

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]. Schistosomiasis 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].

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.

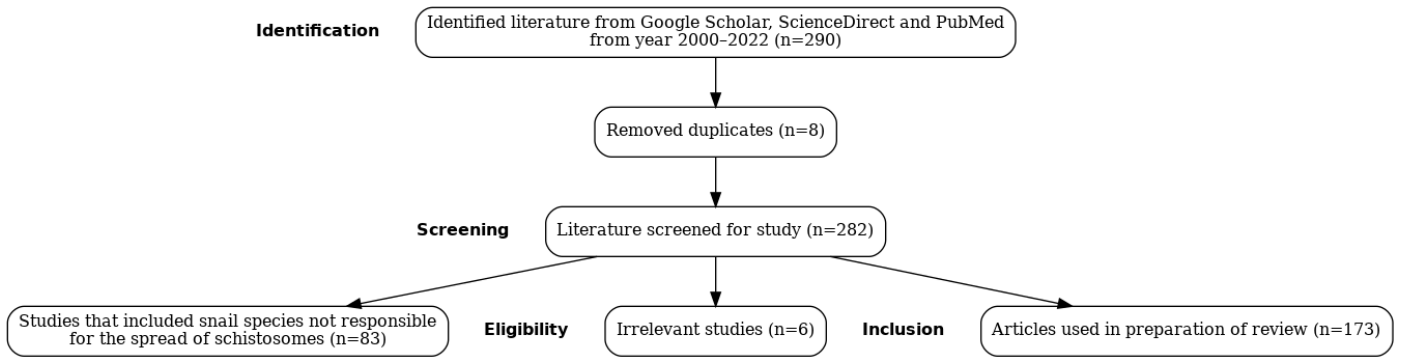


Figure 1: Study design for the review process.

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).

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 | Phytoc constituent | 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 | <i>Carica papaya</i> | 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 <i>Daphnia magna</i> | |
| | Egypt | <i>Origanum majorana</i> | 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 | <i>Ziziphus christi</i> spina- | 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] |

| | | | | | | | | | | |
|--|-------|------------------------------|------------|--------|-----------------------|--|----------|-------------------|--|------|
| | | | | | | ne, guanosin e, desulpho sinigrin, phenanth renemeth anol and thienopyr idine | | | | |
| | Egypt | Salvia fruticosa | Lamiaceae | Leaves | Aqueous extract | Quinol ol, tetrasilox ane, androstad ienol, purinol, spirosten, tetradeca noic acid, benzene methanol and cystathio nineand terphenyl | In-vitro | LC50= 69 mg/ml | Less effective against miracidial activity and 100 % cercarial activity at 100 mg/ml | |
| | Egypt | Ziziphus christi spina | Rhamnaceae | Leaves | Ethanollic extract | ----- | In-vitro | LC50= | Increased apoptosis and condensed zygotene | [24] |

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|-------|---------------------------|----------------|-------------|---------------------------------------|--------------|----------|---|---|------|--|
| | | | | | | | | 108.7 mg/l | | |
| Egypt | <i>Moringa oleifera</i> | Moringaceae | Leaves | Ethanollic extract | ----- | In-vitro | LC50= 209.4 mg/l | Increased apoptosis and condensed zygote | | |
| Egypt | <i>Tecoma stans</i> | Bignoniaceae | Leaves | Ethanollic extract | ----- | In-vitro | LC50= 256 mg/l | Increased apoptosis and condensed zygote | | |
| Egypt | <i>Carica papaya</i> | 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 | <i>Anagalis arvensis</i> | Primulaceae | Whole plant | Ethanollic 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 | <i>Anagallis arvensis</i> | Agavaceae | 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 | <i>Viburnum tinus</i> | 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 | Aqueous 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 | <i>Asparagus densiflorus</i> | Asparagaceae | Leaves | Aqueous extract | ----- - | In-vivo | LC50 = 75 ppm LC90 = 102 ppm | Caused atrophy in gonadal cells, reduced reproductive rate and 100% mortality | [32] |
| Egypt | <i>Oreopanax guatemalensis</i> | Araliaceae | Leaves | Aqueous extract | ----- - | In-vivo | LC50 = 160 ppm LC90 = 188 ppm | 100 % motality rate at 1000 mg/L within 24 h | |
| Egypt | <i>Juniperus horizontalis</i> | Cupressaceae | Aerial parts | Methanolic extract | Thujone, D-limonene, β -myrcene, sabinene and methyl citronella te | In-vitro | LC50 = 38.9 ppm | Proved toxic against snail sp. | [33] |
| Egypt | <i>Juniperus communis</i> | Cupressaceae | Aerial parts | Methanolic extract | Sabinene, β -myrcene, D-limonene, | In-vitro | LC50 = 22.9 ppm | Proved toxic against snail sp. | |

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|--|-------|--------------------|------------|-------------|--------------------|--|----------------------|--------------------------------|---|------|
| | | | | | | 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-methoxy-cinnamoyloxyhexacosanoyl)] glycerol | In-vivo | LC50= 72 ppm LC90 = 120 ppm | 90 % mortality rate after 24h | [34] |
| | Egypt | Agave angustifolia | Agavaceae | Whole plant | Aqueous suspension | ----- - | In-vivo, In-vitro | LC90= 120 ppm | Decreased egg laying capacity and survival rate | [35] |

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|-------|--|----------------|------------------------|--------------------|---|----------------------|---|--|------|
| Egypt | <i>Pittosporum tobira</i> | Pittosporaceae | Whole plant | Aqueous suspension | ----- - | In-vivo, In-vitro | LC90= 120 ppm | Decrease in cercaricidal mortality by 81% and miracidia by 87 % | |
| Egypt | <i>Euphorbia peploides</i> | Euphorbiaceae | Aerial parts | Methanolic extract | Quercetin, luteolin, gallic acid, β -amyryn, 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 | <i>Callistemon viminalis</i> | 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 | <i>Eucalyptus globulus</i> , <i>Melaleuca styphelioides</i> | Myrtaceae | Leaves | Methanolic extract | Eucalbanin B, tellimagrandin I, pentagallic acid | 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, casuarini n and 1,2,3,4,6- Penta-O- galloyl-b- D- glucopyr anose | | LC90= 245.5 ppm | phosphatase and 113 % increase in aspartate aminotransferase | |
| | Egypt | Citrus limon | Rutaceae | Peel | Aqueous 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 | Ethanollic 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 sinicum | Solanaceae | Leaves | Ethanollic, 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 | Ethanollic, 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 | Ethanollic 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 | <i>Furcraea selloa marginata</i> | 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 | <i>Euphorbia milii</i> | Euphorbiaceae | Latex | Aqueous solution | ----- - | In-vitro | LC50= 19 ppm LC90= 38 ppm | Proved toxic against snail sp. | [47] |
| Egypt | <i>Meryta denhamii</i> | Araliaceae | Flower | Methanolic extract | Oleonolic acid-3-O- α -arabinopyranoside, oleonic 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 | <i>Guayacum officinalis</i> | Zygophyllaceae | Whole plant | Methanolic, aqueous and ethanolic extract | ----- - | In-vitro | LC50= 120 ppm LC90= 210 ppm | Decreased acetylcholinesterase and Succinate dehydrogenase | [49] |

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

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|-------------------------------|--------------|-------------------------------|---------------|-----------------------|--|--|---------|-------------------|--|------|
| | Egypt | <i>Yucca elephantipes</i> | Agavaceae | Leaves | Methanolic extract | saponin | In-vivo | LC90= 4 ppm | Strong molluscicidal activity | [54] |
| | Egypt | <i>Ambrosia Maritima</i> | Asteraceae | Whole plant | Dry powder | ----- --- | In-vivo | ----- | 95 % decrease number of snails in first month | [55] |
| | Egypt | <i>Azolla pinnata</i> | Salviniaceae | Whole plant | Dry powder | ----- --- | In-vivo | ----- | 94 % decrease number of snails in first month | |
| | Egypt | <i>Commiphora molmol</i> | Burseraceae | Whole plant | Oil and resin extract | ----- --- | In-vivo | LC50= 4 ppm | 100 % mortality rate of both snail sp. | [56] |
| | Saudi Arabia | <i>Rosmarinus officinalis</i> | Lamiaceae | Whole plant | Pet-ether and ethanolic extracts | ----- - | In-vivo | LC50= 236.81 ppm | 85 % mortality rate | [57] |
| | Italy | <i>Vitex trifolia</i> | Verbenaceae | Leaves, stem and seed | chloroform, n-hexane and ethanolic extract | Platonic 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] |
| <i>Biomphalaria pfeifferi</i> | Zimbabwe | <i>Cucurbita maxima</i> | Cucurbitaceae | Seed | Aqueous 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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|--|---------|----------------------------------|--------------|------------------|--------------------|--|----------|--|---------------------------------------|------|
| | | | | | | | | Aqueous extract = 0.002, Ethanollic extract = 0.002 | | |
| | Nigeria | Balanites aegyptiaca | Balanitaceae | Leaves and fruit | Aqueous 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 | Ethanollic 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 | Ethanollic 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 | Ethanollic 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 | Ethanollic 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 | Ethanollic 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 | <i>Pulicaria crispa</i> | 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 | <i>Achyranthes aspera</i> | 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] |

| | | | | | | | | | | |
|--|-------|----------------------|----------------|-----------------|-----------------|------------|---------|---|--|------|
| | | | | | | | | LC50 = 3.10 ppm LC90 = 11.08 ppm | | |
| | Sudan | Solenostemma argel | Asclepiadaceae | Leaves | Aqueous 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 | Aqueous extract | ----- - | In-vivo | ----- | 40 % mortality rate after 24 h | [65] |
| | Kenya | Balanites aegyptiaca | Zygophyllaceae | Root | Aqueous extract | ----- - | In-vivo | ----- | 36 % mortality rate after 24 h | |
| | Kenya | Aspilia pluriseta | Asteraceae | Leaves | Aqueous extract | ----- - | In-vivo | ----- | 50 % mortality rate after 24 h | |
| | Kenya | Psidium guajava | Myrtaceae | Root and leaves | Aqueous extract | ----- - | In-vivo | ----- | 20 % mortality rate after 24 h | |

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|--|---------|-----------------------------|----------------|-----------------|------------------|---|---------|--|--|------|
| | Kenya | <i>Azadirachta indica</i> | Meliaceae | Root and leaves | Aqueous extract | ----- - | In-vivo | ----- | 58 % mortality rate after 24 h | |
| | Sudan | <i>Solenostemma argel</i> | Apocynaceae | Leaves | Aqueous extract | Alkaloids, terpenoids, flavonoids, saponins and tannins | In-vivo | LD50= 0.103 ppm LD95= 0.187 ppm | Behavioral changes | [66] |
| | Nigeria | <i>Balanites aegyptiaca</i> | Zygophyllaceae | Stem and bark | Aqueous solution | 2-methoxy-4-vinylphenol, benzaldehyde, phenol, 2-methoxy-4-(2-propenyl)-acetate, ethanone, 1-(4hydroxyphenyl)-, alpha-d-6,3-furanose, 4-(3-hydroxy- | In-vivo | LD50 (mg/L): For B. pfeifferi juvenile=1.4 For B. pfeifferi adult=1.6 LD90 (mg/L): For B. pfeifferi juvenile=4.8 For B. pfeifferi 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-octadecanamide and di-n-octylphalate | | | | |
| | Mali | <i>Glinus oppositifolius</i> | 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 | <i>Glinus lotoides</i> | 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 | <i>Balanites aegyptiaca</i> | Zygophyllaceae | Seeds, mesocarp, fruit and endocarp | Aqueous extract | ----- - | In-vivo | LC90 (mg/L): Seed= 77.70, Endocarp= 120.04, Mesocarp= 89.50, Fruit=99.55 | 90 % mortality rate | [70] |
| Kenya | <i>Entada leptostachya</i> | Leguminosae | Root | Ethyl acetate, aqueous 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 | <i>Azadirachta indica</i> | Meliaceae | Leaves | Ethyl acetate, aqueous, methanol extract | Alkaloids, glycosides, saponins, flavonoids and | In-vitro | ----- | Only 5 % mortality | |

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|--|---------|---------------------|------------|-----------------------------|--------------------------------|---|----------|---|---|------|
| | | | | | | 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 | Aqueous 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] |

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|--|---------|----------------------------|------------|--------|-----------------------------|------------|----------|---|--|------|
| | Nigeria | <i>Cymbopogon citratus</i> | 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 | <i>Chromolaena odorata</i> | Asteraceae | Leaves | Ethanol 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 | <i>Acacia seyal</i> | Mimosaceae | 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 | <i>Piper guineense</i> | 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 | <i>Anonna senegalensis</i> | 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= 2379.80 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 | <i>Anogeissus leiocarpus</i> | 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 | Ethanollic 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 | Ethanollic 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 |

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| | | | | | | | | LC50 = 399.86 mg/l LC90= 114.84 mg/l | | |
| Nigeria | Vernonia amygdalina | Asteraceae | Leaves and root | Ethanollic extract | ----- - | In-vivo | For leaves: LC50 = 1913.45mg/l LC90= 6241.61 mg/l For roots: LC50 = 917.79 mg/l LC90= 2384.78 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 | Ethanollic extract | ----- - | In-vivo | LC50 B. pfeifferi=2716.3 ppm LC90= 4515.9 ppm | 50 % mortality rate | | [79] |
| Nigeria | Terminalia catappa | Combretaceae | Leaves | Ethanollic extract | ----- - | In-vivo | LC50 = 864.1 ppm LC90= 1222.8 ppm | 100 % mortality rate | | |

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

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

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

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| | | | | | | 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.) | Amaranthace ae | Aerial parts | Essential oil | α - Terpinen e, ascaridol e, thymol, carvacrol, isoascari dole, p- cymene, limonene and γ - terpinene | In-vitro, In-vivo | LC50= 25.2 μ g/mL | 100 % mortality rate at 50 μ g/mL, non-toxic to Artemia salina larvae and Danio rerio fish | [96] |
| | Brazil | Persea Americana Mill. | Lauraceae | Stem and bark | Ethanollic extract | Quercetin , flavonoid , anthraqui none | 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] |

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| | Brazil | <i>Manilkara subsericea</i> | Sapotaceae | Leaves | Ethanollic crude extract and ethyl acetate fraction | Myrcetin, quercetin and ursolic acid | In-vivo | LD50 (µg/mL): For Ethanollic crude extract= 118.7 For ethyl acetate fraction= 23.41 | 53 % mortality rate at 250 µg/mL | [100] |
| | Brazil | <i>Euphorbia umbellata</i> | Euphorbiaceae | Latex | Latex aqueous dilutions | Triterpenes | In-vivo | LC50=1.36 mg/L LC90 =3.69 mg/L | 90 % mortality rate after 24 h, | [101] |
| | Brazil | <i>Anadenanthera colubrina</i> | 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 | <i>Moringa oleifera</i> Lam. | Moringaceae | Flower | Aqueous 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 | <i>Jatropha elliptica</i> | Euphorbiaceae | Root | Ethanol 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 | <i>Schinopsis brasiliensis</i> | Anacardiaceae | Stem, bark | Hydroethanol extract | Xanthones, flavanones and tannin | In-vivo | LC90=73 µg/ml | 60 % mortality rate at 50 µg/ml | [105] | |
| Brazil | <i>Jatropha gossypifolia</i> | Euphorbiaceae | Stem, leaves and fruit | Hydroalcoholic 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 | <i>Moringa oleifera</i> | Moringaceae | Seed | Aqueous extract | ----- | In-vivo | LC50 =0.419 g/l; LC90 =1.021 g/l | Toxic for <i>Biomphalaria glabrata</i> | [107] | |
| Brazil | <i>Piper tuberculatum</i> | 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 | <i>Cymbopogon winterianus</i> | 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 | <i>Porophyllum ruderale</i> | 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 | <i>Euphorbia milii</i> | Euphorbiaceae | Latex | Aqueous solution | ----- -- | In-vivo | LC50= 0.7 μ l | Decreased glycogen content, increased glucose and total protein content | [111] |
| | Brazil | <i>Euphorbia milii</i> | Euphorbiaceae | Latex | Aqueous solution | ----- -- | In-vivo | EC50 = 2040 μ g/L | Increased malformation in embryos | [112] |
| | Brazil | <i>Lippia gracilis</i> | 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 | Hydroalcoholic 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 | Aqueous 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 | Aqueous extract | ----- -- | | In-vivo | LC50= 45.2 µg/mL LC90= 56.0 µg/mL | Toxic against the snail sp. | [118] |

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| | Brazil | <i>Solanum diamantinense</i> | 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 | <i>Solanum paludosum</i> | Solanaceae | Fruit | Methanolic extract | ----- -- | In-vivo | LC50= 48.07 µg/mL LC90= 82.86 µg/mL | High molluscicidal activity against snail sp. | |
| | Brazil | <i>Stryphnodendron adstringens</i> | Mimosoideae | Leaves and bark | Ethanollic extract | Flavano ids | In-vivo | ----- | 90 % mortality rate at 50 ppm | [120] |
| | Brazil | <i>Stryphnodendron polyphyllum</i> | Mimosoideae | Leaves and bark | Ethanollic extract | Flavano ids | In-vivo | ----- | 70 % mortality rate of adult snail | |
| | Brazil | <i>Dimorphandra mollis</i> | Mimosoideae | Leaves and bark | Ethanollic extract | Flavano ids, coumarin s and tannins | In-vivo | ----- | 10 % mortality rate at 100 ppm after 48 h | |
| | Brazil | <i>Caryocar brasiliensis</i> | Caryocaraceae | Leaves and bark | Ethanollic extract | Hydrolys able tannins, flavano ids and condense d tannins | In-vivo | ----- | 90% mortality rate at 100 ppm | |
| | Brazil | <i>Eugenia dysenterica</i> | Myrtaceae | Leaves and bark | Ethanollic extract | Condense d tannins, flavano id | In-vivo | ----- | 100 % mortality rate | |

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

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

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|--------|--------------------------|---------------|-----------------|----------------------------|--|----------|---|---|-------|--|
| | | | | | | | | For egg= 1 | | |
| Brazil | Euphorbia splendens | Euphorbiaceae | Latex | Aqueous 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 | Aqueous extract | ----- -- | In-vitro | LC50= 18.7 g/L | 50 % mortality at 18.7g/L | [125] | |
| Iraq | Ricinus Communis | Euphorbiaceae | Leaves and bark | Aqueous 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 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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| | | | | | | deoxyfur estione | | | | |
| 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 | Aqueous 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 | Ranunculaceae | 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] | |

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| Egypt | <i>Atriplex nummularia</i> | 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 | <i>Glinus oppositifolius</i> | 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 | <i>Sesbania sesban</i> | Leguminosae | Leaves | Methanolic extract | ----- -- | In-vivo, in-vitro | LC50= 15 ppm | Reduced cercarial production and 44 % mortality after 48h | [134] |
| Nigeria | <i>Talinum triangulare</i> | Talinaceae | Root | Ethanollic extracts | ----- -- | In-vivo | LC50= 251 ppm | Ovicidal activity at <300 ppm | [135] |
| Egypt | <i>Adenium obesum</i> | Apocynaceae | Leaves | Methanolic extract | ----- -- | In-vivo | LC25=26.3 % | Reduced protein content in tissues | [136] |
| Sudan | <i>Cymbopogon nervatus</i> | Poaceae | Leaves | Essential oils | ----- -- | In-vivo | LD50 = 237.33 ppm | 100 % mortality rate at 400 ppm | [80] |
| Sudan | <i>Boswellia papyrifera</i> | Burseraceae | Leaves | Essential oils | ----- -- | In-vivo | LD50= 311.05 ppm | 90 % mortality rate at 350 ppm | |

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

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| | | | | | | | | LD90= 95 ppm | | |
| Morocco | <i>Citrus aurantium</i> 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 | <i>Origanum compactum</i> | 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 | <i>Cussonia barteri</i> | Araliaceae | Roots | Methanolic and aqueous extract | ----- --- | In-vitro | | ----- | Extract proved toxic against snail sp. | [85] |
| Mali | <i>Glinus oppositifolius</i> | Aizoaceae | Whole plant | Methanolic and aqueous extract | ----- --- | In-vitro | | ----- | Extract proved toxic against snail sp. | |
| Mali | <i>Lannea velutina</i> | Anacardiaceae | Leaves | Methanolic and aqueous extract | ----- --- | In-vitro | | ----- | Extract proved toxic against snail sp. | |
| Egypt | <i>Commiphora molmol</i> | Burseraceae | Whole plant | Oil and resin extract | ----- --- | In-vivo | | LC50= 3 ppm | 100 % mortality rate | [56] |
| Morocco | <i>Ruta chalepensis</i> L. | Rutaceae | Aerial part | Aqueous and ethanolic extract | Phenol, coumarin, flavanoid, alkaloid, sterol and | In-vivo | | LC50= 1.41 ppm LC90= 2.23 ppm | Strong molluscicidal activity | [139] |

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| | | | | | | terpenoids | | | | |
| Morocco | <i>Zygophyllum gaetulum</i> Emb. | Zygophyllaceae | Aerial part | Aqueous and ethanolic extract | and | Flavonoid and saponin | In-vivo | LC50= 8.69 ppm LC90= 16.82 ppm | High mortality rate | |
| Morocco | <i>Citrus bigaradia</i> Duhamel | Rutaceae | Leaves | Aqueous and ethanolic extract | and | Terpenoid, phenol, coumarins, flavanoid, alkaloid, sterol and terpenoid | In-vivo | LC50= 2.74 ppm LC90= 4.43 ppm | Toxic for adult snails | |
| Morocco | <i>Capparis spinosa</i> L. | Capparidaceae | Aerial part | Aqueous and ethanolic extract | and | Coumarin, alkaloid and sterol | In-vivo | LC50= 70.58 ppm LC90= 122 ppm | Strong molluscicidal activity | |
| Morocco | <i>Chenopodium ambrosioides</i> L. | Chenopodiaceae | Aerial part | Aqueous and ethanolic extract | and | Flavonoid, saponin and terpenoid | In-vivo | LC50= 1.41 ppm LC90= 2.23 ppm | Strong molluscicidal activity | |
| Morocco | <i>Artemisia herba alba</i> Asso. | Asteraceae | Aerial part | Aqueous and ethanolic extract | and | Phenol, flavanoid, alkaloid, | In-vivo | LC50= 62.94 ppm | Strong molluscicidal activity | |

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

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| | Morocco | <i>Chrysanthemum viscidhirtum</i> | Asteraceae | Aerial part | Aqueous and ethanolic extract | Flavonoid and terpenoid | In-vivo | LC50=4.43 ppm LC90=8.39 ppm | Strong molluscicidal activity | |
| | Morocco | <i>Citrullus colocynthis</i> L. | Cucurbitaceae | Fruit, Seed | Aqueous and ethanolic extract | Sterol and terpenoid | In-vivo | LC50= 4.35 ppm LC90= 8.39 ppm | Strong molluscicidal activity | |
| | Morocco | <i>Lavandula stoechas</i> L. | Lamiaceae | Aerial Part | Aqueous and ethanolic extract | Phenol, flavanoid and terpenoid | In-vivo | LC50= 106.7 ppm LC90= 140 ppm | High mortality rate | |
| | China | <i>Solanum xanthocarpum</i> | Solanaceae | Fruit | Ethanolic extract | ----- -- | In-vivo | LC50 (mg/l): =1.35 | 100 % mortality rate | [91] |
| | Germany | <i>Jatropha curcas</i> | Euphorbiaceae | Seed | Methanolic extract | ----- -- | In-vitro | LC100= 1 ppm | 100 % mortality rate of snail specie | [131] |
| <i>Bulinus globosus</i> | Zimbabwe | <i>Cucurbita maxima</i> | Cucurbitaceae | Seed | Aqueous and crude ethanolic extracts | ----- -- | In-vivo | LC50 (mg/ml) for: Aqueous extracts on <i>B. globosus</i> 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 | Amaryllidace ae | 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 | Zygophyllace ae | Stem and bark | Aqueous solution | 2- methoxy- 4- vinylphe nol, benzalde hyde, phenol, 2- methoxy- 4-(2- propenyl) -acetate, ethanone, 1- (4hydrox phenyl)-, 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] |

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| | | | | | | propenyl)-2-methoxy phenol, hexadecanoic acid, 2-butanone, 9-octadecanoic acid, octadecanoic acid, 13-octadecenal, tetradecanoic, 9-octadecanamide and di-n-octylphthalate | | | | |
| | Nigeria | Rhizophora mangle | Rhizophoraceae | Leaves | Methanolic extract | Saponins, glycosides, tannins, alkaloid and flavanoids | In-vivo | LC50 = 87.50 ppm | 90 % mortality rate at 200 ppm | [141] |
| | Nigeria | Rhizophora racemosa | Rhizophoraceae | Leaves | Methanolic extract | Saponins, glycosides, tannins, alkaloid | In-vivo | LC50 = 125 ppm | 100 % mortality rate at 250 ppm | |

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| | | | | | | and flavanoids | | | | |
| Nigeria | <i>Avicennia germinans</i> | Verbenaceae | Leaves | Methanolic extract | Saponins, glycosides, tannins, alkaloid and flavanoids | In-vivo | LC50= 87.50 ppm | 80 % mortality rate at 150 ppm | | |
| Nigeria | <i>Languncularia racemosa</i> | Combretaceae | Leaves | Methanolic extract | Saponins, glycosides, tannins, alkaloid and flavanoids | In-vivo | LC50 = 102.09 ppm | 100 % mortality rate at 50 ppm | | |
| Nigeria | <i>Azadirachta indica</i> | 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 | <i>Talinum triangulare</i> | Portulacaceae | Leaves and root | Ethanol extract | ----- | In-vivo | LC50= 125.89 ppm | 100 % mortality at 160 ppm (root) and 640 ppm (leaves) | [143] | |
| Nigeria | <i>Azadirachta indica</i> | Meliaceae | Leaves, seed and bark | Methanol and decoction extract | Saponin, tannin, flavanoid | In-vitro | ----- | 100 % mortality rate after 24 h | [144] | |

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| | | | | | | and glycoside | | | | |
| | Nigeria | Hyptis suaveolens | Lamiaceae | Leaves | Ethanollic 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 | Ethanollic and methanollic extract | ----- -- | In-vivo | With ethanolic extract: LC50 (ppm) leaf= 0.15 bark = 0.19 Root= 0.18 With methanollic extract: LC50 (ppm) leaf = 0.55 bark= 0.60 root= 0.21 | 100 % mortality rate | [146] |
| | Nigeria | Carica papaya | Caricaceae | Leaves | Ethanollic extract | ----- -- | In-vivo | LC50 = 619.1 ppm LC90= 1180.7 ppm | 100 % mortality rate | [79] |

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| | Nigeria | Terminalia catappa | Combretaceae | Leaves | Ethanol extract | ----- -- | In-vivo | LC50 = 1095.7 ppm LC90 = 1874.9 ppm | 100 % mortality rate | |
| Oncomelania hupensis | China | Camellia oleifera | Theaceae | Seed | Aqueous 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 | Aqueous 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 transferase (GST), carboxylesterase, acid phosphatase and alkaline phosphatase activity | [148] |
| | Philippines | Jatropha curcas L. | Euphorbiaceae | Leaves | Petroleum ether extract | Alkaloids | In-vivo | LD50 = 0.45 mg/mL | 80 % mortality at 1.5 mg/mL | [149] |

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| | | | | | | tannins, terpenoids, flavonoids and saponins | | | | |
| China | <i>Macleaya cordata</i> (Wild) R. | Papaveraceae | Leaves | Aqueous 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 | <i>Buddleja lindleyana</i> | Loganiaceae | Whole plant | Ethanollic extract | Acacetin-7-rutinoside | In-vivo | LC50 = 36:12 mg/L | 100 % mortality at 70 mg/L | [151] | |
| China | <i>Cinnamomum camphora</i> | 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 | Ethanollic 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 | Alcohollic extract | Pulchinoside A3 and Pulchinoside 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 aqueous 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 | <i>Eomecon chionantha</i> | Papaveraceae | Root stalk | Alcoholic extract | Alkaloids | In-vivo | ----- | 100 % mortality rate at 2.5 mg/l and increased amount of alanine aminotransferase | [157] |
| China | <i>Ginkgo biloba</i> | Ginkgoaceae | Leaves | Ethanollic and aqeous extract | ----- -- | In-vivo | ----- | 80 % mortality rate after 24 h, decreased total protein content and glycogen | [158] |
| China | <i>Torreya grandis</i> | Taxaceae | Leaves | Ethanollic and aqeous extract | ----- -- | In-vivo | ----- | 72 % mortality rate after 72 h | |
| China | <i>Ailanthus altissima</i> | Simaroubaceae | Leaves | Ethanollic and aqeous extract | ----- -- | In-vivo | ----- | 40 % mortality rate after 72 h | |
| China | <i>Peucedanum praerutorum</i> | Apiaceae | Root | Ethanollic and aqeous extract | ----- -- | In-vivo | ----- | 83 % mortality rate after 72 h | |
| China | <i>Herba agrimoniae</i> | Rosaceae | Whole plant | Ethanollic and aqeous extract | ----- -- | In-vivo | ----- | 80 % mortality rate after 72 h | |
| China | <i>Buddleja lindleyana</i> | Scrophulariaceae | Leaves | Ethanollic extract | ----- -- | In-vivo | LC50 = 39.91 mg/L LC90 = 59.28 mg/L | 96 % mortality rate after 48 h | [159] |
| China | <i>Eupatorium adenophorum</i> | 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 | Ethanollic extract | ----- -- | In-vitro | LC50= 60.2 mg/L LC90= 145.6 mg/L | Increased activity of <i>alkaline phosphatase and choline esterase</i> | [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 | Ethanollic extract | ----- -- | In-vivo | LC50 = 0.62 mg/l | 100 % mortality rate | [164] |
| Bulinus rholfsi | Nigeria | Rhizophora mangle | Rhizophoraceae | Leaves | Methanollic 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 | Methanollic extract | Saponins, glycosides, tannins, alkaloid and | In-vivo | LC50= 83.51 ppm | 100 % mortality rate at 250 ppm | |

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| | | | | | | flavonoid s | | | | |
| | Nigeria | Avicennia germinans | Verbenaceae | Leaves | Methanolic extract | Saponins, glycoside s, tannins, alkaloid and flavonoid s | In-vivo | LC50 = 123.74 ppm | 80 % mortality rate at 150 ppm | |
| | Nigeria | Languncularia racemosa | Combretacea e | Leaves | Methanolic extract | Saponins, glycoside s, tannins, alkaloid and flavonoid 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 | Phytolaccaceae | 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 | Ethanol 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 and phenoloxidases, deformed egg and sperm | [168] |
| | Egypt | Balanites aegyptiaca | Zygophyllaceae | Fruit | Ethanol extract | Diosgenin and 3,5-spirostadiene | In-vivo | LC50= 0.256 ppm | 73 % mortality rate | [169] |

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| Monacha Obstructa | Egypt | <i>Ricinus communis</i> | Euphorbiaceae | Fruit and leaves | Aqueous 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 | <i>Anagallis arvensis</i> L. | Primulaceae | Leaves and fruit | Hexane extract | Malonic 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 | <i>Solanum nigrum</i> L. | Solanaceae | Leaves and fruit | Hexane extract | ----- - | In-vivo | LC50 after 24h= 2.75 g/ml | Proved 75 % toxic | |
| | Egypt | <i>Cyperus longus</i> L. | Cyperaceae | Rhizome | Hexane extract | ----- - | In-vivo | LC50 after 24h= 3.09 g/ml | Acted as bait (24.2 %) after 96 h | |
| | Saudi Arabia | <i>Adenium obesum</i> | 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 | Aqueous 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 | Ethanollic extract | Tannins, inulin, flavanoids and alkaloids | In-vitro | LC50=83.67 mg/L | 100 % mortality rate after 96h | [176] |
| | Nigeria | Vernonia amygdalina | Asteraceae | Leaves | Ethanollic extract | Tannins, alkaloids, flavanoid | In-vitro | LC50=614.288 mg/L | 100 % mortality rate after 96h | |

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|------------------|---------|--------------------------|-------------|---------------|--------------------|---|----------|--|---|-------|
| | | | | | | s and saponin | | | | |
| | Nigeria | Khaya senegalensis | Meliaceae | Leaves | Ethanollic 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 | Ethanollic 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 | Flavonoids 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 | Ethanollic 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] |

| | | | | | | | | | | |
|---|----------|-----------------------|----------------|------------------------------|--------------------|------------|----------|---|---|--------|
| | | | | | | | | =0.339 g/l; LC90 =0.789 g/l | | |
| Bradybaena similaris | Brazil | Solanum paniculatum | Solanaceae | Leaves | Aqueous 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 | Aqueous extract | ----- - | In-vivo | ----- | 100 % mortality rate at 2000 ppm | [184] |
| Biomphalaria juvenile snails and Bulinus adult snails | Zimbabwe | Curcubita maxima | Cucurbitaceae | Seed | Aqueous extract | ----- - | In-vivo | LC50 (mg/ml): On Biomphalaria juvenile= 0.002 On Bulinus adult = 0.004 | 100 % mortality rate | [185] |

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

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.

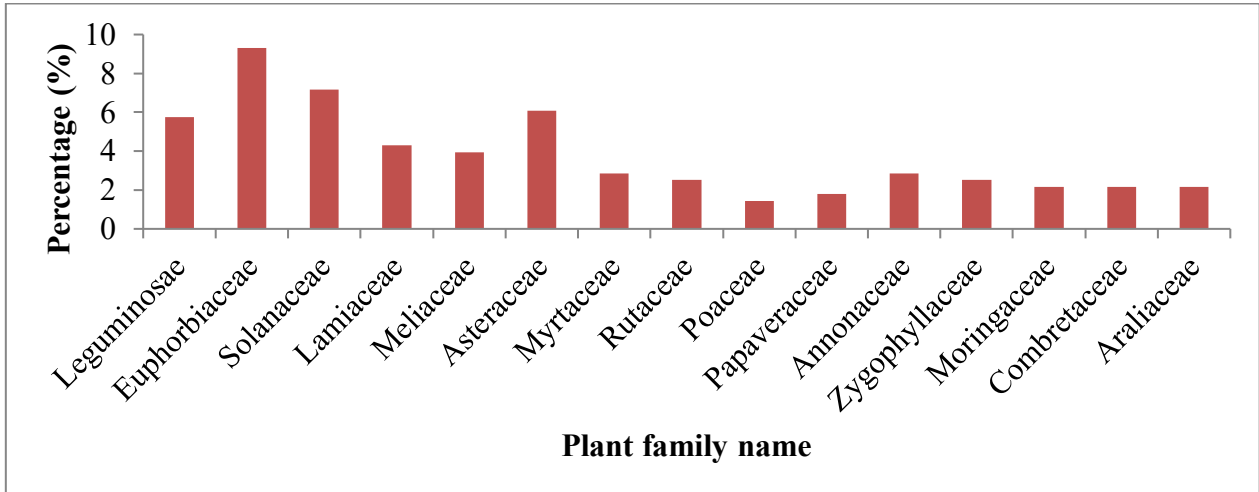


Figure 2: Major plant families exhibiting molluscicidal activity against intermediate snail hosts of schistosomes.

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 %).

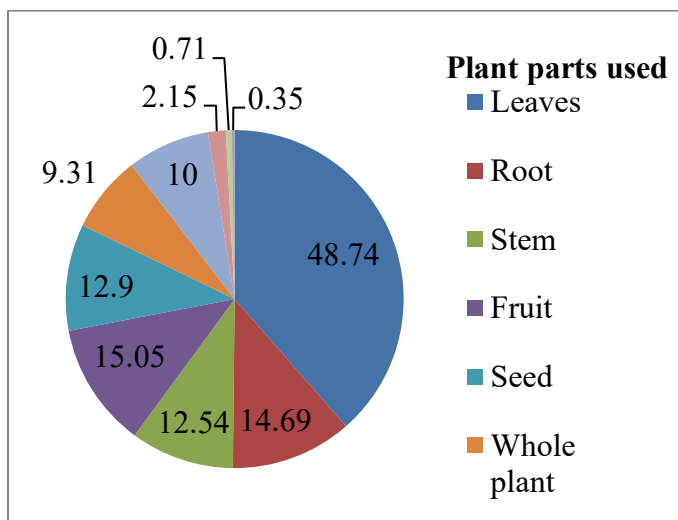


Figure 3: Pie chart depicting the percentage of plant parts used to assess molluscicidal activity.

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*

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

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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