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# Ethnobotanical molluscicides

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**ABSTRACT:** Molluscan are always responsible for human threat direct or indirect ways. A large number of molluscan serve as intermediate host for fasciolosis and schistosomiasis. These both diseases has great outbreak over exploiting the human health and economy. Their prevalence has been increasing worldwide due in large part to programme of water resource development, and poor hygienic conditions. The freshwater gastropods (snails) are the intermediate host for the larval stages of these two trematodes worms where they completed asexual phases of different development stages. Large numbers of treatment are available to tackle the problem of these two neglected tropical disease (NTDs). One of the easiest methods to break the transmission of these diseases is to de-link the intermediate host from helminths life cycle by the use of molluscicides. Currently there is an increased interest to identified the plant and explore their therapeutic potential as a molluscicides. Since the biomolluscicide are the safest, eco-friendly, fast biodegradability and cost effective method for molluscan control as compared to other synthetic counterparts, that are high imported cost, toxicity in non-target biota's, and developing resistance in molluscan. This review is generally concerned with the efforts being made to concise the resources based on the ethnobotanical molluscicides to control the pest population and provide the data source of new researcher to explore the most promising candidates of nature i.e. plant molluscicides, as they are very effective tool for integrated vector management programme yet harmless to other non-target aquatic biota's.

**Keywords:** Ethnobotanical; Molluscicides; Snails; Fasciolosis; Schistosomiasis.

## 1. INTRODUCTION

Mollusca, any soft-bodied invertebrate of the phylum Mollusca, usually wholly or partly enclosed in a calcium carbonate shell secreted by a soft mantle, and successively invaded in both aquatic as well as terrestrial habitat and contributed as second largest species in animal ecosystem [1-3]. Molluscan species can also represent hazards or pest for human activities, snails and slugs can also be serious agricultural pests and accidental or deliberate introduction of some snail species in to new environments has seriously damage some ecosystem. About 100 species of freshwater gastropods are the intermediate hosts of several trematode parasites [4, 5] causing the endemic disease, fasciolosis and schistosomiasis to man and domestic animals [6-10]. Snails act as intermediate host of different trematodes, in which several developing larval stages such as sporocysts, redia and cercaria set up [11]. Only *Lymnaea* group of snails are involved in establishing of life cycle at least 71 species of trematodes [12]. Other species of snails also transmit various trematode parasites of livestock and birds. For example *Indoplanorbis exustus* is responsible for the transmission of *Schistosoma*

*nasale, S. spindal,* and *S. indicum* as well as other trematode such as *Fasciola hepatica* and *F. gigantica*, *Echinostoma* species and some other *Spirorchids* [13, 14]. Age and size of snails, depth of water are some of the factor that appears to affect the prevalence and intensity of digenetic trematode infection in snail intermediate host [15]. Among the various water snails *Lymnaea, Gyraulus, Vivipara* and *Indoplanorbis* species are common cause's trematode infection [16]. These diseases are one of the leading causes of morbidity and mortality both in human and livestock and contribute to socio-economic problem [7, 17-20]. On solution to tackle with the problem of Schistosomiasis/Fasciolosis with the introduction of new and safer drugs for the treatment of NTDs, snail control employed as combating the disease. The use of molluscicides has been and still is the most important method for controlling hosts. These molluscicides may be of synthetic or of plant origin [21, 22]. Researchers have extensively reviewed the different aspect of harmful gastropods control which may be of different type viz- biological, chemical and control by plant derived molluscicide [6, 7, 17, 23] A fast *in vitro* molluscicidal assay may accelerate the development of novel molluscicides. There is a growing interest in phytochemical with potent molluscicidal activity because plants promise to give a wide array of bioactive compounds as molluscicides [24]. Nature has a wide variety of flora, which is rich source of bioactive compounds, about 56 families of angiosperm and more than 1,400 species of plants have been studies for the molluscicidal activity [25].

Extensive researches are going on in different part of the world to explore the molluscicidal property of plants [22, 26-28] and many more might still be waiting to explore. This review is summarized form of the green molluscicides extract from various plant families in recent decade and give the promising result against molluscan pest.

## 2. EUPHORBIACEAE

Family Euphorbiaceae is one of the dominant flowering plant families and has about 7,500 species organized into 300 genera [29, 30]. Several plant of this family has been screen out for their molluscicidal potential. The plants group *Euphorbia royleana, E. antisyphilitica, E. lactea cristata* and *Jatropha gossypifolia* were tested against pest *Lymnaea acuminata* and *Indoplanorbis exustus* and its effect on anti-acetylcholinesterase (anti-AChE) activity was studied [31]. The findings of studied were positive with effective toxicological potential. The order of their effectiveness were: *Euphorbia lactea cristata* > *Euphorbia royleana* > *Jatropha gossypifolia*. The molluscicidal activity of plant extract of *Euphorbia splendens* with cold water, boiled water and organic solvent (methanol, ethanol, acetone and chloroform) against *Biomphalaria alexandrina* snails was evaluated and finally, it was concluded that the application of $LC_{25}$ of methanol extract may be helpful in snail control as it and interferes with the snail's biology and physiology causing significant reduction in their survival and growth rate of treated snails [32] (Table 1).

The Egyptian wild plant namely *Euphorbia splendens* extract was used as botanical toxic agent to study the histopathological effect of on the digestive gland of fresh water snails *B. alexandrina* and *Bulinus trancatus.* The study revealed that *E. splendens* plant has most valuable molluscicidal effect against both the target snails *B. alexandrina* ($LC_{90}$ 51.120 ppm) and *Bulinus trancatus* ($LC_{90}$ 42.871 ppm) [33] (Table 1).

## 3. AGAVOIDEAE

Agavoideae is a subfamily of monocot flowering plants. It has previously been treated as a separate family, Agavaceae. About 640 species are placed in around 23 genera [34, 35]. A number of plants belonging to family Agavaceae have been screen out as molluscicidal agent. The plant of this family *Agave americana*

were tested against eggs and adults of three species of fresh water snails: *Indoplanorbis exustus*, *Lymnaea luteola* and *Gyrau-Lus concexiusculus* and the leaves of *Agave americana* was found to be more potent against all developmental stages of snails [36].

**Table 1.** Families vise molluscicidal activity of plants on intermediate host snail.

| Family | Plant | Active constituents showing molluscicidal potential | Intermediate host snails | References |
|---|---|---|---|---|
| Agavoideae | *Agave americana* | Glycoalkaloids, Azaspirostanol, Saponin | *Indoplanorbis exustus Lymnaea luteola,* | [36] |
| | *Furcraea selloa marginata* | | *Biomphalaria alexandrina* | [37] |
| | *Agave angustifolia, Agave celsii* | | *Biomphalaria alexandrina* | [38, 39] |
| Alliaceae | *Asparagus racemosus* and *Uriginia opigea* | Terpenoids, Steroids, Saponins, Allicin | *Lymnaea natalensis, Bulinus africans* | [45] |
| | *Asparagus racemosus* and *Uriginia opigea* | | *Bulinus africans, Lymnaea natalensis* | [46] |
| | *Allium sativum* | | *L. acuminata and Indoplanorbis exustus* | [47, 48] |
| Amaranthaceae | *Spinacia oleracea* | Chlorophyllin a and b, Triterpenoids and Sterols | *Lymnaea acuminata* | [93] |
| | *Spinacia oleracea* | | *Lymnaea acuminata* | [94-97] |
| | *Amaranthus hybridus* | | *Biomphalaria pfeifferi* | [65] |
| | *Atriplex inflata* | | *Galba truncatula* | [98] |
| | *Achyranthes aspera* | | *Biomphalaria pfeifferi, Lymnaea natalensis* | [99] |
| Apiaceae | *Ammi majus* | Thymols and Acetogenins, Umbeliferon, Limonene | *Biomphalaria alexandrina* | [41] |
| | *Trachyspermum ammi* | | *Lymnaea acuminata* | [42] |
| | *Trachyspermum ammi* | | *Bulinus alexandrina, B. truncatus* and *L. natalensis* | [43] |
| | *Ammi visnaga* | | *Biomphalaria alexandrina* | [39] |
| | *Carum carvi* | | *Lymnaea acuminata* | [40] |
| | *Ferula asafoetida* | | *F. gigantica* inside *L. acuminata* host | [44] |
| | *Ferula asafoetida* | | *Lymnaea acuminata* | [40] |
| Apocynaceae | *Nerium indicum* | Triterpenoids and Saponins | *Lymnaea acuminata* | [52] |
| | *Thevetia peruviana, Nerium indicum* and *Alstonia scholaris, Adenium obesum* | | *L. acuminata and Indoplanorbis exustus* | [53] |
| Araliaceae | *Mertya denhamii* | Monodesmosidic Triterpenoids saponin | *L. natalensis* and *Biomphalaria alexandrina* | [56] |
| Combretaceae | *Terminalia chebula* | Saponin | *L. acuminata* | [67] |
| | *Terminalia catappa* | | *B. globosus* and *B. pfeifferi* | [85] |
| | *Terminalia arjuna* | Arjunolic acid | *Lymnaea acuminata Indoplanorbis exustus* | [59-61] |
| Cucurbitaceae | *Momordica charantia* | Momordicine Benzylamine | *L. acuminata* | [89] |
| | *Momordica charantia* | | *Bulinus globosus* | [90] |
| Cupressaceae | *Juniperus horizontalis* and *Juniperus communis* | Thujone | Sambon worms and *Biomphalaria alexandrina* | [92] |
| Euphorbiaceae | *Euphorbia royleana, E. antisyphilitica, E. lactea cristata Jatropha gossypifolia* | Galic acid, Quarcetin, Apigenin, Milin, Miliamine | *Lymnaea acuminata Indoplanorbis exustus* | [31] |
| | *Euphorbia splendens* | | *B. alexandrina, Bulinus trancatus, B. alexandrina* | [32,33] |

| Family | Plant | Active constituents showing molluscicidal potential | Intermediate host snails | References |
|---|---|---|---|---|
| Fabaceae | *Bauhinia variegata* | Saponin, Procynadine | *Lymnaea acuminata* | [23] |
| | *Delbergia sissoo* | | *Biomphalaria pfeifferi* | [58] |
| | *Tamarindus indica* | | *Lymnaea acuminata Indoplanorbis exustus* | [28, 59-61] |
| Lauraceae | *Cinnamomum tamala* | Linalool | *Lymnaea acuminata Indoplanorbis exustus* | [69] |
| | *Cinnamomum camphora* | | *Oncomelania hupensis. Schistosoma japonicum* | [70] |
| Meliaceae | *Azadirachta indica* | Azadirachtin | *Lymnaea acuminata Indoplanorbis exustus Biomphalaria pfeifferi* | [62, 64, 65] |
| | *Azadirachta indica* oil | | *Achatina fulica* | [63] |
| | *Azadirachta indica* | | *Fasciola gigantica* | [44] |
| Moraceae | *Morus nigra* | Quercetin, Apigenin, Saponins, Cardenolides, Anthraquinones Morusin | *L. acuminata* | [86] |
| | *Ficus exasperate* | | *Biomphalaria pfeifferi* | [87] |
| Moringaceae | *Moringa oleifera* | Momordicine | *L. acuminata* | [89] |
| Piperaceae | *Piper longum* | Piperine | *Lymnaea acuminata* | [73] |
| | *Piper nigrum* | | *L. acuminata, I. exustus* | [74] |
| | *Piper guineense* | | *Biomphalaria pfeifferi* | [75] |
| | *Piper crassinervium* and *P. tuberculatum* | | *B.glabrata* | [76] |
| Sapindaceae | *Sapindus mukorossi* | Saponin | *L. acuminata* | [67] |
| | *Sapindus saponaria* | | *Pomacea canaliculata* | [68] |
| Sapotaceae | *Mimosops elengi* | Quercetin | *Lymnaea acuminata* | [23] |
| | *Manilkara subsericea* | | *Biomphalaria glabrata* | [72] |
| Solanaceae | *Solonum villosum, S. nigrum* and *S. sinaia* | Saponin, Triterpenoids | *B. alexandrina* | [81] |
| | *Solanum xanthocarpum* | | *B. glabrata, Indoplanorbis exustus* | [82] |
| | *Solanum nigrum var. villosum* | | *Galba truncatula* | [83] |
| | *Solanum mammosum* | | *Pomacea canaliculata* | [68] |
| | *Solanum seaforthianum Solanum macrocarpon* | | *B. alexandrina* | [84] |
| Zygophyllaceae | *Tribulus terrestris* | Harmane, Harmine | *Lymnaea acuminata* | [73] |
| | *Guayacum officinalis* | | *B. alexandrina* | [32] |
| | *Balanites aegyptiaca* | | *Lymnaea natalensis, B. pfeifferi* | [78] |
| | *Balanites aegyptiaca* | | *Lymnaea natalensis* | [79] |

The molluscicidal activity of dry leaves powder water suspension of plant *Furcraea selloa marginata* against *Biomphalaria alexandrina* snails was evaluated. The obtained results indicated that the $LC_{50}$ and $LC_{90}$ values after 24h exposure were 53.66 and 84.35 ppm, respectively. The plants have also a larvicidal activity against *Schistosoma mansoni* larva (miracidia, cercaria) [37]. It was reported that the chloroform extract of the plant *Agave angustifolia* caused concentration dependent toxicity and showing 90% of mortality at 120 ppm concentration and prove to be the one of the most promising molluscicidal agent against *Biomphalaria alexandrina* snails [38]. The plant *Agave celsii* showed apparent molluscicidal activity. It was reported that the most effective extract was methanol ($LC_{50}$ 10 ppm) while cold water, boiled water, ethanol, acetone and

chloroform extracts ($LC_{50}$ 32, 21, 30, 44 and 52 ppm, respectively) showed less molluscicidal effect on *Biomphalaria alexandrina* snails [39] (Table 1).

## 4. APIACEAE

Apiaceae (Umbelliferae) the parsley family, in the order Apiales, comprising between 300 and 400 genera of plants distributed throughout a wide variety of habitats and is a 16th-largest family of flowering plants, with more than 3,700 species in 434 genera [35]. The plant *Carum carvi* confirms the presence of toxicological potential against tested species of snail. It has been reported that 96h $LC_{50}$ of column purified fraction of seed powder of *C. carvi* was 5.40 mg/l whereas those of flower bud powder of *Syzygium aromaticum* and dried root latex powder of *Ferula asafoetida* were 7.87 and 9.67 mg/l, respectively against the snail *Lymnaea acuminata* [40]. The water suspension of the plant *Ammi majus* has a highly molluscicidal effect against *Biomphalaria alexandrina* snail as it reduced the total protein and total lipid contents of the hemolymph treated snails. Sublethal doses of copper sulphate (24h $LC_{50}$ 1.79 ppm) and *Ammi majus* flowers water suspension (24h $LC_{50}$ 738.27 ppm) proved to most effective in suppressing egg laying capacity of snails compared to other tested sulphate salts and cold and boiled water extracts of the same plant parts [41] (Table 1).

Member of family Umbelliferae contain compounds that are potential source of molluscicides. *Trachyspermum ammi* fruit extract contains thymols as active constituent's potent molluscicides. It was observed that thymol in single and binary combinations with other herbal molluscicides and the extracted acetogenins caused a significant alternation in the reproductive physiology (fecundity), and developmental issue viz, hatchability and survivability of young ones of *Lymnaea acuminata* [42]. Thymol showed considerable molluscicidal effect against aquatic snails *Biomphalaria alexandrina* ($LC_{50}$ 22 ppm), *Bulinus truncatus* ($LC_{50}$ 20 ppm) and *Lymnaea natalensis* ($LC_{50}$ 18 ppm). Thymol also induced an inhibitory effect in the level of enzymes acetylcholinesterase and succinate dehydrogenase activity [43]. The molluscicidal activity of *Ferula asafoetida* and *Carum carvi* against snail *Lymnaea acuminata* was evaluated and the study showed that the toxicity of dried root latex powder of *Ferula asafoetida* (96h $LC_{50}$ 82.71 mg/l) was more pronounced than that of seed powder of *Carum carvi* (96h $LC_{50}$ 140.58 mg/l) [40] (Table 1).

The plant *Ammi visnaga* methanolic extract was most effective ($LC_{50}$ 26 ppm) than cold water, boiled water, ethanol, acetone and chloroform extracts ($LC_{50}$ 53, 42, 62, 66 and 74, respectively) against *B. alexandrina* snails. Toxicity results were significantly positive with high mortality, reduction in growth, hatchability of their eggs and their infection with *S. mansoni* miracidia. [39]. Study reported that umbeliferon (*Ferula asafoetida*) significantly killed the sporocysts, redia and cercaria larva of *F. gigantica* inside the body of vector snail *L. acuminata* [44]. The study was conducted all over the year to find out the variation in toxicity in different month. The *in vivo* maximum toxicity against the redia and cercaria were reported in the month of May and July (redia 8h $LC_{50}$ 0.93, and 0.89 mg/l; cercaria 8h $LC_{50}$ 0.70, 0.92 mg/l), respectively (Table 1).

## 5. ALLIACEAE

Plants of family Alliaceae have been well identified for its molluscicidal activity. The Plant *Asparagus racemosus* biochemical analysis confirms the presence of terpenoids, steroids and saponins in the plant extracts. It has been studied that the alcoholic and aqueous extracts of *Asparagus racemosus* leaves exhibits high mortality rate against *Lymnaea natalensis* ($LC_{50}$ 1.0 mg/l) and *Biomphalaria pfeifferi* ($LC_{50}$ 5.0

mg/l) Hence prove to be well known candidate for the molluscicidal agent to control various snail borne diseases [45] (Table 1).

The plant *Uriginia opigea* leaves exhibits toxicological potential against *Lymnaea natalensis* and *Bulinus africans*. It was also demonstrated that alcoholic and aqueous extracts of leave causes hightest mortality in treated snails [46]. The water extracts of *Allium sativum* showed high molluscicidal activity against snail *Lymnaea acuminata* and *Indoplanorbis exustus* [47, 48]. It was reported that allicin as molluscicidal component in garlic bulb causing snail death by co-migration of the active agent with extracted and synthetic allicin on TLC plates [48]. The Further study findings suggested that toxic effect of allicin is due to the alteration in various enzyme activity (viz, ALP, ACP, AChE and lactic dehydrogenase) in cerebral ganglionic tissue of snail *L. acuminata.* The inhibition kinetics of these enzymes indicates that allicin caused an uncompetitive inhibition of AChE and a competitive inhibition of LDH and alkaline phosphatase [49] (Table 1).

Researchers studied the molluscicidal effect of *Allium sativum* bulb powder against giant African snail *Achatina fulica*. In their comparative study they found that in single treatments experiment comparing with synthetic molluscicides cypermethrin were potent, whereas *Cedrus deodara* oil was more toxic among molluscicides of plant origin against *A. fulica*. But in binary treatments, a combination of *Cedrus deodara* + *Allium sativum* was more toxic [25] (Table 1).

## 6. APOCYNACEAE

Apocynaceae (commonly known as the dogbane family) is a family of flowering plants that includes trees, shrubs, herbs, stem succulents and vines and contains 424 genera [50, 51]. Different parts of *Nerium indicum* (Family Apocynaceae) has been evaluated for its molluscicidal activity. Low concentrations of vacuum-dried ethanolic extract (24h $LC_{50}$ 4.9 mg/l) and purified bark (24h $LC_{50}$ 0.87 mg/l) were more effectively caused mortality in killing the treated snails at 24h of exposure duration and the lyophilized aqueous extract of bark was more potent (24h $LC_{50}$ 34.5 mg/l) than lyophilized boiled water extract (24h $LC_{50}$ 42.5 mg/l) [52]. The three medicinal plants *Thevetia peruviana*, *Nerium indicum* and *Alstonia scholaris* of family Apocynaceae were tested against vector snails on *L. acuminata* and *I. exustus* for molluscicidal properties [53]. The effect of *Adenium obesum* plant agsinst *Bulinus trancatus* snails were studied, the result of study indicate the plant extract caused significant inhibitory effect on the egg production and hatchability of egg of treated snails. It was also found that the effect of continuous exposure (4 weeks) to $LC_{25}$ (10±0.43) of tested plant completely inhibited egg production after 2 weeks while $LC_{10}$ (5±0.82) of the tested plant stopped snail's egg laying after 3 weeks. It also interferes with the snail's biochemistry and physiology [54] (Table 1).

## 7. ARALIACEAE

The Araliaceae is well known family of flowering plants comprising about 55 genera and 1500 species consisting of primarily woody plants and some herbaceous plants [55]. The *Mertya denhamii* fruits and flowers were tested for its toxicity against *Lymnaea natalensis* and *Biomphalaria alexandrina*. The fraction of flowers were prepared in different solvent viz Butanol, chloroform, petroleum ether and ethyl acetate and was screened out for its molluscicidal potential. Among these, butanol fraction was the most potent against the snails *L. natalensis* ($LD_{50}$ 26.4 mg/l) and *B. alexandrina* ($LD_{50}$ 39.8 mg/l), respectively [56] (Table 1).

## 8. FABACEAE

The Fabaceae (Leguminosae), widely distributed, and is the third-largest land plant with about 751 genera and about 19,000 known species, and having the large number of economically important leguminous plants [57]. The various plant of family Fabaceae is known for their toxic effect against snails. The plant *Bauhinia variegata* leaf powder was reported as a molluscicidal candidate against *L. acuminata*. At 24h exposure period the column purified fraction of *B. variegata* ($LC_{50}$ 20.3 mg/l) was found to be more potent than ethanolic extract of leaf ($LC_{50}$ 38.42 mg/l) [23]. Crude, aqueous and ethanol extract of *Delbergia sissoo* leaves, bark and fruit was tested against *Biomphalaria pfeifferi*. The crude ethanolic extracts of *D. sissoo* fruits and roots exhibited promising molluscicidal activities (24h $LC_{90}$ < 100 mg/l: 74.33, 93.93 mg/l, respectively) [58]. The plant of *Tamarindus indica* have great potential source of ethno-botanical molluscicides against fasciolosis vector snails *L. acuminata* and *I. exustus* [59, 60]. The 96h $LC_{50}$ of column purified fraction of *T. indica* bark against *L. acuminata* and *I. exustus* was 13.78 mg/l and 33.10 mg/l, respectively. Toxicity of 96h $LC_{50}$ of column purified fraction of *T. indica* seed against *L. acuminata* and *I. exustus* were 0.71 mg/l and 21.37 mg/l, respectively. *In vivo* and *in vitro* sublethal doses of active constituents plant extract caused significant inhibitory effect on AChE, ACP and ALP activity in the nervous tissue thus caused alteration in its physiological function lead to the death of treated snail [28, 61] (Table 1).

## 9. MELIACEAE

The Meliaceae family mostly trees and shrubs include about 53 genera and about 600 known species [57]. The plant *Azadirachta indica* has been well known for its different aspect of medicinal properties. Its different parts (leaf, bark) as well as different forms (cake, neem oil and neem based pesticides) were test as molluscicides agents. Achook and Nimbecidine were noted to be more potent against two species of vector snails *L. acuminata* and *I. exustus* [62]. The toxic effect of pure azadirachtin against both the snails was greater than the synthetic molluscicides. The effect of singly and binary combinations of oil with other plant derived molluscicides (*Allium sativum* bulb powder, *Cedrus deodara* oil and *Nerium indicum* bark powder) on the reproduction and survivability of the snail *Achatina fulica* were studied [63]. The molluscicidal effects of methanolic extract of neem plant (leaf, seed, bark, and whole plant) were reported. Among the different extract the whole plant extract was more effective followed by seed, leaves, bark, against the snail *L. auricularia* and *I. exustus*. The mortality percentage in *I. exustus* was on higher side compared to *L. auricularia.* As 100% mortality was observed in *I. exustus* upto a dilution of 1:20 within 48h. The mortality percentage increased with exposure of time and decreased with increase in dilution with highest dilution (1:35) showing 61.11% mortality after 96h. 100% mortality was evident in 1:10 concentration after 48h which reached to 100% in 1:15 concentration within 96h [64]. The experiment were setup to study the larvicidal activity of active component of *Azadirachta indica* with different combination against *Fasciola gigantic* larvae. The findings suggested that binary combination of azadirachtin + allicin was highly toxic against redia and cercaria larva of *Fasciola* [44]. At the concentration of 80 ppm the aqueous extract of *Azadirachta indica* showed significantly higher deaths (28.7±3.2) of the snail *Biomphalaria pfeifferi* [65] (Table 1).

## 10. SAPINDACEAE

The soapberry family, Sapindaceae, contains approximately 1900 species into over 140 genera [66]. The chemical analysis of fruit powder *Sapindus mukorossi* show the presence of saponin as active ingredients

and tested for its toxicity against the vector snail *L. acuminata*. The molluscicidal activity of ethanolic extract of *S. mukorossi* fruit powder at 24h exposure was $LC_{50}$ 2.75 mg/l. The 96 h $LC_{50}$ of column-purified fraction of *S. mukorossi* fruit powder was 5.43 mg/l [67]. The result of the study showed the time and concentration dependent toxicity of this plant extract molluscicides. Earlier, the plant species *Sapindus saponaria* ($LC_{50}$ 66.6 mg/l) was tested as molluscicidal agents against the snail *Pomacea canaliculata* under the field condition [68] (Table 1).

## 11. LAURACEAE

The flowering plant Lauraceae comprises about 2850 known species in about 45 genera worldwide [57]. *Cinnamomum tamala* (Tejpat, Family Luraceae) leaf extract were tested for its toxicological potential against *L. acuminata* and *I. exustus* [69]. The study conducted for different organic solvent extract and the findings of result indicate that ethanol extract of leaf powder was more toxic against *L. acuminata* and *I. exustus* than other organic solvent extract. The plant *Cinnamomum camphora* (L.) Prels leaf extract analysis showed the presence of 44 bioactive components out of which linalool was most abundant constituent and shows the molluscicidal against *Oncomelania hupensis.* It exhibits the striking molluscicidal with $LC_{50}$ 0.25 mg/l for *Oncomelania hupensis.* The larvicidal effect against cercaria of *S. japonicum* was also positive with leathal concentration of 0.07 mg/l [70] (Table 1).

## 12. SAPOTACEAE

The flowering plants family, Sapotaceae, contains about 800 species of trees and shrubs in around 65 genera [71]. *Mimusops elengi* bark powder showed molluscicidal activity against *L. acuminata* [23]. The experiment reveals that *M. elengi* bark column purified fraction was more toxic (96h $LC_{50}$ 7.2 mg/l) than its ethanolic extract (96h $LC_{50}$ 15.0 mg/l). Quercetin is identified as the molluscicidal agent that leads to the death of treated snails. It has been reported that crude extract from leaves of *Manilkara subsericea* showed a promising molluscicidal agent against *Biomphalaria glabrata* (Table 1). *Manilkara subsericea* leaves crude extract and ethyl acetate fraction induced 80±4.13% and 86.66±4.59% mortality of adult snails at concentrations of 250 ppm after 96h, and their $LD_{50}$ values were 118.7± 1.62 and 23.41±1.15 ppm, respectively [72].

## 13. PIPERACEAE

Piperaceae are a large family of flowering plants. It is well known as the pepper family. The group includes about 3,600 species belonging 13 genera. Members of the Piperaceae contain small trees, shrubs, or herbs [35]. The toxic result of dried barriers powder of *Piper cubeba* and dried fruit powder of *Piper longum* of family Piperaceae against snail *L. acuminata* has been demonstrated. The experiment reveals that the toxic effect of *Piper longum* fruit powder (96h $LC_{50}$ 48.99 mg/l) was more effective than fruit powder of *Piper cubeba* (96h $LC_{50}$ 54.01 mg/l). 96h $LC_{50}$ of column purified fraction of *Piper cubeba* was 3.57 mg/l and *Piper longum* was 5.03 mg/l, respectively [73]. *Piper nigrum* showed the molluscicidal activity against the snail *L. acuminata* and *I. exustus* [74]. These snails are vectors of the fluke *Fasciola gigantica*, which causes endemic fascioliasis in the cattle. The toxicity of active component piperine (96h $LC_{50}$ 1.44, 0.82 mg/l) was many times higher than crude fruit powder of *P. nigrum* (black) (96h $LC_{50}$ 10.80, 79.93 mg/l) against *L. acuminata* and *I. exustus*, respectively [74]. It has been stated that the extract from the fruits of the tropical plant *Piper guineense* holds promise in the control of *Biomphalaria pfeifferi* (Table 1). The crude ethanolic extract ($LC_{50}$

0.10±0.04 mg/l) was more potent than hot water extract ($LC_{50}$ 5.0±1.4 mg/l) [75]. It has been reported that *Piper crassinervium* (100% of mortality at 20 mg/l) and *P. tuberculatum* (100% mortality at 30 mg/l) extracts showed most promising molluscicidal effects against adult *Biomphalaria glabrata* and their embryos at blastula stage [76].

## 14. ZYGOPHYLLACEAE

Zygophyllaceae is a family of flowering plants that includes around 285 species in 22 genera [57]. The toxic effect of dried fruit powder of *Tribulus terrestris* (96h $LC_{50}$ 83.49 mg/l) against snail *L. acuminata* has been stated out and it reveals that ethanol extract of the plant was more effective than other organic extracts. 96h $LC_{50}$ of column purified fraction of *Tribulus terrestris* was 13.53 mg/l [73]. The molluscicidal activity of some of plant species extract with cold water, boiled water and organic solvent (methanol, ethanol, acetone and chloroform) against *B. alexandrina* has been evaluated. Zygophyllaceae plant *Guayacum officinalis* showed the significant molluscicidal efficiency. It was reported that $LC_{25}$ of methanol extract of the plant caused a considerable reduction in the infectivity of *Schistosoma mansoni* miracidia to the snail *B. alexandrina* [32].

Freshwater snails and copepods act as intermediary hosts of parasites *Fasciola*, *Schistosoma* and guinea worm. They are repelled or destroy by the bark extracts and the fruit of *Balanites aegyptiaca* [77, 78]. It was reported that the aqueous extracts of different parts of *Balanites aegyptiaca* i.e. seeds, endocarp, mesocarp and whole fruit exhibited reasonable molluscicidal activity against *Biomphalaria pfeifferi* ($LC_{50}$ 56.32, 77.53, 65.51 and 66.63 mg/l, respectively) and *Lymnaea natalensis* ($LC_{50}$ 80.33, 92.61, 83.52 and 87.84 mg/l, respectively) as well as 15 mg/l of seed extract of *B. aegyptiaca* showed cercaricidal activity against *S. mansoni* cercariae [78] (Table 1).

The aqueous extract of leaves, stem-back and roots of *Balanites aegyptiaca* showed the molluscicidal activities against adult *Lymnaea natalensis*, the intermediate host of the helminth *Fasciola hepatica* [79]. It was stated that 10% of aqueous extract of leaves showed stronger molluscicidal activity (66.67% mortality rate) within 24h compared to the stem-back and roots extract. Although, after increasing the concentration of the extract (in %) and inoculation time (in hours) the stem-back and roots extract exhibited less mortality rate than leaves extract [79].

## 15. SOLANACEAE

Solanaceae family consists of about 98 genera with 2,700 species. The members of the Solanaceae family contains potent alkaloids, and some are highly toxic [80]. The molluscicidal activity of the leaves of three species of *Solanum* (*S. villosum, S. nigrum* and *S. sinaicum*) against fresh water snail *B. alexandrina* has screened out [81]. When the mortality of different solvent extracts was compared, the maximum mortality was found in ethanolic extract of *S. nigrum* at the concentration of 90 ppm. Extract of mature leaves of *S. nigrum* exhibited more toxic effect followed by *S. sinaicum* and the less one was *S. villosum*. The effect of crude extract of *Solanum xanthocarpum* against snail *Biomphalaria glabrata* ($LC_{50}$ 163.85 mg/l) and *Indoplanorbis exustus* ($LC_{50}$ 198.00 mg/l) has been reported [82]. Molluscicidal activity of *Solanum nigrum* var. *villosum* (morelle velue) extracts and their fractions has been evaluated against the gastropod *Galba truncatula*, intermediate host of *Fasciola hepatica*. The results indicated that the hydro-methanol (MeOH-$H_2O$) immature fruit extract possess the highest molluscicidal activity ($LC_{50}$ 3.96 mg/l) against *Galba truncatula* compared with other tested compounds [83]. Recently, the molluscicidal activities of different extracts and fractions of

the aerial parts of two *Solanum* species- *Solanum seaforthianum* ($LC_{50}$ 18.8 ppm) and *Solanum macrocarpon* ($LC_{50}$ 7.5 ppm) against *Biomphalaria alexandrina* snails was evaluated [84]. Schistosomicidal potency was also noticed for *Solanum macrocarpon* ($LC_{50}$ 7.6 ppm) and *Solanum seaforthianum* ($LC_{50}$ 8.3 ppm) against washed and sterilized *Schistosoma mansoni* adult worms (Table 1).

**16. COMBRETACEAE**

The Combretaceae family is a flowering plants they includes about 530 species in 10 genera [57]. It has evaluated that the molluscicidal activity of *Terminalia chebula* fruit powder against the vector snail *L. acuminata* was time and concentration dependent [67]. The molluscicidal activity of *T. chebula* fruit powder was $LC_{50}$ 93.59 mg/l and its column purified fraction was $LC_{50}$ 7.49 mg/l at 96h, respectively. It was reported that the molluscicidal effects of ethanolic leaf extracts of *Carica papaya* against *B. pfeifferi* ($LC_{50}$ 2716.3 ppm) and *B. globosus* ($LC_{50}$ 619.1 ppm) snails and *Terminalia catappa* against both snails ($LC_{50}$ 864.1 ppm, $LC_{50}$ 1095.7 ppm), respectively [85]. *Terminalia arjuna* bark and its different organic extract showed the molluscicidal activity against fasciolosis vector snail *Lymnaea acuminata* and *Indoplanorbis exustus* [59, 60]. The result exposed that the toxicity of column purified fraction was higher among all the treatments of *Terminalia arjuna* bark. The 96h $LC_{50}$ of column purified fraction against *L. acuminata* and *I. exustus* was 3.12 mg/l and 14.53 mg/l, respectively (Table 1). Toxicity of arjunolic acid at 24h was 8.00 mg/l and 96h $LC_{50}$ was 1.30 mg/l, respectively against *L. acuminata*. 24h and 96h $LC_{50}$ of *T. arjuna* against *I. exustus* were 30.80 mg/l and 14.53 mg/l, respectively. They further study about the mode of activity of these molluscicides within snail's body and study shows that these treatments have concentration dependent inhibition in key enzymes i.e. AChE, ACP and ACP activities in the nervous tissue of vector snail [61].

**17. MORACEAE**

The Moraceae called mulberry flowering plant comprising 1100 species in 38 genera [57]. The Moraceae plant *Morus nigra* showed molluscicidal activity against snail *L. acuminata* [86]. In the study it was demonstrated that the lethal value of *Morus nigra* fruit powder at 96h was 353.21 mg/l. The ethanolic and aqueous extracts of roots, leaves, bark and seeds of *Ficus exasperata* (Vahl) showed the molluscicidal potency against juvenile and adult *Biomphalaria pfeifferi* [87]. Bark ethanolic extract showed the maximum molluscicidal potency with $LC_{50}$ 0.36 ppm for juveniles and this was followed by leaf ethanolic extracts with $LC_{50}$ 0.39 ppm for adults (Table 1).

**18. MORINGACEAE**

The family Moringaceae is woody tree congaing one genus with 12 species in Madagascar, northeast and southeast Africa and Arabia, with three species in India [88]. The molluscicidal activity of the leaf powder of *Moringa oleifera* has been observed against snail *L. acuminata* [89]. The 96h $LC_{50}$ of the column purified fraction of *M. oleifera* leaf powder was 22.52 ppm. During *in vivo* and *in vitro* experiment, momordicine i.e. the active constituents of *M. oleifera* leaf significantly inhibited the acetylcholinesterase (AChE), acid and alkaline phosphatase (ACP/ALP) activities in the nervous tissues of *L. acuminata*. Inhibition of AChE, ACP and ALP activity in the nervous tissues of *L. acuminata* by momordicine may be responsible for the molluscicidal activity of *M. oleifera* [89] (Table 1).

## 19. CUCURBITACEAE

The Cucurbitaceae family is a plant family they includes about 965 species in around 95 genera [57]. The lyophilized fruit powder of *Momordica charantia* showed molluscicidal effect against snail *L. acuminata.* At 96h of observation period 50% snails were dead at 318.29 mg/l molluscicides. The further study indicated that the active constituents of molluscicides effect on AChE, ACP and ALP activity in the cerebral tissue of *L. acuminata* and leads to the death of treated organism [89]. It has been stated that the lethal concentration ($LC_{50}$) of aqueous, methanolic and ethanolic extracts of *Momordica charantia* showed most promising molluscicidal effect on juvenile (558.99 ppm, 269.86 ppm, and 236.9 ppm, respectively) and adult *Bulinus globosus* (473.49 ppm, 388.46 ppm and 479.84 ppm, respectively) [90] (Table 1).

## 20. CUPRESSACEAE

The Cupressaceae is a conifer includes more than 27 genera includes about 130 species worldwide distribution [91]. Two Juniperus species i.e. *Juniperus horizontalis* Moench and *Juniperus communis* L. are cultivated in Egypt. They showed schistosomicidal and molluscicidal activities. *In vitro* bioassay screening of total methanolic extracts of both *Juniperus* species was carried out. In this experiment *Schistosoma mansoni* Sambon worms and *Biomphalaria alexandrina* (Ehrenberg) snails were used. The result showed that both of the plant extract had similar schistosomicidal activity ($LC_{50}$ 91 µg/ml) while *Juniperus communis* ($LC_{50}$ 22.9 ppm) have more potent molluscicidal activity than *Juniperus horizontalis* ($LC_{50}$ 38.9 ppm) respectively [92] (Table 1).

## 21. AMARANTHACEAE

A flowering plants family, Amaranthaceae, contains 2040 species belonging 165 genera [57]. Spinach (*Spinacia oleracea*) belongs to the family Amaranthaceae. Chlorophyll is found in green leafy vegetables and the richest source is spinach which contains 5.7% of chlorophyll. Chlorophyllin is a semi-synthetic mixture of sodium copper salts derived from chlorophyll. A number of research works proves that chlorophyllin acts as a potent molluscicide. Chlorophyllin showed an effective larvicidal activity against *F. gigantica*. Highest toxicity against both redia and cercaria larvae under red light ($LC_{50}$ 0.788 mg/ml, $LC_{50}$ 1.199 mg/ml, respectively) and lowest under green light ($LC_{50}$ 3.212 mg/ml, $LC_{50}$ 4.380 mg/ml, respectively) was noted [93] and chlorophyllin showed strong anti-reproductive activity against snail *Lymnaea acuminata.* Treatment with 60% of 24h $LC_{50}$ of chlorophyllin caused minimum fecundity (57 eggs/20 snails, 48h) in summer [94]. It was observed that chlorophyllin bait and red light reduce reproduction capacity in snails. Sublethal feeding of chlorophyllin bait with starch (468±0.10/20 snails) or serine (319±0.29/20 snails) attractant to snails caused significant reduction in fecundity, hatchability and survivability. In sunlight and red spectral band maximum fecundity was also observed [95]. Photodynamic activity of chlorophyllin has been observed against snail *L. acuminata* at different wavelengths of visible light (highest in yellow light $LC_{50}$ 392.77 mg/l, lowest in green light $LC_{50}$ 833.02 mg/l) and sunlight (extracted and pure chlorophyllin 331.01 mg/l and 2.60 mg/l, respectively), [96]. Higher Performance Liquid Chromatography (HPLC) study revealed that molluscicidal activity of chlorophyllin is due to their active components i.e. chlorophyllin a and chlorophyllin b [27]. In the cerebral ganglion of snail *Lymnaea acuminata* the biochemical changes was also observed due to the effect of photodynamic chlorophyllin [97]. Maximum reduction was observed in protein (50.19% of control) and enzyme acetylcholinesterase (45.06% of control). *Amaranthus hybridus* exhibited the

best results in terms of toxicity against the vector snail *Biomphalaria pfeifferi*. At the concentration of 80 ppm, *Amaranthus hybridus* extracts of the plant could be more preferred for development of a molluscicide as they resulted in high number of dead snails [65]. It was observed that hexane ($LC_{50}$ 7.59 mg/l, 6.69 mg/l) and ethyl acetate ($LC_{50}$ 5.90 mg/l, 7.32 mg/l) extracts of leaves and fruits of *Atriplex inflata* showed most effective and promising result against *Galba truncatula* snail [98]. It was also noticed that *Achyranthes aspera* has a molluscicidal potential against the snails *Biomphalaria pfeifferi* (24h $LC_{50}$ 72.4 ppm) and *Lymnaea natalensis* (24h $LC_{50}$ 69.5 ppm) [99] (Table 1).

## 22. CONCLUSION

Snails are well known as carriers of diseases and vector of pests. Being largely herbivorous land snails causes immense damage to both cultivated and non-cultivated plants. Control of snail intermediate hosts has been proved to be a fast and efficient approach for interrupting the transmission. Phytochemical screening of various plants has indicated that many plants are endowed with molluscicidal properties that can be harnessed cheaply for vector control and plant extracts have been studied as alternatives to chemical molluscicides. The National and International medicinal system focus towards the natural system of medicine for snail control program. Considering the traditional claim this review assesses the brief description of ethnobotanical molluscicides to control the snail borne control strategy. This plant derived metabolites can also be applied as an alternative drug in modern system of medicine. There immense operational research should be suggested in order to determine its ability to control highly prevalent parasitic disease like schistosomiasis and fasciolosis.

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