspera	Amaranthaceae	Leaves	Hydro-ethanolic extract	Flavonoids, saponins, alkaloids and terpenoids	In-vivo	In immersion: LC50(ppm) = 20.37 LC90 (ppm) = 46.84; In immersion:	30-40 % mortality rate after 24 hr at 100 ppm	[63]

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								LC50 = 3.10 ppm LC90= 11.08 ppm		
	Sudan	Solenostemma argel	Asclepiadaceae	Leaves	Aqeous extract	------------	In-vivo	For egg masses, LD50 =2921.3 ppm LD95 = 3515 ppm; For neonates, LD50 =368 ppm, LD95 = 1699 ppm	50 % mortality rate of eggs and 95 % of neonates	[64]
	Kenya	Aloe secundiflora	Asphodelaceae	Leaves	Aqeous extract	------------	In-vivo	------------	40 % mortality rate after 24 h	[65]
	Kenya	Balanites aegyptiaca	Zygophyllaceae	Root	Aqeous extract	------------	In-vivo	------------	36 % mortality rate after 24 h	
	Kenya	Aspilia pluriseta	Asteraceae	Leaves	Aqeous extract	------------	In-vivo	------------	50 % mortality rate after 24 h	
	Kenya	Psidium guajava	Myrtaceae	Root and leaves	Aqeous extract	------------	In-vivo	------------	20 % mortality rate after 24 h	

	Kenya	Azadirachta indica	Meliaceae	Root and leaves	Aqeous extract	-------------	In-vivo	------------	58 % mortality rate after 24 h	
	Sudan	Solenostemma argel	Apocynaceae	Leaves	Aqeous extract	Alkaloids, terpenoids, flavanoids, saponins and tannins	In-vivo	LD50= 0.103 ppm LD95= 0.187 ppm	Behavioral changes	[66]
	Nigeria	Balanites aegyptiaca	Zygophyllaceae	Stem and bark	Aqeous solution	2-methoxy-4-vinylphenol, benzaldehyde, phenol, 2-methoxy-4-(2-propenyl)-acetate, ethanone, 1-(4hydroxphenyl)-, alpha-d-6,3-furanose, 4-(3-hydroxy-	In-vivo	LD50 (mg/L): For B. pfeifferri juvenile=1.4 For B. pfeifferri adult=1.6 LD90 (mg/L): For B. pfeifferri juvenile=4.8 For B. pfeifferri adult=4.2	100 % mortality rate of both snail species at 40mg/L	[67]

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						1-propenyl)-2-methoxy phenol, hexadecanoic acid, 2-butanone, 9- octadecanoic acid, octadecanoic acid, 13-octadecenal, tetradecanoic, 9-octadecenamide and di-n-octylphalate				
	Mali	Glinus oppositifolius	Aizoaceae	Whole plant	Crude extract	12-Glucosyl-GO1	In-vivo	LC50 of Butanol extract= 91.7 ppm; LC50 of Ethanolic extract= 116.6 ppm	100 % mortality rate of both snail species at 200ppm	[68]

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	Ethopia	Glinus lotoides	Molluginaceae	Fruit	Aqueous and crude extract	------------	In-vitro	LC50= 47.1 mg/L LC90= 56.96 mg/L	20 % mortality rate of cercariae, and 100 % snail mortality at 37.5-80 mg/L	[69]
	Ethopia	Balanites aegyptiaca	Zygophyllaceae	Seeds, mesocarp, fruit and endocarp	Aqeous extract	------------	In-vivo	LC90 (mg/L): Seed= 77.70, Endocarp= 120.04, Mesocarp= 89.50, Fruit=99.55	90 % mortality rate	[70]
	Kenya	Entada leptostachya	Leguminosae	Root	Ethyl acetate, aqeous and methanol extract	Tannins, glycosides, Saponins, flavonoids and triterpenes	In-vitro	LD50 (mg/l): Juvenile= 30.12 Adult= 40.93	100 % mortality rate on juveniles and 95 % on adult	[71]
	Kenya	Azadirachta indica	Meliaceae	Leaves	Ethyl acetate, aqeous, methanol extract	Alkaloids, glycosides, saponins, flavonoids and	In-vitro	------------	Only 5 % mortality	

						triterpenes				
	Nigeria	Chromolaena odorata	Asteraceae	Leaves	Aqueous and ethanolic extract	-------------	In-vivo	LC50 (ppm) for Aqueous extract: Eggs= 65.75 Juveniles= 75.59 Adults= 217.57 LC50 (ppm) for Ethanolic extract: Eggs= 44.03 Juveniles= 44.68 Adults= 88.04	100 % mortality rate after 24 h	[72]
	Nigeria	Ficus exasperata	Moraceae	Root, bark, seed and leaves	Aqeous and ethanolic extracts	Flavonoids, alkaloids, tannins, saponins, anthraquinones and cardenolides	In-vitro	LC50= 0.3187 ppm LC90= 0.7555 ppm	Mitochondrial eruption, degeneration of epithelial cells and 100 % mortality rate	[73]

	Nigeria	Cymbopogon citratus	Poaceae	Leaves	Ethanol and aqueous extract	------------	In-vivo	LC50 for aqueous extract= 140.74 ppm LC50 for ethanolic extract= 254.92 ppm	100 % mortality in ethanol extract	[74]
	Nigeria	Chromolaena odorata	Asteraceae	Leaves	Ethanolic and aqueous extract	------------	In-vivo	Aqueous extract: LC50 =65.75 ppm LC90=139.54 ppm Ethanolic extract LC50 =44.03 ppm LC90 =119.3 ppm	100 % mortality rate at 100 ppm	[75]
	Sudan	Acacia seyal	Mimosaceaeis	Bark	Methanolic extract	------------	In-vitro	IC50 (ppm): At 24 h =80.79, At 48 h =34.33	100 % mortality at 62.5 ppm after 48 h	[76]

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	Nigeria	Piper guineense	Piperaceae	Fruit	Aqueous and ethanolic extract	------------	In-vivo	For ethanolic extract: LC50 = 0.10 mg/L LC90= 0.9 mg/L For aqueous extract: LC50 = 5.0 mg/L LC90= 8.5 mg/L	90% mortality rate at 9 mg/L	[77]
	Nigeria	Anonna senegalensis	Annonaceae	Leaves and root	Ethanolic extract	------------	In-vivo	For leaves: LC50 = 88.93 mg/l LC90= 285.44 mg/l For roots: LC50 = 861.38 mg/l LC90= 2 379.80 mg/l	100 % mortality rate of adult snail at 500 mg/l and 75% death rate of egg masses at 250 mg/l	[78]
	Nigeria	Anogeissus leiocarpus	Combretaceae	Leaves and	Ethanolic extract	------------	In-vivo	For leaves:	65 % mortality rate of adult snail at 1000 mg/l and 90% death rate of egg masses at 4000 mg/l	

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				root				LC50 = 1 213.39 mg/l LC90= 3 263.00 mg/l For roots: LC50 = 653.60 mg/l LC90= 1 503.03 mg/l		
	Nigeria	Crotalaria retusa	Leguminosae	Leaves and root	Ethanolic extract	------------	In-vivo	For leaves: LC50 = 73.84 mg/l LC90= 176.94 mg/l For roots: LC50 = 290.35 mg/l LC90= 714.89 mg/l	70 % mortality rate of adult snail at 500 mg/l, 69 % death rate of egg masses at 1000 mg/l	
	Nigeria	Dalbergia sissoo	Leguminosae	Fruit, stem and bark	Ethanolic extract	------------	In-vivo	For fruits: LC50 = 30.74 mg/l LC90= 74.33 mg/l For bark:	85 % mortality rate of adult snail at 500 mg/l and 81 % death rate of egg masses at 500 mg/l	

								LC50 = 399.86 mg/l LC90= 1 114.84 mg/l		
	Nigeria	Vernonia amygdalina	Asteraceae	Leaves and root	Ethanolic extract	------------	In-vivo	For leaves: LC50 = 1 913.45mg/l LC90= 6 241.61 mg/l For roots: LC50 = 917.79 mg/l LC90= 2 384.78 mg/l	85 % mortality rate of adult snail at 2000 mg/l and 89 % death rate of egg masses at 4000 mg/l	
	Nigeria	Carica papaya	Caricaceae	Leaves	Ethanolic extract	------------	In-vivo	LC50 B. pfeifferi=27 16.3 ppm LC90= 4515.9 ppm	50 % mortality rate	[79]
	Nigeria	Terminalia catappa	Combretaceae	Leaves	Ethanolic extract	------------	In-vivo	LC50 = 864.1 ppm LC90= 1222.8 ppm	100 % mortality rate	

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	Sudan	Cymbopogon nervatus	Poaceae	Leaves	Essential oils	------------	In-vivo	LD50 = 213.099 ppm	100 % mortality rate at 400 ppm	[80]
	Sudan	Boswellia papyrifera	Burseraceae	Leaves	Essential oils	------------	In-vivo	LD50 213.31 ppm	90 % mortality rate at 350 ppm	
	Nigeria	Dalbergia sissoo	Leguminosae	Fruit, root, stem and leaves	Ethanolic and aqueous extracts	------------	In-vitro	LC90 =89.29 mg/l	93 % death rate of snail eggs at 500 mg/l	[81]
	Nigeria	Dalbergia sissoo	Leguminosae	Fruit, root, leaves and stem	Aqeous and ethanolic extract	------------	In-vitro	------------	Un-hatched embryo death	[82]
	South Africa	Barringtonia racemosa	Lecythidaceae	Fruit and seed	Aqeous extract	------------	In-vitro	LD50 for fruit= 521.48 ppm LD50 for seed= 556.23 ppm	More toxic effects are produced by fruit extract	[83]
	Sudan	Azadirachta indica	Meliaceae	Leaves and seeds	Aqeous extract	------------	In-vivo	------------	75 % decrease in snail species after 5 days	[84]
	Mali	Cussonia barteri	Araliaceae	Roots	Methanolic and aqeous extract	------------	In-vitro	------------	Extract proved toxic against snail sp.	[85]
	Mali	Glinus oppositifolius	Aizoaceae	Whole plant	Methanolic and aqeous extract	------------	In-vitro	------------	Extract proved toxic against snail sp.	

	Mali	Lannea velutina	Anacardiaceae	Leaves	Methanolic and aqeous extract	------------	In-vitro	------------	Extract proved toxic against snail sp.	
	Kenya	Solanum aculeastrum	Solanaceae	Root, bark and fruit	Methanolic extract	------------	In-vivo	------------	100 % mortality rate	[86]
	Saudi Arabia	Jatropha glauca	Euphorbiaceae	Leaves	Chloroform extract	------------	In-vivo	LD50= 66.7 ppm LD90= 114 ppm	Decreased efficacy with increased time	[87]
	Saudi Arabia	Euphorbia helioscopia	Euphorbiaceae	Leaves	Methanolic extract	------------	In-vivo	LD50= 50.8 ppm LD90= 68.2 ppm	Decreased efficacy with increased time	
	Saudi Arabia	Euphorbia schimperiana	Euphorbiaceae	Stem	Methanolic extract	------------	In-vivo	LD50= 34 ppm LD90= 41.7 ppm	100 % mortality rate	
Biomphalaria glabrata	Egypt	Origanum syriacum	Lamiaceae	Seed	Ethanolic extract	------------	In-vitro	LC50= 215.2 ppm LC90= 415.7 ppm	Chromosomal aberration in both snail species	[40]
	Nigeria	Lycopersicon esculentum	Solanaceae	Seed	Methanolic extract	------------	In-vivo	LC50 = 873.6 ppm	78 % mortality at 1000 µg/ml	[88]

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	Nigeria	Blighia unijugata	Sapindaceae	Stem, fruit, seed and leaves	Ethanolic extract	Saponin	In-vivo	LC50= 7.6 µg/ml	100 % mortality rate at 1000 ppm	[89]
	Angola	Euphorbia conspicua	Euphorbiacea e	Latex	Methanolic extract	----------- -	In-vivo	LC100 = 1 µg/mL	Toxic against the snail sp.	[90]
	Mali	Cussonia barteri	Araliaceae	Roots	Methanolic and aqeous extract	----------- -	In-vitro	------------	Extract proved toxic against snail sp.	[85]
	Mali	Glinus oppositifolius	Aizoaceae	Whole plant	Methanolic and aqeous extract	----------- -	In-vitro	------------	Extract proved toxic against snail sp.	
	Mali	Lannea velutina	Anacardiacea e	Leaves	Methanolic and aqeous extract	----------- -	In-vitro	------------	Extract proved toxic against snail sp.	
	Thailand	Solanum xanthocarpum	Solanaceae	Fruit	Ethanolic crude extract	----------- -	In-vivo, In-vitro	LC50= 163.85 mg/l LC90= 219.33 mg/l	Extract proved toxic against snail	[91]
	Pakistan	Euphorbia cauducifolia	Euphorbiacea e	Latex	DMSO suspension	Deoxyph orbol Esters	In-vivo	LC50=12.3 ng/ml	Induces imbalance in nutrient and water absorption	[92]
	Colombo	Croton floribundus	Euphorbiacea e	Leaves and bark	Ethanolic and methanolic extract	Kaurenoi c acid	In-vivo	LC50=4.2 µg/mL LC90=11.5 µg/mL	High molluscicidal activity	[93]
	Japan	Ambrosia maritima	Asteraceae	Root	Chloroform extract	Ambrosi n and	In-vivo	LC50 = 0.37ppm	80 % molluscicidal activity after 72h	[94]

						Pentayne ene				
	Brazil	Parkia pendula	Leguminosae	Seed	Saline extract	------------	In-vitro, In-vivo	LC50 (mg/mL) values: Blastula= 237.19 Gastrula= 244.62 Adult= 4.99	Proved toxic at 3.0, 4.0 and 5.0 mg/mL, decrease in defense cells and detection of nuclear damage	[95]
	Brazil	Dysphania ambrosioides (L.)	Amaranthaceae	Aerial parts	Essential oil	α-Terpinene, ascaridole, thymol, carvacrol, isoascaridole, p-cymene, limonene and γ-terpinene	In-vitro, In-vivo	LC50= 25.2 μg/mL	100 % mortality rate at 50 μg/mL, non-toxic to Artemia salina larvae and Danio rerio fish	[96]
	Brazil	Persea Americana Mill.	Lauraceae	Stem and bark	Ethanolic extract	Quercetin, flavonoid, anthraquinone	In vivo, In vitro	LC50 (ppm): For embryo =27.06	Increased embryo mortality at 144 h, 100 % mortality in adult, lethargy and shell reduction after 96 h	[97]

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						heterosides, coumarins and tannins		For newly hatched= 30.6 For adult =55.55		
	Brazil	Pimenta dioica	Myrtaceae	Leaves	Essential oil	Octenol, mirceno, limonene, linalol, terpinol, chavicol and eugenol	In-vivo	LC50= 18.62 mg/L	90 % mortality rate after 72 h at 75 mg/L	[98]
	Brazil	Citrus limon	Rutaceae	Fruit peel	Essential oil	Limonene, sabinene, β-pinene, γ-terpinene, β-citral, α-citral, α-pinene and β-Bisabolene	In-vivo	------------	100 % mortality at 100 mg/L	[99]

	Brazil	Manilkara subsericea	Sapotaceae	Leaves	Ethanolic crude extract and ethyl acetate fraction	Myrcetin, quercetin and ursolic acid	In-vivo	LD50 (µg/mL): For Ethanolic crude extract= 118.7 For ethyl acetate fraction= 23.41	53 % mortality rate at 250 µg/mL	[100]
	Brazil	Euphorbia umbellata	Euphorbiaceae	Latex	Latex aqeous dilutions	Triterpenes	In-vivo	LC50=1.36 mg/L LC90 =3.69 mg/L	90 % mortality rate after 24 h,	[101]
	Brazil	Anadenanthera colubrina	Planorbidae	Bark	Crude extract	Terpenoids, tannins and phenols	In-vivo	LC50 For adult= 0.155 mg/mL For embryo= 0.692 mg/mL	100 % mortality of adult snail and embryo at 0.5, 1.0 mg/mL respectively	[102]
	Brazil	Moringa oleifera Lam.	Moringaceae	Flower	Aqeous extract	Xanthone, saponin, tannin, flavanol, polyphen	In-vivo	LC50= 2.37mg/mL	95 % mortality rate at 4 mg/mL	[103]

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						ol and flavones				
	Brazil	Jatropha elliptica	Euphorbiaceae	Root	Ethanolic extract	diethyl 4-phenyl-2,6-dimethyl-3,5-pyridinedicarboxylate	In-vivo	LC90=36.43 µg/mL	100 % mortality rate of schistosomes and snail	[104]
	Brazil	Schinopsis brasiliensis	Anacardiaceae	Stem, bark	Hydroethanol extract	Xanthones, flavanones and tannin	In-vivo	LC90=73 µg/ml	60 % morality rate at 50 µg/ml	[105]
	Brazil	Jatropha gossypiifolia	Euphorbiaceae	Stem, leaves and fruit	Hydroalcohlic extract	Alkaloids, tannins, triterpenoids, saponins and steroids	In-vivo	-------------	100 % mortality rate at 25 ppm, significant reduction in oviposition ability and complete repression of feeding ability	[106]
	Brazil	Moringa oleifera	Moringaceae	Seed	Aqeous extract	-------------	In-vivo	LC50 =0.419 g/l; LC90 =1.021 g/l	Toxic for Biomphalaria glabrata	[107]
	Brazil	Piper tuberculatum	Piperaceae	Stem, leaves,	Methanolic extract	Piplartine	In-vitro	LC50 (µg/ml):	100 % mortality rate of blastula, gastrula and adult	[108]

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				fruit and root				Root= 20.28 Stem=200 Leaves= 310.27 Fruit= 126.27		
	Brazil	Cymbopogon winterianus	Poaceae	Leaves	Essential oil	Geraniol, citronellol, citronellal and elemol	In-vivo	LC50=54.0 mg/L, LC90=97.0 mg/L,	90 % mortality rate after 72 h	[109]
	Brazil	Porophyllum ruderale	Asteraceae	Flower and leaves	Essential oil	β-pineno, mircene, (E)-β-ocimeno and (Z)-β-ocimeno,	In-vivo	LC50 = 774.82ppm LC90 = 812.43ppm	Proved toxic at less than 1000 ppm	[110]
	Brazil	Euphorbia milii	Euphorbiaceae	Latex	Aqueous solution	-------------	In-vivo	LC50= 0.7 µl	Decreased glycogen content, increased glucose and total protein content	[111]
	Brazil	Euphorbia milii	Euphorbiaceae	Latex	Aqueous solution	-------------	In-vivo	EC50 = 2040 µg/L	Increased malformation in embryos	[112]
	Brazil	Lippia gracilis	Solanaceae	Leaves	Essential oil	Thymol, methyl-thymol	In-vivo	LC50 = 62.2 ppm	Proved highly lethal to snail sp.	[113]

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						and p-cymene		LC90= 82.8 ppm		
	Brazil	Turnera ulmifolia	Turneraceae	Leaves	Hydroalcohlic extract	Glycosides, flavonoids, alkaloids, tannins and steroids	In-vivo	-------------	No activity against snail sp.	[114]
	Brazil	Solanum asperum	Solanaceae	Fruit	Methanolic extract	Solanandaine and solamargine	In-vivo	LC50= 25.1 µg/mL LC90= 44.1 µg/mL	90 % mortality rate after 24h	[115]
	Brazil	Ocotea bracteosa	Lauraceae	Stem and bark	Essential oil	Cadinene, ledene and globulol	In-vivo	LC90 = 8.3 µg/mL	Proved toxic against the snail sp.	[116]
	Brazil	Euphorbia splendens	Euphorbiaceae	Latex	Aqeous stock solution	-------------	In-vitro	LD50 = 1 mg/l LD90 = 2.3 mg/l	Increased protein conc. and decreased glycogen content	[117]
	Brazil	Solanum stipulaceum	Solanaceae	Stem	Aqeous extract	-------------	In-vivo	LC50= 45.2 µg/mL LC90= 56.0 µg/mL	Toxic against the snail sp.	[118]

	Brazil	Solanum diamantinense	Solanaceae	Aerial parts	Methanolic extract	-------------	In-vivo	LC50= 33.36 µg/mL LC90= 52.8 µg/mL	High molluscicidal activity against snail sp.	[119]
	Brazil	Solanum paludosum	Solanaceae	Fruit	Methanolic extract	-------------	In-vivo	LC50= 48.07 µg/mL LC90= 82.86 µg/mL	High molluscicidal activity against snail sp.	
	Brazil	Stryphnodendron adstringens	Mimosoideae	Leaves and bark	Ethanolic extract	Flavanoids	In-vivo	-------------	90 % mortality rate at 50 ppm	[120]
	Brazil	Stryphnodendron polyphyllum	Mimosoideae	Leaves and bark	Ethanolic extract	Flavanoids	In-vivo	-------------	70 % mortality rate of adult snail	
	Brazil	Dimorphandra mollis	Mimosoideae	Leaves and bark	Ethanolic extract	Flavanoids, coumarins and tannins	In-vivo	-------------	10 % mortality rate at 100 ppm after 48 h	
	Brazil	Caryocar brasiliensis	Caryocaraceae	Leaves and bark	Ethanolic extract	Hydrolysable tannins, flavanoids and condensed tannins	In-vivo	-------------	90% mortality rate at 100 ppm	
	Brazil	Eugenia dysenterica	Myrtaceae	Leaves and bark	Ethanolic extract	Condensed tannins, flavanoid	In-vivo	-------------	100 % mortality rate	

						s, phenolic acid and coumarins				
	Brazil	Annona crassiflora	Annonaceae	Leaves	Ethanolic extract	Flavanoids and tannin	In-vivo	-------------	Less than 10 % mortality rate	
	Puerto Rico	Didymopanax morototoni	Araliaceae	Leaves	Methanolic extract	-------------	In-vivo	-------------	100 % mortality rate at 50 ppm	[121]
	Puerto Rico	Mammea americana	Clusiaceae	Leaves	Methanolic extract	-------------	In-vivo	-------------	100 % mortality rate	
	Puerto Rico	Furcraea tuberosa	Agavaceae	Leaves	Methanolic extract	-------------	In-vivo	-------------	100 % mortality rate	
	Puerto Rico	Argemone mexicana	Papaveraceae	Leaves	Methanolic extract	-------------	In-vivo	-------------	67 % mortality rate at 100 ppm	
	Puerto Rico	Paullinia pinnata	Sapindaceae	Leaves	Methanolic extract	-------------	In-vivo	-------------	50 % mortality rate at 50 ppm	
	Puerto Rico	Solanum americanum	Solanaceae	Leaves	Methanolic extract	-------------	In-vivo	-------------	33 % mortality rate at 50 ppm	
	Brazil	Annona crassiflora	Annonaceae	Pulp, seed, stem and root	Ethanolic extract	-------------	In-vivo	LD90 (ppm): For adult= 2.34 For egg= 1	80 % mortality rate	[122]

	Brazil	Annona glabra	Annonaceae	Leaves and seed	Ethanolic extract	-------------	In-vivo	LD90 (ppm): For adult= 3.79 For egg= 1	80 % mortality rate	
	Brazil	Annona muricata	Annonaceae	Leaves and stem bark	Ethanolic extract	-------------	In-vivo	LD90 (ppm): For adult= 3.79 For egg= 1	60 % mortality rate	
	Brazil	Annona pisonis	Annonaceae	Leaves and stem bark	Ethanolic extract	-------------	In-vivo	LD90 (ppm): For adult= 6.21 For egg= 1	80 % mortality rate at 60ppm	
	Brazil	Annona salmani	Annonaceae	Leaves	Ethanolic extract	-------------	In-vivo	LD90 (ppm): For adult= 0.66 For egg= 1	100 % mortality rate	
	Brazil	Annona squamosa	Annonaceae	Seed, stem, root, and leaves	Ethanolic extract	-------------	In-vivo	LD90 (ppm): For adult= 8.55	100 % mortality rate	

							For egg= 1		
Brazil	Euphorbia splendens	Euphorbiaceae	Latex	Aqeous solution	-------------	In-vivo	LD50= 0.60ppm LD90= 0.83 ppm	Extract proved toxic against snail sp.	[123]
Iraq	Cucumis melo	Cucurbitaceae	Leaves and stem	Aquatic extract	-------------	In-vivo	LC50 (g/L): Leaves=40, Stem=50	15 % mortality rate with leaves extract while 12.5 % mortality rate with stem extract	[124]
Iraq	Thymus Vulgaris	Lamiaceae	Leaves	Aqeous extract	-------------	In-vitro	LC50= 18.7 g/L	50 % mortality at 18.7g/L	[125]
Iraq	Ricinus Communis	Euphorbiaceae	Leaves and bark	Aqeous extract	-------------	In-vivo	LC50 for 50 g/L Bark=191% Leaves= 32%	Abnormal behavioral patterns	[126]
France	Croton campestris	Euphorbiaceae	Root and bark	dichloromethanolic extract	velamone, velamolone and velamolone acetate	In-vivo	LD100 =50 ppm	100 % mortality rate	[127]
France	Caryopteris x clandonensis	Lamiaceae	Root and bark	Chloroform extract	Fuerstione, α-Caryopterone and 15-	In-vivo	LD100= <3 ppm	100 % mortality rate	[128]

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	United Kingdom	Euphorbia myrsinites	Euphorbiaceae	Leaves and stem	Aqueous extract	-------------	In-vivo	LC50 = 8.9 ppm	75 % reduced activity and 100 % mortality rate	[129]
	Belgium	Maesa ceolata	Myrsinaceae	Leaves	Aqeous extract	Saponin	In-vivo	-------------	>70 % mortality rate	[130]
	Germany	Jatropha curcas	Euphorbiaceae	Seed	Methanolic extract	-------------	In-vitro	LC100 =25 ppm	100 % mortality rate	[131]
	Egypt	Nigella sativa	Ranunculacea	Seed	Oil	-------------	In-vitro	LC50= **5.8** ppm	Laceration of vacuolated tissues in foot region	[132]
	Egypt	Pelargonium graveolens	Geraniaceae	Seed	Oil	------------	In-vitro	LC50= 15.0 ppm	Significant miracidicidal and cercaricidal activity	
	Egypt	Azadirachta indica	Meliaceae	Seed	Oil	------------	In-vitro	LC50= 28.0 ppm	Formation of vacuoles in cytoplasm of digestive glands	
	Egypt	Euphorbia pulcherima	Euphorbiaceae	Whole plant	Methanolic extract	-------------	In-vivo	LC50= 43 ppm	After 3 hour, mortality rate of cercariae is 50 % at 15 ppm, 100 % mortality rate of miracidia at 100 ppm, 28.4 % reduction in total protein and 40 % decrease in lactate dehydrogenase	[133]

	Egypt	Atriplex nummularia	Amaranthaceae	Whole plant	Methanolic extract	-------------	In-vivo	LC50= 32 ppm	After 3 hour, mortality rate of cercariae is 70 % at 15 ppm, 100 % mortality rate of miracidia at 100 ppm, 51 % reduction in total protein and 62.1 % decrease in lactate dehydrogenase	
	Mali	Glinus oppositifolius	Aizoaceae	Whole plant	Crude extract	12-Glucosyl-GO1	In-vivo	LC50 of Butanol extract= 64.3 ppm, LC50 of Ethanolic extract= 86.2 ppm	100 % mortality rate of both snail species at 200 ppm	[68]
	Egypt	Sesbania sesban	Leguminosae	Leaves	Methanolic extract	-------------	In-vivo, in-vitro	LC50= 15 ppm	Reduced cercarial prodcution and 44 % mortality after 48h	[134]
	Nigeria	Talinum triangulare	Talinaceae	Root	Ethanolic extracts	-------------	In-vivo	LC50= 251 ppm	Ovicidal activity at <300 ppm	[135]
	Egypt	Adenium obesum	Apocynaceae	Leaves	Methanolic extract	-------------	In-vivo	LC25=26.3 %	Reduced protein content in tissues	[136]
	Sudan	Cymbopogon nervatus	Poaceae	Leaves	Essential oils	-------------	In-vivo	LD50 = 237.33 ppm	100 % mortality rate at 400 ppm	[80]
	Sudan	Boswellia papyrifera	Burseraceae	Leaves	Essential oils	-------------	In-vivo	LD50= 311.05 ppm	90 % mortality rate at 350 ppm	

	Morocco	Withania somnifera	Solanaceae	Leaves and fruit	Aqeous and methanolic extract	Flavanoids, terpenes, alkaloids, saponins, tannins	In-vivo	LC50 = 94 ppm	Proved toxic to snail specie	[137]
	Morocco	Withania frutescens	Solanaceae	Root, leaves and fruit	Aqeous extract	Terpenes, alkaloids, tannins and saponins	In-vivo	------------	Proved toxic to snail specie	
	Morocco	Solanum elaeagnifolium	Solanaceae	Fruit, Root	Aqeous extract	Alkaloids , tannins and saponins	In-vivo	LC50 = 9.5 ppm	Potential molluscicide against snail	
	Morocco	Silene cucubalus	Caryophyllaceae	Root	Aqeous and n-butanol extract	Saponins, tannins and terpenes	In-vivo	------------	Potential molluscicide against snail	
	Morocco	Spergularia marginata	Caryophyllaceae	Root	Aqeous extract	Saponins	In-vivo	------------	Proved toxic to snail specie	
	Morocco	Saponaria vaccaria	Caryophyllaceae	Root	Aqeous extract	Saponins	In-vivo	------------	Potential molluscicide against snail	
	Sudan	Azadirachta indica	Meliaceae	Leaves and seeds	Aqeous extract	-------------	In-vivo	------------	75 % decrease in snail species after 5 days	[84]
	Egypt	Commiphora molmol	Bruseraceae	Whole plant	Oil extract	-------------	In-vivo	LD50= 50 ppm	100 % mortality rate	[53]

								LD90= 95 ppm		
	Morocco	Citrus aurantium var. valencia	Rutaceae	Fruit	Essential oil	α-pinene, sabinene, myrcene and linionene	In-vivo	LC50= 0.28 ppm	Toxic against the snail sp.	[138]
	Morocco	Origanum compactum	Lamiaceae	Aerial parts	Essential oil	Thymol, α-terpineol, γ-terpinene and α-pinene	In-vivo	LC50= 0.44 ppm	Toxic against the snail sp.	
	Mali	Cussonia barteri	Araliaceae	Roots	Methanolic and aqeous extract	--------------	In-vitro	--------------	Extract proved toxic against snail sp.	[85]
	Mali	Glinus oppositifolius	Aizoaceae	Whole plant	Methanolic and aqeous extract	--------------	In-vitro	--------------	Extract proved toxic against snail sp.	
	Mali	Lannea velutina	Anacardiaceae	Leaves	Methanolic and aqeous extract	--------------	In-vitro	--------------	Extract proved toxic against snail sp.	
	Egypt	Commiphora molmol	Burseraceae	Whole plant	Oil and resin extract	--------------	In-vivo	LC50= 3 ppm	100 % mortality rate	[56]
	Morocco	Ruta chalepensis L.	Rutaceae	Aerial part	Aqeous and ethanolic extract	Phenol, coumarins,flavanoid, alkaloid, sterol and	In-vivo	LC50= 1.41 ppm LC90= 2.23 ppm	Strong molluscicidal activity	[139]

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						terpenoid s				
	Morocco	Zygophyllum gaetulum Emb.	Zygophyllace ae	Aerial part	Aqeous and ethanolic extract	Flavanoi d and saponin	In-vivo	LC50= 8.69 ppm LC90= 16.82 ppm	High mortality rate	
	Morocco	Citrus bigaradia Duhamel	Rutaceae	Leaves	Aqeous and ethanolic extract	Terpenoi d, phenol, coumarin s, flavanoid , alkaloid, sterol and terpenoid	In-vivo	LC50= 2.74 ppm LC90= 4.43 ppm	Toxic for adult snails	
	Morocco	Capparis spinosa L.	Capparidacea e	Aerial part	Aqeous and ethanolic extract	Coumari n, alkaloid and sterol	In-vivo	LC50= 70.58 ppm LC90= 122 ppm	Strong molluscicidal activity	
	Morocco	Chenopodium ambrosioides L.	Chenopodiac eae	Aerial part	Aqeous and ethanolic extract	Flavanoi d, saponin and terpenoid	In-vivo	LC50= 1.41 ppm LC90= 2.23 ppm	Strong molluscicidal activity	
	Morocco	Artemisia herba alba Asso.	Asteraceae	Aerial part	Aqeous and ethanolic extract	Phenol, flavanoid , alkaloid,	In-vivo	LC50= 62.94 ppm	Strong molluscicidal activity	

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						sterol and terpenoid		LC90= 92 ppm		
	Morocco	Origanum compactum	Lamiaceae	Aerial part	Aqeous and ethanolic extract	Phenol, flavanoid, saponin and terpenoid	In-vivo	LC50= 8.22 ppm LC90= 1.99 ppm	Strong molluscicidal activity	
	Morocco	Melia azedarach L.	Meliaceae	Leaves	Aqeous and ethanolic extract	Flavanoid, alkaloid and terpene	In-vivo	LC50= 3.53 ppm LC90= 4.20 ppm	High mortality rate	
	Morocco	Delphinium staphisagria L.	Ranunculaceae	Flower	Aqeous and ethanolic extract	Alkaloid and saponin	In-vivo	LC50= 3.5 ppm LC90= 8.39 ppm	Toxic for adult snails	
	Morocco	Nigella sativa	Ranunculaceae	Aerial part	Aqeous and ethanolic extract	Coumarins, alkaloid, terpenoid, saponin and sterol	In-vivo	LC50= 106.7 ppm LC90= 140 ppm	Toxic for adult snails	
	Morocco	Zizyphus vulgaris Lamk.	Rhamnaceae	Leaves	Aqeous and ethanolic extract	Phenol, saponin and alkaloid	In-vivo	LC50= 4.12 ppm LC90= 8.41 ppm	High mortality rate	

	Morocco	Chrysanthemum viscidehirtum	Asteraceae	Aerial part	Aqeous and ethanolic extract	Flavanoid and terpenoid	In-vivo	LC50=4.43 ppm LC90=8.39 ppm	Strong molluscicidal activity	
	Morocco	Citrullus colocynthis L.	Cucurbitaceae	Fruit, Seed	Aqeous and ethanolic extract	Sterol and terpenoid	In-vivo	LC50= 4.35 ppm LC90= 8.39 ppm	Strong molluscicidal activity	
	Morocco	Lavandula stoechas L	Lamiaceae	Aerial Part	Aqeous and ethanolic extract	Phenol, flavanoid and terpenoid	In-vivo	LC50= 106.7 ppm LC90= 140 ppm	High mortality rate	
	China	Solanum xanthocarpum	Solanaceae	Fruit	Ethanolic extract	-------------	In-vivo	LC50 (mg/l): =1.35	100 % mortality rate	[91]
	Germany	Jatropha curcas	Euphorbiaceae	Seed	Methanolic extract	-------------	In-vitro	LC100= 1 ppm	100 % mortality rate of snail specie	[131]
Bulinus globosus	Zimbabwe	Cucurbita maxima	Cucurbitaceae	Seed	Aqeous and crude ethanolic extracts	-------------	In-vivo	LC50 (mg/ml) for: Aqeous extracts on B. globosus adults= 0.004 Ethanolic extracts on	100 % mortality rate at 2 mg/mL	[59]

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								B. globosus adults= 0.19		
	Nigeria	Allium cepa, Allium sativum	Amaryllidaceae	Bulb and cloves	Methanolic extract	--------------	In-vivo	LC50 (60 mg/l): For Allium cepa=15; For Allium sativum= 19.37	Mortality is higher in case of Allium sativum than Allium sepa and highest mortality rate is observed in 42.15 mg/l	[140]
	Nigeria	Balanites aegyptiaca	Zygophyllaceae	Stem and bark	Aqeous solution	2-methoxy-4-vinylphenol, benzaldehyde, phenol, 2-methoxy-4-(2-propenyl)-acetate, ethanone, 1-(4hydroxphenyl)-, alpha-d-6,3-furanose, 4-(3-hydroxy-1-	In-vivo	LD50 (mg/L): For juvenile= 5.7 For adult= 6.2 LD90 (mg/L): For juvenile= 6.8 For adult= 7.2	100 % mortality rate of both snail species at 40mg/L	[67]

						propenyl) -2- methoxy phenol, hexadeca noic acid, 2- butanone, 9- octa decanoic acid, octadeca noic acid, 13- octadece nal, tetradeca noic, 9- octadece namide and di-n- octylphal ate				
	Nigeria	Rhizophora mangle	Rhizophorace ae	Leaves	Methanolic extract	Saponins, glycoside s, tannins, alkaloid and flavanoid s	In-vivo	LC50 = 87.50 ppm	90 % mortality rate at 200 ppm	[141]
	Nigeria	Rhizophora racemosa	Rhizophorace ae	Leaves	Methanolic extract	Saponins, glycoside s, tannins, alkaloid	In-vivo	LC50 = 125 ppm	100 % mortality rate at 250 ppm	

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						and flavanoids				
	Nigeria	Avicennia germinans	Verbenaceae	Leaves	Methanolic extract	Saponins, glycosides, tannins, alkaloid and flavanoids	In-vivo	LC50= 87.50 ppm	80 % mortality rate at 150 ppm	
	Nigeria	Languncularia racemosa	Combretaceae	Leaves	Methanolic extract	Saponins, glycosides, tannins, alkaloid and flavanoids	In-vivo	LC50 = 102.09 ppm	100 % mortality rate at 50 ppm	
	Nigeria	Azadirachta indica	Meliaceae	Root and bark	Ethanol, chloroform, acetone and n-hexane extract	Triterpenes, flavanoids, glycosides and tannins	In-vivo	LC50 = 0.35 ppm	100 % mortality rate	[142]
	Nigeria	Talinum triangulare	Portulaceae	Leaves and root	Ethanolic extract	--------	In-vivo	LC50= 125.89 ppm	100 % mortality at 160 ppm (root) and 640 ppm (leaves)	[143]
	Nigeria	Azadirachta indica	Meliaceae	Leaves, seed and bark	Methanol and decoction extract	Saponin, tannin, flavanoid	In-vitro	--------------	100 % mortality rate after 24 h	[144]

						and glycoside				
	Nigeria	Hyptis suaveolens	Lamiaceae	Leaves	Ethanolic extracts	-------------	In-vivo	At egg stage LC50= 0.614 ppm; At adult stage LC50= 0.077 ppm	80 % mortality rate at 0.8 ppm	[145]
	Nigeria	Securidaca longepedunculata, Tephrosia brateolata	Polygalaceae, Leguminosae	Root , leaves, stem and bark	Ethanolic and methanolic extract	-------------	In-vivo	With ethanolic extract: LC50 (ppm) leaf= 0.15 bark = 0.19 Root= 0.18 With methanolic extract: LC50 (ppm) leaf = 0.55 bark= 0.60 root= 0.21	100 % mortality rate	[146]
	Nigeria	Carica papaya	Caricaceae	Leaves	Ethanolic extract	-------------	In-vivo	LC50 = 619.1 ppm LC90= 1180.7 ppm	100 % mortality rate	[79]

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	Nigeria	Terminalia catappa	Combretaceae	Leaves	Ethanolic extract	-------------	In-vivo	LC50 = 1095.7 ppm LC90 = 1874.9 ppm	100 % mortality rate	
Oncomelania hupensis	China	Camellia oleifera	Theaceae	Seed	Aqeous solution	Tea-seed distilled saponin	In-vivo	LD50 at 24 hr in laboratory = 0.701 mg/L	Mortality rate is 72-98 %	[147]
	China	Macleaya cordata	Papaveraceae	Fruit	Aqeous solution	Quaternary benzo[c] phenanthridine alkaloids (sanguinarine and chelerythrine) and protopine alkaloids (protopine and α-allocryptopine)	In-vivo, In-vitro	LC50=1.29 mg/L; LC90=2.92 mg/L	Decrease in glutathione stransferase (GST), carboxylesterase, cid phosphatase and alkaline phosphatase activity	[148]
	Philippines	Jatropha curcas L.	Euphorbiaceae	Leaves	Petroleum ether extract	Alkaliods,	In-vivo	LD50 = 0.45 mg/mL	80 % mortality at 1.5 mg/mL	[149]

						tannins, terpenoids, flavonoids and saponins				
	China	Macleaya cordata (Wild) R.	Papaveraceae	Leaves	Aqeous solution	Alkaloids	In-vivo	LC50 = 6.35 mg/L LC90= 121.23 mg/L	Mortality rate is 73 % at 25 mg/L, Increase in alanine aminotransferase, aspartate transaminase and decrease in esterase isozyme	[150]
	China	Buddleja lindleyana	Loganiaceae	Whole plant	Ethanolic extract	Acacetin-7-rutinoside	In-vivo	LC50 = 36:12 mg/L	100 % mortality at 70 mg/L	[151]
	China	Cinnamomum camphora	Lauraceae	Leaves	---------	Linalool, α-terpineol, 4-terpineol, camphora, β-phellandrene, 1,8-cineole and spathulenol	In-vitro	LC50 = 0.25 mg/L	Disfigurement noted in hepatopancrease and gills	[152]

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	China	Ginkgo biloba	Ginkgoaceae	Leaves and sarcotesta	Ethanolic extract	-----------	In-vivo	LD50= 47.64 mg/L	Negatively affect the functioning of dihydronicotinamide adenine dinucleotide, cytochrome c oxidase, cytochrome b and (NADH) dehydrogenase, adenosine triphosphate (ATP) synthase	[153]
	China	Pulsatilla chinensis	Ranunculaceae	Whole plant	Alcohlic extract	Pulchinenoside A3 and Pulchinenoside B	In-vitro	LC50 =0.48 mg/L	Significant inhibition of cholinesterase, aspartate transaminase and alkaline phosphatase	[154]
	China	Sapium sebiferum	Euphorbiaceae	Leaves, branch, root and seed	Aqeous, ethyl acetate and ethnolic extract	--------------	In-vivo	--------------	Decreased protein content in liver and 100 % mortality rate	[155]
	China	Macleaya cordata	Papaveraceae	Fruit	Dechlorinized aqeous extract	Bisulfates of sanguinarine, total alkaloids and chelerythrine	In-vivo	LC50= 0.19 mg/L	100 % mortality rate at 72h	[156]

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	China	Eomecon chionantha	Papaveraceae	Root stalk	Alcohlic extract	Alkaloids	In-vivo	-------------	100 % mortality rate at 2.5 mg/l and increased amount of alanine aminotransferase	[157]
	China	Ginkgo biloba	Ginkgoaceae	Leaves	Ethanolic and aqeous extract	-------------	In-vivo	-------------	80 % mortality rate after 24 h, decreased total protein content and glycogen	[158]
	China	Torreya grandis	Taxaceae	Leaves	Ethanolic and aqeous extract	-------------	In-vivo	-------------	72 % mortality rate after 72 h	
	China	Ailanthus altissima	Simaroubaceae	Leaves	Ethanolic and aqeous extract	-------------	In-vivo	-------------	40 % mortality rate after 72 h	
	China	Peucedanum praerutorum	Apiaceae	Root	Ethanolic and aqeous extract	-------------	In-vivo	-------------	83 % mortality rate after 72 h	
	China	Herba agrimoniae	Rosaceae	Whole plant	Ethanolic and aqeous extract	-------------	In-vivo	-------------	80 % mortality rate after 72 h	
	China	Buddleja lindleyana	Scrophulariaceae	Leaves	Ethanolic extract	-------------	In-vivo	LC50 = 39.91 mg/L LC90 = 59.28 mg/L	96 % mortality rate after 48 h	[159]
	China	Eupatorium adenophorum	Asteraceae	Leaves, stem and root	Aqueous extracts	-------------	In-vivo	-------------	100 % mortality rate after 58 h	[160]

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	China	Ginkgo biloba	Ginkgoaceae	Seed	Petroleum ether extracts	Ginkgolic acids	In-vivo	LD50 = 7.81ppm	100 % mortality rate after 48h	[161]
	China	Arisaema erubescens	Araceae	Tubers	Ethanolic extract	-------------	In-vitro	LC50= 60.2 mg/L LC90= 145.6 mg/L	Increased activity of *alkaline phosphatase and* choline esterase	[162]
	China	Ginkgo biloba	Ginkgoaceae	Seed	Benzinum extracts	-------------	In-vivo	LC50= 0.65 mg/L LC90= 5.5 mg/L	Decreased activity of alkaline phosphatase, choline esterase, malic dehydrogenase and alanine aminotransferase	[163]
	China	Solanum xanthocarpum	Solanaceae	Fruit	Ethanolic extract	-------------	In-vivo	LC50 = 0.62 mg/l	100 % mortality rate	[164]
Bulinus rholfsi	Nigeria	Rhizophora mangle	Rhizophoraceae	Leaves	Methanolic extract	Saponins, glycosides, tannins, alkaloid and flavanoids	In-vivo	LC50 = 108.22 ppm	90 % mortality rate at 200 ppm	[141]
	Nigeria	Rhizophora racemosa	Rhizophoraceae	Leaves	Methanolic extract	Saponins, glycosides, tannins, alkaloid and	In-vivo	LC50= 83.51 ppm	100 % mortality rate at 250 ppm	

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						flavanoid s				
	Nigeria	Avicennia germinans	Verbenaceae	Leaves	Methanolic extract	Saponins, glycoside s, tannins, alkaloid and flavanoid s	In-vivo	LC50 = 123.74 ppm	80 % mortality rate at 150 ppm	
	Nigeria	Langunculаria racemosa	Combretacea e	Leaves	Methanolic extract	Saponins, glycoside s, tannins, alkaloid and flavanoid s	In-vivo	LC50= 152.03 ppm	100 % mortality rate at 50 ppm	
Bulinus natalensis	Germany	Jatropha curcas	Euphorbiacea e	Seed	Methanolic extract	----------- ---	In-vitro	LC100= 1 ppm	100 % mortality rate of snail specie	[165]
Lymnaea luteola	India	Sapindus trifoliatus	Sapindaceae	fruit	Methanolic extract	----------- ---	In-vitro	LC50= 50 ppm LC90= 87 ppm	80 % mortality rate	[166]
	India	Acacia concinna	Leguminosae	fruit	Methanolic extract	----------- ---	In-vitro	LC50= 360 ppm LC90= 451 ppm	90 % mortality rate at 300 ppm	

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	India	Madhuca indica	Sapotaceae	Seed	Methanolic extract	--------------	In-vitro	LC50= 62 ppm LC90= 100 ppm	90 % mortality rate at 80 ppm	
	India	Phytolacca acinosa	Phytolaccacea	fruit	Methanolic extract	--------------	In-vitro	LC50= 193 ppm LC90= 399 ppm	80 % mortality rate	
Monacha cartusiana	Egypt	Syzygium aromaticum	Myrtaceae	Flower bud	Acetone and ethanol extract	------------	In-vivo	LC50 =1.06; LC95=26.83	Excessive mucosal secretion, hyperactivity and 40-60 % mortality rate	[167]
	Egypt	Zingiber officinale	Zingiberaceae	Rhizome	Ethanolic extract	--------------	In-vitro, In-vivo	------------	90 % mortality at 28th day, Increased cell lysis and vacuole formation in digestive gland with disrupted calcium spherules and accumulation of pyknotic nuclei, increased levels of ALT, AST, α & β esterases andphenoloxidases, deformed egg and sperm	[168]
	Egypt	Balanites aegyptiaca	Zygophyllaceae	Fruit	Ethanolic extract	Diosgenin and 3,5-spirostadiene	In-vivo	LC50= 0.256 ppm	73 % mortality rate	[169]

Monacha Obstructa	Egypt	Ricinus communis	Euphorbiaceae	Fruit and leaves	Aqeous and ethanolic extract	Rinisine, ricinoleic acid, linoleic acid and quinic acid	In-vivo	LC50= 0.215 LC90= 16.128	80 % mortality rate after 72 hr	[170]
	Egypt	Anagallis arvensis L.	Primulaceae	Leaves and fruit	Hexane extract	Malonamic acid, aromadendrene, 2-tertbutyl–4-isopropyl–5-methylphenol and phosphoric acid tributyl ester	In-vivo	LC50 after 24h= 1.70 g/ml	Extract induced 34 % toxicity to adult snails	[171]
	Egypt	Solanum nigrum L.	Solanaceae	Leaves and fruit	Hexane extract	------------	In-vivo	LC50 after 24h= 2.75 g/ml	Proved 75 % toxic	
	Egypt	Cyperus longus L.	Cyperaceae	Rhizome	Hexane extract	------------	In-vivo	LC50 after 24h= 3.09 g/ml	Acted as bait (24.2 %) after 96 h	
	Saudi Arabia	Adenium obesum	Apocynaceae	Stem	Hydro-ethanolic extract	Cerberin and neriifolin	In-vivo	LD50 (μg/g):	Toxicity index of Cerberin is 79.81 while of neriifolin is 100	[172]

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								Of Cerberin = 4.3 Of neriifolin = 5.39		
Indoplanorbis exustus	India	Artemisia annua	Asteraceae	Leaves	Crude extract	------------	In-vitro	LC50= 5.9 ppm	Abnormal behavior (rapid movement)	[173]
	India	Leucas aspera, Parthenium hysterophorus	Lamiaceae, Asteraceae	Leaves	Aqeous solution	----------------	In-vivo	-----------	90 % mortality rate	[174]
Monacha cantiana	Saudi Arabia	Calotropis procera, Adenium arabicum	Apocynaceae	Latex and stem	Cardenolide and methonyl extract	Glycosides	In-vivo	LD50 values 12.62 mg/kg for cardenolide LD50 for methomyl was 116.62 mg/kg	80 % mortality rate	[175]
Lanistes ovum	Nigeria	Senna occidentalis	Leguminosae	Leaves	Ethanolic extract	Tannins, inulin, flavanoids and alkaloids	In-vitro	LC50=83.67 mg/L	100 % mortality rate after 96h	[176]
	Nigeria	Vernonia amygdalina	Asteraceae	Leaves	Ethanolic extract	Tannins, alkaloids, flavanoid	In-vitro	LC50=614.288 mg/L	100 % mortality rate after 96h	

						s and saponin				
	Nigeria	Khaya senegalensis	Meliaceae	Leaves	Ethanolic extract	Tannins, flavanoids, alkaloids, saponins and inulin	In-vitro	LC50=395.58 mg/L	Inhibition of alpha-glucosidase and reduced glucose level	
Physa acuta	Iraq	Melia azadirachta	Meliaceae	Fruit	Fruit extract	------------	In-vivo	At 24th hr, LC50=10 ppm ; LC90 4.4 ppm	Reduced juvenile movement, Irregular heartbeat and reduced to 58 beats/min from 88 beats/min, 100 % mortality rate at 5 ppm	[177]
Cornu aspersum	Lebanon	Styrax officinalis	Styracaceae	Fruit	Ethanolic extract	Saponins, triterpenes and tannins	In-vivo	------------	Disintegrated membrane tissues	[178]
Subulina octona	Brazil	Mikania glomerata	Asteraceae	Leaves	Aqeous extract	Tannins	In-vivo	LC50=45 mg/mL	100% mortality rate at 60th day	[179]
	Brazil	Bidens pilosa Linné	Asteraceae	Aerial parts	Aqeous extract	Flavanoids and saponin	In-vivo	LC50=51.4 mg/mL; LC90=74.1 mg/mL	Reduced hatchability to 61 %, 100 % mortality rate after 48 h	[180]
Lanistes lybicus	Nigeria	Erythrophleum suaveolens	Leguminosae	Stem and bark	Ethanolic extract	Saponin	In-vivo	38.74 µg/ml	100 % mortality rate at 50 µg/ml	[181]
Physa marmorata	Brazil	Moringa oleifera	Moringaceae	Seed	Aqeous extract	------------	In-vivo	P. marmorata LC50	Toxic for Physa marmorata	[107]

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								=0.339 g/l; LC90 =0.789 g/l		
Bradybaena similaris	Brazil	Solanum paniculatum	Solanaceae	Leaves	Aqeous extract	------------	In-vivo	------------	75 % mortality rate after 24 h, significant reduction of glucose, glycogen and galactogen	[182]
Bulinus sp.	Kenya	Balanites aegyptiaca	Balanitaceae	Leaves, root, stem and fruit	Methanolic extract	------------	In-vitro	LD50= 2.0931	38 % mortality rate	[183]
	Kenya	Phytolacca dodecandra	Phytolaccaceae	Leaves, root, stem and fruit	Methanolic extract	------------	In-vitro	LD50= 2.5332	32 % mortality rate	
	Kenya	Phytolacca octandra	Phytolaccaceae	Leaves, root, stem and fruit	Methanolic extract	------------	In-vitro	LD50= 2.2627	36 % mortality rate	
	Nigeria	Moringa oleifera	Moringaceae	Seeds	Aqeous extract	------------	In-vivo	------------	100 % mortality rate at 2000 ppm	[184]
Biomphalaria juvenile snails and Bulinus adult snails	Zimbabwe	Curcurbita maxima	Cucurbitaceae	Seed	Aqeous extract	------------	In-vivo	LC50 (mg/ml): On Biomphalaria juvenile= 0.002 On Bulinus adult = 0.004	100 % mortality rate	[185]

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Different snail sp.	Sudan	Khaya grandifoliola	Meliaceae	Bark	Aqeous and ethanolic extract	------------	In-vivo	------------	100 % mortality rate at 1 g/L	[186]

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A Most of the plants exhibiting molluscicidal activity belonged to the families Euphorbiaceae (9.31 %); Solanaceae (7.16 %); Asteraceae (6.09 %); Leguminosae (5.73 %); Lamiaceae (4.3 %); Meliaceae (3.94 %); Myrtaceae and Annonaceae (2.86 %); Rutaceae and Zygophyllaceae (2.5 %); Moringaceae, Combretaceae, and Araliaceae (2.15 %), as presented in Figure 2. A number of other families (n= <5; <1.79 %; Table 1) also included plants showing efficacy against various snail species.

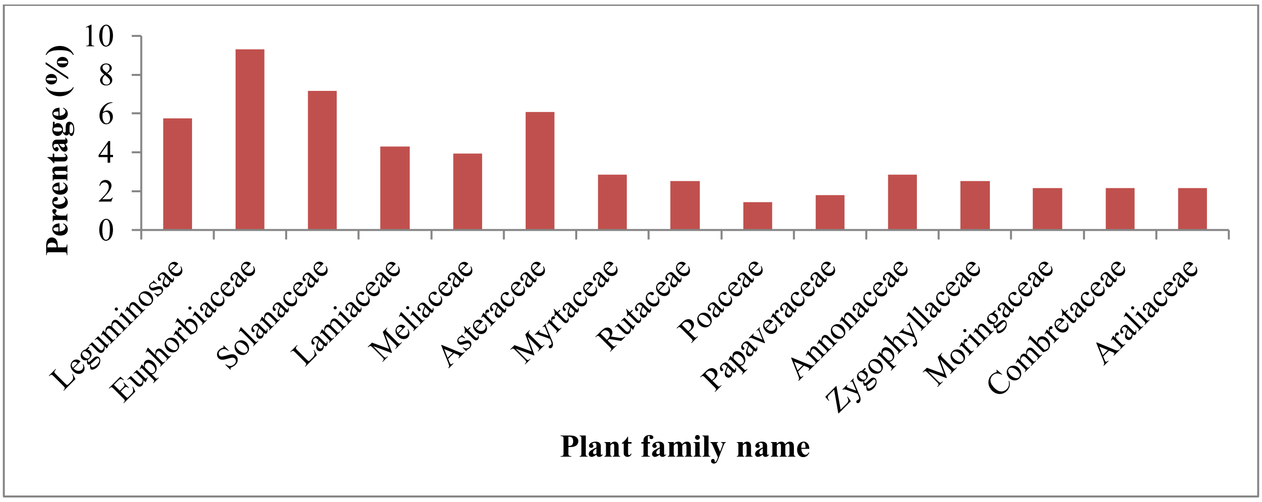

Figure 2: Major plant families exhibiting molluscicidal activity against intermediate snail hosts of schistosomes.

As shown in Figure 3, the key plant parts used to assess molluscicidal activity included leaves (48.74 %), fruit (15.05 %), root (14.69 %), stem (12.54 %), seed (12.9 %), bark (10 %), whole plant (9.31 %), and flower (2.15 %).

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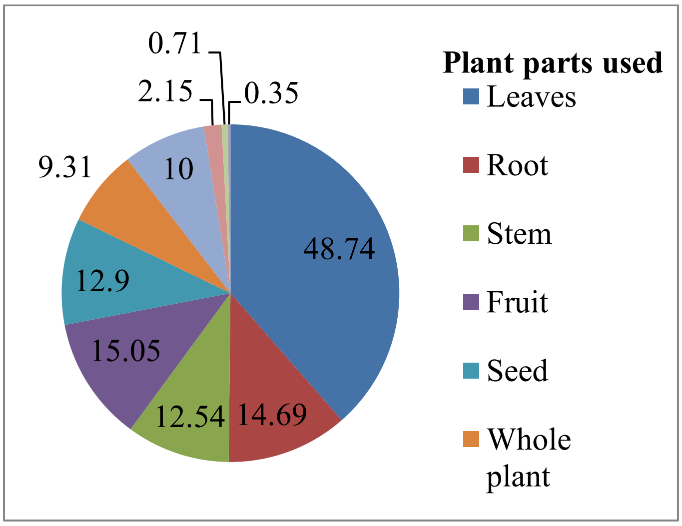

Figure 3: Pie chart depicting the percentage of plant parts used to assess molluscicidal activity.

Discussion

Plant-based molluscicides are receiving increasing recognition because of their higher biodegradability and low cost [63]. These molluscicides include plant secondary metabolites belonging to the category's tannins, glycosides, terpenoids, alkaloids, and phenols. Some of the important phytoconstituents are described below. Saponins are chemical compounds belonging to the category of glycosides. They are further divided into monodesmosidic and bidesmosidic saponins and are effective molluscicides because of their toxicity. One of the studies [18] indicated that the killing effect of Phytolacca dodecandra on snail species was attributed to saponins. In another study [187], saponins present in Ocimum americanum increased the mortality rate of Biomphalaria pfeifferi. Moreover, bidesmosidic saponins extracted from Yucca desmettiana leaves effectively reduced the occurrence of Biomphalaria alexandrina; the lethal concentration (LC50) after 24 h of exposure was 68 mg/L [41].

The concept of essential oils (EOs) is increasingly gaining popularity since it has the potential to perform a wide range of beneficial functions such as combating bacteria, alleviating inflammation, and killing parasites, in particular. Recent research indicates that Schistosoma worms can be prevented to grow by using oils of various plants. Indicatively, A lipid extract of Plectranthus neochilus is very potent in worm-killing, which is primarily due to the presence of 2-caryophyllene and 2-pinene [188]. Likewise, oil of Dysphania ambrosioides is able to kill adult Schistosoma mansoni worms when placed in a laboratory [189]. This implies that we must continue to screen EOs to identify additional plant chemicals effective against schistosomiasis. Similar effects have been found with other EOs, e.g. Mentha x villosa and Foeniculum vulgare, which is why it is believed that EOs may be natural remedies [190]. Analyzing EOs derived from plants can inform not only whether they are effective but also how they are: by rupturing the walls of cells of the parasite or by disrupting its most vital processes (Islam et al., 2020).

A study by [24], showed that alkaloids obtained from the leaf ethanolic extract of Ziziphus spina-christi led to a high apoptotic rate in Biomphalaria alexandrina. These alkaloids are organic compounds that are greatly soluble in chloroform and ethanol than water. They are present in every plant part and are proved highly toxic to the snails. Another study of Tripathi and Singh 2000, reported that isopelletierine isolated from Punica granatum significantly reduced the activity of Lymnaea acuminata. Alkaloids (sanguinarine) purified from Macleaya cordata also significantly decreased the activity of glutathione-S-transferase, carboxylesterase, and alkaline phosphatase in Oncomelania hupensis [150]. Flavonoids are flavone-based compounds in plants proven to exhibit molluscicidal activity. According to one of the studies [192], a well-known flavonoid (quercetin) isolated from the leaf ethanolic extract of Polygonum senegalense showed significant molluscicidal activity in Biomphalaria pfeifferi and Biomphalaria glabrata within 1 day of exposure. Flavonoids isolated from Stryphnodendron adstringens caused 90 % mortality in Biomphalaria glabrata [120]. Flavonoids are toxic for snail species, but flavone glycosides isolated from Asparagus plumosus were non-toxic [193].

Tannins are plant-based organic compounds divided into two groups: hydro-stable tannins and condensed tannins. Various plant species, including Croton megalocarpus, Aloe

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secundiflora, Moringa oleifera, Ipomea batatas, Chromolaena odorata, Ocimum americanum, Stryphnodendron adstringens [107,117,187,194] are reported to contain tannins that are highly toxic to snails. Tannins present in Persea Americana enhanced the mortality rate of Biomphalaria glabrata embryos and caused lethargy in Biomphalaria glabrata adults [97]. Several plant species have been demonstrated to be effective against various snail species, but there are no sufficient data to determine their mechanism of action [195]. In 1998, WHO presented a report that emphasized the need to investigate the mode of action of molluscicidal plants, as they are economical, sustainable to use, and commonly available [196].

Plant molluscicides are classified on the basis of their mode of action into the following categories: enzyme inhibitors, neurotransmitter inhibitors (neurotoxins), stomach poisons, respiratory poisons, contact poisons, and growth inhibitors. The findings of some studies that investigated the mechanism of action of molluscicidal plants are discussed below: In recent years, a few studies have investigated the system of mollusks affected by molluscicides. [92] demonstrated that the latex of Euphorbia cauducifolia disrupted water absorption in Biomphalaria glabrata. The snail species that act as intermediate hosts of schistosomes are mainly in fresh water; therefore, the hemolymph of these snails is hyper-osmotic in nature. Consequently, it is crucial that the nutrients and water are in continuous equilibrium; their imbalance leads to reduced functioning and altered behavior (rapid and disoriented movement). It also causes tissue swelling, which makes snails more susceptible to plant molluscicides [8].

Plant molluscicides cause significant hormonal changes in snails, leading to a high mortality rate [14]. Enzymes such as acetylcholinesterase, succinate dehydrogenase, and alkaline phosphatase are used as indicators of plant molluscicidal activity. Biomphalaria alexandrina exposed to dry powdered Datura stramonium exhibited an increase in the levels of alanine transaminase and alkaline phosphatases [172]. Another study [49] showed that the methanolic extract of Guayacum officinalis decreased the levels of acetylcholinesterase and succinate dehydrogenase in Biomphalaria alexandrina. An aqueous extract of Arisaema erubescens was also shown to decrease the levels of superoxide dismutase and peroxidase in the liver of Oncomelania hupensis; in contrast, the malondialdehyde content increased, which indicates the oxidative stress damage caused by the plant extract, leading to snail mortality [162]. Molluscicides may also act by negatively affecting the growth and development of snails. The findings of Ibrahim et al. [20] indicated that cerium oxide nanocomposites isolated from Moringa oleifera significantly reduced the reproductive rate of Biomphalaria alexandrina, with an LC50 of 314.5 mg/L. The results of this study also indicated the deformation of hermaphrodite and digestive glands in the Biomphalaria alexandrina. Certain flavonoids are highly toxic to schistosomes and others are not. This disparity is based on their structure, which influences the interaction with cell and their availability within the body. The hydroxyl groups of flavor compounds tend to make the flavonoids better antioxidants and antiparasites when they are present compared to when they are absent [197]. Hence, the research on the structure-activity relationship (SAR) of these compounds should be examined by scientists to inform future studies on flavonoid drugs against schistosomiasis.

Schistosomiasis also depends on the temperature of the surrounding environment to be spread. Research demonstrates that increased temperatures accelerate Bulinus snail life cycle and lead to more cercariae being released, and other research illustrates that high temperatures cause stress in the snails and lower their parasite-carrying capacity [198]. Such mixed evidence implies we require more ecological models to anticipate how schistosomiasis will evolve with different temperatures, particularly with the rising heat extremes with climate change.

When snails encounter a toxic substance, they produce more mucus in an attempt to excrete the noxious substance and detoxify their body [196]. The mucus forms a protective barrier around the skin and reduces the harmful effect of molluscicides [199]. Similarly, several other factors have been reported to decrease the molluscicidal activity of plants. The surface-to-volume ratio of snails is another factor responsible for the variation in the efficacy of plant molluscicides. According to [59], the effect of Cucurbita maxima extracts on Biomphalaria pfeifferi juveniles and adults are different. The LC50 values for adults and juveniles were 0.002 and 0.004 mg/mL, respectively. The reason is the less absorption of extract leads to more adult snail susceptibility towards toxic effect of molluscicides. Apart from these biological factors, certain chemical factors influence the susceptibility of snails to these plant extracts. For example, enzymatic analysis suggests that animals—more specifically, invertebrates—have mixed-function oxidases in their hepatopancreas that oxidize toxic chemical compounds to make them non-toxic [199].

Environmental factors such as light, temperature and extraction technique also affect the efficacy of plant-based molluscicides. A study by [112] indicated that an increase in temperature decreased the molluscicidal activity of Euphorbia milli. In contrast, an increase in temperature during phytochemical extraction helps these chemicals to easily penetrate the snail tissue [200]. Notably, [195] reported that the mortality rate of Lymnea acuminata treated with oleoresin decreased during winter.

Conclusion

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This review highlights the significant potential of plant-derived compounds as eco-friendly molluscicides for controlling schistosomiasis. The evidence indicates that several plants and their phytochemicals exhibit strong molluscicidal activity, providing a promising alternative to synthetic chemicals. However, most studies remain limited to laboratory settings, and translation into large-scale field application is still scarce. Future research should focus on standardizing extraction methods, evaluating long-term safety and environmental impacts, and conducting field trials to validate laboratory findings. Collaborative efforts between researchers, policymakers, and public health authorities are essential to integrate plant-based molluscicides into schistosomiasis control programs. Such an approach could help reduce transmission while promoting sustainable and cost-effective disease management strategies.

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Conflicts of Interest

The authors declare no conflicts of interest.

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