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Plant extracts and compounds for combating schistosomiasis

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Abstract Schistosomiasis is a vector-borne water-based disease caused by *Schistosoma* blood flukes. It mostly affects people in low-income regions, 90% of reported cases being in developing countries. *Schistosoma* has a complex lifecycle, alternately infecting mammalian hosts and snails. The snails hosting the parasite are the most viable targets. Selective preparations for reducing the parasite pool in snails and infected water are required as current molluscicides are also nontoxic to other organisms, including fish, and thus affect food supplies in infected areas. Plants (e.g. *Annona crassiflora* Mart., *A. muricata* L., and *A. montana* Macfad.) are attractive potential sources as alternative molluscicides and novel entity to treat the disease owned to their diverse biologically potent compounds including; saponins, alkaloids, terpenoids, and tannins. Additionally, they can be locally cultivated, providing income for farmers and reducing treatment costs. Here, we review plants, plant extracts and isolated compounds that have shown activities against the host snails or *Schistosoma* in various parts of its life cycle. Plants have a lot of potential and will continue to contribute feasible, effective medicines and/or pesticides; more research is warranted to fully explore their future applications.

Dedicated with great pleasure and honor to Prof. Lars Bohlin, Uppsala University, Sweden and Prof. Rob Verpoorte, Leiden University, Netherland on the occasion of their 75th birthday.

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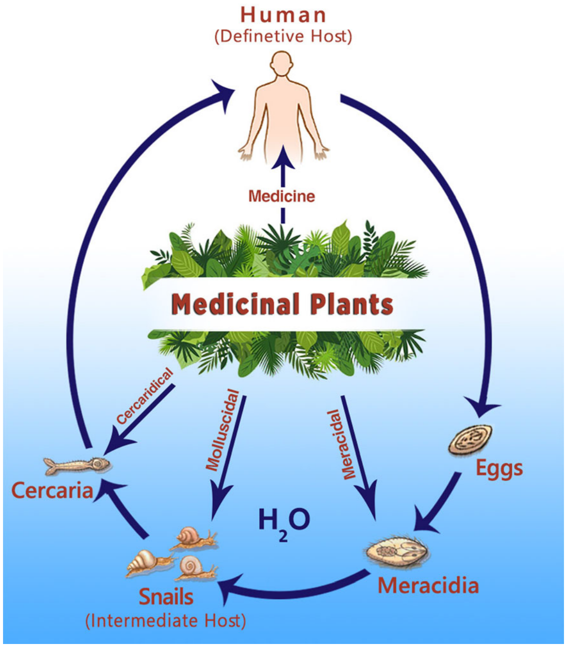
Graphical abstract



Keywords *Schistosomiasis* · Natural products · Molluscicides · Saponins · Glycoalkaloids · Phorbol esters

Introduction

Schistosomiasis, a vector-borne water-based disease caused by *Schistosoma* blood flukes, is one of the most devastating parasitic diseases in tropical and subtropical regions (Walz et al. 2015). It is regarded by World Health Organization (WHO) as the third most common tropical disease, following malaria and intestinal helminthiasis (Murungi et al. 2021). It is also recognized as one of the neglected tropical diseases with high morbidity and mortality rates, affecting a billion of the world's poorest people, mainly in the developing countries (Pereira et al. 2011). The disease is an underappreciated global burden and linked geographically to poverty, and poor health services (Payne and Fitchett 2010). It mostly affects young adults in their productive years, and children younger than 10 years. Untreated infections in young people impair their immunity, increasing their vulnerability to growth retardation, malnutrition and cognitive disorders (Dabo et al. 2011). More than 500,000 people die every year from this parasitic disease (Botelho et al. 2009).

Schistosoma has a complex lifecycle, alternately infecting mammalian hosts and snails especially *S. japonicum* which spreads via all kinds of mammals (Nelwan 2019). One in 30 of the total human

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population surveyed in endemic areas were apparently infected by *Schistosoma* flukes via contaminated water or direct contact with mammals hosting the parasite (Sheir et al. 2001). Molluscicides have a long history of both failures and successes in the control of schistosomiasis (Fenwick et al. 2006). Their application is now considered a key element that has significantly contributed to the decline in schistosomiasis infection and morbidity rates in a number of African countries during the last decades (Brackenbury and Appleton 1997). Chemotherapy and chemoprophylaxis with, praziquantel (PZQ), currently play a crucial role in curing, controlling and preventing the disease (Yousif et al. 2007). PZQ is highly valuable, due to its broad activity spectrum, for instance, it has a potent effect against *S. mansoni* especially at 6–7 weeks old infections. PZQ is thought to target the β subunits of voltage-gated Ca^{2+} channels in *Schistosoma* (Doenhoff et al. 2008). Despite the success, resistance to PZQ is apparently emerging and exacerbating challenges in the management of schistosomiasis globally (Melman et al. 2009). Pinto-Almeida and his colleagues analyze the proteome of *S. mansoni* PZQ-resistant adult worms and compare it with its parental fully PZQ-susceptible strain, using a high throughput LC–MS/MS identification. The results revealed that different proteins of the *S. mansoni* proteome in worms, were downregulated after the exposure to PZQ (Pinto-Almeida et al. 2018). Cotton and Doyle recently identified a gene responsible for PZQ resistance in experimentally selected resistant *S. mansoni*. This study shows that variation at or near Sm. (*S. mansoni*) TRPMPZQ is associated with the resistance (Cotton and Doyle 2022).

Nature has always been a valuable source of drugs and continues to deliver important drug leads (Tulp and Bohlin 2004). WHO estimates that 65–80% of the developing world's population relies on traditional medicine to meet primary health care needs (Kumar et al. 2021) and traditional medicinal plants have supplied numerous pharmacologically active compounds (Yousif et al. 2007). Thus, considerable efforts have been made to identify plants products that are environmentally safe, non-toxic and selectively active for the integrated control of schistosomiasis, and several of them have shown promising results. For example, we have recently shown that the Egyptian medicinal plant *Asparagus stipularis* Forssk. has anti-schistosomal activity (El-Seedi et al. 2012). Recent reports documented the potential of some natural products such as *Pulsatilla chinensis* (Bunge) Regel extracts (Table 1) and its molluscicidal activity against *O. hupensis*. They are less harmful to non-target aquatic organisms than the reference molluscicide niclosamide (Chen et al. 2012). In addition, *Agave attenuata* Salm-Dyck is toxic to the target snail *Bulinus africanus* but has fewer (or no) adverse effects on fish and mammals (Brackenbury and Appleton 1997).

Both synthetic molluscicides and molluscicides derived from plants have made progress in the field of host snails eradication. The rising expense and toxicity to non-target organisms of synthetic molluscicides has rekindled interest in plant-based molluscicides (Clark et al. 1997; Zheng et al. 2021).

This review highlights the use of medicinal plants as new alternatives that could either complement or replace conventional control approaches. Potential molluscicidal plant species and their bioactive constituent based on traditional uses (Tables 2 and 3), are listed, in accordance to the literature survey done on the biological control of *Schistosoma* in the field using natural products, at all life stages.

Life cycle of *Schistosoma* species

There are three main species of human helminth parasites of the genus *Schistosoma*: *S. haematobium*, found in Africa and Asia; *S. mansoni*, present in Africa, the Middle-East and South America; and *S. japonicum*, endemic in China and Southwest Asia (Colley et al. 2014). There are also two minor species, *S. intercalatum* and *S. mekongi*, found in West and central Africa (Colley et al. 2014). The adult worms are live in mesenteric vessels (*S. mansoni* and *S. japonicum*) or the vessels surrounding the bladder (*S. haematobium*). The females produce large numbers of

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Table 1 Bioactive plant extracts reported to have mollusicidal activity against intermediate vector snails

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Acanthaceae						
Acanthus mollis L.-leaves	Bear's Breeches	Petroleum ether	ND	LC_{50} = 6.92 µg/ml LC_{90} = 15.5 µg/ml after 24 h (*B. alexandrina*)	+++ ++	Ahmed and Rifaat (2004)
Acanthaceae + *Iridaceae*						
Binary combination (1:1) of *A. mollis* L. + *Iris pseudacorus* L.	Bear's Breeches + Yellow iris	Petroleum ether	ND	LC_{50} = 3.8 µg/ml after 24 h (*B. alexandrina*)	+++	Ahmed and Rifaat (2004)
Acanthaceae + *Solanaceae*						
Binary combination (1:1) of *A. mollis* L. + *Solanum nigrum* L.	Bear's Breeches + Black nightshade	Petroleum ether	ND	LC_{50} = 5.1 µg/ml LC_{90} = 10.3 µg/ml after 24 h (*B. alexandrina*)	+++ ++	Ahmed and Rifaat (2004)
Agavaceae						
Agave filifera Salm-Dyck-whole plant	Thread-leaf Agave, Thread Agave	Aqueous-suspension	Saponins, catechins, tannins and carbohydrates	LC_{50} = 42.3 µg/ml LC_{90} = 85.6 µg/ml after 24 h (*B. alexandrina*)	++ ++	Rawi et al. (2011)
		Cold-aqueous	Saponins, catechins, tannins and carbohydrates	LC_{50} = 463.0 µg/ml LC_{90} = 692.7 µg/ml after 24 h (*B. alexandrina*)	+ +	
		Boiled-aqueous	Saponins, catechins, tannins and carbohydrates	LC_{50} = 257.0 µg/ml LC_{90} = 328.9 µg/ml after 24 h (*B. alexandrina*)	+ +	

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Amaryllidaceae						
Crinum zeylanicum L.-whole parts	Crinum Lily	Aqueous	Steroids, alkaloids, catechic tannins, flavonoids, albuminoids, phenols, lipoids, aldehydes, mucilages and terpenoids	LC_0 = 10 mg/ml LC_{50} = 50 mg/ml LC_{100} = 100 mg/ml *(B. pfeifferi)* after 24 h	– – – – – –	Chifundera et al. (1993)
		Ethanol	Steroids, alkaloids, catechic tannins, flavonoids, albuminoids, phenols, lipoids, aldehydes, mucilages and terpenoids	LC_0 = 5 mg/ml LC_{50} = 50 mg/ml LC_{100} = 100 µg/ml (*B. pfeifferi*) after 24 h	– – – + – –	
Annonaceae						
Annona crassiflora Mart.-pulps and seeds	Araticum & marolo	Ethanol	Acetogenins	LC_{10} = 0.2 µg/ml LC_{50} = 1.67 µg/ml LC_{90} = 13.2 µg/ml (*B. glabrata*-adult) LC_{10} = 1.0 µg/ml LC_{50} = 1.0 µg/ml LC_{90} = 1.0 µg/ml (*B. glabrata*-egg) after 24 h	+++ +++ ++ +++ +++ +++	dos Santos and Sant'Ana (2001)
A. crassiflora Mart.-stems	Araticum & marolo	Ethanol	Acetogenins	LC_{10} = 0.4 µg/ml LC_{50} = 1.0 µg/ml LC_{90} = 2.3 µg/ml (*B. glabrata*-adult) LC_{10} = 1.0 µg/ml LC_{50} = 1.0 µg/ml LC_{90} = 1.0 µg/ml (*B. glabrata*-egg) after 24 h	+++ +++ +++ +++ +++ +++	dos Santos and Sant'Ana (2001)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
A. crassiflora Mart.-roots wood	Araticum & marolo	Ethanol	Acetogenins	LC_{10} = 8.3 µg/ml LC_{50} = 16.9 µg/ml LC_{90} = 34.5 µg/ml (*B. glabrata*-adult) LC_{10} = 1.0 µg/ml LC_{50} = 1.0 µg/ml LC_{90} = 1.0 µg/ml (*B. glabrata*-egg) after 24 h	++ ++ ++ +++ +++ +++	dos Santos and Sant'Ana (2001)
A. crassiflora Mart.-roots bark	Araticum & marolo	Ethanol	Acetogenins	LC_{10} = 0.3 µg/ml LC_{50} = 1.0 µg/ml LC_{90} = 3.8 µg/ml (*B. glabrata*-adult) LC_{10} = 1.0 µg/ml LC_{50} = 1.0 µg/ml LC_{90} = 1.0 µg/ml (*B. glabrata*-egg) after 24 h	+++ +++ +++ +++ +++ +++	dos Santos and Sant'Ana (2001)
Annona glabra L.-seeds	Pond-apple	Ethanol	Acetogenins	LC_{10} = 5.0 µg/ml LC_{50} = 9.2 µg/ml LC_{90} = 17.0 µg/ml (*B. glabrata*-adult) LC_{10} = 1.0 µg/ml LC_{50} = 1.0 µg/ml LC_{90} = 1.0 µg/ml (*B. glabrata*-egg) after 24 h	++ ++ ++ +++ +++ +++	dos Santos and Sant'Ana (2001)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
A. glabra L.-leaves	Pond-apple	Ethanol	Acetogenins	LC_{10} = 61.7 μg/ml	++	dos Santos and Sant'Ana (2001)
				LC_{50} = 1.0 μg/ml	+++	
				LC_{90} = 3.8 μg/ml	+++	
				(*B. glabrata*-adult)	+++	
				LC_{10} = 1.0 μg/ml	+++	
				LC_{50} = 1.0 μg/ml	+++	
				LC_{90} = 1.0 μg/ml		
				(*B. glabrata*-egg)		
				after 24 h		
Annona muricata L. .-leaves	Graviola,soursop and gunbanana	Ethanol	Acetogenins	LC_{10} = 0.3 μg/ml	+++	dos Santos and Sant'Ana (2001)
				LC_{50} = 1.6 μg/ml	+++	
				LC_{90} = 8.8 μg/ml	++	
				(*B. glabrata*-adult)	++	
				LC_{10} = 9.2 μg/ml	++	
				LC_{50} = 20.3 μg/ml	++	
				LC_{90} = 44.8 μg/ml		
				(*B. glabrata*-egg)		
				after 24 h		
		Ethanol	Flavonoids, xanthones and steroids	$LC_{80} \geq 100$ μg/ml	+	de S. Luna et al. (2005)
				(*B. glabrata*)		
A. muricata L.-stems bark	Graviola,soursop and gunbanana	Ethanol	Acetogenins	LC_{10} = 0.25 μg/ml	+++	dos Santos and Sant'Ana (2001)
				LC_{50} = 0.97 μg/ml	+++	
				LC_{90} = 3.8 μg/ml	+++	
				(*B. glabrata*-adult)	+++	
				LC_{10} = 1 μg/ml	+++	
				LC_{50} = 1 μg/ml	+++	
				LC_{90} = 1 μg/ml		
				(*B. glabrata*-egg)		
				after 24 h		

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Annona montana Macfad Mart.-leaves	Sinini	Ethanol	Acetogenins	LC_{10} = 22.6 µg/ml	++	dos Santos and Sant'Ana (2001)
				LC_{50} = 62.7 µg/ml	++	
				LC_{90} = 173.9 µg/ml	+	
				(*B. glabrata*-adult)	++	
				LC_{10} = 61.6 µg/ml	++	
				LC_{50} = 91.6 µg/ml	+	
				LC_{90} = 136.2 µg/ml		
				(*B. glabrata*-egg)		
				after 24 h		
A. montana.-stems bark	Sinini	Ethanol	Acetogenins	LC_{10} = 0.55 µg/ml	+++	dos Santos and Sant'Ana (2001)
				LC_{50} = 1.9 µg/ml	+++	
				LC_{90} = 6.2 µg/ml	++	
				(*B. glabrata*-adult)	+++	
				LC_{10} = 1 µg/ml	+++	
				LC_{50} = 1 µg/ml	+++	
				LC_{90} = 1 µg/ml		
				(*B. glabrata*-egg)		
				after 24 h		
Annona salzmannii A.DC.-leaves	Araticum-da-mata" and "araticumapé	Ethanol	Acetogenins	LC_{10} = 0.66 µg/ml	+++	dos Santos and Sant'Ana (2001)
				LC_{50} = 0.95 µg/ml	+++	
				LC_{90} = 1.37 µg/ml	+++	
				(*B. glabrata*-adult)	+++	
				LC_{10} = 1 µg/ml	+++	
				LC_{50} = 1 µg/ml	+++	
				LC_{90} = 1 µg/ml		
				(*B. glabrata*-egg)		
				after 24 h		

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Annona squamosa L.-seeds	Custard apple	Ethanol	Acetogenins	LC_{10} = 0.3 µg/ml	+++	dos Santos and Sant'Ana (2001)
				LC_{50} = 7.5 µg/ml	++	
				LC_{90} = 164.02 µg/ml	+	
				(*B. glabrata*-adult)	+++	
				LC_{10} = 1 µg/ml	+++	
				LC_{50} = 1 µg/ml	+++	
				LC_{90} = 1 µg/ml		
				(*B. glabrata*-egg)		
				after 24 h		
A. squamosa L.-stems bark	Custard apple	Ethanol	Acetogenins	LC_{10} = 5.8 µg/ml	++	dos Santos and Sant'Ana (2001)
				LC_{50} = 14.0 µg/ml	++	
				LC_{90} = 34.4 µg/ml	++	
				(*B. glabrata*-adult)	++	
				LC_{10} = 26.4 µg/ml	++	
				LC_{50} = 51.7 µg/ml	+	
				LC_{90} = 101.4 µg/ml		
				(*B. glabrata*-egg)		
				after 24 h		
A. squamosa L.-roots	Custard apple	Ethanol	Acetogenins	LC_{10} = 1.7 µg/ml	+++	dos Santos and Sant'Ana (2001)
				LC_{50} = 3.8 µg/ml	+++	
				LC_{90} = 8.55 µg/ml	++	
				(*B. glabrata*-adult)	++	
				LC_{10} = 16.8 µg/ml	++	
				LC_{50} = 28.8 µg/ml	++	
				LC_{90} = 49.2 µg/ml		
				(*B. glabrata*-egg)		
				after 24 h		

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
A. squamosa L.-leaves	Custard apple	Ethanol	Acetogenins	LC_{10} = 5.4 μg/ml LC_{50} = 44.6 μg/ml LC_{90} = 368.0 μg/ml (*B. glabrata*-adult) LC_{10} = 1 μg/ml LC_{50} = 1 μg/ml LC_{90} = 1 μg/ml (*B. glabrata*-egg) after 24 h	++ ++ + +++ +++ +++	dos Santos and Sant'Ana (2001)
Apiaceae (Umbelliferae)						
Ammi majus L.-flowers	Khella shytani or bullwort	Aqueous-suspension	Saponins, catechins, tannins and carbohydrates	LC_{50} = 747.7 μg/ml LC_{90} = 1370.3 μg/ml after 24 h (*B. alexandrina*)	+ –	Rawi et al. (2011)
		Cold-aqueous	Saponins, catechins, tannins and carbohydrates	LC_{50} = 2126.5 μg/ml LC_{90} = 6775.2 pm after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)
		Boiled-aqueous	Saponins, catechins, tannins and carbohydrates	LC_{50} = 944.9 μg/ml LC_{90} = 1394. μg/ml after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)
A. majus L.-leaves	Khella shytani or bullwort	Aqueous-suspension	Saponins, catechins, tannins and carbohydrates	LC_{50} = 738.3 μg/ml LC_{90} = 1157.2 μg/ml after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)
		Cold-aqueous	Saponins, catechins, tannins and carbohydrates	LC_{50} = 4731.7 μg/ml LC_{90} = 10,377.1 μg/ml after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Boiled-aqueous	Saponins, catechins, tannins and carbohydrates	LC_{50} = 1364.9 µg/ml LC_{90} = 2537.3 µg/ml after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)
		Aqueous	Saponins	$LC_{50\ (N)}$ = 11.100 mg/ml (*B. alexandrina*) $LC_{50\ (N)}$ = 6.700 mg/ml (*Bu. truncatus)* $LC_{50\ (T)}$ = 2.650 mg/ml (*B. alexandrina)* $LC_{50\ (T)}$ = 2.830 mg/ml (*Bu. truncatus)* after 4 w	– – – –	Rawi et al. (1996)
A. majus L.-stems	Khella shytani or bullwort	Aqueous	Saponins	$LC_{50\ (N)}$ = 17.500 mg/ml (*B. alexandrina*) $LC_{50\ (N)}$ = 10.000 mg/ml (*Bu. truncatus)* $LC_{50\ (T)}$ = 4.000 mg/ml (*B. alexandrina)* $LC_{50\ (T)}$ = 3.450 mg/ml (*Bu. truncatus)* after 4 w	– – – –	Rawi et al. (1996)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
A. majus L.-roots	Khella shytani or bullwort	Aqueous	Saponins	$LC_{50\ (N)}$ = 22.500 mg/ml (*B. alexandrina*) $LC_{50\ (N)}$ = 8.400 mg/ml (*Bu. truncatus)* $LC_{50\ (T)}$ = 10.600 mg/ml (*B. alexandrina*) $LC_{50\ (T)}$ = 5.900 mg/ml (*Bu. truncatus)* after 4 w	– – – –	Rawi et al. (1996)
A. majus L.-flowers	Khella shytani or bullwort	Aqueous	Saponins	$LC_{50\ (N)}$ = 1 mg/ml (*B. alexandrina*) $LC_{50\ (N)}$ = 720 µg/ml (*Bu. truncatus)* $LC_{50\ (T)}$ = 815 µg/ml (*B. alexandrina*) $LC_{50\ (T)}$ = 390 µg/ml (*Bu. truncatus)* afer 4 w	+ + + +	Rawi et al. (1996)
Apocynaceae						
Carissa carandas L.-leaves	Karonda	Dry leaves	ND	$LC_{50} > 500$ µg/ml after 24 h (*B. alexandrina*-adult)	+	Mahmoud et al. (2011)
Rauvolfia caffra Sond.-leaves	Quinine tree	Aqueous	ND	LC_{50} = 19.45.2 mg/ml LC_{90} = 7.706 mg/ml after 24 h (*Bu. africanus*)	– –	Clark and Appleton (1997)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Arecaceae						
Areca catechu L.-seeds	Betel nut	Ethanol	Alkaloids	LC_{50} = 17.2 μg/ml after 24 h LC_{50} = 14.1 μg/ml after 48 h LC_{50} = 11.3 μg/ml after 72 h LC_{50} = 8.1 μg/ml after 96 h (***Lymnaea acuminata***)	++ ++ ++ ++	Jaiswal and Singh (2008)
		Powder	Alkaloids	LC_{50} = 27.2 μg/ml after 24 h LC_{50} = 23.3 μg/ml after 48 h LC_{50} = 17.5 μg/ml after 72 h LC_{50} = 12.3 μg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Jaiswal and Singh (2008)
		Chloroform	Alkaloids	LC_{50} = 37.2 μg/ml after 24 h LC_{50} = 28.5 μg/ml after 48 h LC_{50} = 25.5 μg/ml after 72 h LC_{50} = 14.7 μg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Jaiswal and Singh (2008)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Ether	Alkaloids	$LC_{50} = 17.7$ µg/ml after 24 h $LC_{50} = 15.9$ µg/ml after 48 h $LC_{50} = 13.6$ µg/ml after 72 h $LC_{50} = 11$ µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Jaiswal and Singh (2008)
		Acetone	Alkaloids	$LC_{50} = 36$ µg/ml after 24 h $LC_{50} = 28$ µg/ml after 48 h $LC_{50} = 20.3$ µg/ml after 72 h $LC_{50} = 13$ µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Jaiswal and Singh (2008)
		Column purified	Alkaloids	$LC_{50} = 11.3$ µg/ml after 24 h $LC_{50} = 8.4$ µg/ml after 48 h $LC_{50} = 6.7$ µg/ml after 72 h $LC_{50} = 4$ µg/ml after 96 h (*L. acuminata*)	++ ++ ++ +++	Jaiswal and Singh (2008)
Asclepiadaceae						
Marsdenia altissima (Jacq.) Dugand-woods bark	Cipó-Seda	Ethanol	Flavonoids, flavonones, flavones, xanthones, pentacyclic triterpenes and leucoanthocyni-dins	$LC_{80} \geq 100$ µg/ml (*B. glabrata*-adult)	+	de S. Luna et al. (2005)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Calotropis procera -Dry and-whole overground parts	Apple of Sodom	Cold-aqueous suspension	ND	LC_0 = 24.3 µg/ml LC_{10} = 98 µg/ml LC_{25} = 134 µg/ml LC_{50} = 243 µg/ml LC_{90} = 360 µg/ml after 24 h (*B. alexandrina*)	++ ++ + + +	Bakry (2009)
Asparagaceae						
Anemarrhena asphodeloides Bunge-rhizomes	Anemarrhena rhizome, Zhi mu	*n*-Butanol	Saponins and steroidal saponins	LD_{98} = 5 µg/ml after 72 h (*O. hupensis*)	+++	Cui et al. (1999)
Cratylia floribunda Benth.-seeds	Cratylia	*n*-Hexane	Lectins	LC_{10} = 12.9 µg/ml LC_{50} = 25.5 µg/ml LC_{90} = 50.30 µg/ml (*B. glabrata*)	++ ++ ++	dos Santos et al. (2010)
Dioclea guianensis Benth.-seeds		*n*-Hexane	Lectins	LC_{10} = 13 µg/ml LC_{50} = 23.1 µg/ml LC_{90} = 41 µg/ml (*B. glabrata*)	++ ++ ++	dos Santos et al. (2010)
Aspidiaceae						
Elaphoglossum piloselloides (C. Presl) T. Moore-rhizomes, roots and sterile fronds	–	Diethyl ether	Bicyclic phloroglucinols	LC_{50} = 19.6 µg/ml $LC_{100} \leq$ 50.0 µg/ml (*B. peregrine*)	+ +	Socolsky et al. (2009)
Asteraceae (Compositae)						
Achyrocline satureioides (Lam.) DC.-aerial parts	Macela or marcela	Ethanol	Terpenoids, phenylpropanoids, flavonoids	LC_{90} = 43 µg/ml after 24 h (*B. glabrata*)	++	Mendes et al. (1999)
Actinoseris angustifolia (Gardner) Cabrera-aerial parts	–	Ethanol	ND	LC_{90} = 33 µg/ml after 24 h (*B. glabrata*)	++	Mendes et al. (1999)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Alomia myriadenia Sch.Bip. ex Baker-aerial parts	–	Ethanol	ND	LC_{90} = 33 µg/ml after 24 h (*B. glabrata*)	++	Mendes et al. (1999)
Ambrosia maritima L.- aerial parts	Damasissa or sea ragweed	Chloroform	Sesquiterpene lactone	LC_{90} = 3.000 mg/ml (*L. cailliaudi*) LC_{100} = 200 µg/ml (*B. glabrata*)	+ –	Slacanin et al. (1988), Abou Basha et al. (1994)
Artemisia herba-alba Asso-aerial parts	Shih or desert wormwood	Petrol	Phenols, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 62.9 µg/ml LC_{90} = 92 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		n-Hexane	Phenols, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 106.7 µg/ml LC_{90} = 140 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Dichloromethane	Phenols, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 106.7 µg/ml LC_{90} = 140 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Ethyl acetate	Phenols, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 62.9 µg/ml LC_{90} = 92 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Methanol	Phenols, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 106.7 µg/ml LC_{90} = 140 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Aqueous	Phenols, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 2.598 mg/ml LC_{90} = 2.922 mg/ml after 24 h (*Bu. truncatus*)	– –	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Calendula officinalis L.-flowers	African Marigold, Calendula, Common Marigold, Garden Marigold, Marigold, Pot Marigold, Zergul in India, Butterblume in Germany, Chin Chan Ts'ao in China, Galbinele in Romania, and Ringblomma in Sweden	Aqueous	ND	$LC_{50\ (N)}$ = 98 µg/ml (*B. alexandrina*) $LC_{50\ (N)}$ = 81 µg/ml (*Bu. truncatus)* $LC_{50\ (T)}$ = 50 µg/ml (*B. alexandrina*) $LC_{50\ (T)}$ = 18 µg/ml (*Bu. truncatus)* after 4 w	++ ++ ++ ++	Rawi et al. (1996)
C. officinalis L.-leaves		Aqueous	ND	$LC_{50\ (N)}$ = 10 µg/ml (*B. alexandrina*) $LC_{50\ (N)}$ = 81 µg/ml (*Bu. truncatus)* $LC_{50\ (T)}$ = 67 µg/ml (*B. alexandrina*) $LC_{50\ (T)}$ = 40 µg/ml (*Bu. truncatus)* after 4 w	+++ ++ ++ ++	Rawi et al. (1996)
C. officinalis L.-roots		Aqueous	ND	$LC_{50\ (N)}$ = 205 µg/ml (*B. alexandrina*) $LC_{50\ (N)}$ = 183 µg/ml (*Bu. truncatus)* $LC_{50\ (T)}$ = 137 µg/ml (*B. alexandrina*) $LC_{50\ (T)}$ = 109 µg/ml (*Bu. truncatus)* after 4 w	+ + + +	Rawi et al. (1996)
C. officinalis L.-stems		Aqueous	ND	$LC_{50\ (N)}$ = 250 µg/ml (*B. alexandrina*) $LC_{50\ (N)}$ = 210 µg/ml (*Bu. truncatus)* $LC_{50\ (T)}$ = 98 µg/ml (*B. alexandrina*)	+ + ++ ++	Rawi et al. (1996)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				$LC_{50\ (T)}$ = 86 µg/ml (*Bu. truncatus*) after 4 w		
Chromolaena odorata (L.) R.M.King & H.Rob.-leaves	Siam weed, devil weed, French weed, communist weed, hagonoy, co ho	Ethanol	ND	LC_{50} = 44 µg/ml LC_{90} = 119.3 µg/ml after 24 h (*B. pfeifferi*)	++ +	Benson (2012)
		Aqueous	ND	LC_{50} = 65.8 µg/ml LC_{90} = 139.5 µg/ml after 24 h (*B. pfeifferi*)	++ +	Benson (2012)
Chrysanthemum viscidehirtum (Schott) Thell.-aerial parts	Uqhuwan	Petrol	Flavonoids andterpenoids	LC_{50} = 4.4 µg/ml LC_{90} = 8.4 µg/ml after 24 h (*Bu. truncatus*)	+++ ++	Hmamouchi et al. (2000)
		n-Hexane	Flavonoids and terpenoids	LC_{50} = 14.1 µg/ml LC_{90} = 28 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Dichloromethane	Flavonoids and terpenoids	LC_{50} = 5.9 µg/ml LC_{90} = 14.1 µg/ml after 24 h (*Bu. truncatus*)	+++ ++	Hmamouchi et al. (2000)
		Aqueous	Flavonoids and terpenoids	LC_{50} = 891 µg/ml LC_{90} = 1342 µg/ml after 24 h (*Bu. truncatus*)	+ -	Hmamouchi et al. (2000)
Conyza dioscoridis (L.) Desf.-whole overground parts	–	Cold-aqueous suspension	ND	LC_{0} = 300 µg/ml LC_{10} = 2.300 mg/ml LC_{25} = 2.600 mg/ml LC_{50} = 3.000 µg/ml LC_{90} = 4100 mg/ml after 24 h (*B. alexandrina*)	+ – – – –	Bakry (2009)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Echinops ellenbeckii O. Hoffm.-roots	Kebercho	Methanol	Polyphenols and carotenoids	LC_{100} = 20.25 µg/ml after 24 h (*B. pfeifferi*)	++	Hymete et al. (2005)
Echinops longisetus A. Rich.-roots	-	Methanol	Alkaloids, saponins, phytosterols, polyphenols and carotenoids	LC_{100} = 4 µg/ml after 24 h (*B. pfeifferi*)	+++	Hymete et al. (2005)
Piptocarpha rotundifolia (Less.) Baker-aerial parts	Ashdaisy	Ethanol	ND	LC_{90} = 99 µg/ml after 24 h (*B. glabrata*)	++	Mendes et al. (1999)
Vanillosmopsis erythropappa (DC.) Sch.Bip.-aerial parts	Candeia	Ethanol	ND	LC_{90} = 99 µg/ml after 24 h (*B. glabrata*)	++	Mendes et al. (1999), Silvério et al. (2013)
Verbesina clausseni Sch.Bip. ex Baker-aerial parts	–	Ethanol	ND	LC_{90} = 78 µg/ml after 24 h (*B. glabrata*)	++	Mendes et al. (1999)
Buddlejaceae						
Buddleja lindleyana Fortune- Leaves	–	Ethanol	ND	LC_{50} = 39.9 µg/ml LC_{90} = 59.3 µg/ml after 48 h (*O. hupensis*)	++ ++	Han et al. (2010)
Burseraceae						
Commiphora molmol (Engl.) Engl. ex Tschirch-stems	Myrrh	Oil	Essential oil	LC_{50} = 5 µg/ml (*L. natalensis*) LC_{50} = 15 µg/ml (*B. alexandrina*) LC_{50} = 8.5 µg/ml (*Bu. truncatus*) after 24 h LC_{50} = 4 µg/ml (*L. natalensis*) LC_{50} = 6 µg/ml (*B. alexandrina*)	++ ++ ++ +++ ++ ++ +++ +++ ++	Masoud et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				LC_{50} = 7 µg/ml (*Bu. truncatus*) after 48 h LC_{50} = 3 µg/ml (*L. natalensis*) LC_{50} = 3.5 µg/ml (*B. alexandrina*) LC_{50} = 6 µg/ml (*Bu. truncatus*) after 96 h		
Cannaceae						
Canna indica L.-flowers	Indian shot, African arrowroot,	Aqueous-suspension	Saponins, catechins, tannins and carbohydrates	LC_{50} = 7.6001 mg/ml LC_{90} = 13.891 mg/ml after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)
		Cold-aqueous	Saponins, catechins, tannins and carbohydrates	$LC_{50} > 10{,}000$ µg/ml after 24 h (*B. alexandrina*)	–	Rawi et al. (2011)
		Boiled-aqueous	Saponins, catechins, tannins and carbohydrates	LC_{50} = 4.172 mg/ml LC_{90} = 5.160 µg/ml after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)
C. indica L.-leaves	Indian shot, African arrowroot	Aqueous-suspension	Saponins, catechins, tannins and carbohydrates	LC_{50} = 7.220 mg/ml LC_{90} = 14.105 g/ml after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)
		Cold-aqueous	Saponins, catechins, tannins and carbohydrates	$LC_{50} > 10$ mg/ml after 24 h (*B. alexandrina*)	–	Rawi et al. (2011)
		Boiled-aqueous	Saponins, catechins, tannins and carbohydrates	LC_{50} = 7.435 mg/ml LC_{90} = 9.072 mg/ml after 24 h (*B. alexandrina*)	– –	Rawi et al. (2011)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Cannellaceae						
Warburgia salutaris (G.Bertol.) Chiov.-leaves	Pepper-bark tree	Aqueous	ND	LC_{50} = 2.486 mg/ml LC_{90} = 17.370 mg/ml after 24 h (*Bu. africanus*)	– –	Clark and Appleton (1997)
Caricaceae						
Carica papaya L.-seeds and latex	Pappali or papaw or pawpaw	Ethanol	Proteins	LC_{50} = 53.4 mg/ml after 24 h LC_{50} = 43 µg/ml after 48 h LC_{50} = 23 µg/ml after 72 h LC_{50} = 15.9 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Jaiswal and Singh (2008)
		Seed powder	Proteins	LC_{50} = 127.3 µg/ml after 24 h LC_{50} = 102.9 µg/ml after 48 h LC_{50} = 80.9 µg/ml after 72 h LC_{50} = 61.6 µg/ml after 96 h (*L. acuminata*)	+ + ++ ++	Jaiswal and Singh (2008)
		Chloroform	Proteins	LC_{50} = 111.9 µg/ml after 24 h LC_{50} = 103.9 µg/ml after 48 h LC_{50} = 65.7 µg/ml after 72 h LC_{50} = 41.2 µg/ml after 96 h	+ + ++ ++	Jaiswal and Singh (2008)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				(*L. acuminata*)		
		Carbon tetrachloride	Proteins	LC$_{50}$ = 81.2 µg/ml after 24 h LC$_{50}$ = 58.6 µg/ml after 48 h LC$_{50}$ = 42.2 µg/ml after 72 h LC$_{50}$ = 30.8 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Jaiswal and Singh (2008)
		Ether	Proteins	LC$_{50}$ = 111.9 µg/ml after 24 h LC$_{50}$ = 93.5 µg/ml after 48 h LC$_{50}$ = 67.6 µg/ml after 72 h LC$_{50}$ = 13.1 µg/ml after 96 h (*L. acuminata*)	+ ++ ++ ++	Jaiswal and Singh (2008)
		Acetone	Proteins	LC$_{50}$ = 97.8 µg/ml after 24 h LC$_{50}$ = 66.3 µg/ml after 48 h LC$_{50}$ = 41.8 µg/ml after 72 h LC$_{50}$ = 31.7 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Jaiswal and Singh (2008)
		Column purified	Proteins	LC$_{50}$ = 27.3 µg/ml after 24 h LC$_{50}$ = 20.1 µg/ml after 48 h LC$_{50}$ = 12.5 µg/ml	++ ++ ++ ++	Jaiswal and Singh (2008)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				after 72 h LC_{50} = 7.1 µg/ml after 96 h (*L. acuminata*)		
		Lyophilized latex powder	Proteins	LC_{50} = 19.9 µg/ml after 24 h LC_{50} = 16.5 µg/ml after 48 h LC_{50} = 11.9 µg/ml after 72 h LC_{50} = 8.4 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Jaiswal and Singh 2008)
C. papaya L.- Leaves	Pappali or papaw or pawpaw	Ethanol	Polysaccharides, minerals, vitamins, proteins, enzymes, alkaloids, glycosides, fats, oils, lectins, saponins, flavonoids and sterols	LC_{50} = 2716.3 µg/ml LC_{90} = 4.516 mg/ml (*B. pfeifferi*-adult) LC_{50} = 619.1 µg/ml LC_{90} = 1.181 mg/ml (*Bu. globosus*-adult) after 24 h	– – – –	Adetunji and Salawu (2010)
Olea europaea L - waste	Mission olive mill	*n*-hexane	Biophenols	LC_{50} = 424 µg/ml (*Isidorella newcombi*)	+	Obied et al. (2007)
Frantoio olive mill waste		*n*-hexane	Biophenols	LC_{50} = 541 µg/ml (*I. newcombi*)	+	Obied et al. (2007)
Caryocaraceae						
Caryocar brasiliense A.St.-Hil.-leaves	Pequi, souari nut	Ethanol	Tannins, flavanoids and terpenoids	LC_{50} = 20 µg/ml LC_{100} = 90 µg/ml after 48 h (*B. glabrata*)	++ ++	Bezerra et al. (2002)
C. brasiliense A.St.-Hil.-barks	Pequi, souari nut	Ethanol	Tannins, hydrolysable tannins and flavanoids	LC_{50} = 10 µg/ml LC_{100} = 90 µg/ml after 48 h (*B. glabrata*)	++ ++	Bezerra et al. (2002)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Capparidaceae						
Capparis spinosa L.- aerial parts	Flinders rose or caper bush	Petrol	Coumarins, alkaloids, sterols and essential oils	LC_{50} = 70.6 µg/ml LC_{90} = 122 µg/ml after 24 h (*Bu. truncatus*)	++ +	Hmamouchi et al. (2000)
		n-Hexane	Coumarins, alkaloids, sterols and essential oils	LC_{50} = 62.9 µg/ml LC_{90} = 135.5 µg/ml after 24 h (*Bu. truncatus*)	++ +	Hmamouchi et al. (2000)
		Dichloromethane	Coumarins, alkaloids, sterols and essential oils	LC_{50} = 106.7 µg/ml LC_{90} = 140 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Ethyl acetate	Coumarins, alkaloids, sterols and essential oil	LC_{50} = 79.2 µg/ml LC_{90} = 135.5 µg/ml after 24 h (*Bu. truncatus*)	++ +	Hmamouchi et al. (2000)
		Methanol	Coumarins, alkaloids, sterols and essential oils	LC_{50} = 170.6 µg/ml LC_{90} = 194 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Aqueous	Coumarins, alkaloids, sterols and essential oils	LC_{50} = 2.236 mg/ml LC_{90} = 2.846 mg/ml after 24 h (*Bu. Truncates*)	– –	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Chenopodiaceae						
Atriplex stylosa Viv.-whole overground parts	Atriplex	Methanol	ND	LC_0 = 3.1 µg/ml	+++	Bakry (2009)
				LC_{10} = 14 µg/ml	++	
				LC_{25} = 21 µg/ml	++	
				LC_{50} = 31 µg/ml	++	
				LC_{90} = 54 µg/ml	++	
				after 24 h		
				(*B. alexandrina*)		
		Cold-aqueous	ND	LC_0 = 5.3 µg/ml	+++	Bakry (2009)
				LC_{10} = 32 µg/ml	++	
				LC_{25} = 39 µg/ml	++	
				LC_{50} = 53 µg/ml	++	
				LC_{90} = 88 µg/ml	++	
				after 24 h		
				(*B. alexandrina*)		
		Cold-aqueous suspension	ND	LC_0 = 9.2 µg/ml	+++	Bakry (2009)
				LC_{10} = 38 µg/ml	++	
				LC_{25} = 46 µg/ml	++	
				LC_{50} = 94 µg/ml	++	
				LC_{90} = 180 µg/ml	+	
				after 24 h		
				(*B. alexandrina*)		
		Boiled-aqueous	ND	LC_0 = 4.2 µg/ml	+++	Bakry (2009)
				LC_{10} = 22 µg/ml	++	
				LC_{25} = 30 µg/ml	++	
				LC_{50} = 42 µg/ml	++	
				LC_{90} = 56 µg/ml	++	
				after 24 h		
				(*B. alexandrina*)		
		Ethanol	ND	LC_0 = 9.8 µg/ml	++	Bakry (2009)
				LC_{10} = 42 µg/ml	++	
				LC_{25} = 49 µg/ml	++	
				LC_{50} = 62 µg/ml	++	

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				LC_{90} = 98 µg/ml after 24 h (*B. alexandrina*)	++	
		Acetone	ND	LC_{0} = 6.6 µg/ml LC_{10} = 42 µg/ml LC_{25} = 53 µg/ml LC_{50} = 66 µg/ml LC_{90} = 110 µg/ml after 24 h (*B. alexandrina*)	++ ++ ++ ++ +	Bakry (2009)
		chloroform	ND	LC_{0} = 7.4 µg/ml LC_{10} = 54 µg/ml LC_{25} = 62 µg/ml LC_{50} = 74 µg/ml LC_{90} = 130 µg/ml after 24 h (*B. alexandrina*)	++ ++ ++ ++ +	Bakry (2009)
Chenopodium ambrosioides L.-leaves	Mexican tea	Ethanol	Caryophyllene oxide	LC_{10} = 1.99 µg/ml LC_{50} = 13.51 µg/ml LC_{50} = 91.57 pm after 96 h (*B. glabrata*)	+++ ++ ++	dos Santos et al. (2012)
C. ambrosioides L.-aerial parts	Mexican tea	Petrol	Flavonoids, saponins, terpenoids and essential oils	LC_{50} = 7.7 µg/ml LC_{90} = 14.1 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Hexane	Flavonoids, saponins, terpenoids and essential oils	LC_{50} = 1.4 µg/ml LC_{90} = 2.2 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		Dichloromethane	Flavonoids, saponins, terpenoids and essential oils	LC_{50} = 6.5 µg/ml LC_{90} = 9.2 µg/ml after 24 h	++ ++	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				(*Bu. truncatus*)		
		Ethyl acetate	Flavonoids, saponins, terpenoids and essential oils	LC_{50} = 14.1 µg/ml	++	Hmamouchi et al. (2000)
				LC_{90} = 28.0 µg/ml	++	
				after 24 h		
				(*Bu. truncatus*)		
		Methanol	Flavonoids, saponins, terpenoids and essential oils	LC_{50} = 6.9 µg/ml	++	Hmamouchi et al. (2000)
				LC_{90} = 16.8 µg/ml	++	
				after 24 h		
				(*Bu. truncatus*)		
C. murale L.-whole overground parts	Nettle-leaved goosefoot	Cold-aqueous suspension	ND	LC_{25} = 1100 µg/ml	–	Bakry (2009)
				LC_{50} = 2450 µg/ml	–	
				LC_{90} = 5200 µg/ml	–	
				after 24 h		
				(*B. alexandrina*)		
C. ugandae (Aellen) Aellen-whole parts	–	Ethanol	Terpenoids, lipoids, alkaloids, glucides-glycosides, flavonoids, albuminoids, saponins and essential oils	LC_0 = 1 mg/ml	+	Chifundera et al. (1993)
				LC_{50} = 5 mg/ml	–	
				LC_{100} = 10 mg/ml	–	
				(*B. pfeifferi*)	–	
				LC_0 = 1 mg/ml	–	
				LC_{50} = 5 m/ml	–	
				LC_{100} = 10 m/ml		
				(*L. natalensis*)		
				after 24 h		
		Aqueous	Terpenoids, lipoids, alkaloids, glucides-glycosides, flavonoids, albuminoids, saponins and essential oils	LC_0 = 1 mg/ml	+	Chifundera et al. (1993)
				LC_{50} = 5 mg/ml	–	
				LC_{100} = 10 mg/ml	–	
				(*B. pfeifferi*)	–	
				LC_0 = 1 mg/ml	–	
				LC_{50} = 5 × 10^3 mg/ml	–	
				LC_{100} = 10 × 10^3 mg/ml		
				(*L. natalensis*)		
				after 24 h		

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Chrysobalanaceae						
Licania cariae Cardozo-leaves	–	Methanol	Catechins, flavonoid glycosides and sugars	LC_{50} = 25 µg/ml LC_{100} = 400 µg/ml after 24 h (*B. glabrata*)	++ +	Bilia et al. (2000a)
L. densiflora Kleinh.-leaves	–	Methanol	Catechins, flavonoids, flavonoid glycosides, sugars and tannins	LC_0 = 200 µg/ml LC_{100} = 400 µg/ml after 24 h (*B. glabrata*)	+ +	Bilia et al. (2000a)
L. heteromorpha Benth.-leaves	–	Methanol	Catechins, flavonoids, flavonoid glycosides, sugars and tannins	LC_0 = 100 µg/ml LC_{100} = 400 µg/ml after 24 h (*B. glabrata*)	– +	Bilia et al. (2000a)
L. licaniiflora (Sagot) S.F.Blake-leaves	–	Methanol	Flavonoids, flavonoid glycosides Triterpenes and triterpene glycosides	LC_0 = 400 µg/ml after 24 h (*B. glabrata*)	–	Bilia et al. (2000a)
L. pittieri Prance-leaves	–	Methanol	Catechins, flavonoids and flavonoid glycosides	LC_{50} = 25 µg/ml LC_{100} = 400 µg/ml after 24 h (*B. glabrata*)	++ +	Bilia et al. (2000a)
L. pyrifolia Griseb.-leaves	Merecure	Methanol	Catechins, flavonoids, flavonoid glycosides and carbohydrates	LC_{50} = 25 µg/ml LC_{100} = 400 µg/ml after 24 h (*B. glabrata*)	++ +	Bilia et al. (2000a)
		Chloroform/ Methanol	Triterpenes, triterpene glycosides, catechins, flavonoids and flavonoid glycosides	LC_0 = 50 µg/ml LC_{50} = 100 µg/ml LC_{100} = 400 µg/ml after 24 h (*B. glabrata*)	++ + +	Bilia et al. (2000a)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Combretaceae						
Commiphora molmol (Engl.) Engl. ex Tschirch	Myrrh	Emulsified oil	Terpenes	LC_{50} = 155 µg/ml LC_{90} = 195 µg/ml (*B. alexandrina)* LC_{50} = 50 µg/ml LC_{90} = 95 µg/ml (*B. truncates*) LC_{50} = 50 µg/ml LC_{90} = 85 µg/ml (*L. cailliaudi*) after 24 h	+ + ++ ++ ++ ++	Allam et al. (2001)
Meryta denhamii Seem.-flowers	Pacific puka	Methanol	ND	LC_{50} = 72.4 µg/ml LC_{90} = 125 µg/ml (*L. cailliaudi)* LC_{50} = 85 µg/ml LC_{90} = 155 µg/ml (*B. alexandrina)*	++ + ++ +	Hassan et al. (2010)
		Butanol	ND	LC_{50} = 26.4 µg/ml LC_{90} = 70.8 µg/ml (*L. cailliaudi)* LC_{50} = 39.8 µg/ml LC_{90} = 79.4 µg/ml (*B. alexandrina)*	++ ++ ++ ++	Hassan et al. (2010)
		Chloroform	ND	LC_{50} = 306 µg/ml LC_{90} = 125.8 µg/ml (*L. cailliaudi)*	+ +	Hassan et al. (2010)
		Petroleum ether	ND	LC_{50} = 236.7 µg/ml LC_{90} = 931.8 µg/ml (*L. cailliaudi)*	+ +	Hassan et al. (2010)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
M. denhamii Seem.-fruits	Pacific puka	Methanol	ND	LC_{50} = 100 µg/ml LC_{90} = 165 µg/ml (*L. cailliaudi)* LC_{50} = 85 µg/ml LC_{90} = 138 µg/ml (*B. alexandrina)*	+ + ++ +	Hassan et al. (2010)
Terminalia catappa L.-leaves	Indian-almond	Ethanol	ND	LC_{50} = 864.1 µg/ml LC_{90} = 1222.8 µg/ml (*B. pfeifferi*-adult) LC_{50} = 1095.7 µg/ml LC_{90} = 1874.9 µg/ml *(Bu. globosus*-adult) after 24 h	+ – – –	Adetunji and Salawu (2010)
Cucurbitaceae						
Citrullus colocynthis (L.) Schrad.- fruits and seeds	Handal	Petrol	Sterols and terpenoids	LC_{50} = 6.5 µg/ml LC_{90} = 9.2 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		n-Hexane	Sterols and terpenoids	LC_{50} = 4.4 µg/ml LC_{90} = 8.4 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		Dichloromethane	Sterols and terpenoids	LC_{50} = 13.0 µg/ml LC_{90} = 18.3 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Ethyl acetate	Sterols and terpenoids	LC_{50} = 135.5 µg/ml LC_{90} = 186 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Methanol	Sterols and terpenoids	LC_{50} = 70.6 µg/ml LC_{90} = 122 µg/ml after 24 h (*Bu. truncatus*)	++ +	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Dioscoreaceae						
Dioscorea zingiberensis C.H.Wright-rhizomes	Yams	*n*-Butanol	Saponins and steroidalsaponins	$LC_{98} = 5$ µg/ml after 72 h (*O. hupensis*)	+++	Cui et al. (1999)
Dipsacaceae						
Cephalaria ambrosioides (Sm.) Roem. & Schult.- roots	Mexican tea	Acetone/ Methanol	Terpenoids and saponins	$LC_{100} > 50$ µg/ml after 24 h (*B. glabrata*)	+++	Pasi et al. (2009)
Euphorbiaceae						
Acalypha indica L.- Leaves	Indian Nettle	Ethanol	Glycosides, steroids and terpenoids	$LC_{50} = 30$ µg/ml after 24 h $LC_{50} = 26$ µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Distilled water	Glycosides, steroids and terpenoids	$LC_{50} = 50$ µg/ml after 24 h $LC_{50} = 45$ µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Chlorinated water	Glycosides, steroids and terpenoids	$LC_{50} = 80$ µg/ml after 24 h $LC_{50} = 70$ µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Tap water	Glycosides, steroids and terpenoids	$LC_{50} = 80$ µg/ml after 24 h $LC_{50} = 70$ µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Euphorbia aphylla Brouss. ex Willd.-aerial parts	Leafless Spurge	Ethanol	ND	LC_{50} = 0.66 µg/ml LC_{90} = 0.88 µg/ml (*L. cailliaudi*) LC_{50} = 87.6 µg/ml LC_{90} = 142.5 µg/ml (*B. alexandrina*) after 24 h	+++ +++ ++ +	Hassan et al. (2012)
Euphorbia helioscopia L.-fresh leaves	Sun spurge	Cold-aqueous	ND	LC_{50} = 80 µg/ml LC_{90} = 109.6 µg/ml after 24 h (*Bu. wrighti*)	++ +	Al-Zanbagi (2005)
		Hot-aqueous	ND	LC_{50} = 96.6 µg/ml LC_{90} = 117.7 µg/ml after 24 h (*Bu. wrighti*)	++ +	Al-Zanbagi (2005)
		Methanol	ND	LC_{50} = 11.3 µg/ml LC_{90} = 18.3 µg/ml after 24 h (*Bu. wrighti*)	++ ++	Al-Zanbagi (2005)
		Chloroform	ND	LC_{50} = 80.5 µg/ml LC_{90} = 173.4 µg/ml after 24 h (*Bu. wrighti*)	++ +	Al-Zanbagi (2005)
		Acetone	ND	LC_{50} = 8.9 µg/ml LC_{90} = 17.5 µg/ml after 24 h (*Bu. wrighti*)	++ ++	Al-Zanbagi (2005)
		n-Hexane	ND	LC_{50} = 99.0 µg/ml LC_{90} = 127.7 µg/ml after 24 h (*Bu. wrighti*)	++ +	Al-Zanbagi (2005)
		Methanol	ND	LC_{50} = 44.3 µg/ml	++ ++	Al-Zanbagi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				LC_{90} = 65.5 µg/ml after 24 h (*B. pfeifferi*)		
		Chloroform	ND	LC_{50} = 76.9 µg/ml LC_{90} = 114.6 µg/ml after 24 h (*B. pfeifferi*)	++ +	Al-Zanbagi et al. (2000)
		Acetone	ND	LC_{50} = 91 µg/ml LC_{90} = 110 µg/ml after 24 h (*B. pfeifferi*)	++ +	Al-Zanbagi et al. (2000)
Euphorbia helioscopia L.-dry leaves	Sun spurge	Methanol	ND	LC_{50} = 50.8 µg/ml LC_{90} = 68.2 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Acetone	ND	LC_{50} = 85.3 µg/ml LC_{90} = 101.4 µg/ml after 24 h (*B. pfeifferi*)	++ +	Al-Zanbagi et al. (2000)
Euphorbia helioscopia L.-fresh stems	Sun spurge	Methanol	ND	LC_{50} = 95 µg/ml LC_{90} = 111.7 µg/ml after 24 h (*B. pfeifferi*)	++ +	Al-Zanbagi et al. (2000)
		Chloroform	ND	LC_{50} = 55.9 µg/ml LC_{90} = 73 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Acetone	ND	LC_{50} = 50 µg/ml LC_{90} = 57.4 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		n-Hexane	ND	LC_{50} = 23 µg/ml LC_{90} = 31.7 µg/ml after 24 h	++ ++	Al-Zanbagi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				(*B. pfeifferi*)		
Euphorbia helioscopia L.-dry stems	Sun spurge	Chloroform	ND	LC_{50} = 75 µg/ml LC_{90} = 102 µg/ml after 24 h (*B. pfeifferi*)	++ +	Al-Zanbagi et al. (2000)
		Acetone	ND	LC_{50} = 69.3 µg/ml LC_{90} = 81.1 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
Euphorbia hirta L.-leaves	Ammampachcharisi Garden Spurge	Ethanol	Glycosides, steroids and terpenoids	LC_{50} = 20 µg/ml after 24 h LC_{50} = 17 µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Distilled water	Glycosides, steroids and terpenoids	LC_{50} = 40 µg/ml after 24 h LC_{50} = 35 µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Chlorinated water	Glycosides, steroids and terpenoids	LC_{50} = 60 µg/ml after 24 h LC_{50} = 55 µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Tap water	Glycosides, steroids and terpenoids	LC_{50} = 70 µg/ml after 24 h LC_{50} = 60 µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
E. hirta L.-latex	Ammampachcharisi Garden Spurge	Powder	ND	LC_{50} = 7.3 µg/ml after 24 h LC_{50} = 5.5 µg/ml after 48 h LC_{50} = 4.9 µg/ml after 72 h LC_{50} = 3.9 µg/ml after 96 h (*L. acuminata*)	+++ +++ +++ +++	Yadav and Singh (2011)
Euphorbia milii Des Moul	Christplant	ND	ND	LC_{50} = 19 µg/ml LC_{90} = 38 µg/ml *(B. alexandrina)*	++ ++	Bakry and Mohamed (2011)
Euphorbia schimperiana Scheele-fresh leaves	–	Hot-aqueous	ND	LC_{50} = 72.8 µg/ml LC_{90} = 140.6 µg/ml after 24 h (*Bu. wrighti*)	++ +	Al-Zanbagi (2005)
		Cold-aqueous	ND	LC_{50} = 81.8 µg/ml LC_{90} = 106 µg/ml after 24 h (*Bu. wrighti*)	++ +	Al-Zanbagi (2005)
		Methanol	ND	LC_{50} = 2.3 µg/ml LC_{90} = 6.9 µg/ml after 24 h (*Bu. wrighti*)	+++ ++	Al-Zanbagi (2005)
		Chloroform	ND	LC_{50} = 3 µg/ml LC_{90} = 7.7 µg/ml after 24 h (*Bu. wrighti*)	+++ ++	Al-Zanbagi (2005)
		Acetone	ND	LC_{50} = 10.1 µg/ml LC_{90} = 13.99 pm after 24 h (*Bu. wrighti*)	++ ++	Al-Zanbagi (2005)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		n-Hexane	ND	LC_{50} = 18 µg/ml LC_{90} = 38.6 µg/ml after 24 h (*Bu. wrighti*)	++ ++	Al-Zanbagi (2005)
		Methanol	ND	LC_{50} = 18.6 µg/ml LC_{90} = 23.8 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Chloroform	ND	LC_{50} = 2.2 µg/ml LC_{90} = 5.6 µg/ml after 24 h (*B. pfeifferi*)	+++ +++	Al-Zanbagi et al. (2000)
		Acetone	ND	LC_{50} = 17.7 µg/ml LC_{90} = 24.4 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		n-Hexane	ND	LC_{50} = 11.2 µg/ml LC_{90} = 20.8 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
E. schimperiana Scheele-dry leaves	–	Methanol	ND	LC_{50} = 73.3 µg/ml LC_{90} = 95.9 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Chloroform	ND	LC_{50} = 34.8 µg/ml LC_{90} = 56.9 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Acetone	ND	LC_{50} = 73.6 µg/ml LC_{90} = 79.9 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		n-Hexane	ND	LC_{50} = 49.0 µg/ml LC_{90} = 71.6 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
E. schimperiana Scheele-fresh stems		Acetone	ND	LC_{50} = 19.5 µg/ml LC_{90} = 26 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Methanol	ND	LC_{50} = 53.8 µg/ml LC_{90} = 86 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Chloroform	ND	LC_{50} = 10.5 µg/ml LC_{90} = 19.2 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		n-Hexane	ND	LC_{50} = 15 µg/ml LC_{90} = 28.4 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
E. schimperiana Scheele-dry stems	=	Methanol	ND	LC_{50} = 7.6 µg/ml LC_{90} = 11.8 µg/ml after 24 h (*B. pfeifferi*)	+++ ++	Al-Zanbagi et al. (2000)
		Chloroform	ND	LC_{50} = 40.5 µg/ml LC_{90} = 47.5 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Acetone	ND	LC_{50} = 20.9 µg/ml LC_{90} = 33.3 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		n-Hexane	ND	LC_{50} = 27 µg/ml LC_{90} = 38.8 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
E. splendens Bojer ex Hook.-whole overground parts	–	Cold-aqueous suspension	ND	LC_0 = 4 µg/ml LC_{10} = 22 µg/ml LC_{25} = 29 µg/ml LC_{50} = 40 µg/ml LC_{90} = 73 µg/ml after 24 h (*B. alexandrina*)	+++ ++ ++ ++ ++	Bakry (2009)
		Cold-aqueous	ND	LC_0 = 3.2 µg/ml LC_{10} = 13 µg/ml LC_{25} = 21 µg/ml LC_{50} = 32 µg/ml LC_{90} = 54 µg/ml after 24 h (*B. alexandrina*)	+++ ++ ++ ++ ++	Bakry (2009)
		Boiled-aqueous	ND	LC_0 = 2.1 µg/ml LC_{10} = 11 µg/ml LC_{25} = 15 µg/ml LC_{50} = 21 µg/ml LC_{90} = 28 µg/ml after 24 h (*B. alexandrina*)	+++ ++ ++ ++ ++	Bakry (2009)
		Methanol	ND	LC_0 = 1.1 µg/ml LC_{10} = 6.2 µg/ml LC_{25} = 8.4 µg/ml LC_{50} = 11 µg/ml LC_{90} = 27 µg/ml after 24 h (*B. alexandrina*)	+++ ++ ++ ++ ++	Bakry (2009)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Ethanol	ND	LC_0 = 3 µg/ml LC_{10} = 18 µg/ml LC_{25} = 23 µg/ml LC_{50} = 30 µg/ml LC_{90} = 48 µg/ml after 24 h (*B. alexandrina*)	+++ ++ ++ ++ ++	Bakry (2009)
		Acetone	ND	LC_0 = 4.4 µg/ml LC_{10} = 22 µg/ml LC_{25} = 31 µg/ml LC_{50} = 44 µg/ml LC_{90} = 62 µg/ml after 24 h (*B. alexandrina*)	+++ ++ ++ ++ ++	Bakry (2009)
		Chloroform	ND	LC_0 = 5.2 µg/ml LC_{10} = 30 µg/ml LC_{25} = 41 µg/ml LC_{50} = 52 µg/ml LC_{90} = 78 µg/ml after 24 h (*B. alexandrina*)	++ ++ ++ ++ ++	Bakry (2009)
Euphorbia splendens Bojer ex Hook.-latex	–	Aqueous	ND	LC_{90} (S.) = 1.5 µg/ml LC_{90} (Su.) = 0.55 µg/ml LC_{90} (F.) = 0.7 µg/ml LC_{90} (W.) = 0.9 µg/ml after 24 h (*L. columella*)	+++ +++ +++ +++	de Vasconcellos and de Amorim (2003)
Jatropha curcas L.- Latex	Physic nut	Acetonitrile	ND	LC_{50} = 6 µg/ml LC_{90} = 10 µg/ml after 24 h (*B. alexandrina*)	+++ +++	Abdel-Hamid (2003)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
J. curcas L.-seeds	Physic nut	Methanol	Phorbol esters	LC_{50} = 5 µg/ml LC_{100} = 25 µg/ml after 24 h (*B. glabrata*)	+++ ++	Rug and Ruppel (2000)
		Aqueous	Phorbol esters	LC_{50} = 5.000 mg/ml after 24 h (*B. glabrata)*	–	Rug and Ruppel (2000)
		Crude oil	Phorbol esters	LC_{50} = 50 µg/ml LC_{100} = 100 µg/ml after 24 h (*B. glabrata*)	++ +	Rug and Ruppel (2000)
		Methanol	Phorbol esters	LC_{50} = 0.2 µg/ml (*Bu. truncatus*) LC_{100} = 1 µg/ml (*Bu. natalensis)* after 24 h	+++ +++	Rug and Ruppel (2000)
Jatropha glauca Vahl-dry leaves		Cold-aqueous	ND	LC_{50} = 73.3 µg/ml LC_{90} = 118.8 µg/ml after 24 h (*B. pfeifferi*)	++ +	Al-Zanbagi et al. (2000)
		Methanol	ND	LC_{50} = 84.9 µg/ml LC_{90} = 160.7 µg/ml after 24 h (*B. pfeifferi*)	++ +	Al-Zanbagi et al. (2000)
		Chloroform	ND	LC_{50} = 16.5 µg/ml LC_{90} = 46.8 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
		Acetone	ND	LC_{50} = 102.6 µg/ml LC_{90} = 129 µg/ml after 24 h (*B. pfeifferi*)	+ +	Al-Zanbagi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		n-Hexane	ND	LC_{50} = 96 µg/ml LC_{90} = 118 µg/ml after 24 h (*B. pfeifferi*)	++ +	Al-Zanbagi et al. (2000)
J. glauca Vahl-fresh leaves	–	Acetone	ND	LC_{50} = 6.8 µg/ml LC_{90} = 12.5 µg/ml after 24 h (*B. pfeifferi*)	+++ ++	Al-Zanbagi et al. (2000)
		Methanol	ND	LC_{50} = 21.7 µg/ml LC_{90} = 29.8 µg/ml after 24 h (*B. pfeifferi*)	++ ++	Al-Zanbagi et al. (2000)
J. mollissima (Pohl) Baill.-stems	Pinhão-branco	Ethanol		LC_{10} = 20 µg/ml LC_{50} = 33.6 µg/ml LC_{50} = 56.3 µg/ml after 96 h (*B. glabrata*)	++ ++ ++	dos Santos et al. (2012)
Phyllanthus nummulariifolius Poir.-whole plants	–	Ethanol	Saponins, alkaloids, carotenoids, catechic tannins, glucides-glycosides, flavonoids, albuminoids, steroids, terpenoids, lipoids, anthocyanins, starch and phenols	LC_{0} = 1 mg/ml LC_{50} = 10 mg/ml LC_{100} = 100 mg/ml (*B. pfeifferi*) LC_{0} = 1 mg/ml LC_{50} = 10 mg/ml LC_{100} = 100 mg/ml (*L. natalensis*) after 24 h	– – – – – –	Chifundera et al. (1993)
		Aqueous	Saponins, alkaloids, carotenoids, catechic tannins, glucides-glycosides, flavonoids, albuminoids, steroids, terpenoids, lipoids, anthocyanins, starch and phenols	LC_{0} = 10 mg/ml LC_{50} = 50 × 10^{3} µg/ml LC_{100} = 100 mg/ml (*B. pfeifferi*) LC_{0} = 10 mg/ml LC_{50} = 50 mg/ml LC_{100} = 100 mg/ml	– – – – – –	Chifundera et al. (1993)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				(*L. natalensis*) after 24 h		
Ricinus communis L.- Leaves	Castor oil	Ethanol	Glycosides, steroids and terpenoids	LC_{50} = 12 µg/ml after 24 h LC_{50} = 10 µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Distilled water	Glycosides, steroids and terpenoids	LC_{50} = 60 µg/ml after 24 h LC_{50} = 50 µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Chlorinated water	Glycosides, steroids and terpenoids	LC_{50} = 80 µg/ml after 24 h LC_{50} = 70 µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
		Tap water	Glycosides, steroids and terpenoids	LC_{50} = 90 µg/ml after 24 h LC_{50} = 85 µg/ml after 48 h (*L. acuminata*)	++ ++	Sharma et al. (2009)
Fabaceae (Leguminosae)						
Acacia nilotica (L.) Delile-leaves	Gum arabic tree	Aqueous	ND	LC_{50} = 3616.1 µg/ml LC_{90} = 15,587.8 µg/ml after 24 h (*Bu. africanus*)	– –	Clark and Appleton (1997)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Bauhinia variegate L.-leaves	Mountain ebony	Powder	Saponins and quercetins	LC_{50} = 244.7 μg/ml after 24 h LC_{50} = 203.5 μg/ml after 48 h LC_{50} = 155.9 μg/ml after 72 h LC_{50} = 126.7 μg/ml after 96 h (*L. acuminata*)	+ + + +	Singh et al. (2012)
		Ethanol	Saponins and quercetins	LC_{50} = 38.4 μg/ml after 24 h LC_{50} = 28.7 μg/ml after 48 h LC_{50} = 20.9 μg/ml after 72 h LC_{50} = 14.4 μg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Singh et al. (2012)
		Ether	Saponins and quercetins	LC_{50} = 57.2 μg/ml after 24 h LC_{50} = 34.8 μg/ml after 48 h LC_{50} = 20.7 μg/ml after 72 h LC_{50} = 15.03 μg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Singh et al. (2012)
		Acetone	Saponins and quercetins	LC_{50} = 38.6 μg/ml after 24 h LC_{50} = 30.1 μg/ml after 48 h	++ ++ ++ ++	Singh et al. (2012)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				LC_{50} = 21.5 μg/ml after 72 h LC_{50} = 15.5 μg/ml after 96 h (*L. acuminata*)		
		Chloroform	Saponins and quercetins	LC_{50} = 43.3 μg/ml after 24 h LC_{50} = 35.4 μg/ml after 48 h LC_{50} = 22.5 μg/ml after 72 h LC_{50} = 15.2 μg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Singh et al. (2012)
Mimosa tenuiflora Benth.-stems	Jurema preta	Ethanol	Flavonoids	LC_{10} = 6.6 μg/ml LC_{50} = 20.2 μg/ml LC_{90} = 62.1 μg/ml after 96 h (*B. glabrata*)	+++ ++ ++	dos Santos et al. (2012)
Poincianella pyramidalis (Tul.) L.P.Queiroz-leaves	Catingueira, pau-de-rato, catinga-de-porco,catingueira	Ethanol	Flavonoids	LC_{10} = 0.04 μg/ml LC_{50} = 0.94 μg/ml LC_{90} = 20.03 μg/ml after 96 h (*B. glabrata*)	+++ +++ ++	dos Santos et al. (2012)
Sesbania sesban (L.) Merr.-leaves	Egyptian sesban	Methanol	ND	LC_0 = 1.8 μg/ml LC_{10} = 8 μg/ml LC_{25} = 14 μg/ml LC_{50} = 18.0 μg/ml	+++ +++ ++ ++	Hasheesh et al. (2011)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				LC_{90} = 31.0 μg/ml after 24 h (*Bu. truncatus)*	++	
S. sesban (L.) Merr.-leaves	Egyptian sesban	Dry powder	ND	LC_0 = 5.1 μg/ml LC_{10} = 39.5 μg/ml LC_{25} = 44.9 μg/ml LC_{50} = 51.0 μg/ml LC_{90} = 62.4 μg/ml after 24 h (*B. alexandrina*-adult)	+++ ++ ++ ++ ++	Mahmoud et al. (2011)
Ginkoaceae						
Ginkgo biloba L.-leaves	Ginkgo	Petroleum ether	Terpene trilactones, flavonol glycosides, alkylphenols, phenolic acids, polysacaharides and amino acids	LC_{50} = 7.8 μg/ml LC_{90} = 32.7 μg/ml after 24 h (*O. hupensis*)	++ ++	Yang et al. (2008)
		Ethyl acetate	Terpene trilactones, flavonol glycosides, alkylphenols, phenolic acids, polysacaharides and amino acids	LC_{50} = 27.3 μg/ml LC_{90} = 54.9 μg/ml after 24 h (*O. hupensis*)	++ ++	Yang et al. (2008)
		Ethanol	Terpene trilactones, flavonol glycosides, alkylphenols, phenolic acids, polysacaharides and amino acids	LC_{50} = 64.1 μg/ml LC_{90} = 170.1 μg/ml after 24 h (*O. hupensis*)	++ +	Yang et al. (2008)

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Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Ginkgo sarcotestas L.	–	Petroleum ether	Ginkgolic acids	LD_{50} = 13.4 µg/ml after 24 h	++	Yang et al. (2006)
Icacinaceae						
Apodytes dimidiate E.Mey. ex Arn.-leaves	White pear	Aqueous	ND	LC_{50} = 1252.4 µg/ml LC_{90} = 3407.9 µg/ml after 24 h (*Bu. africanus*)	– –	Clark and Appleton (1997)
Lamiaceae						
Caryopteris clandonensis auct.-roots bark	Bluebeard, blue spirea or blue mist	Chloroform	ND	$LC_{100} < 5$ µg/ml after 24 h (*Bu. truncatus*)	+++	Hannedouche et al. (2002)
Hyptis pectinate (L.) Poit.-leaves	Comb bushmint	Ethanol	ND	LC_{10} = 8.5 µg/ml LC_{50} = 25.3 µg/ml LC_{50} = 75.7 µg/ml after 96 h (*B. glabrata*)	+++ ++ ++	dos Santos et al. (2012)
Lavandula stoechas L.-aerial parts	Spanish lavender, French lavender	Petrol	Phenols, flavonoids, saponins, sterols, terpenoids and essential oils	LC_{50} = 106.7 µg/ml LC_{90} = 140 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		n-Hexane	Phenols, flavonoids, saponins, sterols, terpenoids and essential oils	LC_{50} = 116.4 µg/ml LC_{90} = 143.0 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Dichloromethane	Phenols, flavonoids, saponins, sterols, terpenoids and essential oils	LC_{50} = 122.5 µg/ml LC_{90} = 144 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Ethyl acetate	Phenols, flavonoids, saponins, sterols, terpenoids and essential oils	LC_{50} = 106.7 µg/ml LC_{90} = 140 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Methanol	Phenols, flavonoids, saponins, sterols, terpenoids and essential oils	LC_{50} = 116.4 µg/ml LC_{90} = 143 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Aqueous	Phenols, flavonoids, saponins, sterols, terpenoids and essential oils	LC_{50} = 1682 µg/ml LC_{90} = 259 µg/ml after 24 h (*Bu. truncatus*)	– –	Hmamouchi et al. (2000)
Marrubium vulgare L.-aerial parts	White horehound	Essential oil	Terpenoids	LC_{50} = 50 µg/ml LC_{90} = 100 µg/ml after 3 h (*B. alexandrina*-adult) LC_{100} = 200 µg/ml after 24 h (*B. alexandrina*-egg)	++ + +	Salama et al. (2012)
Origanum compactum Benth.-aerial parts	Oregano	Petrol	Phenols, flavonoids, saponins, terpenoids and essential oils	LC_{50} = 85.2 µg/ml LC_{90} = 135.5 µg/ml after 24 h (*Bu. truncatus*)	++ +	Hmamouchi et al. (2000)
		n-Hexane	Phenols, flavonoids, saponins, terpenoids and essential oils	LC_{50} = 17.8 µg/ml LC_{90} = 33.6 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Dichloromethane	Phenols, flavonoids, saponins, terpenoids and essential oils	LC_{50} = 8.2 µg/ml LC_{90} = 16.8 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Ethyl acetate	Phenols, flavonoids, saponins, terpenoids and essential oils	LC_{50} = 1.0 µg/ml LC_{90} = 2.0 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Methanol	Phenols, flavonoids, saponins, terpenoids and essential oils	LC_{50} = 33.5 μg/ml LC_{90} = 67.0 μg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
Thymus capitatus Hoff. et Link.-aerial parts	–	Essential oil	Terpenoids	LC_{50} = 200 μg/ml LC_{90} = 400 μg/ml LC_{100} = no effect after 3 h (*B. alexandrina*-adult)	+ +	Salama et al. (2012)
Liliaceae						
Asparagus racemosus Willd.-whole parts	Satawar, Satamuli, Satavari	Ethanol	Steroids, alkaloids, carotenoids, catechic tannins, glucosides-glycosides, albuminoids, coumarins, phenols, aldehydes, lipoids, saponins and flavonoids	LC_0 = 1 mg/ml LC_{50} = 5 × 10^3 μg/ml LC_{100} = 10 mg/ml (*B. pfeifferi*) LC_0 = 0.1 mg/ml LC_{50} = 1 mg/ml LC_{100} = 10 mg/ml (*L. natalensis*) after 24 h	– – – – – –	Chifundera et al. (1993)
		Aqueous	Steroids, alkaloids, carotenoids, catechic tannins, glucosides-glycosides, albuminoids, coumarins, phenols, aldehydes, lipoids, saponins and flavonoids	LC_0 = 5 mg/ml LC_{50} = 7.5 mg/ml LC_{100} = 10 mg/ml (*B. pfeifferi*) LC_0 = 5 mg/ml LC_{50} = 1 mg/ml LC_{100} = 10 mg/ml (*L. natalensis*) after 24 h	– – – – – –	Chifundera et al. (1993)
Liriope graminifolia (L.) Baker-flowers	Lilyturf	*n*-Butanol	Saponins and steroidal saponins	LC_{98} = 5 μg/ml after 72 h (*O. hupensis*)	+++	Cui et al. (1999)
Meliaceae						

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Melia azedarach L.- fruits	Mallayvembu	Hexane	Flavans, flavonoids and alkaloids	LC_{50} = 4.44 μg/ml LC_{90} = 14.14 μg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		Petrol	Flavans, flavonoids, terpenoids and alkaloids	LC_{50} = 5.93 μg/ml LC_{90} = 14.14 μg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Dichloromethane	Flavans, flavonoids, terpenoids and alkaloids	LC_{50} = 11.11 μg/ml LC_{90} = 17.77 μg/ml after 24 h (*Bu. truncatus*)	+++ ++	Hmamouchi et al. (2000)
		Ethyl acetate	Flavans, flavonoids, terpenoids and alkaloids	LC_{50} = 122.4 μg/ml LC_{90} = 144 μg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Methanol	Flavans, flavonoids, terpenoids and alkaloids	LC_{50} = 164.6 μg/ml LC_{90} = 193 μg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
Mimosoideae						
Dimorphandra mollis Benth.-barks	Fava-d'anta	Ethanol	Tannins, coumarins and flavanoids	LC_{100} = 10 μg/ml after 48 h (*B. glabrata*)	++	Bezerra et al. (2002)
Stryphnodendron polyphyllum Mart.-barks	Barbatimão	Ethanol	Tannins	LC_{20} = 40 μg/ml LC_{50} = 70 μg/ml LC_{100} = 100 μg/ml after 48 h (*B. glabrata*)	++ ++ +	Bezerra et al. (2002)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
S. polyphyllum Mart.-leaves	Barbatimão	Ethanol	Tannins and flavanoids	LC_{20} = 10 µg/ml LC_{50} = 70 µg/ml LC_{100} = 100 µg/ml after 48 h (*B. glabrata*)	+++ ++ ++	Bezerra et al. (2002)
S. adstringens (Mart.) Coville-leaves	Barbatimão	Ethanol	Tannins and flavanoids	LC_{20} = 10 µg/ml LC_{50} = 90 µg/ml LC_{100} = 100 µg/ml after 48 h (*B. glabrata*)	+++ ++ +	Bezerra et al. (2002)
S. adstringens (Mart.) Coville-barks	Barbatimão	Ethanol	Tannins	LC_{50} = 60 µg/ml LC_{100} = 100 µg/ml after 48 h (*B. glabrata*)	++ ++	Bezerra et al. (2002)
Myrisinaceae						
Maesa lanceolata Forssk.-whole parts	False assegai	Ethanol	Saponins, alkaloids, carotenoids, catechic tannins, glucosides, flavonoids, albuminoids, phenols, terpenoids, lipoids and anthocyanins	LC_0 = 10 µg/ml LC_{50} = 100 mg/ml LC_{100} = 10 mg/ml (*B. pfeifferi*) LC_0 = 100 µg/ml LC_{50} = 0. 500 mg/ml LC_{100} = 1 mg/ml (*L. natalensis*) after 24 h	++ ++ + + + +	Chifundera et al. (1993)
		Aqueous	Saponins, alkaloids, carotenoids, catechic tannins, glycosides, flavonoids, albuminoids, phenols, terpenoids, lipoids and anthocyanins	LC_0 = 0.5 mg/ml LC_{50} = 1 mg/ml LC_{100} = 10 mg/ml (*B. pfeifferi*) LC_{00} = 0.5 mg/ml LC_{50} = 1 mg/ml LC_{100} = 10 mg/ml (*L. natalensis*) after 24 h	+ + – + + –	Chifundera et al. (1993)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Myrtaceae						
Eugenia dysenterica DC.- leaves	Cagaiteira	Ethanol	Tannins and flavonoids	LC_{50} = 10 µg/ml LC_{100} = 100 µg/ml after 48 h (*B. glabrata*)	++ +	Bezerra et al. (2002)
Piperaceae						
Piper aduncum L.-stems	Pimenta-de-macaco		Dichloromethane: Methanol (2:1)	ND		LC_{90} = 6.4 µg/ml after 24 h (*B. glabrata*-adult)
+++	Rapado et al. (2011)					
Piper crassinervium Kunth- Stems	Jaborandi		Dichloromethane: Methanol (2:1)	ND		
LC_{90} = 38.2 µg/ml after 24 h (*B. glabrata*-adult)	++	Rapado et al. (2011)				
Piper cuyabanum C. DC.-stems	Pimenta do mato		Dichloromethane: Methanol (2:1)	ND		
LC_{90} = 12.9 µg/ml after 24 h (*B. glabrata*-adult)	++	Rapado et al. (2011)				
Piper diospyrifolium Kunth-stems	–		Dichloromethane: Methanol (2:1)	ND		
LC_{90} = 23.3 µg/ml after 24 h (*B. glabrata*-adult)	++	Rapado et al. (2011)				
Piper hostmannianum (Miq.) C.DC.-stems	–		Dichloromethane: Methanol (2:1)	ND		
LC_{90} = 34.3 µg/ml	++					

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
after 24 h (*B. glabrata*-adult)		Rapado et al. (2011)				
Phytolaccaceae						
Phytolacca dodecandra L'Hér.- Berries	Soap berry endod	Aqueous	Saponins	LC_{50} = 8.0 μg/ml (*B. glabrata*)	+++	Thiilborg et al. (1994)
Ranunculaceae						
Delphinium staphisagria L.-seeds	Stavesacre	Petrol	Alkaloids and sterols	LC_{50} = 28.2 μg/ml LC_{90} = 67 μg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		n-Hexane	Alkaloids and sterols	LC_{50} = 3.5 μg/ml LC_{90} = 8.4 μg/ml after 24 h (*Bu. truncatus*)	+++ ++	Hmamouchi et al. (2000)
		Dichloromethane	Alkaloids and sterols	LC_{50} = 46.1 μg/ml LC_{90} = 85.2 μg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Ethyl acetate	Alkaloids and sterols	LC_{50} = 17.8 μg/ml LC_{90} = 33.6 μg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Methanol	Alkaloids and sterols	LC_{50} = 8.9 μg/ml LC_{90} = 28.2 μg/ml after 24 h (*Bu. truncatus*)	+++ ++	Hmamouchi et al. (2000)
Nigella sativa L.-aerial parts	Habbet elbarakah or black cumin	Petrol	Coumarins, alkaloids, saponins, sterols, terpenoids and essential oils	LC_{50} = 106.7 μg/ml LC_{90} = 140 μg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		n-Hexane		LC_{50} = 122.45 μg/ml LC_{90} = 144 μg/ml	+ +	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
			Coumarins, alkaloids, saponins, sterols, terpenoids and essential oils	after 24 h (*Bu. truncatus*)		
		Dichloromethane	Coumarins, alkaloids, saponins, sterols, terpenoids and essential oils	LC_{50} = 128.8 μg/ml LC_{90} = 173 μg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Ethyl acetate	Coumarins, alkaloids, saponins, sterols, terpenoids and essential oils	LC_{50} = 122.5 μg/ml LC_{90} = 144 μg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Methanol	Coumarins, alkaloids, saponins, sterols, terpenoids and essential oils	LC_{50} = 128.8 μg/ml LC_{90} = 173 μg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Aqueous	Coumarins, alkaloids, saponins, sterols, terpenoids and essential oils	LC_{50} = 433 μg/ml LC_{90} = 600 μg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
Pulsatilla chinensis (Bunge) Regel	Baitouweng or white-haired old man	Alcohol	Triterpenoidal saponins	LC_{50} = 0.48 μg/ml LC_{90} = 2.6 μg/ml after 24 h (*O. hupensis)*	+++ +++	Chen et al. (2012)
Ziziphus *spina-christi* (L.) Desf.-aerial parts	Pulsatillae radix, Baitouweng	Ethanol	ND	LC_{50} = 311 μg/ml LC_{90} = 500 μg/ml after 24 h (*L. cailliaudi*)	+ +	Hassan et al. (2012)
Ziziphus vulgaris Lamk.- leaves	Chinesedate	Petrol	Phenols, flavans, flavonoids, alkaloids, saponins, sterols and terpenoids	LC_{50} = 11.2 μg/ml LC_{90} = 17.8 μg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Dichloromethane	Phenols, flavans, flavonoids, alkaloids, saponins, sterols and terpenoids	LC_{50} = 8.2 μg/ml LC_{90} = 16.8 μg/ml after 24 h	+++ ++	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
				(*Bu. truncatus*)		
		Ethyl acetate	Phenols, flavans, flavonoids, alkaloids, saponins, sterols and terpenoids	LC_{50} = 23.8 µg/ml LC_{90} = 56.3 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Methanol	Phenols, flavans, flavonoids, alkaloids, saponins, sterols and terpenoids	LC_{50} = 4.1 µg/ml LC_{90} = 8.4 µg/ml after 24 h (*Bu. truncatus*)	+++ ++	Hmamouchi et al. (2000)
		Aqueous	Phenols, flavans, flavonoids, alkaloids, saponins, sterols and terpenoids	LC_{50} = 424 µg/ml LC_{90} = 548 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
Rosaceae						
Agrimonia eupatoria auct. fl. amer.- aerial parts	Agrimony	Chloroform	Triterpenes, sterols and sesquiterpenes	LC_0 = 100 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	+ +	Bilia et al. (2000b)
		Methanol	Triterpene glycosides, flavonoid glycosides and tannins	LC_0 = 50.0 µg/ml LC_{100} = 500.0 µg/ml after 24 h (*B. glabrata*)	++ +	Bilia et al. (2000b)
Cotoneaster nebrodensis (Guss.) K.Koch-stems and leaves	-	Methanol	Flavonoid glycosides, tannins and sugars	LC_0 = 50 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	++ +	Bilia et al. (2000b)
Prunus africana (Hook.f.) Kalkman-stem barks	African cherry, pygeum	Methanol	Catechins, sugars, A-type and B-type proanthocyanidins, lignans and aromatic derivatives	LC_0 = 50 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	++ +	Bilia et al. (2000b)
Prunus prostrata Labill.-aerial parts	Rock cherry, Mountain cherry, Prostrate cherry	Methanol	Coumarin glycosides, flavanoid glycosides, sugars and A-type and B-type proanthocyan-idins	LC_0 = 50 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	++ +	Bilia et al. (2000b)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Potentilla montana Brot.-ipogeal parts	–	Methanol	Catechin glycosides, A-type and B-type proanthocyanidins and sugars	LC_0 = 100 µg/ml LC_{50} = 250 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	+ + +	Bilia et al. (2000b)
Potentilla tormentilla Stokes-aerial parts	Tormentil	Methanol	Triterpene glycosides, sugars and tannins	LC_0 = 100 µg/ml LC_{50} = 250 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	+ + +	Bilia et al. (2000b)
Pyracantha coccinea M.Roem.-roots	Scarlet firethorn	Methanol	Flavonoid glycosides, sugars and aromatic derivatives glycosides and lignin glycosides	LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	+	Bilia et al. (2000b)
P. coccinea M.Roem.-leaves	Scarlet firethorn	Methanol	Flavonoid, glycosides and sugars	LC_0 = 100 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	+ +	Bilia et al. (2000b)
Pyrus bourgaeanea Decne.-leaves and stems	Iberian pears	Methanol	Triterpene glycosides, flavonoid glycosides and aromatic derivatives glycosides	LC_0 = 100 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	+ +	Bilia et al. (2000b)
		Chloroform/ Methanol	Coumarins, aromatic derivative glycosides and flavonoid glycosides	LC_0 = 100 µg/ml LC_{50} = 250 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	+ + +	Bilia et al. (2000b)
Quillaja saponaria Molina-leaves	Soapbark	Aqueous	ND	LC_{100} = 2 mg/ml after 24 h (*B. glabrata*)	–	Bilia et al. (2000b)
Q. saponaria Molina-bark	Soapbark	Aqueous	ND	LC_{100} = 7.5 mg/ml after 24 h (*B. glabrata*)	–	Bilia et al. (2000b)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Q. saponaria Molina-stems	Soapbark	Aqueous	ND	LC_{50} = 10 mg/ml after 24 h (*B. glabrata*)	–	Bilia et al. (2000b)
Rosa sempervirens L.-aerial parts	Evergreen rose	Methanol	Flavonoid glycosides and sugars	LC_{0} = 100 µg/ml LC_{50} = 250 µg/ml LC_{100} = 500 µg/ml after 24 h (*B. glabrata*)	+ + +	Bilia et al. (2000b)
Rubiaceae						
Gardenia thunbergia Thunb.-leaves	Forest gardenia	Aqueous	ND	LC_{50} = 57.2 µg/ml LC_{90} = 196.2 µg/ml after 24 h *(Bu. africanus)*	++ +	Clark and Appleton (1997)
Rutaceae						
Citrus bigaradia Duhamel-leaves	Bittersweet orange	Petrol	Phenols, coumarins, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 4.1 µg/ml LC_{90} = 8.4 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		n-Hexane	Phenols, coumarins, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 2.7 µg/ml LC_{90} = 4.4 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		Dichloromethane	Phenols, coumarins, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 3.5 µg/ml LC_{90} = 7.1 µg/ml after 24 h (*Bu. truncatus*)	+++ ++	Hmamouchi et al. (2000)
		Ethyl acetate	Phenols, coumarins, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 106.7 µg/ml LC_{90} = 140 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Methanol	Phenols, coumarins, flavonoids, alkaloids, sterols, terpenoids and essential oils	LC_{50} = 170.6 µg/ml after 24 h (*Bu. truncatus*)	+	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
C. bigaradia Duhamel-fruits	Bittersweet orange	Petrol	Phenols, coumarins, flavonoids, alkaloids, saponins, terpenoids and essential oils	LC_{50} = 106.7 µg/ml LC_{90} = 140 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		n-Hexane	Phenols, coumarins, flavonoids, alkaloids, saponins, terpenoids and essential oils	LC_{50} = 3.5 µg/ml LC_{90} = 7.1 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		Dichloromethane	Phenols, coumarins, flavonoids, alkaloids, saponins, terpenoids and essential oils	LC_{50} = 2.1 µg/ml LC_{90} = 4.2 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		Ethyl acetate	Phenols, coumarins, flavonoids, alkaloids, saponins, terpenoids and essential oils	LC_{50} = 4.1 µg/ml LC_{90} = 8.4 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		Methanol	Phenols, coumarins, flavonoids, alkaloids, saponins, terpenoids and essential oils	LC_{50} = 128.8 µg/ml LC_{90} = 173 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
Ruta chalepensis L.-aerial parts	Fringed rue	Petrol	Phenols, coumarins, flavonoids, alkaloids, sterols and essential oils	LC_{50} = 2.1 µg/ml LC_{90} = 4.2 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		n-Hexane	Phenols, coumarins, flavonoids, alkaloids, sterols and essential oils	LC_{50} = 1.4 µg/ml LC_{90} = 2.2 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)
		Dichloromethane	Phenols, coumarins, flavonoids, alkaloids, sterols and essential oils	LC_{50} = 1.6 µg/ml LC_{90} = 3.5 µg/ml after 24 h (*Bu. truncatus*)	+++ +++	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Ethyl acetate	Phenols, coumarins, flavonoids, alkaloids, sterols and essential oils	LC_{50} = 70.6 µg/ml LC_{90} = 122 µg/ml after 24 h (*Bu. truncatus*)	++ +	Hmamouchi et al. (2000)
		Methanol	Phenols, coumarins, flavonoids, alkaloids, sterols and essential oils	LC_{50} = 154.8 µg/ml LC_{90} = 190 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Aqueous	Phenols, coumarins, flavonoids, alkaloids, sterols and essential oils	LC_{50} = 1092 µg/ml LC_{90} = 1556 µg/ml after 24 h (*Bu. truncatus*)	– –	Hmamouchi et al. (2000)
Sapotaceae						
Mimusops elengi L.- barks	Spanish cherry	Powder	Saponins and quercetins	LC_{50} = 91.2 µg/ml after 24 h LC_{50} = 69.7 µg/ml after 48 h LC_{50} = 47.2 µg/ml after 72 h LC_{50} = 36.4 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Singh et al. (2012)
		Ethanol	Saponins and quercetins	LC_{50} = 44.6 µg/ml after 24 h LC_{50} = 31.4 µg/ml after 48 h LC_{50} = 21.7 µg/ml after 72 h LC_{50} = 15.1 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Singh et al. (2012)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Ether	Saponins and quercetins	LC_{50} = 45.1 µg/ml after 24 h LC_{50} = 36.9 µg/ml after 48 h LC_{50} = 29.4 µg/ml after 72 h LC_{50} = 23.5 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Singh et al. (2012)
		Acetone	Saponins and quercetins	LC_{50} = 58.3 µg/ml after 24 h LC_{50} = 46.3 µg/ml after 48 h LC_{50} = 34.1 µg/ml after 72 h LC_{50} = 25.8 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Singh et al. (2012)
		Chloroform	Saponins and quercetin	LC_{50} = 52.8 µg/ml after 24 h LC_{50} = 46.5 µg/ml after 48 h LC_{50} = 34.25 µg/ml after 72 h LC_{50} = 26.02 µg/ml after 96 h (*L. acuminata*)	++ ++ ++ ++	Singh et al. (2012)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Solanaceae						
Cestrum parqui (Lam.) L'Hér.-whole overground parts	Willow-leaved jessamine, green cestrum, palqui	Cold-aqueous suspension	ND	LC_0 = 86 µg/ml	++	Bakry (2009)
				LC_{10} = 422 µg/ml	+	
				LC_{25} = 620 µg/ml	+	
				LC_{50} = 860 µg/ml	+	
				LC_{90} = 1.600 mg/ml	–	
				after 24 h		
				(*B. alexandrina*)		
Cestrum diurnum L.-leaves	Day-blooming jasmine	Dry powder	ND	LC_0 = 189.3 µg/ml	+	Mahmoud et al. (2011)
				LC_{10} = 207.3 µg/ml	+	
				LC_{25} = 217.7 µg/ml	+	
				LC_{50} = 229.3 µg/ml	+	
				LC_{90} = 251.4 µg/ml	+	
				after 24 h		
				(*B. alexandrina*-adult)		
Datura stramonium L.-leaves	Thorn-apple, Jamestown	Dry powder	ND	LC_0 = 2.5 µg/ml	+++	Mahmoud et al. (2011)
				LC_{10} = 11.3 µg/ml	++	
				LC_{25} = 18.2 µg/ml	++	
				LC_{50} = 25.8 µg/ml	++	
				LC_{90} = 40.4 µg/ml	++	
				after 24 h		
				(*B. alexandrina*-adult)		
Physalis angulate L.-whole plant	Angular winter cherry, balloon cherry, camapu, cutleaf groundcherry	Acetone	ND	LC_{50} = 178.2 µg/ml	+	dos Santos et al. (2003)
				LC_{90} = 321.3 µg/ml	+	
				(*B. tenagophila)*		
		Ethyl acetate	ND	LC_{50} = 55.3 µg/ml	++	dos Santos et al. (2003)
				LC_{90} = 139.4 µg/ml	+	
				(*B. tenagophila)*		

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Solanum aculeastrum Dunal-berries	Soda apple, goat bitter apple or poison apple	Methanol	Steroidal glucosaponins and steroidal glucoalkaloids	LC_{100} = 50 µg/ml after 24 h (*B. pfeifferi*)	++	Wanyonyi et al. (2002, 2003)
		DCCC fractions	Steroidal glucosaponins and steroidal glucoalkaloids	LC_{100} = 20.0 µg/ml after 24 h (*B. pfeifferi*)	++	Wanyonyi et al. (2002, 2003)
S. aculeastrum Dunal-root barks	Soda apple, goat bitter apple or poison apple	Methanol	ND	LC_{30} = 13 µg/ml LC_{50} = 37 µg/ml LC_{100} = 53 µg/ml after 24 h (*B. pfeifferi*)	+++ ++ ++ ++	Wanyonyi et al. (2003)
Solanum elaeagnifolium Cav.-berries	Silverleaf nightshade	Methanol	Glycoalkaloids	LC_{50} = 9.5 µg/ml LC_{90} = 13 µg/ml after 24 h (*Bu. truncatus*)	+++ ++	Bekkouche et al. (2000)
S. elaeagnifolium Cav.-roots	Silverleaf nightshade	Aqueous	Alkaloids, tannins and saponins	LC_{50} = 79.9 µg/ml after 24 h (*Bu. truncatus*)	++	Larhsini et al. (2010)
		n-Butanol	Alkaloids, tannins and saponins	LC_{50} = 12.2 µg/ml after 24 h (*Bu. truncatus*)	++	Larhsini et al. (2010)
S. elaeagnifolium Cav.-fruits	Silverleaf nightshade	Glycoalkaloids extract	Alkaloids, tannins and saponins	LC_{50} = 9.5 µg/ml after 24 h (*Bu. truncatus*)	+++	Larhsini et al. (2010)
		Aqueous	Alkaloids, tannins and saponins	LC_{50} = 81.1 µg/ml after 24 h (*Bu. truncatus*)	++	Larhsini et al. (2010)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Solanum nigrum L.- Leaves	Black nightshade	Aqueous	ND	LC_{50} = 18.6 μg/ml LC_{90} = 37.7 μg/ml (*B. alexandrina*) LC_{50} = 14.5 μg/ml LC_{90} = 32.2 μg/ml (*Bu. truncatus*) LC_{50} = 17.7 μg/ml LC_{90} = 34.7 μg/ml after 24 h (*L. natalensis*)		Ahmed and Ramzy (1997)
		Ethanol	ND	LC_{50} = 2.98 μg/ml LC_{90} = 5.95 μg/ml after 24 h (*B. alexandrina*)	+++ ++	El-Sherbini et al. (2009)
		Methanol	ND	LC_{50} = 6.9 μg/ml LC_{90} = 16.2 μg/ml after 24 h (*B. alexandrina*)	++ ++	El-Sherbini et al. (2009)
		Acetone	ND	LC_{50} = 6.6 μg/ml LC_{90} = 11.7 μg/ml after 24 h (*B. alexandrina*)	++ ++	El-Sherbini et al. (2009)
		Chloroform	ND	LC_{50} = 70.8 μg/ml LC_{90} = 142.7 μg/ml after 24 h (*B. alexandrina*)	++ +	El-Sherbini et al. (2009)
		Petroleum ether	ND	LC_{50} = 4.2 μg/ml LC_{90} = 8.6 μg/ml after 24 h (*B. alexandrina*)	+++ +++	El-Sherbini et al. (2009)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Solanum sinaicum Boiss.-leaves	–	Ethanol	ND	LC_{50} = 3.2 µg/ml LC_{90} = 6.04 µg/ml after 24 h (*B. alexandrina*)	+++ +++	El-Sherbini et al. (2009)
		Methanol	ND	LC_{50} = 7.8 µg/ml LC_{90} = 17.5 µg/ml after 24 h (*B. alexandrina*)	+++ ++	El-Sherbini et al. (2009)
		Acetone	ND	LC_{50} = 8.7 µg/ml LC_{90} = 11.2 µg/ml after 24 (*B. alexandrina*)	+++ ++	El-Sherbini et al. (2009)
		Chloroform	ND	LC_{50} = 82.5 µg/ml LC_{90} = 164.7 µg/ml after 24 h (*B. alexandrina*)	++ +	El-Sherbini et al. (2009)
		Petroleum ether	ND	LC_{50} = 5.8 µg/ml LC_{90} = 9.9 µg/ml after 24 h (*B. alexandrina*)	+++ +++	El-Sherbini et al. (2009)
Solanum sodomaeum Dunal-leaves	Dead sea apple	Methanol	Glycoalkaloids	LC_{50} = 14.5 µg/ml LC_{90} = 21 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Bekkouche et al. (2000)
S. sodomaeum Dunal-seeds	Dead sea apple	Methanol	Glycoalkaloids	LC_{50} = 15.5 µg/ml LC_{90} = 27 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Bekkouche et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Solanum villosum Mill.-leaves	Inab al-deeb or red-fruit nightshade, hairy nightshade, Red nightshade	Ethanol	ND	LC_{50} = 4.88 μg/ml LC_{90} = 8.95 μg/ml after 24 h (*B. alexandrina*)	+++ +++	El-Sherbini et al. (2009)
		Methanol	ND	LC_{50} = 8.4 μg/ml LC_{90} = 18.3 μg/ml after 24 h (*B. alexandrina*)	+++ ++	El-Sherbini et al. (2009)
		Acetone	ND	LC_{50} = 9.67 μg/ml LC_{90} = 12.9 μg/ml after 24 h (*B. alexandrina*)	+++ ++	El-Sherbini et al. (2009)
		Chloroform	ND	LC_{50} = 90 μg/ml LC_{90} = 175.7 μg/ml after 24 h (*B. alexandrina*)	++ +	El-Sherbini et al. (2009)
		Petroleum ether	ND	LC_{50} = 6.3 μg/ml LC_{90} = 11.02 μg/ml after 24 h (*B. alexandrina*)	+++ ++	El-Sherbini et al. (2009)
Solanum asperum Rich.-fruits	'jussara' or 'coça-coça'	Methanol	Glycoalkaloid	LC_{10} = 7 μg/ml LC_{50} = 25.1 μg/ml LC_{90} = 44.1 μg/ml after 24 h (*B. glabrata*)	+++ ++ ++	Silva et al. (2008)
		Alkaloidal fraction	Glycoalkaloid	LC_{10} = 2.9 μg/ml LC_{50} = 9.7 μg/ml LC_{90} = 17.3 μg/ml after 24 h (*B. glabrata*)	+++ +++ ++	Silva et al. (2008)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
S. jabrense Agra & M. Nee-aerial parts	–	Methanol	Alkaloids	LC_{50} = 56 μg/ml LC_{90} = 80.3 μg/ml after 24 h (*B. glabrata*)	++ ++	Silva et al. (2006)
		Ethanol	Alkaloids	LC_{50} = 22.8 μg/ml LC_{90} = 39.8 μg/ml after 24 h (*B. glabrata*)	++ ++	Silva et al. (2006)
		n-Butanol	Alkaloids	LC_{50} = 30.5 μg/ml LC_{90} = 46.3 μg/ml after 24 h (*B. glabrata*)	++ ++	Silva et al. (2006)
Solanum stipulaceum Roem. & Schult.-stems	–	Alkaloids extract	Alkaloids	LC_{50} = 45.2 μg/ml LC_{90} = 56 μg/ml after 24 h (*B. glabrata*)	++ ++	Silva et al. (2006)
Withania somnifera (L.) Dunal-leaves	Ashwagandha or winter cherry	Dichloromethane	Alkaloids, flavonoids, terpenes/sterols, tannins and saponins	LC_{50} = 94 μg/ml after 24 h (*Bu. truncatus*)	++	Larhsini et al. (2010)
Verbenaceae						
Lantana camara L.-whole overground parts	Lantana	Cold-aqueous suspension	ND	LC_{0} = 123 μg/ml LC_{10} = 520 μg/ml $LC_{2\ 5}$ = 820 μg/ml LC_{50} = 1230 μg/ml LC_{90} = 2400 μg/ml after 24 h (*B. alexandrina*)	++ ++ ++ ++ ++	Bakry (2009)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
Zygophyllaceae						
Guayacum officinalis-whole overground parts	Roughbark lignum-vitae	Methanol	ND	LC_0 = 3.5 µg/ml	+++	Bakry (2009)
				LC_{10} = 17 µg/ml	++	
				LC_{25} = 24 µg/ml	++	
				LC_{50} = 35 µg/ml	++	
				LC_{90} = 62 µg/ml	++	
				after 24 h		
				(*B. alexandrina*)		
		Cold-aqueous suspension	ND	LC_0 = 15 µg/ml	++	Bakry (2009)
				LC_{10} = 62 µg/ml	++	
				LC_{25} = 97 µg/ml	++	
				LC_{50} = 120 µg/ml	+	
				LC_{90} = 210 µg/ml	+	
				after 24 h		
				(*B. alexandrina*)		
		Cold-aqueous	ND	LC_0 = 11 µg/ml	++	Bakry (2009)
				LC_{10} = 78 µg/ml	++	
				LC_{25} = 88 µg/ml	++	
				LC_{50} = 110 µg/ml	+	
				LC_{90} = 230 µg/ml	+	
				after 24 h		
				(*B. alexandrina*)		
		Boiled-aqueous	ND	LC_0 = 9 µg/ml	++	Bakry (2009)
				LC_{10} = 48 µg/ml	++	
				LC_{25} = 62 µg/ml	++	
				LC_{50} = 90 µg/ml	++	
				LC_{90} = 140 µg/ml	+	
				after 24 h		
				(*B. alexandrina*)		

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Ethanol	ND	LC_0 = 7.8 µg/ml LC_{10} = 42 µg/ml LC_{25} = 57 µg/ml LC_{50} = 78 µg/ml LC_{90} = 120 µg/ml after 24 h (*B. alexandrina*)	+++ ++ ++ ++ +	Bakry (2009)
		Acetone	ND	LC_0 = 14 µg/ml LC_{10} = 52 µg/ml LC_{25} = 61 µg/ml LC_{50} = 84 µg/ml LC_{90} = 140 µg/ml after 24 h (*B. alexandrina*)	++ ++ ++ ++ +	Bakry (2009)
		Chloroform	ND	LC_0 = 10 µg/ml LC_{10} = 52 µg/ml LC_{25} = 65 µg/ml LC_{50} = 100 µg/ml LC_{90} = 180 µg/ml after 24 h (*B. alexandrina*)	+++ ++ ++ ++ +	Bakry (2009)
Zygophyllum gaetulum Emb. Maire-aerial parts	–	Petrol	Flavonoids, terpenoids and saponins	LC_{50} = 8.7 µg/ml LC_{90} = 16.8 µg/ml after 24 h (*Bu. truncatus*)	+++ ++	Hmamouchi et al. (2000)
		n-Hexane	Flavonoids, terpenoids and saponins	LC_{50} = 13 µg/ml LC_{90} = 18.3 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)
		Dichloromethane	Flavonoids, terpenoids and saponins	LC_{50} = 28.2 µg/ml LC_{90} = 67 µg/ml after 24 h (*Bu. truncatus*)	++ ++	Hmamouchi et al. (2000)

Table 1 continued

Species-part	Vernacular or English name	Extract type	Class of compounds	Results	Activity	References
		Ethyl acetate	Flavonoids, terpenoids and saponins	LC_{50} = 122.4 µg/ml LC_{90} = 186 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)
		Aqueous	Flavonoids, terpenoids and saponins	LC_{50} = 372 µg/ml LC_{90} = 437 µg/ml after 24 h (*Bu. truncatus*)	+ +	Hmamouchi et al. (2000)

(+ + +) means strong activity < 5 µg/mL; (+ +) means moderate activity < 100 µg/mL; (+) means weak activity 100–1000 µg/mL; (−) means very weak activity > 1000 µg/mL

that migrate through the blood vessel wall or are excreted with urine or feces (Nation et al. 2020).

The lifecycles of all *Schistosoma* species are quite similar, requiring freshwater snails as intermediate hosts, and mammalian hosts infected via water-borne contact with the free-swimming larvae released from the snails, as illustrated in Fig. 1. (Selbach et al. 2016). The lifecycle involves sexual maturation of adult *schistosomes* in man and an asexual multiplicative stage in the molluscan host (Nanes Sarfati et al. 2021). Differences between the species lie mainly in the type of intermediate host snails and the infective sites in the mammalian host, although there are also differences (*inter alia*) in egg morphology, and rates of both egg production and infection of mammalian hosts (Salvador-Recatalà and Greenberg 2012).

Once eggs reach fresh water they hatch and release swimming miracidia (larvae) that infect specific aquatic snails. The genera *Biomphalaria*, *Oncomelania* and *Bullinus* host *S. mansoni*, *S. japonicum,* and *S. haematobium,* respectively (Fig. 1) (Ross et al. 2002). In the snails, the miracidia asexually multiply after a few weeks and form thousands of cercariae that leave the snail and penetrate the skin of humans (e.g. children, fishermen, farmers, and women doing daily domestic tasks in infected water) or other mammals. If the cercariae penetrate the human body, they develop into schistosomules, then mate and migrate to the perivascular or mesenteric veins (*S. mansoni* and *S. japonicum*) or urinary bladder plexus (*S. haematobium*), where they produce eggs and the cycle starts again (Fig. 1) (Gryseels et al. 2006). *Schistosoma* often live 5–10 years, and even lifespans up to 40 years have been reported (Hokke and Deelder 2001).

History of schistosomiasis

Schistosomiasis has a history in Egypt of more than 5000 years (Barakat 2013; Abou-El-Naga 2018), with reports of *S. haematobium* eggs in ancient mummies (Barakat 2013). The disease was described by the ancient Egyptians on medical papyri as “â-a-â” (Abou-El-Naga 2018) and Avicenna (Ibn-Sina) in his famous book “The Canon of Medicine” (Othman and Soliman 2015), Key scientific discoveries regarding the disease have also been made in Egypt. Theodor Bilharz, a German surgeon who became Chief of the

Table 2 Screening of isolated mollusicicidal bioactive compounds

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
Agavaceae					
3-*O*-β-D-glucopyranosyl-(1 → 3)-β-D-glucopyranosyl-(1 → 3)-β-D-xylopyranoside gloriogenin- Steroidal saponin (77)	*Furcraea selloa* K.Koch- leaves	SiO_2 CC, Sephadex LH-20 CC, Pre-TLC	MP, UV, IR, (EI & D/CI) MS, ^{1}H- &^{13}C-NMR	$LC_{90} = 6$ µg/ml after 24 h (*B. alexandrina*)	El-Nahas et al. (2005)
3-*O*-[α-L-rhamnopyranosyl (1 → 3)-α-L-arabinopyranosyl (1 → 3)-β- D—xylopyranosyl (1 → 3)-β- D -glucopyranosyl]-25R,5α-spirostan-2α,3β-diol- Spirostanol glycoside (36)	*Yucca aloifolia* L.-infloreacences	SiO_2 (CC & TLC)	FAB-MS, ^{1}H- &^{13}C-NMR	$LC_{100} = 10$ µg/ml (*B. glabrata*)	Kishor and Sati (1990)
Apocynaceae					
Plumericin- iridoid (60)	*Plumeria rubra* L.- heartwood	SiO_2 (CC & TLC)	MP, UV, IR, (EI & D/CI) MS, ^{1}H- &^{13}C-NMR (1D, 2D)	$LC_{100} = 6.3$ µg/ml (*B. glabrata*)	Hamburger et al. (1991)
Isoplumericin- iridoid (56)	*P. rubra* L.- heart wood	SiO_2 (CC & TLC)	MP, UV, IR, (EI & D/CI) MS, ^{1}H- &^{13}C-NMR (1D, 2D)	$LC_{100} = 6.3$ µg/ml (*B. glabrata*)	Hamburger et al. (1991)
Araliaceae					
3-*O*-[α-L-arabinopyranosyl]-hederagenin- Triterpenoid saponin (6)	*Polyscias dichro*stachya Baker-leaves	SiO_2 CC, TLC, Sephadex LH-20	D/CIMS, ^{1}H- &^{13}C-NMR	Active at less than 10 µg/ml after 24 h (*B. glabrata*)	Gopalsamy et al. (1990)
3-*O*-[α-L-rhamnopyranosyl -(1 → 2)-α-L-arabinopyranosyl]-hederagenin- triterpenoid saponin (8)	*P. dichro*stachya Baker-leaves	SiO_2 CC, TLC, Sephadex LH-20	D/CIMS, ^{1}H- &^{13}C-NMR,	Active at less than10 µg/ml after 24 h (*B. glabrata*)	Gopalsamy et al. (1990)
3-*O*-[β- D -glucopyranosyl-(1 → 2)-α-L-arabinopyranosyl] hederagenin- triterpenoid saponin (9)	*P. dichro*stachya Baker-leaves	SiO_2 CC, TLC, Sephadex LH-20	D/CIMS, ^{1}H- &^{13}C-NMR	Active at less than10 µg/ml after 24 h (*B. glabrata*)	Gopalsamy et al. (1990)
Asteraceae					
7α-hydroxy-3-desoxyzaluzanin *C*- sesquiterpene lactone (5)	*Podachaenium eminens* (Lag.) Sch.Bip. ex Sch.Bip	SiO_2 CC	^{1}H- &^{13}C- NMR and X-ray diffraction	$LC_{100} = 1$ µg/ml after 24 h (*B. glabrata*)	Fronczek et al. (1984)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
2-*n*-pentylquinoline- quinoline alkaloid (40)	*Galipea bracteate* (Nees & Mart.) Schult.- stems	SiO_2 CC	IR, EI-MS ^{1}H- &^{13}C-NMR	Active at 20 µg/ml (*B. glabrata*)	Vieira and Kubo (1990)
2-(1'-pentenyl)-quinoline- quinoline alkaloid (39)	*G. bracteate* (Nees & Mart.) Schult.-stems	SiO_2 CC	IR, EI-MS ^{1}H- &^{13}C-NMR	Active at 10 µg/ml (*B. glabrata*)	Vieira and Kubo (1990)
2-(3', 4'-methylene- dioxyphenylethyl)-quinoline- quinoline alkaloid (37)	*G. bracteate* (Nees & Mart.) Schult.-stems	SiO_2 CC	IR, EI-MS ^{1}H- &^{13}C-NMR	Active at 5 µg/ml (*B. glabrata*)	Vieira and Kubo (1990)
Rutin (78)	*Calendula officinalis* L.- flowers	CC, TLC	IR, MS and ^{1}H- NMR	LC_{50} = 27.2 µg/ml after 72 h (*B.alexandrina*) LC_{50} = 34.7 µg/ml after 72 h (*B. truncatus*)	El-Sheikh et al. (2012)
Asidiaceae					
Elaphopilosin-A 2-{[2,4-dihydroxy-6 methoxy-3-(1-oxobutyl)phenyl]methyl}-3,5-dihydroxy-4-methyl-4-(3-methylbut-2-enyl)-6-(1-oxobutyl)-2,5-cyclohexa-dien-1-one- bicyclic phloroglucinol (30)	*Elaphoglossum piloselloides* (C. Presl) T. Moore-rhizomes, roots and sterile fronds	SiO_2 CC, RPHPLC	IR, HREIMS, ^{1}H- &^{13}C-NMR	LC_{50} = 2.9 µg/ml LC_{90} = 4.5 µg/ml after 24 h (*B. peregrine*-adult)	Socolsky et al. (2009)
Elaphopilosin-B 2-{[2,4-dihydroxy-6-methoxy-3-(1-oxohexyl)-phenyl]methyl}-3,5-dihy-droxy-4-methyl-4-(3-methylbut-2-enyl)-6-(1-oxobutyl)-2,5-cyclohexa-dien-1-one- bicyclic phloroglucinol (32)	*E. piloselloides* (C. Presl) T. Moore-rhizomes, roots and sterile fronds	SiO_2 CC, RPHPLC	IR, HREIMS, ^{1}H- &^{13}C-NMR	LC_{50} = 0.9 µg/ml LC_{90} = 1.37 µg/ml after 24 h (*B. peregrine*-adult)	Socolsky et al. (2009)
Acetylation of elaphopilosin-A (62)	*E. piloselloides* (C. Presl) T. Moore-rhizomes, roots and sterile fronds	SiO_2 CC, HPLC	IR, FABMS, ^{1}H- &^{13}C-NMR	LC_{50} = 10.6 µg/ml LC_{90} = 14.7 µg/ml after 24 h (*B. peregrine*-adult)	Socolsky et al. (2009)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
Acetylation of elaphopilosin-B (54)	*E. piloselloides* (C. Presl) T. Moore-rhizomes, roots and sterile fronds	SiO_2 CC, HPLC	IR, HRFABMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC, NOESY	LC_{50} = 30 μg/ml LC_{90} = 43.1 μg/ml after 24 h (*B. peregrine*-adult)	Socolsky et al. (2009)
Compositae					
Ambrosin- sesquiterpene lactone (71)	*Ambrosia maritima* L.- aerial parts	CC, HPLC	UV	Molluscicidal (*B. glabrata*)	Slacanin et al. (1988)
Damsin- sesquiterpene lactone (72)	*A. maritima* L.-aerial parts	CC, HPLC	UV	Molluscicidal (*B. glabrata*)	Slacanin et al. (1988)
Dipsacaceae					
6α-hydroxyhederagenic acid- Terpenoid (52)	*Cephalaria ambrosioides* (Sm.) Roem. & Schult.-roots	SiO_2 CC, TLC, MPLC	(HR-FAB & FAB) MS, ^{1}H-&^{13}C-NMR, COSY, HMQC, HMBC, NOESY	$LC_{100} > 50$ μg/ml after 24 h (*B. glabrata*)	Pasi et al. (2009)
Hederagenic acid- terpenoid (51)	*C. ambrosioides* (Sm.) Roem. & Schult.-roots	SiO_2 CC, TLC, MPLC	(HR-FAB & FAB) MS, ^{1}H-&^{13}C-NMR, COSY, HMQC, HMBC, NOESY	$LC_{100} > 50$ μg/ml after 24 h (*B. glabrata*)	Pasi et al. (2009)
Leontoside A (akeboside Stb) -saponin (50)	*C. ambrosioides* (Sm.) Roem. & Schult.-roots	SiO_2 CC, TLC, MPLC	(HR-FAB & FAB) MS, ^{1}H-&^{13}C-NMR, COSY, HMQC, HMBC, NOESY	$LC_{100} = 5.4$ μg/ml after 24 h (*B. glabrata*)	Pasi et al. (2009)
Kalopanax saponin A (α-hederin)- saponin (75)	*C. ambrosioides* (Sm.) Roem. & Schult.-roots	SiO_2 CC, TLC, MPLC	(HR-FAB & FAB) MS, ^{1}H-&^{13}C-NMR, COSY, HMQC, HMBC, NOESY	$LC_{100} = 6.2$ μg/ml after 24 h (*B. glabrata*)	Pasi et al. (2009)
Saponin PG (sapindoside B)- saponin (47)	*C. ambrosioides* (Sm.) Roem. & Schult.-roots	SiO_2 CC, TLC, MPLC	(HR-FAB & FAB) MS, ^{1}H-&^{13}C-NMR, COSY, HMQC, HMBC, NOESY	$LC_{100} = 12.8 \pm 0.3$ μg/ml after 24 h (*B. glabrata*)	Pasi et al. (2009)
Dipsacoside B- saponin (64)	*C. ambrosioides* (Sm.) Roem. & Schult.-roots	SiO_2 CC, TLC, MPLC	(HR-FAB & FAB) MS, ^{1}H-&^{13}C-NMR, COSY, HMQC, HMBC, NOESY	$LC_{100} > 50$ μg/ml after 24 h (*B. glabrata*)	Pasi et al. (2009)
Euphorbiaceae					

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
(2S,3S,4R,5R,6R,11S,13R, 14S,15R,17R)-5,6,11,14,17-pentaacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-seget-8(12)-ene diterpene (22)	*Euphorbia paralias* L.-aerial parts	SiO_2 CC, TLC, HPLC	^1H- & ^{13}C-NMR, COSY, NOSEY	LC_{50} = 40 μg/ml after 24 h (*B. alexandrina*)	Abdelgaleil et al. (2002)
(2S,3S,4R,6R,8R,11S,12S,13R, 14R,15R)-5,6,11,14,17-pentaacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-segetane- diterpene (23)	*E. paralias* L.- aerial parts	SiO_2 CC, TLC, HPLC	^1H- & ^{13}C-NMR, COSY, NOSEY	LC_{50} = 60 μg/ml after 24 h (*B. alexandrina*)	Abdelgaleil et al. (2002)
(2S,3S,4R,5R,6R,8R,11S,12S,13R,14R,15R)-6,11,14,17-tetraacetoxy-5-(2-acetoxyacetoxy)-3-benzoyloxy-15-hydroxy-9-oxo segetane- diterpene (21)	*E. paralias* L.-aerial parts	SiO_2 CC, TLC, HPLC	^1H- & ^{13}C-NMR, COSY, NOESY	LC_{25} = 40 μg/ml LC_{50} = 100 μg/ml after 24 h (*B. alexandrina*)	Abdelgaleil et al. (2002)
(2S,3S,4R,5R,6R,8R,11S,12S,13R,14R,15R)-6,14,17-triacetoxy-5-(2-hydroxyacetoxy)-3-benzoyloxy-15-hydroxy-9-oxo-segetane- diterpene (15)	*E. paralias* L.-aerial parts	SiO_2 CC, TLC, HPLC	^1H- & ^{13}C-NMR, COSY, NOESY	LC_{100} = 10 μg/ml after 24 h (*B. alexandrina*)	Abdelgaleil et al. (2002)
(2R,3R,4S,5R,7S,8R,13R,15R)-2,3,5,7,15-pentaacetoxy-8-iso-butyroyloxy-9,14-dioxojatropha-6(17),11E-diene- diterpene (18)	*E. paralias* L.-aerial parts	SiO_2 CC, TLC, HPLC	^1H- & ^{13}C-NMR, COSY, NOESY	LC_{15} = 20 μg/ml LC_{25} = 60 μg/ml LC_{50} = 100 μg/ml LC_{100} = 100 μg/ml after 24 h (*B.alexandrina*)	Abdelgaleil et al. (2002)
(2R,3R,4S,5R,7S,8R,13R,15R)-2,3,5,7,15-pentaacetoxy-8-angeloyloxy-9,14-dioxo-jatropha-6(17),11E-diene-diterpene (24)	*E. paralias* L.-aerial parts	SiO_2 CC, TLC, HPLC	^1H- & ^{13}C-NMR, COSY, NOESY	LC_{25} = 40 μg/ml LC_{50} = 100 μg/ml after 24 h (*B.alexandrina*)	Abdelgaleil et al. (2002)
(2R,3R,4S,5R,7S,8R,13R,15R)-3,5,7,15-tetraacetoxy-8-isobutyroyloxy-9,14-dioxo-jatropha-6(17),11E-diene-diterpene (29)	*E. paralias* L.-aerial parts	SiO_2 CC, TLC, HPLC	^1H- & ^{13}C-NMR, COSY, NOESY	LC_{25} = 60 μg/ml LC_{50} = 60 μg/ml after 24 h (*B. alexandrina*)	Abdelgaleil et al. (2002)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
(2S,3S,4R,5R,6R,8R,12S,13S,14R,15R)-1,5,8,14-tetraacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-paraliane- diterpene (25)	*E. paralias* L.-aerial parts	SiO_2 CC, TLC, HPLC	^{1}H- &^{13}C-NMR, COSY, NOESY	LC_{15} = 20 μg/ml LC_{25} = 80 μg/ml LC_{50} = 80 μg/ml LC_{100} = 100 μg/ml after 24 h (*B. alexandrina*)	Abdelgaleil et al. (2002)
(2S,3S,4R,5R,6R,8R,12S,13S,14R,15R)-5,8,14-triacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-paraliane- diterpene (26)	*E. paralias* L.-aerial parts	SiO_2 CC, TLC, HPLC	^{1}H- &^{13}C-NMR, COSY, NOESY	LC_{10} = 30 μg/ml LC_{15} = 100 μg/ml LC_{25} = 100 μg/ml LC_{50} = 100 μg/ml after 24 h (*B. alexandrina*)	Abdelgaleil et al. (2002)
Velamone (ent-15,16-epoxy-2-oxo-3,13(16),14-clerodatrien)-terpene (46)	*Croton campestris* A.St.-Hil.-roots bark	SiO_2 CC, Prep TLC	UV, IR, CI-MS, ^{1}H- &^{13}C-NMR, COSY, HMQC, HMBC, NOESY	LC_{100} = 3 μg/ml after 24 h (*Bu. truncatus*)	El Babili et al. (1998), El Babili et al. (2006)
Velamolone acetate (*ent-* 15,16-epoxy-20-acetoxy-2-oxo-3,13(16),14-clerodatrien)-terpene (48)	*C. campestris* A.St.-Hil.-roots bark	SiO_2 CC, Prep TLC	UV, IR, CI-MS, ^{1}H- &^{13}C-NMR, COSY, HMQC, HMBC, NOESY	LC_{100} = 6 μg/ml after 24 h (*Bu. truncatus*)	EL Babili et al. (1998), El Babili et al. (2006)
Velamolone ((*ent-15,16-epoxy-20-hydroxy-2-oxo*-3,13(16),4-clerodatrien) - terpene (49)	*C. campestris* A.St.-Hil.-roots bark	SiO_2 CC, Prep TLC	UV, IR, CI-MS, ^{1}H- &^{13}C-NMR, COSY, HMQC, HMBC, NOESY	LC_{100} = 20 μg/ml after 24 h (*Bu. truncatus*)	EL Babili et al. (1998), El Babili et al. (2006)
Milliamine L- terpene (79)	*E. milii* Des Moul.-latex	Sephadex LH-20, LPLC, HPTLC, MPLC, semi prep HPLC	UV, IR, (D/CI & EI) MS, ^{1}H- &^{13}C-NMR, COSY	LC_{100} = 2.5 × 10^3 μg/ml after 24 h (*B. glabrata*)	Zani et al. (1993)
Milliamine M- terpene (28)	*E. milii* Des Moul.-latex	Sephadex LH-20, LPLC, HPTLC, MPLC, semi prep HPLC	UV, IR, (D/CI & EI) MS, ^{1}H- &^{13}C-NMR, COSY	LC_{100} = 10 × 10^3 μg/ml after 24 h (*B. glabrata*)	Zani et al. (1993)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
Milliamine D- terpene (27)	*E. milii* Des Moul.-latex	Sephadex LH-20, LPLC, HPTLC, MPLC, semi prep HPLC	UV, IR, (D/CI & EI) MS, ^{1}H- &^{13}C-NMR, COSY	$LC_{100} = 100 \times 10^3$ µg/ml after 24 h (*B. glabrata*)	Zani et al. (1993)
Fabaceae					
Quercetin (3,3,4,5,7–penta hydroxyflavone) (33)	*Bauhinia variegate* L.- Leaves	CC, TLC	ND	$LC_{50} = 12.1$ µg/ml after 24 h $LC_{50} = 9.9$ µg/ml after 48 h $LC_{50} = 6.8$ µg/ml after 72 h $LC_{50} = 5.4$ µg/ml after 96 h (*L. acuminata*)	Singh et al. (2012)
Ginkoaceae					
Ginkgolic acid C13:0 (80)	*Ginkgo biloba* L.-sarcotesta granules	SiO_2 CC, HPLC	LC–MS-ESI, ^{1}H- & ^{13}C-NMR,	$LC_{50} = 3.95$ µg/ml $LC_{90} = 5.9$ µg/ml after 24 h $LC_{50} = 2.7$ µg/ml $LC_{90} = 3.6$ µg/ml after 48 h (*O. hupensis*)	Yang et al. (2008)
Ginkgolic acid C15:1 (81)	*G. biloba* L.-sarcotesta granules	SiO_2 CC, HPLC	LC–MS-ESI, ^{1}H- & ^{13}C-NMR	$LC_{50} = 1.5$ µg/ml $LC_{90} = 4.7$ µg/ml after 24 h $LC_{50} = 0.8$ µg/ml $LC_{90} = 2.2$ µg/ml after 48 h (*O. hupensis*)	Yang et al. (2008)
	G. sarcotestas	CC, HPLC	LC–MS-ESI, ^{1}H- & ^{13}C-NMR	$LD_{50} = 13.4$ µg/ml after 24 h	Yang et al. (2006)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
Ginkgolic acid C17:1 (82)	*G. biloba* L.-sarcotesta granules	SiO_2 CC, HPLC	LC–MS-ESI, ^{1}H- & ^{13}C-NMR,	LC_{50} = 11.4 µg/ml LC_{90} = 17.8 µg/ml after 24 h LC_{50} = 6.25 µg/ml LC_{90} = 10.01 µg/ml after 48 h (*O. hupensis*)	Yang et al. (2008)
Icacinaceae					
Genipin- iridoid (35)	*Apodytes dimidiate* E.Mey. ex Arn.- barks	SiO_2 CC, CC, SiO_2 TLC	(HR & EI) MS, ^{1}H- &^{13}C-NMR	LC_{50} = 25.3 µg/ml LC_{90} = 32.6 µg/ml (*Bu. africanus*)	Drewes et al. (1996)
Genipin 10-acetate-iridoid (34)	*A. dimidiata* E.Mey. ex Arn.- barks	SiO_2 CC, CC, SiO_2 TLC	(HR & EI) MS, ^{1}H- &^{13}C-NMR	LC_{50} = 21.7 µg/ml LC_{90} = 39.4 µg/ml (*Bu. africanus*)	Drewes et al. (1996)
Lamiaceae					
15-deoxyfuerstione (10)	*Caryopteris clandonensis* auct.- roots bark	ND	ND	LD_{100} = 3- 4 µg/ml after 24 h (*Bu. truncatus*)	Hannedouche et al. (2002)
Fuerstione (13)	*C. clandonensis* auct.- roots bark	ND	ND	LD_{100} = 3- 4 µg/ml after 24 h (*Bu. truncatus*)	Hannedouche et al. (2002)
α-caryopterone (42)	*C. clandonensis* auct.- roots bark	ND	ND	LD_{100} = 1- 2 µg/ml after 24 h (*Bu. truncatus*)	Hannedouche et al. (2002)
Leguminosae					
2′-hydroxy 3,7,8,4′,5′-pentamethoxy flavones (58)	*Parkia clappertoniana* Keay- leaves	TLC, CC	UV, IR, EIMS, ^{1}H- &^{13}C-NMR, NOE	LC_{80} = 25 µg/ml (*B. glabrata*)	Lemmich et al. (1996)
Pachyelaside A- triterpene saponin (57)	*Pachyelasma tessmannii* (Harms) Harms- roots bark	CC, HPLC	IR, MALDI-TOF–MS ^{1}H-&^{13}C-NMR, DEPT, DQF-COSY, HSQC, HMBC, HOHAHA, NOE, NOESY	LC_{50} = 2 µg/ml after 24 h (*B. glabrata*)	Nihei et al. (2005)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
Pachyelaside B- triterpene saponin (55)	*P. tessmannii* (Harms) Harms- roots bark	CC, HPLC	IR, MALDI-TOF–MS ^{1}H- &^{13}C-NMR, DEPT, DQF-COSY, HSQC, HMBC, HOHAHA, NOE, NOESY	LC$_{50}$ = 2 μg/ml after 24 h (*B. glabrata*)	Nihei et al. (2005)
Pachyelaside C- triterpene saponin (61)	*P. tessmannii* (Harms) Harms- roots bark	CC, HPLC	IR, MALDI-TOF–MS, ^{1}H- &^{13}C-NMR, DEPT, DQF-COSY, HSQC, HMBC, HOHAHA, NOE, NOESY	LC$_{50}$ = 2 μg/ml after 24 h (*B. glabrata*)	Nihei et al. (2005)
Pachyelaside D- triterpene saponin (63)	*P. tessmanii* (Harms) Harms-roots bark	CC, HPLC	IR, MALDI-TOF–MS ^{1}H- &^{13}C-NMR, DEPT, DQF-COSY, HSQC, HMBC, HOHAHA, NOE, NOESY	LC$_{50}$ = 8 μg/ml after 24 h (*B. glabrata*)	Nihei et al. (2005)
Myrsinaceae					
Maesasaponin VI$_2$ 3-*β*-*O*-[[α-L-rhamnopyranosyl-(1 → 2)-*β*-D-galactopyranosyl-(1 → 3)]-[*β*-D-galactopyranosyl-(1 → 2)]-*β*-D glucopyranuronyl]-21*β*,22α-diangeloyloxy-13 *β*,28-epoxyolean-16α,28α-diol- triterpenoid saponin (76)	*Maesa lanceolata* Forssk.- leaves	Semi-prep HPLC	Comparison with reported data	LC$_{50}$ = 0.5 μg/ml (*B. glabrata*)	Apers et al. (2001)
Papaveraceae					
Sanguinarine- alkaloid (BSA) (70)	*Macleaya* *cordata* (Willd.) R.Br.- fruits	SiO$_2$ CC, HPLC	ND	LC$_{50}$ = 0.59 μg/ml LC$_{90}$ = 1.38 μg/ml after 48 h LC$_{50}$ = 0.19 μg/ml LC$_{90}$ = 0.54 μg/ml after 72 h (*O. hupensis*)	Ming et al. (2011)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
Chelerythrine- alkaloid (BCHE) (73)	*M. cordata* (Willd.) R.Br.- fruits	SiO_2 CC, HPLC	ND	LC_{50} = 2.7 µg/ml LC_{90} = 5.2 µg/ml after 48 h LC_{50} = 2.01 µg/ml LC_{90} = 4.86 µg/ml after 72 h (*O. hupensis*)	Ming et al. (2011)
Primulaceae					
Anagalloside B- oleanane saponin (74)	*Anagallis arvensis* L	SiO_2 CC, prep HPLC	HRFABMS, ^{1}H- &^{13}C-NMR,	LC_{100} = 5.0 µg/ml (*B. glabrata*) LC_{100} = 2.5 µg/ml (*O. quadrasi*)	Abdel-Gawad et al. (2000)
Desglucoanagalloside B oleanane saponin (69)	*A. arvensis* L	SiO_2 CC, prep HPLC	HRFABMS, ^{1}H- &^{13}C-NMR,	LC_{100} = 2.5 µg/ml (*B. glabrata*) LC_{100} = 1.25 µg/ml (*O. quadrasi*)	Abdel-Gawad et al. (2000)
Phytolaccaceae					
3-*O*-[3'-(*O*-*β*-D galactopyranosyl)-*β*-D-glucopyranosyl] 2*β*-hydroxyoleanolic acid- oleanane saponin (66)	*Phytolacca dodecandra* L'Hér.-berries	SiO_2 CC, TLC, HPLC	LSIMS, ^{1}H- &^{13}C-NMR, COSY, TOCSY, HETCOR, NOESY	LC_{50} = 5- 10 µg/ml (*B. glabrata*)	Thiilborg et al. (1993, 1994)
Mixture (1:1) of 3-*O*-[*O*-*β*-D-galactopyranosyl-(1 → 3)-*O*-[*β*-D-glucopyranosyl-(1 → 4)]-*β*-glucopyranosyl] bayogenin- saponin (65) + 3-*O*-[2',4'-di-*O*-(*β*-D-glucopyranosyl)-*β*-D-glucopyranosyl] hederagenin- oleanane saponin	*P. dodecandra* L'Hér.-berries	SiO_2 CC, TLC, HPLC	FABMS, ^{1}H- &^{13}C-NMR, COSY, TOCSY, HETCOR, NOESY	LC_{50} = 10–20 µg/ml (*B. glabrata*)	Thiilborg et al. (1993, 1994)
3-*O*-*β*-D-glucopyranosylserjanic acid- saponin (14)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC	LC_{100} = 3.1 µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
3-*O*-(*β*-D-galactopyranosyl-(1 → 3)-*β*-D-glucopyranosyl) serjanic acid- saponin (16)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC	LC_{100} = 3.1 µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)
3-*O*-(*β*-D-glucopyranosyl-(1 → 2)-*β*-D-glucopyranosyl) serjanic acid-saponin (17)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC	LC_{100} = 10 µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)
3-*O*-(*β*-D-glucopyranosyl-(1 → 3)-*β*-D-glucopyranosyl-(1 → 3)-*β*-D-glucopyranosyl) serjanic acid- saponin (19)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC	LC_{100} = 12.5 µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)
3-*O*-(α-L-rhamnopyranosyl-(→)-*β*-D-glucopyranosyl-(1 → 2)-*β*-D-glucopyranosyl) serjanic acid- saponin (20)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC	LC_{100} = 50 µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)
3-*O*-(α-L-rhamnopyranosyl-(1 → 2)-*β*-D-glucopyranosyl-(1 → 2)- *β*-D-glucopyranosyl) spergulagenic acid-saponin (83)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC	$LC_{100} > 50$ µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)
3-*O*-(*β*-D-galactopyranosyl-(1 → 3)-*β*-D-glucopyranosyl) serjanic acid 28-*O*-*β*-D-glucopyranoside -saponin (7)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC, chemical transformation	$LC_{100} > 50$ µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)
3-*O*-(*β*-D-glucopyranosyl-(1 → 2)-*β*-D-glucopyranosyl) serjanic acid 28-*O*-*β*-D-glucopyranoside -Saponin (12)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC, chemical transformation	$LC_{100} > 50$ µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
3-*O*-(α-L-rhamnopyranosyl-(1 → 2)-*β*-D- glucopyranosyl-(1 → 2)-*β*-D-glucopyranosyl) serjanic acid 28-*O*-*β*-D-glucopyranoside – saponin (11)	*P. icosandra* L.-berries	SiO_2 CC, Sephadex LH-20 SiO_2, LPLC on Lobar RP-18 C, CPC, HPLC	ESMS, ^{1}H- &^{13}C-NMR, COSY, HSQC, HMBC, chemical transformation	$LC_{100} > 50$ µg/ml after 24 h (*B. glabrata*)	Treyvaud et al. (2000)
Rubiaceae					
3-*O*-{*O*-α-L-rhamnopyranosyl-(1 → 3)-*O*-[*O*-*β*-D-glucopyranosyl-(1 → 3)]-*β*-D-glucopyranosyl}oleanolic acid oleanane saponin (85)	*Catunaregam nilotica* (Stapf) Tirveng.-fruits	SiO_2 CC, TLC	FABMS, ^{1}H- &^{13}C-NMR, COSY, HETCOR, NOESY	LC_{50} = 3 µg/ml (*B. alexandrina*)	Lemmich et al. (1995)
28-*O*-*β*-D- glucopyranosyl- 3- *O*-{*O*-α-L-rhamnopyranosyl-(1 → 3)-*O*-[*O*-*β*-D-glucopyranosyl-(1 → 3)]-*β*- D-glucopyranosyl} oleanolate -oleanane saponin (87)	*C. nilotica* (Stapf) Tirveng.-fruits	SiO_2 CC, TLC	FABMS, ^{1}H- &^{13}C-NMR, COSY, HETCOR, NOESY	LC_{50} = 3 µg/ml (*B. alexandrina*)	Lemmich et al. (1995)
3-*O*-[2’,3’-di- *O*-(*β*-D-glucopyranosyl)-*β*-D-glucopyranosyl]oleanolic acid- oleanane saponin (86)	*C. nilotica* (Stapf) Tirveng.-fruits	SiO_2 CC, TLC	FABMS, ^{1}H- &^{13}C-NMR, COSY, HETCOR, NOESY	LC_{50} = 26 µg/ml (*B. alexandrina*)	Lemmich et al. (1995)
3-*O*-[*O*-*β*-D-glucopyranosyl(1 → 3)-*β*-D-glucopyranosyl] oleanolic acid- oleanane saponin (84)	*C. nilotica* (Stapf) Tirveng.-fruits	SiO_2 CC, TLC	FABMS, ^{1}H- &^{13}C-NMR, COSY, HETCOR, NOESY	LC_{50} = 3 µg/ml (*B. alexandrina*)	Lemmich et al. (1995)
Rutaceae					
Cuspanine (1-hydroxy-2,3,5,6-tetramethoxy-9-acridone) - alkaloid (59)	*Angostura paniculata* (Engl.) T.S.Elias-leaves	SiO_2 CC	UV, IR, ^{1}H- &^{13}C-NMR, NOESY, X-ray	LC_{50} = 5 µg/ml (*B. glabrata*)	Vieira et al. (1992)
Cusculine (1,2,3,5,6-pentamethoxy-9-acridone) - alkaloid (88)	*A. paniculata* (Engl.) T.S.Elias -leaves	SiO_2 CC	UV, IR, ^{1}H- &^{13}C-NMR, NOESY, X-ray	LC_{50} = 20 µg/ml (*B. glabrata*)	Vieira et al. (1992)
Sapindaceae					
Pulsatilla saponin D (3-*O*-[[*β*- D -glucopyranosyl-(1 → 4)]-[α-L-rhamnopyranosyl-(1 → 2)]-α-L-arabinopyranosyl] hederagenin)- saponin (31)	*Serjania salzmanniana* Schltdl.-stems	CC, Prep TLC, SiO_2 TLC	HRFAB-MS, ^{1}H- &^{13}C-NMR, COSY, HETCOR, NOESY	LC_{10} = 90 µg/ml LC_{20} = 100 µg/ml after 48 h (*B. alexandrina*)	Ekabo et al. (1996)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
3-*O*-[[*β*- D -gluopyranosyl-(1 → 4)]-[α-L-rhamnopyranosyl-(1 → 2)]-α-L-arabinopyranosyl] oleanolic acid- saponin (44)	*S. salzmanniana* Schltdl.-stems	CC, Prep TLC, SiO_2 TLC	LR-FAB-MS, ^{1}H- &^{13}C-NMR, COSY, HETCOR, NOESY	LC_{10} = 100 µg/ml LC_{20} = 100 µg/ml after 48 h (*B. alexandrina*)	Ekabo et al. (1996)
Salzmannianoside A (3-*O*-[[*β*- D -glucopyranosyl-(1 → 4)]-[α-L-rhamnopyranosyl-(1 → 2)]- α-L arabinopyranosyl] gypsogenin)- saponin (45)	*S. salzmanniana* Schltdl.-stems	Prep TLC, SiO_2 TLC and CC	HRFAB-MS, ^{1}H- &^{13}C-NMR, COSY, HETCOR, NOESY	LC_{20} = 100 µg/ml after 48 h (*B. alexandrina*)	Ekabo et al. (1996)
Salzmannianoside B (3-*O*-[[*β*- D glucopyranosyl-(1 → 4)]-[α-L-arabinopyranosyl-(1 → 3)-α-rhamnopyranosyl (1 → 2)]-α-L arabinopyranosyl] hederagenin)- saponin (53)	*S. salzmanniana* Schltdl.-stems	CC, Prep TLC, SiO_2 TLC	(HRFAB & CI) MS, ^{1}H-&^{13}C-NMR, COSY, HETCOR, HOHAHA, NOESY	LC_{10} = 100 µg/ml LC_{20} = 70 µg/ml after 48 h (*B. alexandrina*)	Ekabo et al. (1996)
Sapotaceae					
Sapogenin-saponin (43)	*Mimusops elengi* L.-barks	TLC, CC	ND	LC_{50} = 15.6 µg/ml after 24 h LC_{50} = 13.9 µg/ml after 48 h LC_{50} = 4.3 µg/ml after 72 h LC_{50} = 1.3 µg/ml after 96 h (*L. acuminata*)	Singh et al. (2012)
Solanaceae					
mixture of solamargine + solasonine-glucoalkaloid (2) + (68)	*Solanum mammosum* L.-fruits	SiO_2 TLC	^{1}H- &^{13}C-NMR, COSY, DQF-COSY, TOCSY, HMQC, NOESY	LC_{100} = 25.0 µg/ml (*B. glabrata*)	Mahato et al. (1980), Alzérreca and Hart (1982), Puri et al. (1994)

Table 2 continued

Chemical name-class	Species-part	Separation tools	Spectral analysis	Results	References
Tomatine-glucoalkaloid (89)	*S. mammosum* L.-fruits	SiO_2 CC	Comparison with reported data	LD_{100} = 25 µg/ml (*L. cubensis*) LD_{80} = 25 µg/ml (*B. glabrata*)	Alzérreca and Hart (1982)
Solanandaine-alkaloid (67)	*S. asperum* Rich.-fruits	TLC, Sephadex LH-20	IR, HREIMS, LC–MS, ^{1}H-&^{13}C-NMR, HBBD, DEPT, COSY, HSQC, HMBC TOCSY, NOESY	LC_{10} = 46.4 µg/ml LC_{50} = 73.1 µg/ml LC_{90} = 99.7 µg/ml after 24 h (*B. glabrata*)	Silva et al. (2008)
Solasonine-alkaloid (68)	*S. asperum* Rich.- fruits	TLC, Sephadex LH-20	IR, HREIMS, LC–MS, ^{1}H-&^{13}C- NMR, HBBD, DEPT, COSY, HSQC, HMBC TOCSY, NOESY	LC_{10} = 22 µg/ml LC_{50} = 47 µg/ml LC_{90} = 72 µg/ml after 24 h (*B. glabrata*)	Silva et al. (2008)
Solamargine-Alkaloid (2)	*S. asperum* Rich.- fruits	TLC, Sephadex LH-20	IR, HREIMS, LC–MS, ^{1}H-&^{13}C- NMR, HBBD, DEPT, COSY, HSQC, HMBC, TOCSY,NOESY	LC_{10} = 8.1 µg/ml LC_{50} = 26.3 µg/ml LC_{90} = 63.6 µg/ml after 24 h (*B. glabrata*)	Silva et al. (2008)

HPLC high performance liquid chromatography, *TLC* thin layer chromatography, *CC* column chromatography, *SiO_2* silica gel, *CPC* centrifugal partition chromatography, *LPLC* low pressure liquid chromatography, *MPLC* medium pressure liquid chromatography, *Prep TLC* preparative thin layer chromatography, *DCCC* droplet counter-current chromatography, *NOESY* nuclear over hauser effect spectroscopy, *COSY* homonuclear correlated spectroscopy, *TOCSY* total correlation spectroscopy, *HMBC* heteronuclear multiple bond connectivity, *EI-MS* electron ionization mass spectrometery, *TOF MS* time-of-flight mass spectrometry, *MALDI* matrix-assisted laser desorption/ionization, *NMR* nuclear magnetic resonance, *HETCOR* heteronuclear correlation spectroscopy, *UV* ultraviolet, *IR* infrared, *MP* melting point

Table 3 Plants species (and their localitis) used to cure schistosomiasis in patients based on traditional uses

Species	Common name/English Name	Used part	Locality	Activity in lab	References
Acanthaceae					
Peristrophe bicalyculata (Retz.) Nees	Panicled Foldwing	Aerial parts	Mali	ND	Bah et al. (2006), Gaudani et al. (2010)
Anacardiaceae					
Ozoroa insignis Delile	–	Leaves	Zimbabwe	At 33.8 mg/ml all schistosomules died (*Schistosoma mansoni*)	Mølgaard et al. (2001)
		Roots bark	Zimbabwe	At 25.3 mg/ml all schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
		Twigs	Africa	ND	(He et al. 2002)
Lannea bicolor	Dikbas	Roots	South Africa	ND	Sparg et al. (2000)
Sclerocarya birrea (A.Rich.) Hochst	Jelly plum	Roots	South Africa	ND	Sparg et al. (2000)
Rhus geinzii	–	Roots	South Africa	ND	Sparg et al. (2000)
Annonaceae					
Annona senegalensis Pers.	Wild Custard Apple and Wild Soursop	Roots	Mali	ND	Bah et al. (2006)
A. muricata L.	Graviola, Soursop and Gunbanana	Leaves	Brazil	See Table 1	dos Santos and Sant'Ana (2001)
Apocynaceae					
Carrisa edulis (Forssk.) Vahl.	Climbing num-num, simple-spined num-num	Roots	South Africa	ND	Sparg et al. (2000)
Landolphia kirkii Dyer	Sand apricot-vine, rubber vine	Roots	South Africa	ND	Sparg et al. (2000)
Saba senegalensis (A.DC.) Pichon	Weda	Leaves	Mali	ND	Bah et al. (2006)
Asclepiadaceae					
Calotropis procera (Aiton) Dryand	Apple of Sodom	Roots	Mali	See Table 1	Bah et al. (2006)
Asparagaceae					
Agave attenuate Salm-Dyck	Foxtail agave	Dry leaves	South Africa	ND	Brackenbury and Appleton (1997)

Table 3 continued

Species	Common name/English Name	Used part	Locality	Activity in lab	References
Asparagus africanus Lam	*African asparagus*	Roots	South Africa	ND	Sparg et al. (2000)
Asphodelaceae					
Bulbine abyssinica A.Rich	Bushy bulbine	Roots	South Africa	ND	Sparg et al. (2000)
Asteraceae (Compositae)					
Alomia myriadenia Sch.Bip. ex Baker	–	Aerial parts	Brazil	See Table 1	Mendes et al. (1999)
Achyrocline satureioides (Lam.) DC	Macela or marcela	Aerial parts	Brazil	see Table 1	Mendes et al. (1999)
Actinoseris	–	Aerial parts	Brazil	See Table 1	Mendes et al. (1999)
angustifolia (Gardner) Cabrera					
Berkheya speciosa (DC.) O.Hoffm	–	Roots	South Africa	ND	Sparg et al. (2000)
		Barks, twigs and leaves	South Africa		Ojewole (2004)
Piptocarpha rotundifolia (Less.) Baker	Ashdaisy	Aerial parts	Brazil	See Table 1	Mendes et al. (1999)
Vanillosmopsis erythropappa (DC.) Sch.Bip	Candeia tree	Aerial parts	Brazil	See Table 1	Mendes et al. (1999)
Verbesina clausseni Sch.Bip. ex Baker	–	Aerial parts	Brazil	See Table 1	Mendes et al. (1999)
Balanitaceae					
Balanites maughamii Sprague	-	Fruits, leaves and barks	South Africa		Ojewole (2004)
B. aegyptica (L.) Delile	Desert date Or Haglig	Fruits, leaves and barks	South Africa		Ojewole (2004)
Boraginaceae					
Trichodesma physaloides (Fenzl) A. DC	Chocolate bells	Tubers	South Africa	ND	Sparg et al. (2000)
Caesalpiniaceae					
Afzelia quanzensis Welw	Pod Mahogany	Roots	South Africa	ND	Sparg et al. (2000)
Cannellaceae					

Table 3 continued

Species	Common name/English Name	Used part	Locality	Activity in lab	References
Warburgia ugandensis Sprague	Green heart	Fruits, twigs and leaves	South Africa		Ojewole (2004)
Warburgia salutaris (G.Bertol.) Chiov	Pepper-bark tree	Fruits, twigs and leaves	South Africa		Ojewole (2004)
Capparidaceae					
Cadaba farinosa Forssk	Indian Cadaba	Leaves	Mali	ND	Bah et al. (2006)
Capparis tomentosa Lam	Woolly caper bush	Leaves and roots	Mali	ND	Bah et al. (2006)
Celastraceae					
Maytenus senegalensis (Lam.) Exell	Spike thorn	Roots	South Africa	ND	Sparg et al. (2000)
		Roots brak	Zimbabwe	At 100 mg/ml some of the schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
Chrysobalanaceae					
Licania tomentosa (Benth.) Fritsch	–	Leaves	Venezuela		Bilia et al. (2000a)
Cochlospermaceae					
Cochlospermum tinctorium Perrier ex A.Rich	–	Leaves	Mali	ND	Bah et al. (2006)
Combretaceae					
Anogeissus leiocarpa (DC.) Guill. & Perr	African birch	Leaves	Mali	ND	Bah et al. (2006)
Combretum imberbe Wawra	Leadwood tree	Bark, twigs and leaves	South Africa		Ojewole (2004)
Combretum molle R.Br. ex G.Don	Velvet bushwillow	Bark, twigs and leaves	South Africa		Ojewole (2004)
Combretum micranthum G.Don	Guinean kinkeliba	Leaves	Mali	ND	Bah et al. (2006)
Combretum imberbe	Leadwood tree	Roots	South Africa	ND	Sparg et al. (2000)
Ebenaceae					
Euclea divinorum Hiern	Magic guarri, diamond leaf, toothbrush tree, or diamond leaved *Euclea*	Roots	South Africa	ND	Sparg et al. (2000)
Euclea natalensis	-	Barks	South Africa	ND	Sparg et al. (2000)

Table 3 continued

Species	Common name/English Name	Used part	Locality	Activity in lab	References
Euphorbiaceae					
Antidesma venosum E.Mey. ex Tul	Tassel-berry	Roots	South Africa	ND	Sparg et al. (2000)
Euphorbia splendens Bojer ex Hook	–	Latex	Brazil	See Table 1	Schall et al. (2001)
E. hirta L	Ammampach charisi	Whole plant	Mali	See Table 1	Bah et al. (2006)
Ricinus communis L	Castor oil	Roots	South Africa	See Table 1	Sparg et al. (2000)
Securinega virosa (Roxb. ex Willd.) Baill	White berry bush, snowberry tree or simple-leaf bush weed	Roots	Mali	ND	Bah et al. (2006)
Fabaceae (Leguminosae)					
Abrus precatorius L	Jequirity bean or rosary pea	Roots	South Africa	ND	Sparg et al. (2000)
		Stems	Zimbabwe	At 1.5 mg/ml all schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
		Roots	Zimbabwe	At 0.6 mg/ml all schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
Acacia karroo Hayne	Sweet thorn	Leaves	Zimbabwe	At 103 mg/ml no schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
Albizia antunesiana Harms	–	Roots	Zimbabwe	At 100 mg/ml no schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
Cassia italica (Mill.) F.W.Andrews	–	Leaves	Mali	ND	Bah et al. (2006)
C. nigricans Vahl	–	Whole plant	Mali	ND	Bah et al. (2006)
Cassia sieberiana DC	Drumstick tree	Leaves	Mali	ND	Bah et al. (2006)
Dalbergia sissoo DC	Indian rosewood	Fruits, leaves, roots and stems bark	Nigeria	ND	Adenusi and Odaibo (2009)
Elephantorrhiza goetzei (Harms) Harms	Goetze's elephantorrhiza	Stems bark	Zimbabwe	At 0.8 mg/ml all schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
		Roots	South Africa	ND	Sparg et al. (2000)
Lonchocarpus laxiflorus Guill. & Perr	–	Barks	Mali	ND	Bah et al. (2006)

Table 3 continued

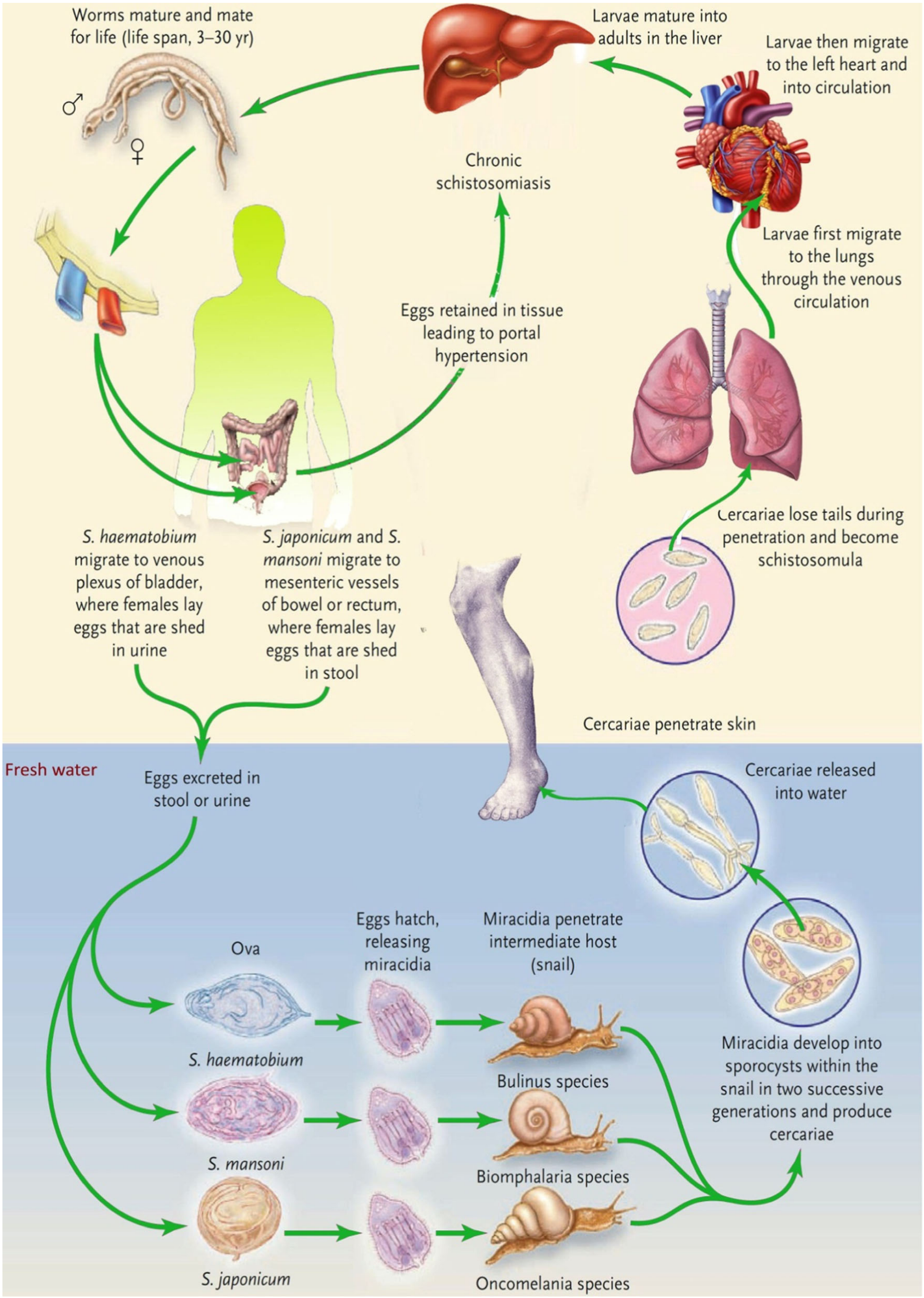
Species	Common name/English Name	Used part	Locality	Activity in lab	References
Peltophorum africanum Sond	Weeping wattle or Afrtcanwattle	Leaves + stems	Zimbabwe	At 100 × 10^3 µg/ml no schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
Pseudarthria hookeri Wight & Arn	–	Leaves and roots	South Africa	ND	Sparg et al. (2000)
Pterocarpus angolensis DC	Muninga, kiaat	Barks and roots	South Africa	ND	Sparg et al. (2000)
		Leaves	Zimbabwe	At 102 mg/ml no schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
		Stems	Zimbabwe	At 117 mg/ml no schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
		Barks	Zimbabwe	At 70 mg/ml for bark some of the schistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
Tetrapleura tetraptera (Schum. & Thonn.) Taub	Aridan	Fruits	Africa	ND	Ojewole (2004)
Stylosanthes erecta P.Beauv		Aerial parts	Mali	ND	Bah et al. (2006)
Sesbania sesban (L.) Merr	Egyptian sesban	Leaves	Egypt	See Table 1	Mahmoud et al. (2011)
Flacourtiaceae					
Flacourtia indica (Burm.f.) Merr	Indian Coffee Plum, Indian plum	Roots	South Africa	ND	Sparg et al. (2000)
Lamiaceae					
Leucas martinicensis (Jacq.) R.Br	–	Whole plant	Mali	ND	Bah et al. (2006)
Liliaceae					
Allium cepa L	Onion	Bulbs	Mali	See Table 4	Bah et al. (2006)
Aloe buettneri A.Berger	–	Roots	Mali	ND	Bah et al. (2006)
Loganiaceae					
Strychnos henningsii Gilg	–	Barks	South Africa	ND	Sparg et al. (2000)
Meliaceae					
Trichilia emetica Vahl	Natal mahogany	Roots	South Africa	ND	Sparg et al. (2000)

Table 3 continued

Species	Common name/English Name	Used part	Locality	Activity in lab	References
Menispermaceae					
Cissampelos mucronata A.Rich	–	Roots	South Africa	ND	Sparg et al. (2000)
Mimosaceae					
Entada Africana Guill. & Perr	“Samanéré’	Roots	Mali	ND	Bah et al. (2006)
Moraceae					
Ficus thonningii Blume	Strangler figs	Leaves	Mali	ND	Bah et al. (2006)
Nympheaceae					
Nymphaea micrantha Guill. & Perr	–	Whole part	Mali	ND	Bah et al. (2006)
Olacaceae					
Ximenia amaricana L	Yellow plum	Roots	Mali	ND	Bah et al. (2006)
		Roots	South Africa	ND	Sparg et al. (2000)
X. caffra Sond	Large sour plum	Roots and leaves	South Africa	ND	Sparg et al. (2000)
Periplocaceae					
Mondia whitei (Hook.f.) Skeels.	“isirigun”	Roots	South Africa	ND	Sparg et al. (2000)
Phytolaccaceae					
Phytolacca dodecandra L’Hér.	Soap berry *endod*	Berries	Ethiopia	Investigated in Table 1	Esser et al. (2003)
Poaceae					
Zea mays L.	Maize	Spikes	Mali	ND	Bah et al. (2006)
Polygalaceae					
Securidaca longepedunculata Fresen	Violet tree, fiber tree and Rhodesian violet	Roots	Mali	ND	Bah et al. (2006)
Ranunculaceae					
Clematis brachiate Thunb	Traveler’s-joy	Stems and leaves	South Africa	ND	Sparg et al. (2000)
Rhamnaceae					

Table 3 continued

Species	Common name/English Name	Used part	Locality	Activity in lab	References
Ziziphus mucronate Willd	Buffalo thorn	Roots	South Africa	ND	Sparg et al. (2000)
		Roots bark	Zimbabwe	At 101 mg/ml noschistosomules died (*S. mansoni*)	Mølgaard et al. (2001)
Rutaceae					
Citrus aurantiifolia (Christm.) Swingle	Swingle Lime; Mexican Lime	Leaves and fruits	Mali	ND	Bah et al. (2006)
Sapotaceae					
Vitellaria paradoxa C.F.Gaertn	Shea tree	Roots and leaves	Mali	ND	Bah et al. (2006)
Solanaceae					
Cestrum diurnum L.	Day-blooming jasmine	Leaves	Egypt	See Table 1	Mahmoud et al. (2011)
Datura stramonium L.	Thorn-apple, Jamestown	Leaves	Egypt	See Table 1	Mahmoud et al. (2011)
Physalis angulate L.	Angular winter cherry, balloon cherry, camapu, cutleaf groundcherry	Whole plant	China	See Table 1	dos Santos et al. (2003)
Solanum nigrum L.	Nightshade	Leaves	Egypt	See Table 1	El-Sherbini et al. (2009)
Solanum sinaicum Boiss.	–		Egypt	See Table 1	El-Sherbini et al. (2009)
Solanum villosum Mill.	Inab al-deeb or red-fruit nightshade, hairy nightshade, Red nightshade		Egypt	See Table 1	El-Sherbini et al. (2009)
Sterculiaceae					
Melochia arenosa Benth.	–	Aerial parts	Brazil	ND	Truiti et al. (2005)
Vitaceae					
Ampelocissus grantii (Baker) Planch	–	Tubercles	Mali	ND	Bah et al. (2006)
Cissus quadrangularis L.	Perandai	Roots, aerial parts and whole part	Mali	ND	Bah et al. (2006)
Zingiberaceae					
Aframomum latifolium K.Schum.	–	Fruits	Mali	ND	Bah et al. (2006)
Zygophyllaceae					
Balanites aegyptiaca (L.) Delile.	Desert date	Roots	Mali	ND	Bah et al. (2006)


Worms mature and mate for life (life span, 3–30 yr)
♂
♀
Larvae mature into adults in the liver
Larvae then migrate to the left heart and into circulation
Chronic schistosomiasis
Larvae first migrate to the lungs through the venous circulation
Eggs retained in tissue leading to portal hypertension
Cercariae lose tails during penetration and become schistosomula
S. haematobium migrate to venous plexus of bladder, where females lay eggs that are shed in urine
S. japonicum and *S. mansoni* migrate to mesenteric vessels of bowel or rectum, where females lay eggs that are shed in stool
Cercariae penetrate skin
Fresh water
Eggs excreted in stool or urine
Cercariae released into water
Ova
Eggs hatch, releasing miracidia
Miracidia penetrate intermediate host (snail)
S. haematobium
Bulinus species
Miracidia develop into sporocysts within the snail in two successive generations and produce cercariae
S. mansoni
Biomphalaria species
S. japonicum
Oncomelania species

◀**Fig. 1** Life cycle of *Schistosoma*

Surgical Services in Kasr El-Ain Hospital and Medical School, Cairo, discovered *Schistosoma* worms in 1851. Their lifecycle was subsequently described by Robert Leiper, while working in Cairo, in 1915 (Di Bella et al. 2018). The Delta Nile was become a favorite habitat for breeding the host snails of both urinary and intestinal schistosomiasis (Malek 1975).

S. japonicum eggs were discovered in two Chinese ancient bodies dating back roughly to 2180 years ago. Symptoms similar to schistosomiasis were described in the earliest Chinese ancient literature of around 4700 years ago. In the mid-1950s, the first nationwide assessment of the disease indicated that schistosomiasis was endemic in 433 cities across 12 provinces globally, affecting about 11.6 million people (Zhou et al. 2021).

Distribution of schistosomiasis

Schistosomiasis is endemic in 77 countries, and most prevalent in tropical and subtropical regions (Tefera et al. 2020). It is estimated that the severe cases are located in Sub-Saharan Africa; other highly endemic areas are Yemen and the Philippine Island of Mindanao. It is also still endemic, but at lower levels, in North Africa and several Middle East countries. In Asia, it is endemic in parts of the Yangtze River Basin in China, and middle reaches of the Mekong River in Laos and Cambodia (Bergquist and Tanner 2010). In China, a national survey in 2007 revealed that the infection rate among residents in the Fork Beach endemic area was 1.87% (Chen et al. 2012). At least 3 million people in Brazil are thought to be infected by *Schistosoma*, and around 25 million are at risk (Chitsulo et al. 2000). It is also endemic in several Venezuelan states, and several foci in Suriname (Zoni et al. 2016).

Economic implications

Calculating economic effects of schistosomiasis is far from straightforward, but it has been estimated to cause annual losses due to disability (complete or partial) amounting to US$ 445, 16, 118, and 60 million in Africa, South-West Asia, South-East Asia and the USA, respectively (at least US$ 641 million in total). These sums do not include all costs of related public health programs, medical care or compensation for illness, which may also be substantial (Wright 1972). For instance, estimated costs for controlling schistosomiasis morbidity among school-age children by selective and mass chemotherapy are US$ 0.67 and 0.59 per infected child, respectively (Talaat and Evans 2000). Thus, reviving large-scale school-based health programs to reduce morbidity rates of school-aged children, and to improve their physical growth and cognitive development, would be very costly (Husein et al. 1996).

Globally, the number of people treated for schistosomiasis rose from 12.4 million in 2006 to 33.5 million in 2010 (Carod Artal 2012). US$150 million have been spent on controlling neglected tropical diseases, including schistosomiasis, in sub-Saharan Africa (Gray et al. 2010). In 2008, a presidential initiative was announced calling for a commitment of US$ 350 million funding by the USA over five years to combat neglected tropical diseases, and an increase in the number of targeted countries (Liese and Schubert 2009). It has been estimated that 1.2 billion PZQ tablets will be needed annually to treat 400 million people in Africa for at least five years, at an annual cost of US$100 million (Utzinger et al. 2009). This sum could not be afforded easily within the endemic areas of the world without help from the developed countries. However, much less money would be required if alternative medicine(s) could be produced locally in appropriate financial and ecological frameworks.

Geographical implications

In many areas with high rates of schistosomiasis the local health systems are under-resourced (Amazigo et al. 2012) and subject to diverse disturbances that disrupt ecological equilibria and contexts, within which disease hosts or vectors and parasites breed, develop, and transmit the disease (Cable et al. 2017). Thus, they may strongly influence the emergence and proliferation of parasitic diseases, including schistosomiasis. It has been estimated that 97% of the infections are on the African continent (Steinmann et al. 2006), at least partly due to the lack (or paucity) of health systems, poverty and general neglect (Utzinger et al. 2011). Furthermore, 95% of all parasitic infections occur in the developing world, since it has the most conducive combinations of human behavior, anthropogenic disturbance and both climatic and physical conditions (Sattenspiel 2000). Notably, in endemic parts of the world schistosomiasis is intimately connected to the construction of infrastructure such as small, multipurpose dams and large hydroelectric dams for power production and irrigation systems (Utzinger et al. 2011). In the modern era, for example, the Aswan High Dam caused ecological changes that stimulated disease transmission (Malek 1975). Schistosomiasis remains the most important water-borne disease, and it was promoted by prevailing socio-ecological systems, since transmission is governed by unsafe human behavior (*e.g.* unprotected direct surface water contacts and open defecation) (Acka et al. 2010).

In Egypt, recent projects have been carried out in many regions to reclaim land from the desert for agriculture using water of the Nile River. This, together with the increased human activities in the reclaimed areas, has stimulated transmission of both *S. mansoni* and *S. haematobium*, manifested by the presence of infected *B. truncatus* and *B. alexandrina*, the intermediate host snails for the respective parasitic species, in these areas. Parts of the desert utilizing Nile water has wider spread of schistosomiasis (El-Kady et al. 2000). Schistosomiasis became a national burden and emerging as a major public health problem in the Egyptian reclaimed areas unless adequate control measures are taken (Abou-El-Naga 2018). There are also cases of human infection in American and European metropolitan areas, due to immigrations (Fuertes et al. 2010; Roure et al. 2017).

Medical implications

Hepatitis has been detected in 70% of surveyed schistosomiasis patients, and *S. mansoni* is one of the two major risk factors, together with viral hepatitis, for chronic liver disease and liver cirrhosis. Thus, millions of the world´s population live under constant risk of both schistosomiasis and hepatitis (Halim et al. 1999). Similarly, clinical history of urinary schistosomiasis is associated with significantly increased risk of bladder cancer (Bedwani et al. 1998). Furthermore, schistosomiasis can infect the children in endemic populations, and disease symptoms in children include anemia, liver fibrosis, immunity impairment, and severe physical and mental disorders (El Baz et al. 2003).

The free-swimming *Schistosoma* larvae penetrate the skin, causing rashes, erythema and itchy skin prior to fever, chills, coughm and muscle aches. As the parasite matures in the host veins (mesenteric or vesical), the symptoms change dramatically, and blood becomes visibly present in patients' urine and stool (Kolářová et al. 2013; Nation et al. 2020). Under chronic conditions and if parasite eggs damage the organ in which they were deposited, the carrier can suffer from liver, kidney, and bladder complications. Advanced intestinal schistosomiasis is manifested with enlarged liver and spleen, fibrosis, and portal hypertension while symptoms of advanced uro-genital schistosomiasis include hydronephrosis and calcification of the bladder (Andrade 2009; Salas-Coronas et al. 2020).

Social implications

Advances in understanding *Schistosoma* epidemiology, and the greater availability of effective diagnosis and new tools have improved both current management and prospects for refining control of schistosomiasis. Nevertheless, infection and morbidity rates of the disease are still high, particularly in poor and otherwise disadvantaged populations. This disease of poverty has proved to be difficult to control for centuries (Utzinger et al. 2011). Despite prolonged mass antiparasitic drug therapy programs and other control measures, it has not been eradicated and continues to spread to new geographical areas (Siddiqui et al. 2011). Globally, WHO has estimated that about (600–779) million people are at risk of infection due to their exposure to contaminated water and 200–209 million people are infected with these parasites (Steinmann et al. 2006; WHO 2012). Schistosome infections require direct contact in water between the skin and the infective cercariae, thus sociocultural factors are strongly linked to infection rates, as illustrated in Fig. 2. In addition, recording and reporting of incidences, prevalence and death rates remain a challenge, and further efforts are needed to improve tracking the disease both nationally and

Fig. 2 Infection by schistosomes is strongly associated with social activities (washing clothes, bathing, etc.) in which people come into direct contact with freshwater inhabited by schistosomes' intermediate host snails

globally. Accordingly, schistosomiasis is still considered one of the major healths, socio-economic and developmental challenges facing many of the world´s poorest countries.

Strategies to eliminate schistosomiasis

There is an urgent need to increase global awareness and support endemic countries' endeavors to develop appropriate methods to control the disease (Rollinson et al. 2013). As already mentioned, it is generally agreed that no single method will be sufficient to eliminate schistosomiasis; integrated approaches will be required due to its complexities (Mo et al. 2014). Application of molluscicides to reduce intermediate host snails populations is one of the most efficient methods for controlling the disease (Rapado et al. 2011). However, there are four major strategies for eradication: (1) treating infected individuals to reduce morbidity and mortality, and preventing the spread of *Schistosoma* parasite eggs, (2) providing communities with adequate, appropriate sanitation and accessible safe water to reduce environmental contamination and hence minimize the chances of miracidia transmission, (3) snail control to block the lifecycle of the parasite, and (4) health education (Fig. 3) (Chimbari 2012). To accelerate progress, a wider application of existing interventions combined with implementation of new methods in a manner tailored to the socio-ecological setting is required. In China, a comprehensive control strategy to reduce rates of *S. japonicum* transmission from humans and cattle to snails was evaluated from 2005 to 2007. The strategy included removing cattle from snail-infested areas, providing farmers with mechanical equipment, improving sanitation and implementing health-education programs in the endemic areas. This integrated strategy reportedly reduced *S. japonicum* infection in humans to less than 1% in an endemic area (Wang et al. 2009).

Medical control of schistosomiasis by treating infected humans

A systematic search for chemotherapeutic drugs has been ongoing for several decades. The synthesis of PZQ in 1970 revolutionized the treatment and led to dramatic reductions in morbidity and mortality rates. PZQ is the only drug being used to treat human schistosomiasis on a large scale (Doenhoff et al. 2008; Mordvinov and Furman 2010), and is highly recommended in disease-control programs (Salvador-Recatalà and Greenberg 2012). The scope of therapeutic programs, as treatment with PZQ has largely been restricted to children attending school due to the lack of infrastructure and other logistical problems in many areas of the developing world (Siddiqui et al. 2011).

Although treatment of schistosomiasis in patients worldwide relies heavily on PZQ and the drug has thoroughly recognized efficacy against schistosomes (Keiser et al. 2010), evidence is now accumulating that PZQ cannot prevent re-infection, and may sometimes even exacerbate it (Chandiwana et al. 1991; Doenhoff et al. 2008). Moreover, PZQ resistance is emerging in endemic areas due to repeated use (Wang et al. 2012). Obviously, there is a need for new alternatives for treating schistosomiasis (Cioli et al. 2014; Bergquist et al. 2017). Important potential sources are plants, and already many have been tested and some showed relevant activities, especially members of the medicinal plants. Many of them have been already tested and some showed relevant activities, especially members of the plant families Euphorbiaceae, Annonaceae, Fabaceae Asteraceae, Asphodelaceae, and Asparagaceae (Tables 1, 2, 3, 4 and 5).

Strategic controls of schistosomiasis by eliminating intermediate host-snails

Schistosoma parasites, like other parasitic helminths, can survive in their hosts for a long time, but the intermediate host is the weakest link in the transmission cycle. Thus, molluscicides are widely used as experimental models in programs to investigate the disease by killing the intermediate host snails (mollusks) (Wang et al. 2018), thereby disrupting the parasite's lifecycle and stopping transmission to people in contact with water in high-risk areas (Birley 1991).

Synthetic molluscicides

The major synthetic molluscicides thatare currently used to control the snail vectors are metaldehyde, niclosamide, carbamate, organophosphate, and synthetic pyrethroids (Singh et al. 2010). Niclosamide is one of the most widely used synthetic molluscicides at present. However, it is highly toxic towards non-target organisms, including fish, and it is also ecologically destructive (He et al. 2017). Nevertheless, it is one of the most important molluscicides approved by WHO due to the lack of robust alternatives (He et al. 2017). It is most active against *O. hupensis* snails with an LC_{50} of 0.12 µg/ml and LC_{90} of 0.98 µg/ml after 24 h (Chen et al. 2007) but it kills amphibians and fish if used in effective concentrations. There are also several chemical molluscicides (*e.g.* copper sulfate, calcium cyanamide, chlorinated lime and carbamate derivatives). However, they are environmentally hazardous,

Fig. 3 Strategies for schistosomiasis eradication

Table 4 Extracts with recognized larvicidal activity

Specie (plant part)	Vernacular name	Type of the extract	Results	References
Amaryllidaceae				
Allium cepa L.	Onion	ND	LC_{50} = 50 µg/ml (miracidia) LC_{50} = 50 µg/ml (cercariae) (*S. mansoni*)	Mantawy et al. (2012)
Allium sativum L.	Garlic	ND	LC_{50} = 100 µg/ml (miracidia) LC_{50} = 10 µg/ml (cercariae) (*S. mansoni*)	Mantawy et al. (2012)
Burseraceae				
Commiphora molmol (Engl.) Engl. ex Tschirch (Arabian or Somali gum)	Myrrh	Oil	LC_{100} = 2.5–10 µg/ml 60–90 min (cercariae) (*S. haematobium*)	Masoud et al. (2000)
Euphorbiaceae				
Jatropha curcas L. (Seeds)	Physic nut	Methanol	LC_{100} = 25 µg/ml (cercariae) LC_{50} = 5 µg/ml (miracidia) (*S. mansoni*)	Rug and Ruppel (2000)
		Water	LC_{50} = 5 mg/ml (miracidia and cercariae) (*S. mansoni*)	Rug and Ruppel (2000)
		Crude oil	250 µg/ml killed all cercariae in 80 min 100 µg/ml kills all larvae within 2 h (*S. mansoni*)	Rug and Ruppel (2000)
Lamiaceae				
Plectranthus tenuiflorus (Vatke) Angew (Leaves)	–	Methanol	LC_{50} = 17.39 mg/ml (cercariae) LC_{50} = 24.37 mg/ml (miracidia) (*S. mansoni*)	Aziz et al. (2011)
Solanaceae				
Solanum nigrum L. (Leaves)	Nightshade	Water	LC_{100} = 30 µg/ml (*S. haematobium*) LC_{100} = 30 µg/ml (*S. mansoni*) LC_{100} = 40 µg/ml (*F. gigantica*) after 30 min (cercariae)	Ahmed and Ramzy (1997)

Table 5 Compounds with antischistosomasis of water larvacidal activity isolated from higher plant

Common name (chemical name)-/class	Species (part)/family	Separation tools	Spectral analysis	Results	References
2-hydroxychrysophanol (1,2,8-trihydroxy 3-methylanthraquinone) (Anthraquinone) (38)	*Hemerocallis fulva* (L.) L. (root)/ Hemerocallidaceae	Repeated ODS, Sephadex LH-20 gel CC	UV, IR, (EI & HR-EI) MS, ^{1}H-&^{13}C-NMR	Immobilized all cercariae within 15 s at 3.1 µg/ml	Cichewicz et al. (2002)
Kwanzoquine E/ (Anthraquinone) (41)	*Hemerocallis fulva* (L.) L. (Root)/ Hemerocallidaceae	Sephadex LH-20 CC, ODS preparative HPLC	UV, IR, (EI & HR-EI) MS, 1H-&13C-NMR, DEPT, HMBC	Immobilized cercariae within 12–14 min at 25 µg/ml	Cichewicz et al. (2002)

and snails develop resistance to them (Bilia et al. 2000b).

Available molluscicides are also costly, which poses major problem for low-income countries where schistosomiasis is widely distributed. Despite all recent research and development current synthetic molluscicides also raise serious environmental concerns and threats to both human health and income (particularly in areas where fishing is a major source of food and income) due to their lack of specificity (Andrews et al. 1982; He et al. 2017). Thus, identifying or developing more selective molluscicidal herbal preparations that do not have adverse effects (or at least acceptably weak effects) in non-target aquatic organisms and are biodegradable remains a high priority (El-Sherbini et al. 2009).

Plant molluscicides

Several thousand synthetic compounds have been tested for their ability to control host snails but none of of them was proven to be as entirely satisfactory as yet. Therefore, natural sources of novel agents came into play an are considered now as attractive alterantives to seek for novel drug leads (Ribeiro et al. 2021; Xing et al. 2021). Primary target sources are medicinal

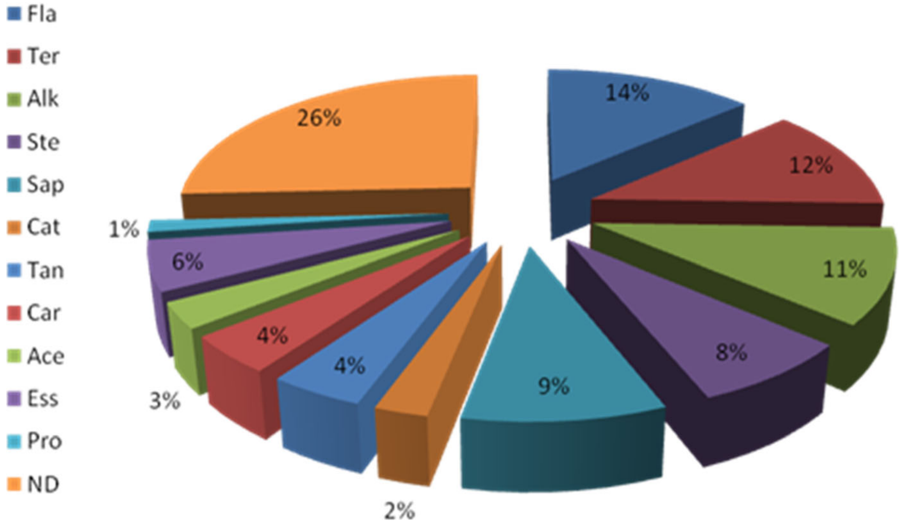


Fig. 4 The most bioactive of natural compounds against snails based on a review of literature: Fla, flavonoids; Ter, Terpenes; Alk, alkaloids; Ste, steroids; Sap, saponins; Cat, catechine; Tan, tannins; Car, carbohydrates; Ace, acetogenine; Ess, essential oils; Pro, proteins; ND, not defined

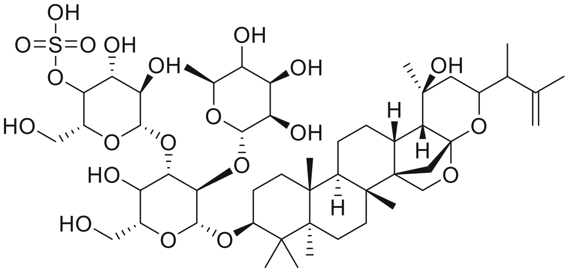


Fig. 5 A novel anti-schistosomiasis triterpene glycoside (Asparagalin A) **(1)**

plants because they are generally a rich source of renewable bioactive organic chemicals, and they may grow well in endemic areas, providing income for local farmers. Furthermore, plant derived molluscicides may have several advantages like low costs, high target specificity, water solubility, high biodegradability, and low toxicity towards normal organs in the human hots (Singh et al. 2010).

Since 1982, the potential utility of more than 150 plant species for controlling freshwater snails has been tested. Numerous groups of compounds plant-derived compounds were toxic to target organisms at acceptable doses, ranging from < 1 to 100 µg/ml (Singh et al. 2010). The molluscicidal activity of plant extracts and often their active compounds have been reported (Tables 1 and 2). Commonly identified active compounds belong to saponins, alkaloids, terpenoids and tannins (Fig. 4). The plant extracts evaluated against the intermediate host (snails and larvae of *Schistosoma*) are listed in Table 4. These include, for instance, methanol and aqueous extracts of *Jatropha curcas* L. (Euphorbiaceae) on snails transmitting *S. mansoni* and *S. haematobium* (Rug and Ruppel 2000). Different parts were traditionally used as antimicrobial agents. The plant had traditional uses as antimicrobial agents. Plant species known to be rich in bioactive molluscidal compounds are presented in Tables 2 and 5. Tannins are particularly suitable for snail control because tannin-containing plants are not only widely distributed but tannins can be also relatively easily isolated (Al-Sayed et al. 2014). The highest contents of molluscicidal agents have been found in members of Euphorbiaceae followed by Annonaceae, Mimosaceae, Polygonaceae, Verbenaceae and Caesalpinaceae families, the active compounds of a number of plants are presented in (Fig. 4).

More extensive efforts are warranted to isolate and identify the remaining unknown compounds from other plants, that could meet all the desirable criteria of molluscicides.

Classes of compounds used as plant molluscicides

Saponins Saponins comprise a structurally diverse class of triterpenes, based on triterpenoids often in the form of glycosides. They occur in plant species and have been also isolated from marine organisms (Challinor and De Voss 2013). Saponins derive their name from the soapwort plant, genus *Saponaria* (Caryophyllaceae). The triterpene skeletons of saponins are formed from the C_{30} precursor oxidosqualene. They are diverse, and decorated with different functional groups in different plant species (Challinor and De Voss 2013). They have hemolytic properties, toxic effects on most cold-blooded animals and proven molluscicidal activity (Francis et al. 2002; Sparg et al. 2004).

Triterpenoids and saponins are widespread in nature. The most active molluscicidal saponin compounds have an oleanolic acid-based aglycone and trisaccharide sugar moiety (Mølgaard et al. 2000). This is consistent with our recent finding that asparagalin A (Fig. 5) **(1)**, a triterpene saponin from the Egyptian species *Asparagus stipularis* Forssk., suppresses *S. mansoni* egg-laying. Shoots and roots of this plant used in folk medicine as diuretic for curing jaundice, liver ailments, against bilharzias (El-Seedi et al. 2012). Sometimes molluscicidal compounds are formed by an enzymatic reaction during extraction of plants, for instance if *Phytolacca dodecandra* L'Hér. berries are crushed with water (Parkhurst et al. 1989).

The desert tree *Balanites aegyptiaca* (L.) Delile (common name Higleeg) (Suleiman 2015) has a well-known molluscicidal activity. It was the first plant reported for the control of schistosomiasis owing to its saponins content (Marston and Hostettmann 1985). The fruits of this plant were used as remedy to eradicate intestinal parasites. This plant species is traditionally (Table 3) used in treatment of malaria and is apparently suitable for vector control (Chothani and Vaghasiya 2011).

Pulsatilla chinensis (Bunge) Regel displayed potent molluscicidal activity against *O. hupensis*, attributable to the presence of the active triterpenoid saponins. The plant roots are widely used in traditional

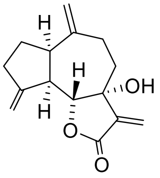
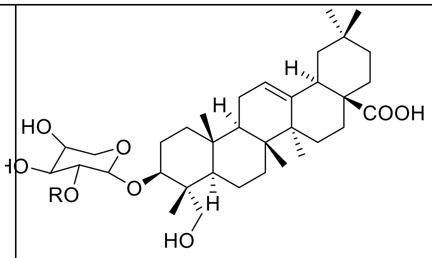
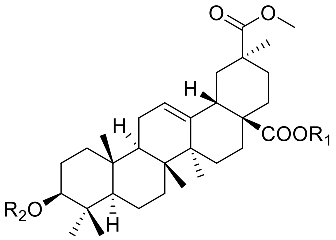
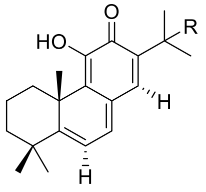
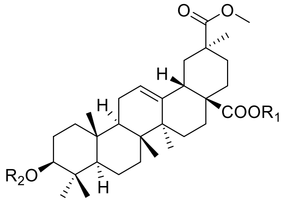
 **7α-hydroxy-3-desoxyzaluzanin C (5)**	 3-*O*-[α-L-arabinopyranosyl]-hederagenin **(6)** **R= H** 3-*O*-[α-L-rhamnopyranosyl -(1→2)-α-L-arabinopyranosyl]-hederagenin **(8)** R= Rha 3-*O*-[*β*- D -glucopyranosyl-(1→2)-α-L-arabinopyranosyl] hederagenin **(9)** R= Glc	 3-*O*-(*β*-D-galactopyranosyl-(1→3)-*β*-D-glucopyranosyl) serjanic acid 28-*O*-*β*-D-glucopyranoside **(7)** R_1= Glc, R_2= Glc^3-Gal
 15-deoxyfuerstione **(10)** R=H Fuerstione **(13)** R=OH	 3-*O*-(α-L-rhamnopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranosyl) serjanic acid 28-*O*-*β*-D-glucopyranoside – saponin **(11)** R_1= Glc, R_2= Glc^2-Glc^2-Rha 3-*O*-(*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranosyl) serjanic acid 28-*O*-*β*-D-glucopyranoside **(12)** R_1= Glc, R_2= Glc^2-Glc 3-*O*-(*β*-D-galactopyranosyl-(1→3)-*β*-D-glucopyranosyl) serjanic acid **(16)** R_1= H R_2= Glc^3-Gal 3-*O*-(*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranosyl) serjanic acid **(17)** R_1= H R_2= Glc^2-Glc 3-*O*-(*β*-D-glucopyranosyl-(1→3)-*β*-D-glucopyranosyl-(1→3)-*β*-D-glucopyranosyl) serjanic acid **(19)** R_1= H R_2= Glc^3-Glc^3-Glc 3-*O*-(α-L-rhamnopyranosyl-(→)-*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranosyl) serjanic acid **(20)** R_1= H R_2= Glc^2-Glc^2-Rha	

Fig. 6 Structures of mollusicicidal bioactive compounds

Chinese medicine as remedies for amebiasis, malaria, vaginal trichomoniasis and bacterial infections. Treatment with a sub-lethal concentration reportedly caused significant inhibition of acetyl cholinesterase (AHE), alanine transaminase (ALT), and alkaline

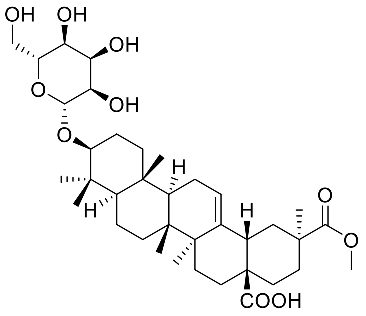
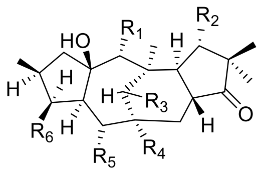
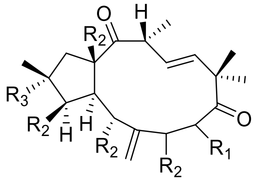
 3-*O*-*β*-D-glucopyranosylserjanic acid **(14)**	 (2S,3S,4R,5R,6R,8R,11S,12S,13R,14R,15R)-6,14,17-triacetoxy-5-(2-hydroxyacetoxy)-3-benzoyloxy-15-hydroxy-9-oxo-segetane-diterpene **(15)** $R_1=R_3=R_4= OCOCH_3$ $R_2=H$, $R_5=OCOCH_2OH$ $R_6= OCOC_6H_5$ (2S,3S,4R,5R,6R,8R,11S,12S,13R,14R,15R)-6,11,14,17-tetraacetoxy-5-(2 acetoxyacetoxy)-3-benzoyloxy-15-hydroxy-9-oxo-segetane **(21)** $R_1= R_2=R_3=R_4= OCOCH_3$, $R_5=OCOCH_2COOCH_3$, $R_6= OCOC_6H_5$ (2S,3S,4R,5R,6R,11S,13R, 14S,15R,17R)-5,6,11,14,17-pentaacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-seget-8(12)-ene diterpene **(22)** $R_1=R_2=R_3=R_4= R_5=OCOCH_3$, $R_6= OCOC_6H_5$ (2S,3S,4R,6R,8R,11S,12S,13R, 14R,15R)-5,6,11,14,17-pentaacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-segetane-diterpene **(23)** $R_1=R_2=R_3=R_4= R_5=OCOCH_3$, $R_6= OCOC_6H_5$
	 (2R,3R,4S,5R,7S,8R,13R,15R)-2,3,5,7,15-pentaacetoxy-8-iso-butyroyloxy-9,14-dioxojatropha-6(17),11E-diene **(18)** R1= $OCOCH(CH_3)_2$, $R_2=R_3=OCOCH_3$ (2R,3R,4S,5R,7S,8R,13R,15R)-2,3,5,7,15-pentaacetoxy-8-angeloyloxy-9,14-dioxo-jatropha-6(17),11E-diene **(24)** $R_1=R_2=R_3=OCOCH_3$ (2R,3R,4S,5R,7S,8R,13R,15R)-3,5,7,15-tetraacetoxy-8-isobutyroyloxy-9,14-dioxo-jatropha-6(17),11E-diene **(29)** R1= $OCOCH(CH_3)_2$, $R_2=OCOCH_3$,

Fig. 6 continued

phosphatase (ALP) activities in the liver and the cephalopodium of *O. hupensis* (Chen et al. 2012).

Extracts of *Calendula officinalis* L. and *Ammi majus* L. (common name, Khilla sheitani) have molluscicidal activity against *Bullinus truncates* and

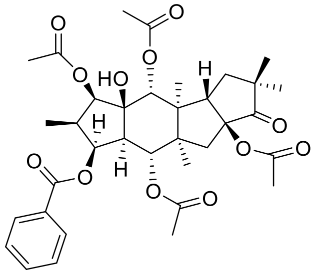
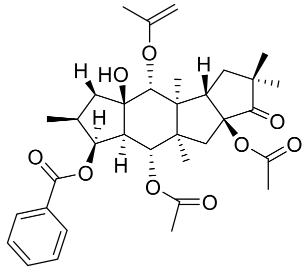
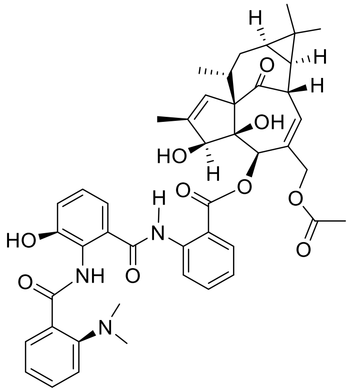
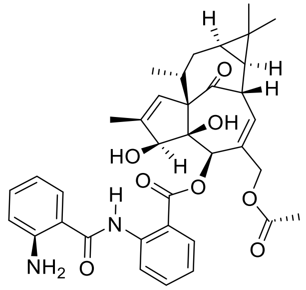
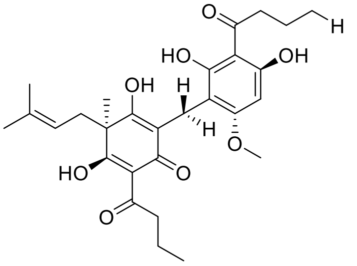
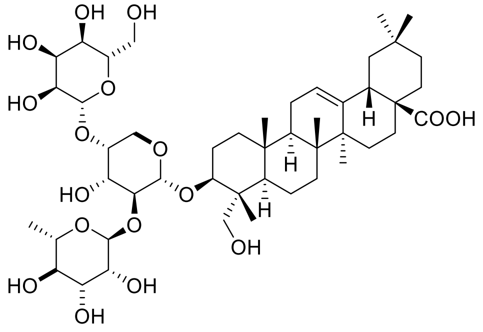
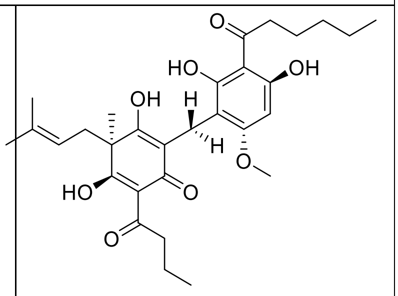
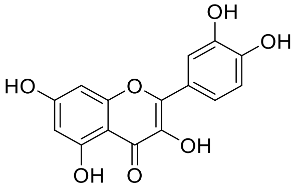
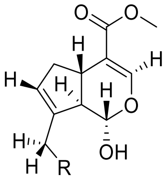
	R_3=H	
 (2S,3S,4R,5R,6R,8R,12S,13S,14R,15R)-1,5,8,14-tetraacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-paraliane **(25)**	 (2S,3S,4R,5R,6R,8R,12S,13S,14R,15R)-5,8,14-triacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-paraliane **(26)**	 Milliamine D **(27)**
 Milliamine M **(28)**	 Elaphopilosin-A **(30)**	
 Pulsatilla saponin D (3-*O*-[[*β*- D -glucopyranosyl-(1→4)]-[*α*-L-rhamnopyranosyl-(1→2)]-*α*-L-arabinopyranosyl] hederagenin) **(31)**		 Elaphopilosin-B **(32)**

Fig. 6 continued

B. Alexandria (less strongly). The recorded LC_{50} and LC_{90} values indicated that *C. officinalis* L. is more toxic to both snails where *A. majus*, and *Bullinus. truncatus* snails are more sensitive to the extracts of both plants than *B. alexandrina*. Prolonged exposure to sub-lethal concentrations of *A. majus* L. affected the egg-laying and survival of both snails. In addition, treatment with sub-lethal doses of extracts of both plants clearly inhibited transaminase activity, diminished the total protein content, and markedly increased

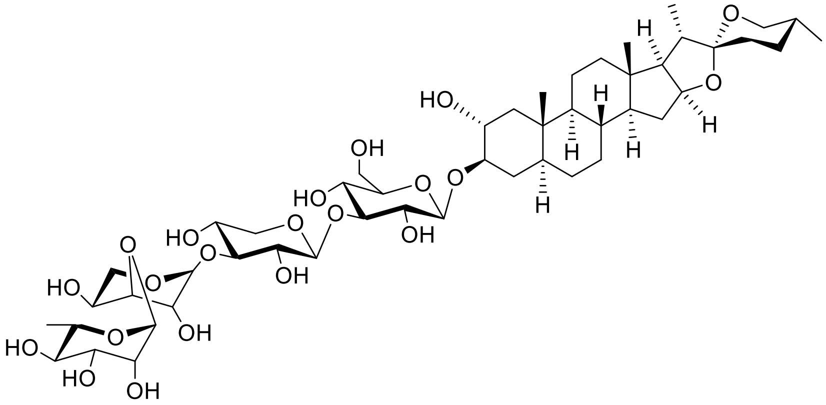


Quercetin **(33)**

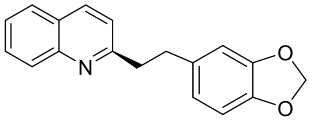


Genipin 10-acetate **(34)** R= CH_3COO

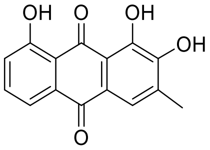
Genipin **(35)** R= OH



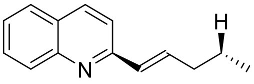
3-*O*-[α-L-rhamnopyranosyl (1→3)-α-L-arabinopyranosyl (1→3)-*β*- D - xylopyranosyl (1→3)-*β*- D - glucopyranosyl]-25R,5α-spirostan-2α,3*β*-diol **(36)**



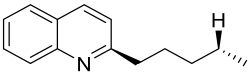
2-(3', 4'-methylene-dioxyphenylethyl)-quinoline **(37)**



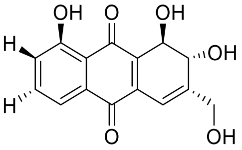
2-hydroxychrysophanol **(38)**



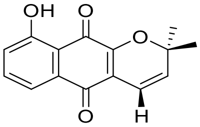
2-(1'-pentenyl)-quinoline **(39)**



2-*n*-pentylquinoline **(40)**



Kwanzoquine E **(41)**

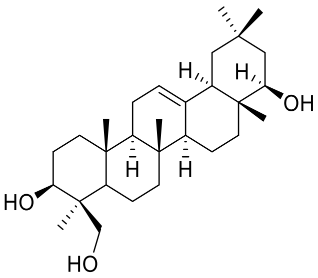


α-caryopterone **(42)**

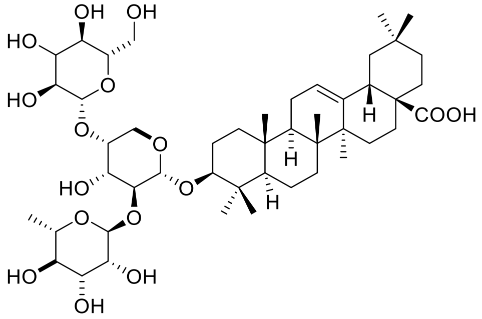
Fig. 6 continued

total lipid contents in both snails hemolymph (Rawi et al. 1996). The activity of *A. majus* L. is thought to be due to saponins, and furocoumarins, although the effect seems to be highly snail species-dependent (Marston and Hostettmann 1985; Rawi et al. 1996).

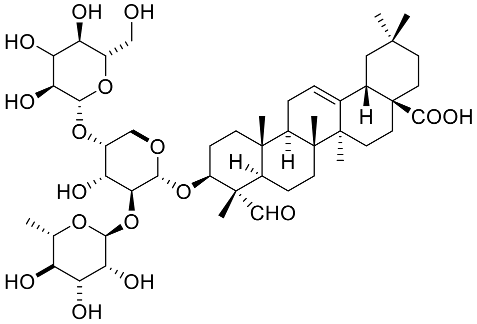
Phytolacca dodecandra L'Hér. is one of the most active molluscicidal plants, and thus has been widely



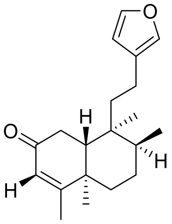
Sapogenin **(43)**



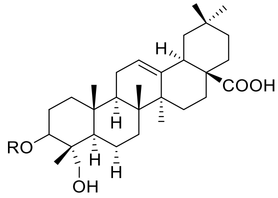
3-*O*-[[*β*- D -gluopyranosyl-(1→4)]-[*α*-L-rhamnopyranosyl-(1→2)]-*α*-L-arabinopyranosyl] oleanolic acid **(44)**



Salzmannianoside A **(45)**

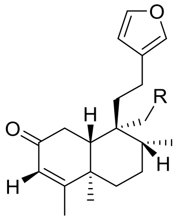


Velamone **(46)**



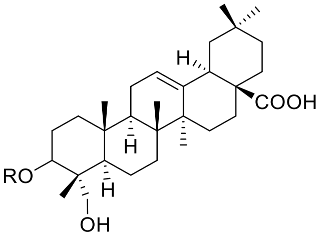
R= Ara ^{2}-Rha ^{3}-Xyl

Saponin PG (sapindoside B)- **(47)**



Velamolone acetate **(48)** R_1= CH_3COO

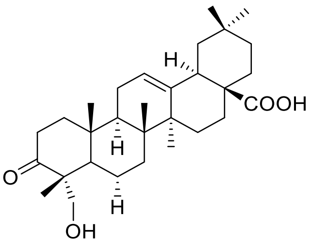
Velamolone **(49)** R_1= OH



Leontoside A **(50)** R= Ara

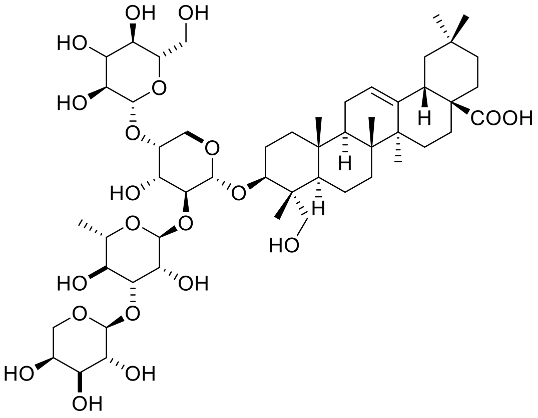
Fig. 6 continued

studied. Its activity was initially reported by Lemma‘s group (Lemma 1965, 1970) and the presence of an active saponin named lemmatoxin was demonstrated (Parkhurst et al. 1974). Aqueous extracts of the dried berries contain up to 25% saponins (Treyvaud et al. 2000) which were stable in water for two days at room temperature (Mølgaard et al. 2000). Some isolated saponins are lethal to snails at very low concentrations. However, a major disadvantage of using saponins as molluscicides is that they are also

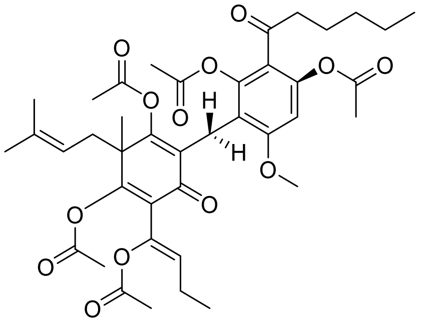


Hederagenic acid **(51)** R=H

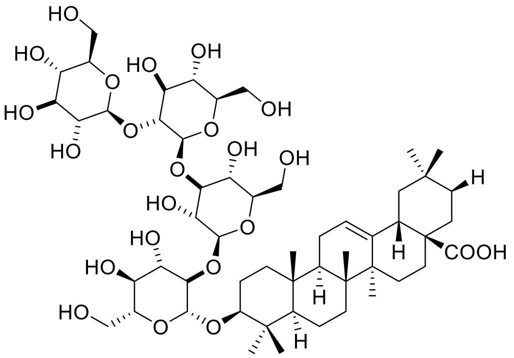
6α-Hydroxyhederagenic acid **(52)** R=OH



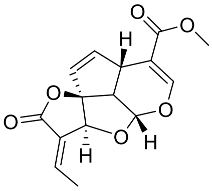
Salzmannianoside B **(53)**



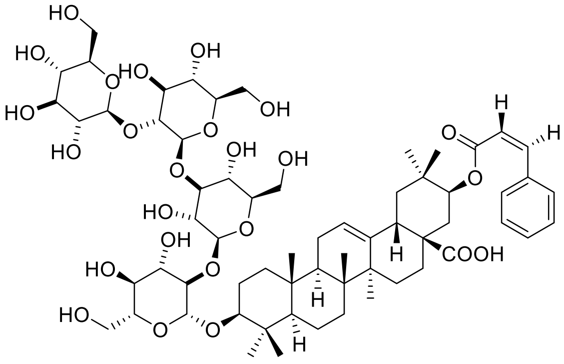
Acetylation of elaphopilosin-B **(54)**



Pachyelaside B **(55)**



Isoplumericin **(56)**



Pachyelaside A **(57)**

Fig. 6 continued

generally lethal to fish compared to flavonoids and other phenolics that are generally less toxic to non-target organisms (Wei et al. 2002).

Glycoalkaloids Several glycoalkaloids (Fig. 6) identified from *Solanum* species are molluscicidal. Extracts of *S. elaegnifolium* Cav. berries, and *S.*

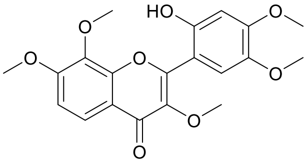
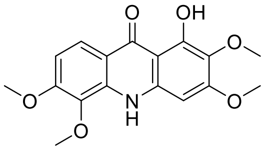
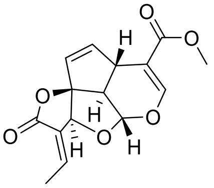
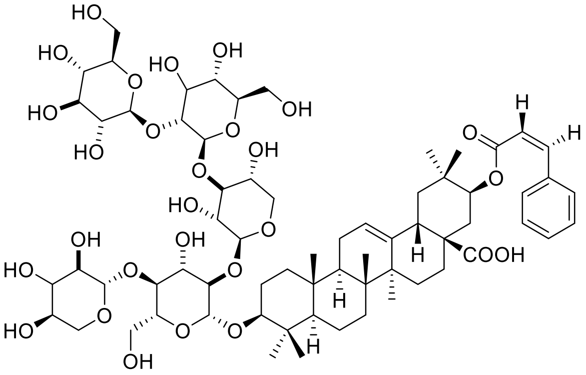
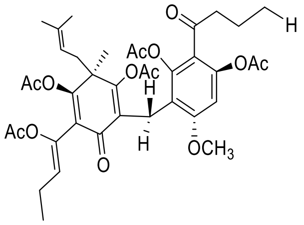
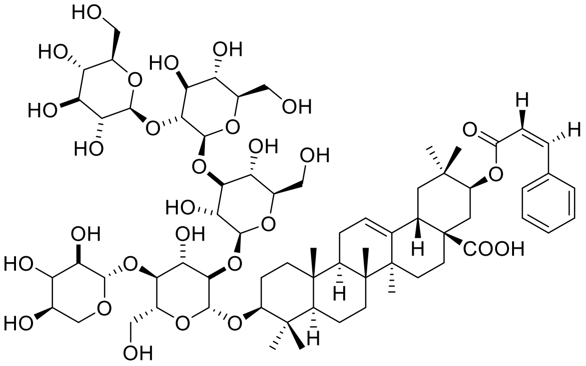
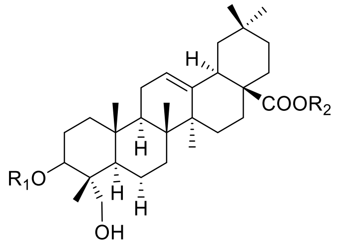
 2′-Hydroxy 3,7,8,4′,5′-pentamethoxy flavones **(58)**	 Cuspanine **(59)**
 Plumericin **(60)**	 Pachyelaside C **(61)**
 Acetylation of elaphopilosin-A **(62)**	 Pachyelaside D **(63)**

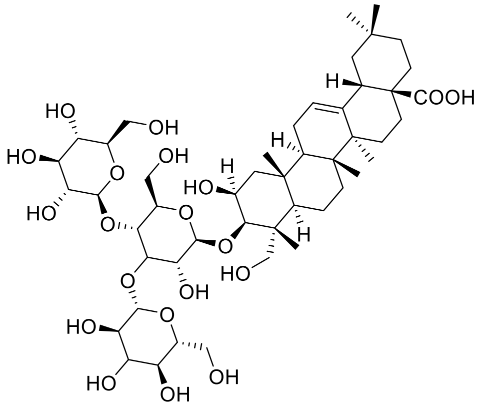
Fig. 6 continued

sodomaeum Dunal leaves and seeds reveal molluscicidal activity against *Bu. truncates*, the intermediate host of *S. haematobium* (Table 2) (Bekkouche et al. 2000). In addition, *S. sisymbriifolium* Lam. fruits are active against the snails, the active fractions contain the steroidal alkaloids solamargine (Fig. 7) **(2)** and *β*-solamarine (Bagalwa et al. 2010), but solamargine is the most effective of these compounds, due to its specific sugar substitution (Miranda et al. 2012). Solamargine (containing a chacotriose sugar chain moiety) is also more active than solasonine, (containing a solatriose sugar chain moiety) against adult *S. mansoni* worms (Miranda et al. 2012).

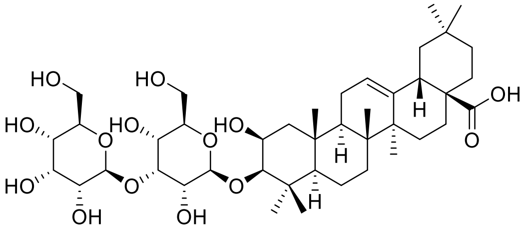
Phorbol esters Phorbol (Fig. 8) **(3)** was initially isolated in 1934 as a hydrolysis product of *Croton tiglium* L. vegetable oil (Flaschenträger, v. Wolffersdorff 1934; Abegaz and Kinfe 2020), and its structure was subsequently elucidated by Hecker and



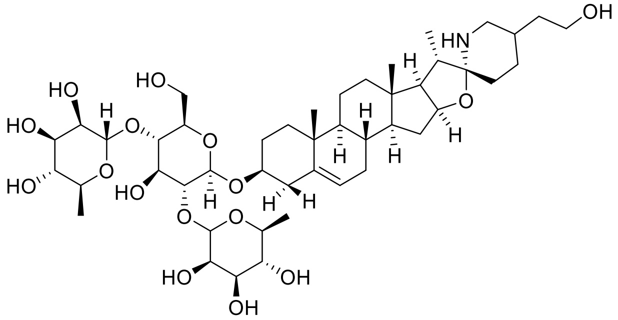
Dipsacoside B **(64)** R_1= Ara ^{2}-Rha; R_2= Glu ^{6}-Glu



3-*O*-[*O*-*β*-D-galactopyranosyl-(l→3)-*O*-[*β*-D-glucopyranosyl-(1→4)]-*β*-glucopyranosyl] bayogenin **(65)**



3-*O*-[3'-(*O*-*β*-D galactopyranosyl)-*β*-D-glucopyranosyl] 2*β*-hydroxyoleanolic acid **(66)**

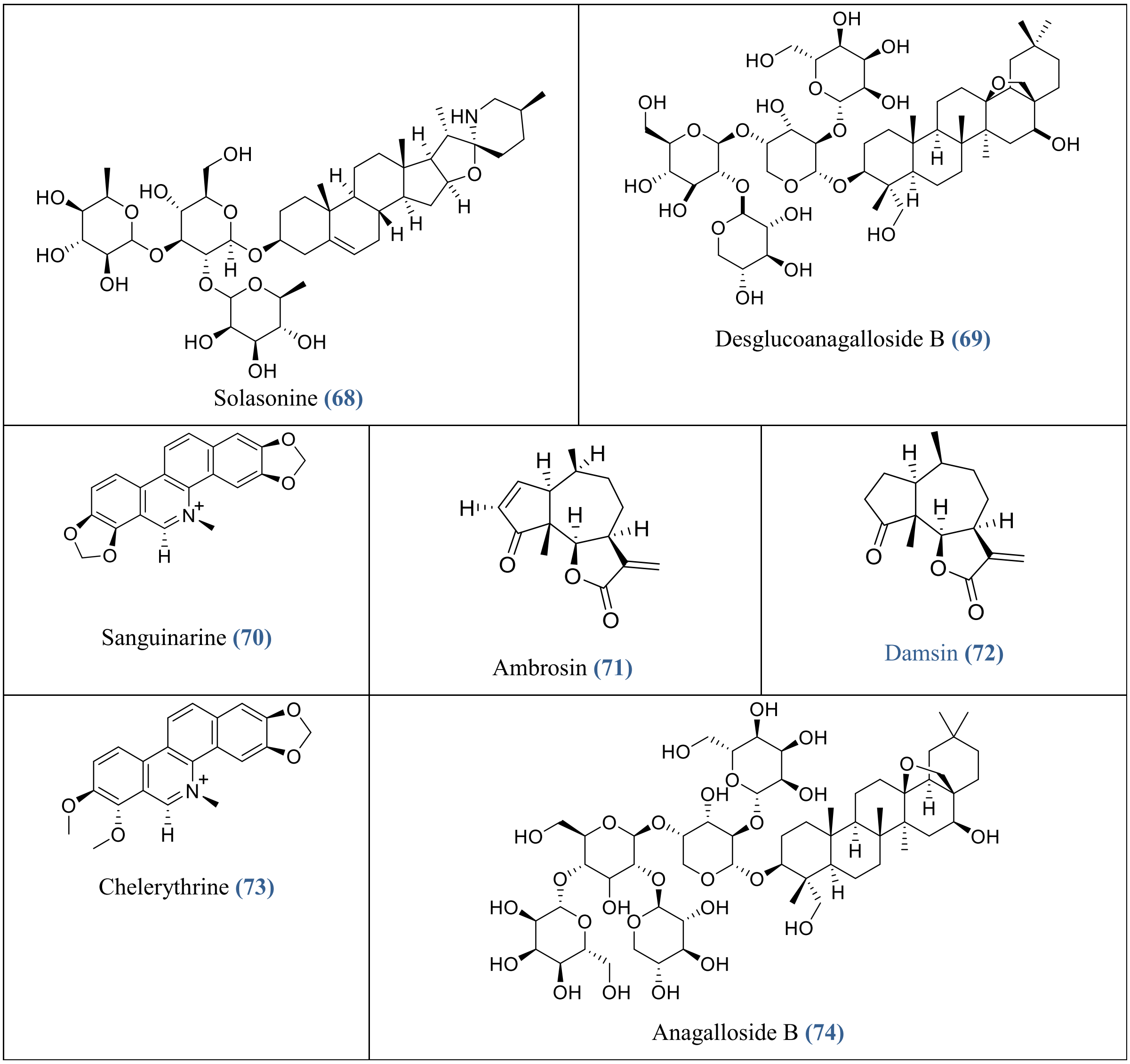


Solanandaine **(67)**

Fig. 6 continued

colleagues (Hecker 1967). Phorbol esters are diterpenes, which are, among others, major constituents of *Jatropha curcas* L. oil. They exhibit molluscicidal activity against aquatic snails (Liu et al. 1997). Some of the phorbol esters are mutagenic and thus not suited as a molluscicidal medicine (Liu et al. 1997).

Phorbol esters (and anthraquinone) are also the most bioactive compounds tested against miracidia and cercaria (Fig. 9). There have been few attempts to


Solasonine **(68)**

Desglucoanagalloside B **(69)**

Sanguinarine **(70)**

Ambrosin **(71)**

Damsin **(72)**

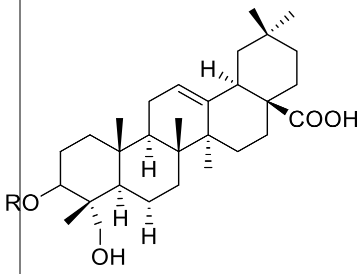
Chelerythrine **(73)**

Anagalloside B **(74)**

Fig. 6 continued

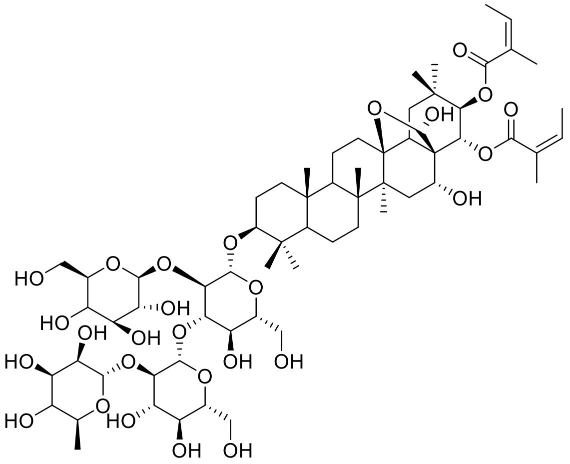
isolate bioactive water larvicidal compounds; however, more extensive investigations are warranted.

Neolignins Neolignans are a group of dimeric phenylpropanoids that are formed in Myristicaceae and other primitive plant families (e.g. Piperaceae, Eucommiaceae and Lauraceae) by oxidative coupling of allyl and phenyl propanoids (Alves et al. 2002). The biological activities of neolignan derivatives have been investigated against fungi such as *Microsporum canis, M. gypseum, Tricophyton mentagrophytes, T. rubrum,* and *Epidermophyton floccosum* (Zacchino et al. 1997), bacteria (e.g. *Staphylococcus aureus* and *Bacillus subtilis*) (Pessini et al. 2003), and a panel of cancer cell lines (Siripong et al. 2006). A number of these compounds displayed anti-schistosomiasis activity (Mengarda et al. 2021), Structure–activity relationships of 18 synthetic neolignan derivatives have also been studied (Alves et al. 2002). Two neolignans isolated from the leaves of *Virola surinamensis* (Rol. ex Rottb.) Warb., virolin

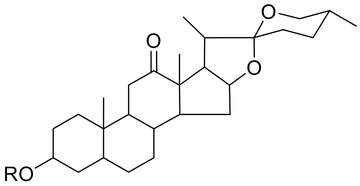


Kalopanax saponin A

(75) R= Ara ^{2}- Rha



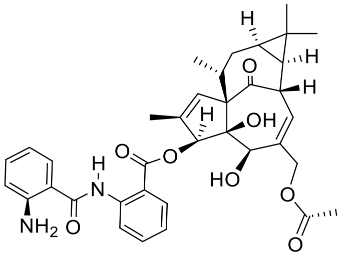
Maesasaponin VI$_2$ **(76)**



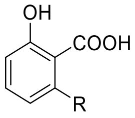
R= Xyl^{3}-Glc^{3}-Glc

3-*O*-*β*-D-glucopyranosyl-(1 →3)-*β*-D-glucopyranosyl-(1→3)-*β*-D-xylopyranoside gloriogenin **(77)**

Rutin **(78)**



Milliamine L **(79)**



Ginkgolic acid C13:0 **(80)**

Ginkgolic acid C13:0 **(80)** R= $C_{13}H_{27}$

Ginkgolic acid C15:1 **(81)** R= $C_{15}H_{25}$

Ginkgolic acid C17:1 **(82)** R= $C_{17}H_{33}$

Fig. 6 continued

(Fig. 10) **(4)** and surinamensin have been active against *S. mansoni* (Alves et al. 1998).

Latex with molluscicidal activity Latex from Euphorbiaceae species has strong molluscicidal activity, particularly against aquatic snails (Bah et al.

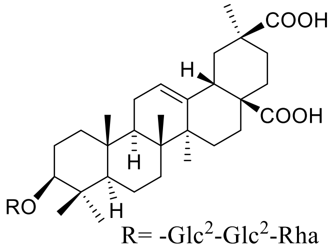
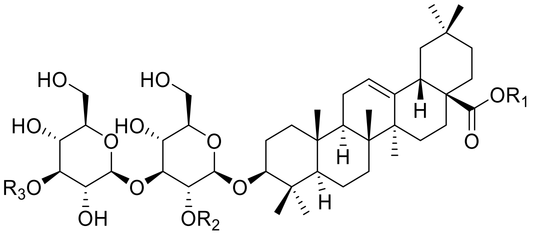
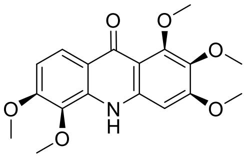
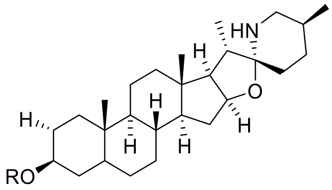
 R= -Glc^2-Glc^2-Rha 3-*O*-(α-L-rhamnopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→2)- *β*-D-glucopyranosyl) spergulagenic acid-saponin **(83)**	 3-*O*-[*O*-*β*-D- glucopyranosyl(1→3)-*β*-D-glucopyranosyl] oleanolic acid **(84)** R_1=H, R_2= H, R_3=H 3-*O*-{*O*-α-L-rhamnopyranosyl-(1→3)-*O*-[*O*-*β*-D -glucopyranosyl-(1→3)]-*β*-D-glucopyranosyl}oleanolic acid **(85)** R1= H, R2= H, R3= α-L-Rhap 3-*O*-[2',3'-di- *O*-(*β*-D- glucopyranosyl)-*β*-D- glucopyranosyl]oleanolic acid **(86)** R_1= H, R_2= *β*-D-Glup , R_3= H 28-*O*-*β*-D- glucopyranosyl- 3- *O*-{*O*- α-L-rhamnopyranosyl-(1→3)-*O*-[*O*-*β*-D-glucopyranosyl-(1→3)]-*β*- D- glucopyranosyl} oleanolate **(87)** R_1= *β*-D-Glup, R_2=H, R_3= α-L-Rhap
 Cusculine **(88)**	 R= Xyl-2Glc-Gal Tomatine **(89)**

Fig. 6 continued

2006). The crude latex of *Euphorbia milii* var. *hislopii*, the most powerful molluscicidal agent, has activity against the schistosomiasis-transmitting snails, *B. glabrata* and *B. tenagophila*, (Yadav and Jagannadham 2008). This could be due to the presence of triterpenes, flavonoids, macrolides, ingenol and a phorbol ester (Zani et al. 1993). The latex had stronger effects than the molluscicide niclosamide and was less less harmful to nontarget aquatic organisms (Oliveira-Filho et al. 1999; dos Santos et al. 2007). It also affects the cercaeia and larval stage of *Schistosoma* species (De-Carvalho et al. 1998).

Latex of *E. splendens* Bojer ex Hook. is also a potent and specific molluscicide ($LC_{90} < 1.5$ µg/ml) against the vector snails (Schall et al. 1998). It did not show acute toxicity or mutagenic activity towards non-target species at the concentrations of 10–12 µg/ml (Schall et al. 1991). Attempts to identify the components responsible for the effects on snails

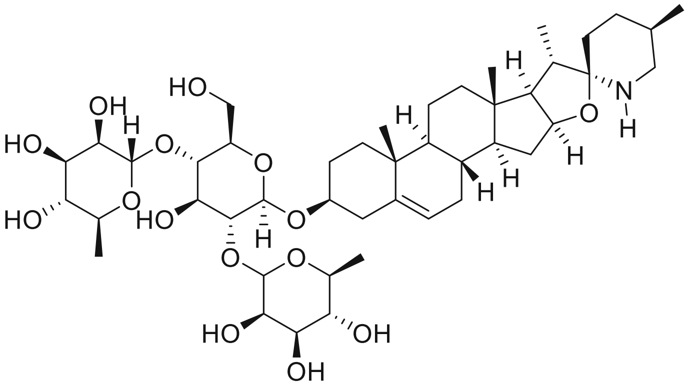


Fig. 7 Solamargine, a glucoalkaloid containing a chacotriose sugar chain moiety with molluscicidal activity **(2)**

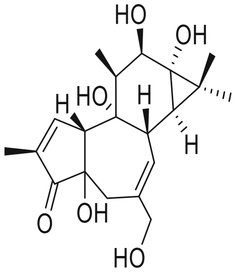


Fig. 8 Chemical structure of phorbol **(3)**

showed that normal, processed, non-proteinaceous and proteinaceous fractions had molluscicidal activity, but the proteinaceous fraction containing alkaloids had the strongest physiological and lethal effects on fresh water snails (*B. glabarata*) (Yadav and Singh 2011).

Clinical trials for uses medicinal plants against schistosomiasis 70 schistosomiasis haematobium patients both sexes (aged > 15–60 years old) were treated with Mirazid at10 mg/Kg. The cure rate reached 91.9% after two months and 95.2% on the 3rd post-Mirazid treatment month (El Baz et al. 2003).

In total, 268 school children infected with *S. mansoni* were divided into three groups: PZQ (87), arachidonic acid (ARA, 91), and PZQ plus ARA (90). Over the course of three weeks, and for 15 days, PZQ 40 mg/kg/day, ARA 10 mg/kg/day, or PZQ combined with ARA (40 mg/kg on the first day of treatment, then 15 doses of ARA 10 mg/kg per day for 5 doses/week) were administrated. In children with light and heavy infections, PZQ and ARA together evoked cure rates of 83% and 78%, respectively. ARA, like PZQ, induced moderate cure rates (50% and 60%, respectively) in school children with light infection and modest cure rates (21% and 20%, respectively) in school children with high infection. Taken together, combination of PZQ and ARA might be useful for treatment of children with schistosomiasis in high-endemicity regions (Barakat et al. 2015).

Conclusion

Schistosomiasis is a major neglected tropical disease with high public health impact. It is difficult to control the disease due to the complex life cycle of the parasite and its wide distribution in tropical and subtropical areas where health and sanitation services are poorly developed. Field control currently relies mostly on some synthetic compounds, which are costly, especially for the low-income regions where the disease is endemic. Since 1981 more than 150 plant species have been tested for molluscicidal activity, and more than 60 natural molluscicidal compounds have been isolated. Preliminary results are encouraging but further investigations are needed to bring more significant progress to a to a large-scale application in the field, including rigorous pharmaceutical validation, particularly to assess candidate compounds' specificity. More screening of natural sources is also needed, with particular emphasis on structure–activity relationships and action mechanisms. Saponins, for example, specifically block homeostatic circuits.

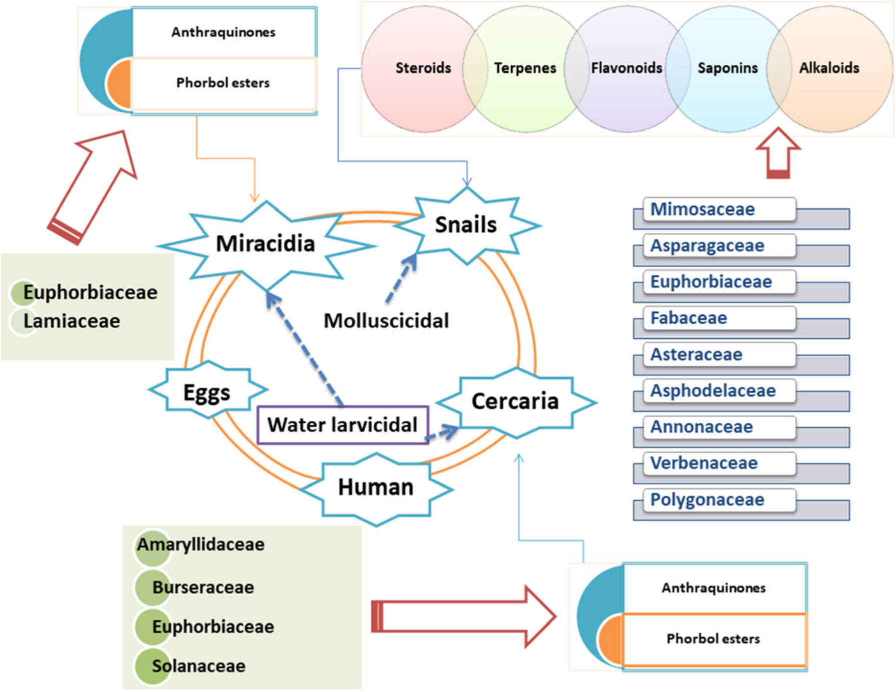


Fig. 9 Lifecycle stages of *Schistosoma* targeted by natural compounds, and the most active plant families

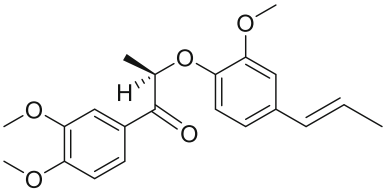


Fig. 10 Chemical structure of virolin **(4)**

More research is also needed to discover and identify new environmentally friendly molluscicides and larvicides of plant origin that are not toxic to non-target aquatic organisms. Establishment of a global database of the distribution of schistosomiasis vector snails is also necessary for large-scale application of plant molluscicides and optimization of control programs.

The present review here shows that nature offers a plethora of possibilities for improving schistosomiasis control. Production of locally growing plants with molluscicidal and/or anti-schistosome activities would be an attractive alternative, since they could provide abundant agents to interfere with multiple stages of the parasite's lifecycle without imposing excessive financial burdens. Natural products are likely to be the strongest defense; myriads remain to be discovered.

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Declarations

Conflict of interest The authors declare no conflict of interest.

References

Abdelgaleil SAM, El-Aswad AF, Nakatani M (2002) Molluscicidal and anti-feedant activities of diterpenes from *Euphorbia paralias* L. Pest Manag Sci 58:479–482. https://doi.org/10.1002/ps.487

Abdel-Gawad MM, El-Amin SM, Ohigashi H et al (2000) Molluscicidal saponins from *Anagallis arvensis* against schistosome intermediate hosts. Jpn J Infect Dis 53:17–19

Abdel-Hamid HF (2003) Molluscicidal and in-vitro schistosomicidal activities of the latex and some extracts of some plants belonging to *Euphorbiacea*. J Egypt Soc Parasitol 33:947–954

Abegaz BM, Kinfe HH (2020) 1. Secondary metabolites, their structural diversity, bioactivity, and ecological functions: an overview. In: Ntie-Kang F (ed) Fundam, vol 1. Bost. De Gruyter, Berlin, pp 7–54

Abou Basha LM, el Sayad MH, Allam AF, Osman MM (1994) The effect of *Ambrosia maritima* (Damsissa) on the viability of *Lymnaea cailliaudi*; An experimental study. J Egypt Soc Parasitol 24:513–517

Abou-El-Naga IF (2018) Towards elimination of schistosomiasis after 5000 years of endemicity in Egypt. Acta Trop 181:112–121. https://doi.org/10.1016/j.actatropica.2018.02.005

Acka CA, Raso G, N'Goran EK et al (2010) Parasitic worms: knowledge, attitudes, and practices in western Côte d'Ivoire with implications for integrated control. PLoS Negl Trop Dis 4:e910

Adenusi AA, Odaibo A (2009) Effects of varying concentrations of the crude aqueous and ethanolic extracts of *Dalbergia sissoo* plant parts on *Biomphalaria pfeifferi* egg masses. Afr J Tradit Complement Altern Med 6:139–149

Adetunji VO, Salawu OT (2010) Efficacy of ethanolic leaf extracts of *Carica papaya* and *Terminalia catappa* as molluscicides against the snail intermediate hosts of schistosomiasis. J Med Plants Res 4:2348–2352

Ahmed AH, Ramzy RMR (1997) Laboratory assessment of the molluscicidal and cercaricidal activities of the Egyptian weed, *Solanum nigrum* L. Ann Trop Med Parasitol 91:931–937. https://doi.org/10.1080/00034983.1997.11813221

Ahmed AH, Rifaat MMA (2004) Molluscicidal and cercaricidal efficacy of *Acanthus mollis* and its binary and tertiary combinations with *Solanum nigrum* and Iris pseudacorus against *Biomphalaria alexandrina*. J Egypt Soc Parasitol 34:1041–1050

Allam AF, El Sayad MH, Khalil SS (2001) Laboratory assessment of the molluscicidal activity of *Commiphora molmol* [myrrh] on *Biomphalaria alexandria*, *Bulinus truncatus* and lymnaea calilliaudi. J Egypt Soc Parasitol 31:683–690

Al-Sayed E, Hamid HA, Abu El Einin HM (2014) Molluscicidal and antischistosomal activities of methanol extracts and isolated compounds from *Eucalyptus globulus* and *Melaleuca styphelioides*. Pharm Biol 52:698–705. https://doi.org/10.3109/13880209.2013.865240

Alves CN, Barroso LP, Santos LS, Jardim IN (1998) Structure-activity relationship of compounds which are anti-schistosomiasis active. J Braz Chem Soc 9:577–582

Alves CN, de Macedo LGM, Honório KM et al (2002) A structure-activity relationship (SAR) study of neolignan compounds with anti-schistosomiasis activity. J Braz Chem Soc 13:300–307

Al-Zanbagi NA (2005) Two molluscicides from saudi arabian euphorbia lesagainst bulinus wrighti. J King Abdel Aziz Univ Sci 17:11–19

Al-Zanbagi NA, Banaja A-EA, Barrett J (2000) Molluscicidal activity of some Saudi Arabian Euphorbiales against the snail *Biomphalaria pfeifferi*. J Ethnopharmacol 70:119–125. https://doi.org/10.1016/S0378-8741(99)00155-5

Alzérreca A, Hart G (1982) Molluscicidal steroid glycoalkaloids possessing stereoisomeric spirosolane structures. Toxicol Lett 12:151–155. https://doi.org/10.1016/0378-4274(82)90178-3

Amazigo UV, Leak SGA, Zoure HGM et al (2012) Community-driven interventions can revolutionise control of neglected tropical diseases. Trends Parasitol 28:231–238. https://doi.org/10.1016/j.pt.2012.03.002

Andrade ZA (2009) Schistosomiasis and liver fibrosis: review article. Parasite Immunol 31:656–663. https://doi.org/10.1111/j.1365-3024.2009.01157.x

Andrews P, Thyssen J, Lorke D (1982) The biology and toxicology of molluscicides, bayluscide. Pharmacol Ther 19:245–295. https://doi.org/10.1016/0163-7258(82)90064-X

Apers S, Barónikova S, Sindambiwe JB et al (2001) Antiviral, haemolytic and molluscicidal effects of triterpenoid saponins from *Maesa lanceolata*: establishment of structure-activity relationships. Planta Med 67:528–532

Aziz IZA, El-bady A, El-Gayed SH (2011) In vitro anti-schistosomal activity of "*Plectranthus tenuiflorus*" on miracidium, cercaria and schistosomula stages of *Schistosoma mansoni*. Res J Parasitol 6:74–82

Bagalwa J-JM, Voutquenne-Nazabadioko L, Sayagh C, Bashwira AS (2010) Evaluation of the biological activity of the molluscicidal fraction of *Solanum sisymbriifolium* against non target organisms. Fitoterapia 81:767–771. https://doi.org/10.1016/j.fitote.2010.04.003

Bah S, Diallo D, Dembélé S, Paulsen BS (2006) Ethnopharmacological survey of plants used for the treatment of schistosomiasis in Niono District, Mali. J Ethnopharmacol 105:387–399. https://doi.org/10.1016/j.jep.2005.11.026

Bakry FA (2009) Use of some plant extracts to control *Biomphalaria alexandrina* snails with emphasis on some biological effects. Pestic Biochem Physiol 95:159–165. https://doi.org/10.1016/j.pestbp.2009.08.007

Bakry FA, Mohamed RT (2011) Impact of *Euphorbia milii* latex on infectivity of *Schistosoma mansoni* larval stages to their hosts. J Evol Biol Res 3:101–107

Barakat RMR (2013) Epidemiology of schistosomiasis in Egypt: travel through time: review. J Adv Res 4:425–432. https://doi.org/10.1016/j.jare.2012.07.003

Barakat R, Abou El-Ela NE, Sharaf S et al (2015) Efficacy and safety of arachidonic acid for treatment of school-age children in *Schistosoma mansoni* high-endemicity regions. Am J Trop Med Hyg 92:797–804. https://doi.org/10.4269/ajtmh.14-0675

Bedwani R, Renganathan E, El Kwhsky F et al (1998) Schistosomiasis and the risk of bladder cancer in Alexandria.

Egypt Br J Cancer 77:1186–1189. https://doi.org/10.1038/bjc.1998.197

Bekkouche K, Markouk M, Larhsini M et al (2000) Molluscicidal properties of glycoalkaloid extracts from Moroccan *Solanum* species. Phyther Res 14:366–367. https://doi.org/10.1002/1099-1573(200008)14:5%3c366::AID-PTR640%3e3.0.CO;2-E

Benson O (2012) Efficacy of *Chromolaena odorata* leaf extracts on *Biomphalaria pfeifferi* eggs in control of schistosomiasis. Zool Ecol 22:236–239. https://doi.org/10.1080/21658005.2012.745269

Bergquist R, Utzinger J, Keiser J (2017) Controlling schistosomiasis with praziquantel: how much longer without a viable alternative? Infect Dis Poverty 6:74. https://doi.org/10.1186/s40249-017-0286-2

Bergquist R, Tanner M (2010) Chapter 5: Controlling schistosomiasis in Southeast Asia: a tale of two countries. In: Zhou X-N, Bergquist R, Olveda R, Utzinger JBT-A in P (eds) Important helminth infect. Southeast Asia divers. Potential control elimin. Part A. Academic Press, pp 109–144

Bezerra JCB, Silva IA, Ferreira HD et al (2002) Molluscicidal activity against *Biomphalaria glabrata* of Brazilian Cerrado medicinal plants. Fitoterapia 73:428–430. https://doi.org/10.1016/S0367-326X(02)00121-1

Bilia AR, Braca A, Mendez J, Morelli I (2000a) Molluscicidal and piscicidal activities of Venezuelan Chrysobalanaceae plants. Life Sci 66:PL53–PL59. https://doi.org/10.1016/S0024-3205(99)00600-1

Bilia AR, Nieri E, Braca A, Morelli I (2000b) Screening of mediterranean *Rosaceae* plants for their molluscicidal and piscicidal activities. Phyther Res 14:126–129. https://doi.org/10.1002/(SICI)1099-1573(200003)14:2%3c126::AID-PTR553%3e3.0.CO;2-V

Birley MH (1991) Guidelines for forecasting the vector-borne disease implications of water resources development. World Heal Organ Retrieved

Botelho M, Ferreira AC, Oliveira MJ et al (2009) *Schistosoma haematobium* total antigen induces increased proliferation, migration and invasion, and decreases apoptosis of normal epithelial cells. Int J Parasitol 39:1083–1091. https://doi.org/10.1016/j.ijpara.2009.02.016

Brackenbury TD, Appleton CC (1997) A comprehensive evaluation of *Agave attenuata*, a candidate plant molluscicide in South Africa. Acta Trop 68:201–213. https://doi.org/10.1016/S0001-706X(97)00095-8

Cable J, Barber I, Boag B et al (2017) Global change, parasite transmission and disease control: lessons from ecology. Philos Trans R Soc B Biol Sci 372:20160088

Carod Artal FJ (2012) Cerebral and spinal schistosomiasis. Curr Neurol Neurosci Rep 12:666–674. https://doi.org/10.1007/s11910-012-0305-4

Challinor VL, De Voss JJ (2013) Open-chain steroidal glycosides, a diverse class of plant saponins. Nat Prod Rep 30:429–454. https://doi.org/10.1039/C3NP20105H

Chandiwana SK, Woolhouse MEJ, Bradley M (1991) Factors affecting the intensity of reinfection with *Schistosoma haematobium* following treatment with praziquantel. Parasitology 102:73–83. https://doi.org/10.1017/S0031182000060364

Chen S-X, Wu L, Yang X-M et al (2007) Comparative molluscicidal action of extract of Ginko biloba sarcotesta, arecoline and niclosamide on snail hosts of *Schistosoma japonicum*. Pestic Biochem Physiol 89:237–241. https://doi.org/10.1016/j.pestbp.2007.07.010

Chen YQ, Xu QM, Liu YL et al (2012) Laboratory evaluation of the molluscicidal activity of *Pulsatilla chinensis* (*Bunge*) *Regel* saponins against the snail *Oncomelania hupensis*. Biomed Environ Sci 25:224–229. https://doi.org/10.3967/0895-3988.2012.02.015

Chifundera K, Baluku B, Mashimango B (1993) Phytochemical screening and molluscicidal potency of some Zairean medicinal plants. Pharmacol Res 28:333–340. https://doi.org/10.1006/phrs.1993.1135

Chimbari MJ (2012) Enhancing schistosomiasis control strategy for Zimbabwe: building on past experiences. J Parasitol Res 2012:353768. https://doi.org/10.1155/2012/353768

Chitsulo L, Engels D, Montresor A, Savioli L (2000) The global status of schistosomiasis and its control. Acta Trop 77:41–51. https://doi.org/10.1016/s0001-706x(00)00122-4

Chothani DL, Vaghasiya HU (2011) A review on *Balanites aegyptiaca* Del (desert date): phytochemical constituents, traditional uses, and pharmacological activity. Pharmacogn Rev 5:55–62. https://doi.org/10.4103/0973-7847.79100

Cichewicz RH, Lim K, Mckerrow H, Nair MG (2002) Kwanzoquinones A–G and other constituents of *Hemerocallis fulva* 'Kwanzo' roots and their activity against the human pathogenic trematode *Schistosoma mansoni*. Tetrahedron 58:8597–8606

Cioli D, Pica-Mattoccia L, Basso A, Guidi A (2014) Schistosomiasis control: praziquantel forever? Mol Biochem Parasitol 195:23–29. https://doi.org/10.1016/j.molbiopara.2014.06.002

Clark TE, Appleton CC (1997) The molluscicidal activity of *Apodytes dimidiata* E. Meyer ex Arn (Icacinaceae), *Gardenia thunbergia* L.f. (Rubiaceae) and *Warburgia salutaris* (Bertol. F.) Chiov. (Cannelaceae), three South African plants. J Ethnopharmacol 56:15–30. https://doi.org/10.1016/S0378-8741(96)01496-1

Clark TE, Appleton CC, Drewes SE (1997) A semi-quantitative approach to the selection of appropriate candidate plant molluscicides: a South African application. J Ethnopharmacol 56:1–13. https://doi.org/10.1016/S0378-8741(96)01495-X

Colley DG, Bustinduy AL, Secor WE, King CH (2014) Human schistosomiasis. Lancet (London, England) 383:2253–2264. https://doi.org/10.1016/S0140-6736(13)61949-2

Cotton JA, Doyle SR (2022) A genetic TRP down the channel to praziquantel resistance. Trends Parasitol 38:351–352. https://doi.org/10.1016/j.pt.2022.02.006

Cui T-Y, Zheng Q-A, Mi L-X et al (1999) Screening for molluscicidal activity in medicinal plant. Stud Plant Sci 6:230–232. https://doi.org/10.1016/S0928-3420(99)80031-7

Dabo A, Badawi HM, Bary B, Doumbo OK (2011) Urinary schistosomiasis among preschool-aged children in Sahelian rural communities in Mali. Parasit Vectors 4:21. https://doi.org/10.1186/1756-3305-4-21 de Vasconcellos MC, de Amorim A (2003) Molluscicidal action of the latex of *Euphorbia splendens* var. hislopii NEB (" Christ's Crown")(*Euphorbiaceae*) against *Lymnaea columella* (Say, 1817)(Pulmonata: Lymnaeidae), intermediate host of *Fasciola hepatica* Linnaeus, 1758 (Trematode: Fasciolidae): 1-t. Mem Inst Oswaldo Cruz 98:557–563

de S. Luna J, dos Santos AF, de Lima MRF et al (2005) A study of the larvicidal and molluscicidal activities of some medicinal plants from northeast Brazil. J Ethnopharmacol 97:199–206. https://doi.org/10.1016/j.jep.2004.10.004

De-Carvalho RR, Maldonado A Jr, de Oliveira-Filho EC et al (1998) Effects of *Euphorbia milii* latex on *Schistosoma mansoni* eggs, miracidia and cercariae. Mem Inst Oswaldo Cruz 93:235–237

Di Bella S, Riccardi N, Giacobbe DR, Luzzati R (2018) History of schistosomiasis (bilharziasis) in humans: from Egyptian medical papyri to molecular biology on mummies. Pathog Glob Health 112:268–273. https://doi.org/10.1080/20477724.2018.1495357

Doenhoff MJ, Cioli D, Utzinger J (2008) Praziquantel: mechanisms of action, resistance and new derivatives for schistosomiasis. Curr Opin Infect Dis 21:659–667

dos Santos AF, Sant'Ana AEG (2001) Molluscicidal properties of some species of *Annona*. Phytomedicine 8:115–120. https://doi.org/10.1078/0944-7113-00008

dos Santos JAA, Tomassini TCB, Xavier DCD et al (2003) Molluscicidal activity of *Physalis angulata* L. extracts and fractions on *Biomphalaria tenagophila* (d'Orbigny, 1835) under laboratory conditions. Mem Inst Oswaldo Cruz 98:425–428

dos Santos AF, de Azevedo DPL, dos Santos Mata R da C et al (2007) The lethality of *Euphorbia conspicua* to adults of *Biomphalaria glabrata*, cercaria of *Schistosoma mansoni* and larvae of *Artemia salina*. Bioresour Technol 98:135–139. https://doi.org/10.1016/j.biortech.2005.11.020

dos Santos AF, Cavada BS, da Rocha BAM et al (2010) Toxicity of some glucose/mannose-binding lectins to *Biomphalaria glabrata* and *Artemia salina*. Bioresour Technol 101:794–798. https://doi.org/10.1016/j.biortech.2009.07.062

dos Santos EA, de Carvalho CM, Costa ALS et al (2012) Bioactivity evaluation of plant extracts used in indigenous medicine against the snail, *Biomphalaria glabrata*, and the larvae of *Aedes aegypti*. Evid Based Complement Altern Med 2012:846583. https://doi.org/10.1155/2012/846583

Drewes SE, Kayonga L, Clark TE et al (1996) Iridoid molluscicidal compounds from *Apodytes dimidiata*. J Nat Prod 59:1169–1170. https://doi.org/10.1021/np960404y

Ekabo OA, Farnsworth NR, Henderson TO et al (1996) Antifungal and molluscicidal saponins from *Serjania salzmanniana*. J Nat Prod 59:431–435. https://doi.org/10.1021/np960208r

El Babili FE, Moulis C, Bon M et al (1998) Three furanoditerpenes from the bark of *Croton campestris*. Phytochemistry 48:165–169. https://doi.org/10.1016/S0031-9422(97)00701-2

El Babili F, Fabre N, Moulis C, Fouraste I (2006) Molluscicidal activity against *Bulinus truncatus* of *Croton campestris*. Fitoterapia 77:384–387. https://doi.org/10.1016/j.fitote.2006.03.003

El Baz MA, Morsy TA, El Bandary MM, Motawea SM (2003) Clinical and parasitological studies on the efficacy of Mirazid in treatment of *Schistosomiasis haematobium* in Tatoon, Etsa Center, El Fayoum Governorate. J Egypt Soc Parasitol 33:761–776

El-Kady GA, Shoukry A, Reda LA, El-Badri YS (2000) Survey and population dynamics of freshwater snails in newly settled areas of the Sinai Peninsula. Egypt J Biol 2:42–48

El-Nahas HA, Abdel-Hameed ES, Sabra AA, El-Wakil EA (2005) Steroidal glycosides of *Furcraea selloa* and their biological properties against different *Schistosoma mansoni* stages. Bull Pharm Sci Assiut 28:169–183. https://doi.org/10.21608/bfsa.2005.65283

El-Seedi HR, El-Shabasy R, Sakr H et al (2012) Anti-schistosomiasis triterpene glycoside from the Egyptian medicinal plant *Asparagus stipularis*. Rev Bras Farm 22:314–318

El-Sheikh YWA, Eltamny HM, Soliman HA et al (2012) Molluscicidal activity of eco-friendly natural compound (Rutin) gained from ethanolic flowers extract of *Calendula officinalis* on *B. alexandrina*, *B. truncatus* and *Lymanea* snails. New York Sci J 5:19–27

El-Sherbini GT, Zayed RA, El-Sherbini ET (2009) Molluscicidal activity of some *Solanum* species extracts against the snail *Biomphalaria alexandrina*. J Parasitol Res 2009:474360. https://doi.org/10.1155/2009/474360

Esser KB, Semagn K, Wolde-Yohannes L (2003) Medicinal use and social status of the soap berry endod (*Phytolacca dodecandra*) in Ethiopia. J Ethnopharmacol 85:269–277. https://doi.org/10.1016/S0378-8741(03)00007-2

Fenwick A, Rollinson D, Southgate V (2006) Implementation of human schistosomiasis control: challenges and prospects. In: Molyneux DHBT-A in P (ed) Control Hum. Parasit. Dis. Academic Press, pp 567–622

Flaschenträger B, v. Wolffersdorff R (1934) Über den Giftstoff des Crotonöles. 1. Die Säuren des Crotonöles. Helv Chim Acta 17:1444–1452. https://doi.org/10.1002/hlca.193401701179

Francis G, Kerem Z, Makkar HPS, Becker K (2002) The biological action of saponins in animal systems: a review. Br J Nutr 88:587–605. https://doi.org/10.1079/BJN2002725

Fronczek FR, Vargas D, Fischer NH, Hostettmann K (1984) The molecular structure of 7α-hydroxy-3-desoxyzaluzanin C, a molluscicidal sesquiterpene lactone. J Nat Prod 47:1036–1039. https://doi.org/10.1021/np50036a026

Fuertes PZ, Pérez-Ayala A, Pérez Molina JA et al (2010) Clinical and epidemiological characteristics of imported infectious diseases in Spanish travelers. J Travel Med 17:303–309. https://doi.org/10.1111/j.1708-8305.2010.00433.x

Gaudani R, Patel J, Prajapati H et al (2010) Peristrophe bicalyculata: a review. Pharmacogn J 2:39–45. https://doi.org/10.1016/s0975-3575(10)80070-7

Gopalsamy N, Gueho J, Julien HR et al (1990) Molluscicidal saponins of *Polyscias dichroostachya*. Phytochemistry 29:793–795. https://doi.org/10.1016/0031-9422(90)80020-H

Gray DJ, McManus DP, Li Y et al (2010) Schistosomiasis elimination: lessons from the past guide the future. Lancet Infect Dis 10:733–736. https://doi.org/10.1016/S1473-3099(10)70099-2

Gryseels B, Polman K, Clerinx J, Kestens L (2006) Human schistosomiasis. Lancet 368:1106–1118. https://doi.org/10.1016/S0140-6736(06)69440-3

Halim A-B, Garry RF, Dash S, Gerber MA (1999) Effect of schistosomiasis and hepatitis on liver disease. Am J Trop Med Hyg 60:915–920

Hamburger MO, Cordell GA, Ruangrungsi N (1991) Traditional medicinal plants of Thailand XVII biologically active constituents of *Plumeria rubra*. J Ethnopharmacol 33:289–292. https://doi.org/10.1016/0378-8741(91)90091-Q

Han B, Chen J, Yang X et al (2010) Molluscicidal activities of medicinal plants from eastern China against *Oncomelania hupensis*, the intermediate host of *Schistosoma japonicum*. Rev Bras Farm 20:712–718

Hannedouche S, Souchard JP, Jacquemond-Collet I, Moulis C (2002) Molluscicidal and radical scavenging activity of quinones from the root bark of Caryopteris x clandonensis. Fitoterapia 73:520–522. https://doi.org/10.1016/S0367-326X(02)00163-6

Hasheesh WS, Mohamed RT, Abd El-Monem S (2011) Biological and physiological parameters of *Bulinus truncatus* snails exposed to methanol extract of the plant *Sesbania sesban* plant. Adv Biol Chem 1:65

Hassan SE, Rahman EHA, El-Monem ARA (2010) Molluscicidal activity of butanol fraction of *Meryta denhamii* flowers against *Lymnaea natalensis* and *Biomphalaria alexandrina*. Glob Vet 4:15–21

Hassan AA, Mahmoud AE, Attia RAH, Huseein EAM (2012) Evaluation of the ethanolic extracts of three plants for their molluscicidal activities against snails intermediate hosts of *Schistosoma mansoni* and *Fasciola*. Int J Basic Appl Sci 1:235–249

He W, Van Puyvelde L, Bosselaers J et al (2002) Activity of 6-pentadecylsalicylic acid from Ozoroa insignis against marine crustaceans. Pharm Biol 40:74–76. https://doi.org/10.1076/phbi.40.1.74.5862

He P, Wang W, Sanogo B et al (2017) Molluscicidal activity and mechanism of toxicity of a novel salicylanilide ester derivative against *Biomphalaria* species. Parasit Vectors 10:383. https://doi.org/10.1186/s13071-017-2313-3

Hecker E (1967) Phorbol esters from croton oil chemical nature and biological activities. Sci Nat 54:282–284. https://doi.org/10.1007/BF00620887

Hmamouchi M, Lahlou M, Agoumi A (2000) Molluscicidal activity of some Moroccan medicinal plants. Fitoterapia 71:308–314. https://doi.org/10.1016/S0367-326X(99)00152-5

Hokke CH, Deelder AM (2001) Schistosome glycoconjugates in host-parasite interplay. Glycoconj J 18:573–587. https://doi.org/10.1023/A:1020634602161

Husein MH, Talaat M, El-Sayed MK et al (1996) Who misses out with school-based health programmes? A study of schistosomiasis control in Egypt. Trans R Soc Trop Med Hyg 90:362–365. https://doi.org/10.1016/S0035-9203(96)90506-4

Hymete A, Iversen T-H, Rohloff J, Erko B (2005) Screening of *Echinops ellenbeckii* and *Echinops longisetus* for biological activities and chemical constituents. Phytomedicine 12:675–679. https://doi.org/10.1016/j.phymed.2004.01.013

Jaiswal P, Singh DK (2008) Molluscicidal activity of *Carica papaya* and *Areca catechu* against the freshwater snail *Lymnaea acuminata*. Vet Parasitol 152:264–270. https://doi.org/10.1016/j.vetpar.2007.12.033

Keiser J, N'Guessan NA, Adoubryn KD et al (2010) Efficacy and safety of mefloquine, artesunate, mefloquine-artesunate, and praziquantel against *Schistosoma haematobium*: randomized, exploratory open-label trial. Clin Infect Dis 50:1205–1213. https://doi.org/10.1086/651682

Kishor N, Sati OP (1990) A new molluscicidal spirostanol glycoside of *Yucca aloifolia*. J Nat Prod 53:1557–1559. https://doi.org/10.1021/np50072a025

Kolářová L, Horák P, Skírnisson K et al (2013) Cercarial dermatitis, a neglected allergic disease. Clin Rev Allergy Immunol 45:63–74. https://doi.org/10.1007/s12016-012-8334-y

Kumar M, Rawat S, Nagar B et al (2021) Implementation of the use of ethnomedicinal plants for curing diseases in the Indian Himalayas and its role in sustainability of livelihoods and socioeconomic development. Int J Environ Res Public Health 18:1509

Larhsini M, Sebbane R, Kchakech H et al (2010) Screening of some Moroccan plant extracts for molluscicidal activity. Asian J Exp Biol Sci 1:964–967

Lemma A (1965) A preliminary report on the molluscicidal property of endod (*Phytolacca dodecandrd*). Ethiop Med J 3:187–190

Lemma A (1970) Laboratory and field evaluation of the molluscicidal properties of *Phytolacca dodecandra*. Bull World Health Org 42:597–612

Lemmich E, Cornett C, Furu P et al (1995) Molluscicidal saponins from *Catunaregam nilotica*. Phytochemistry 39:63–68. https://doi.org/10.1016/0031-9422(94)00866-R

Lemmich E, Adewunmi CO, Furu P et al (1996) 5-deoxyflavones from *Parkia clappertoniana*. Phytochemistry 42:1011–1013. https://doi.org/10.1016/0031-9422(96)00101-X

Liese BH, Schubert L (2009) Official development assistance for health–how neglected are neglected tropical diseases? An analysis of health financing. Int Health 1:141–147. https://doi.org/10.1016/j.inhe.2009.08.004

Liu SY, Sporer F, Wink M et al (1997) Anthraquinones in *Rheum palmatum* and *Rumex dentatus*(Polygonaceae), and phorbol esters in *Jatropha curcas*(Euphorbiaceae) with molluscicidal activity against the schistosome vector snails *Oncomelania*, *Biomphalaria*, and *Bulinus*. Trop Med Int Health 2:179–188. https://doi.org/10.1046/j.1365-3156.1997.d01-242.x

Mahato SB, Sahu NP, Ganguly AN et al (1980) Steroidal alkaloids from *Solanum khasian um*: application of 13C NMR spectroscopy to their structural elucidation. Phytochemistry 19:2017–2020. https://doi.org/10.1016/0031-9422(80)83026-3

Mahmoud MB, Ibrahim WL, Abou-El-Nour BM et al (2011) Biological and biochemical parameters of *Biomphalaria alexandrina* snails exposed to the plants *Datura stramonium* and *Sesbania sesban* as water suspensions of their dry powder. Pestic Biochem Physiol 99:96–104. https://doi.org/10.1016/j.pestbp.2010.11.005

Malek EA (1975) Effect of the Aswan High Dam on prevalence of schistosomiasis in Egypt. Trop Geogr Med 27:359–364

Mantawy MM, Aly HF, Zayed N, Fahmy ZH (2012) Antioxidant and schistosomicidal effect of *Allium sativum* and *Allium cepa* against *Schistosoma mansoni* different stages. Eur Rev Med Pharmacol Sci 16(Suppl 3):69–80

Marston A, Hostettmann K (1985) Review article number 6: plant molluscicides. Phytochemistry 24:639–652. https://doi.org/10.1016/S0031-9422(00)84870-0

Masoud AM, Fawzy SM, Salama OM (2000) Laboratory studies on the molluscicidal and cercaricidal activities of *Commiphora molmol*. Egypt J Aquat Biol Fish 4:251–266. https://doi.org/10.21608/ejabf.2000.1671

Melman SD, Steinauer ML, Cunningham C et al (2009) Reduced susceptibility to praziquantel among naturally occurring Kenyan isolates of *Schistosoma mansoni*. PLoS Negl Trop Dis 3:e504

Mendes NM, Queiroz RO, Grandi TSM et al (1999) Screening of Asteraceae (Compositae) plant extracts for molluscicidal activity. Mem Inst Oswaldo Cruz 94:411–412

Mengarda AC, Silva MP, Cirino ME et al (2021) Licarin A, a neolignan isolated from *Nectandra oppositifolia* Nees & Mart. (Lauraceae), exhibited moderate preclinical efficacy against *Schistosoma mansoni* infection. Phyther Res 35:5154–5162. https://doi.org/10.1002/ptr.7184

Ming Z, Gui-Yin LI, Jian-Guo Z et al (2011) Evaluation of molluscicidal activities of benzo [c] phenanthridine alkaloids from *Macleaya cordata* (Willd) R. Br. on snail hosts of *Schistosoma japonicum*. J Med Plants Res 5:521–526

Miranda MA, Magalhães LG, Tiossi RFJ et al (2012) Evaluation of the schistosomicidal activity of the steroidal alkaloids from *Solanum lycocarpum* fruits. Parasitol Res 111:257–262. https://doi.org/10.1007/s00436-012-2827-8

Mo AX, Agosti JM, Walson JL et al (2014) Schistosomiasis elimination strategies and potential role of a vaccine in achieving global health goals. Am J Trop Med Hyg 90:54–60. https://doi.org/10.4269/ajtmh.13-0467

Mølgaard P, Chihaka A, Lemmich E et al (2000) Biodegradability of the molluscicidal saponins of *Phytolacca dodecandra*. Regul Toxicol Pharmacol 32:248–255. https://doi.org/10.1006/rtph.2000.1390

Mølgaard P, Nielsen SB, Rasmussen DE et al (2001) Anthelmintic screening of Zimbabwean plants traditionally used against schistosomiasis. J Ethnopharmacol 74:257–264. https://doi.org/10.1016/S0378-8741(00)00377-9

Mordvinov VA, Furman DP (2010) The digenea parasite *Opisthorchis felineus*: a target for the discovery and development of novel drugs. Infect Disord Drug Targets Disord 10:385–401

Murungi JN, Karanja S, Wanjau P (2021) A deterministic analysis of the effectiveness of non-clinical approaches in the control of transimission of schistosomiasis: case study of Mwea irrigation scheme, Kenya. Eur J Math Stat. https://doi.org/10.24018/ejmath.2021.2.6.70

Nanes Sarfati D, Li P, Tarashansky AJ, Wang B (2021) Single-cell deconstruction of stem-cell-driven schistosome development. Trends Parasitol 37:790–802. https://doi.org/10.1016/j.pt.2021.03.005

Nation CS, Da'dara AA, Marchant JK, Skelly PJ (2020) Schistosome migration in the definitive host. PLoS Negl Trop Dis 14:e0007951

Nelwan ML (2019) Schistosomiasis: life cycle, diagnosis, and control. Curr Ther Res Clin Exp 91:5–9. https://doi.org/10.1016/j.curtheres.2019.06.001

Nihei K, Ying B, Murakami T et al (2005) Pachyelasides A−D, novel molluscicidal triterpene saponins from *Pachyelasma tessmannii*. J Agric Food Chem 53:608–613. https://doi.org/10.1021/jf048570w

Obied HK, Bedgood DR, Prenzler PD, Robards K (2007) Bioscreening of Australian olive mill waste extracts: biophenol content, antioxidant, antimicrobial and molluscicidal activities. Food Chem Toxicol 45:1238–1248. https://doi.org/10.1016/j.fct.2007.01.004

Ojewole JAO (2004) Indigenous plants and schistosomiasis control in South Africa: molluscicidal activity of some Zulu medicinal plants. Bol Latinoam Caribe Plantas Med Aromat 3:8–22

Oliveira-Filho EC, De-Carvalho RR, Paumgartten FJR (1999) The influence of environmental factors on the molluscicidal activity of *Euphorbia milii* latex. J Environ Sci Health Part B 34:289–303. https://doi.org/10.1080/03601239909373198

Othman AA, Soliman RH (2015) Schistosomiasis in Egypt: A never-ending story? Acta Trop 148:179–190. https://doi.org/10.1016/j.actatropica.2015.04.016

Parkhurst RM, Thomas DW, Skinner WA, Cary LW (1974) Molluscicidal saponins of *Phytolaccadodecandra*: Lemmatoxin. Can J Chem 52:702–705. https://doi.org/10.1139/v74-110

Parkhurst RM, Mthupha BM, Liang Y-S et al (1989) The molluscicidal activity of *Phytolacca dodecandra* I. Location of the activating esterase. Biochem Biophys Res Commun 158:436–439. https://doi.org/10.1016/S0006-291X(89)80066-X

Pasi S, Aligiannis N, Pratsinis H et al (2009) Biologically active triterpenoids from *Cephalaria ambrosioides*. Planta Med 75:163–167

Payne L, Fitchett JR (2010) Bringing neglected tropical diseases into the spotlight. Trends Parasitol 26:421–423. https://doi.org/10.1016/j.pt.2010.06.002

Pereira AR, Etzbach L, Engene N et al (2011) Molluscicidal metabolites from an assemblage of Palmyra Atoll cyanobacteria. J Nat Prod 74:1175–1181. https://doi.org/10.1021/np200106b

Pessini GL, Dias Filho BP, Nakamura CV, Cortez DAG (2003) Antibacterial activity of extracts and neolignans from *Piper regnellii* (Miq.) C. DC. var. *pallescens* (C. DC.) Yunck. Mem Inst Oswaldo Cruz 98:1115–1120

Pinto-Almeida A, Mendes T, Ferreira P et al (2018) Comparative proteomics reveals characteristic proteins on praziquantel-resistance in *Schistosoma mansoni*. bioRxiv. https://doi.org/10.1101/314724

Puri R, Wong TC, Puri RK (1994) 1H- and 13C-Nmr assignments and structural determination of a novel glycoalkaloid from *Solanum platanifolium*. J Nat Prod 57:587–596. https://doi.org/10.1021/np50107a004

Rapado LN, Nakano E, Ohlweiler FP et al (2011) Molluscicidal and ovicidal activities of plant extracts of the Piperaceae on *Biomphalaria glabrata* (Say, 1818). J Helminthol 85:66–72. https://doi.org/10.1017/S0022149X10000258

Rawi SM, El-Gindy H, Abd-El-Kader A (1996) New possible molluscicides from *Calendula micrantha officinalis* and

Ammi majus: II. Molluscicidal, physiological, and egg-laying effects against *Biomphalaria alexandrina* and *Bulinus truncatus*. Ecotoxicol Environ Saf 35:261–267. https://doi.org/10.1006/eesa.1996.0109

Rawi SM, Al-Hazmi M, Al Nassr FS (2011) Comparative study of the molluscicidal activity of some plant extracts on the snail vector of *Schistosoma monsoni*, *Biomphalaria alexandrina*. Int J Zool Res 7:169–189

Ribeiro ECG, Leite JAC, Luz TRSA et al (2021) Molluscicidal activity of monoterpenes and their effects on inhibition of acetylcholinesterase activity on *Biomphalaria glabrata*, an intermediate host of *Schistosoma mansoni*. Acta Trop. https://doi.org/10.1016/j.actatropica.2021.106089

Rollinson D, Knopp S, Levitz S et al (2013) Time to set the agenda for schistosomiasis elimination. Acta Trop 128:423–440. https://doi.org/10.1016/j.actatropica.2012.04.013

Ross AG, Bartley PB, Sleigh AC et al (2002) Current concepts. N Engl J Med 346:1212–1220

Roure S, Valerio L, Pérez-Quílez O et al (2017) Epidemiological, clinical, diagnostic and economic features of an immigrant population of chronic schistosomiasis sufferers with long-term residence in a non-endemic country (North Metropolitan area of Barcelona, 2002–2016). PLoS ONE 12:e0185245

Rug M, Ruppel A (2000) Toxic activities of the plant Jatropha curcas against intermediate snail hosts and larvae of schistosomes. Trop Med Int Health 5:423–430. https://doi.org/10.1046/j.1365-3156.2000.00573.x

Salama MM, Taher EE, El-Bahy MM (2012) Molluscicidal and mosquitocidal activities of the essential oils of *Thymus capitatus* Hoff. et Link. and *Marrubium vulgare* L. Rev Inst Med Trop Sao Paulo 54:281–286

Salas-Coronas J, Vázquez-Villegas J, Lozano-Serrano AB et al (2020) Severe complications of imported schistosomiasis, Spain: a retrospective observational study. Travel Med Infect Dis 35:101508. https://doi.org/10.1016/j.tmaid.2019.101508

Salvador-Recatalà V, Greenberg RM (2012) Calcium channels of schistosomes: unresolved questions and unexpected answers. Wiley Interdiscip Rev Membr Transp Signal 1:85–93. https://doi.org/10.1002/wmts.19

Sattenspiel L (2000) Tropical environments, human activities, and the transmission of infectious diseases. Am J Phys Anthr 113:3–31. https://doi.org/10.1002/1096-8644(2000)43:31+%3c3::AID-AJPA2%3e3.0.CO;2-Z

Schall VT, Vasconcellos MC, Valent GU et al (1991) Evaluation of the genotoxic activity and acute toxicity of *Euphorbia splendens* latex, a molluscicide for the control of schistosomiasis. Braz J Med Biol Res Rev = Bras Pesqui Med Biol 24:573–582

Schall VT, Vasconcellos MC, Rocha RS et al (2001) The control of the schistosome-transmitting snail *Biomphalaria glabrata* by the plant Molluscicide *Euphorbia splendens* var. *hislopii* (syn *milli* Des. Moul): a longitudinal field study in an endemic area in Brazil. Acta Trop 79:165–170. https://doi.org/10.1016/S0001-706X(01)00126-7

Schall VT, De Vasconcellos MC, De Souza CP, Baptista DF (1998) The molluscicidal activity of Crown of Christ (*Euphorbia splendens var. hislopii*) latex on snails acting as intermediate hosts of *Schistosoma mansoni* and *Schistosoma haematobium*. Am J Trop Med Hyg 58(1):7–10

Selbach C, Soldánová M, Sures B (2016) Estimating the risk of swimmer's itch in surface waters: a case study from Lake Baldeney, River Ruhr. Int J Hyg Environ Health 219:693–699. https://doi.org/10.1016/j.ijheh.2015.03.012

Sharma S, Singh T, Vijayvergia R (2009) Molluscicidal activity of some medicinal plants. J Herb Med Toxicol 3:155–157

Sheir Z, Nasr AA, Massoud A et al (2001) A safe, effective, herbal antischistosomal therapy derived from myrrh. Am J Trop Med Hyg 65:700–704

Siddiqui AA, Siddiqui BA, Ganley-Leal L (2011) Schistosomiasis vaccines. Hum Vaccin 7:1192–1197. https://doi.org/10.4161/hv.7.11.17017

Silva TMS, Câmara CA, de Fátima Agra M et al (2006) Molluscicidal activity of *Solanum* species of the Northeast of Brazil on *Biomphalaria glabrata*. Fitoterapia 77:449–452. https://doi.org/10.1016/j.fitote.2006.05.007

Silva TMS, Camara CA, Freire KRL et al (2008) Steroidal glycoalkaloids and molluscicidal activity of *Solanum asperum* Rich. Fruits. J Braz Chem Soc 19:1048–1052

Silvério MS, Del-Vechio-Vieira G, Pinto MAO et al (2013) Chemical composition and biological activities of essential oils of *Eremanthus erythropappus* (DC) McLeisch (Asteraceae). Molecules 18:9785–9796. https://doi.org/10.3390/molecules18089785

Singh SK, Yadav RP, Singh A (2010) Molluscicides from some common medicinal plants of eastern Uttar Pradesh, India. J Appl Toxicol 30:1–7. https://doi.org/10.1002/jat.1498

Singh KL, Singh DK, Singh VK (2012) Characterization of the molluscicidal activity of *Bauhinia variegata* and *Mimusops elengi* plant extracts against the fasciola vector *Lymnaea acuminata*. Rev Inst Med Trop Sao Paulo 54:135–140

Siripong P, Kanokmedakul K, Piyaviriyagul S et al (2006) Antiproliferative naphthoquinone esters from *Rhinacanthus nasutus* Kurz. roots on various cancer cells. J Tradit Med 23:166–172. https://doi.org/10.11339/jtm.23.166

Slacanin I, Vargas D, Marston A, Hostettmann K (1988) Determination of molluscicidal sesquiterpene lactones from *Ambrosia maritima* (compositae). J Chromatogr A 457:325–331. https://doi.org/10.1016/S0021-9673(01)82080-X

Socolsky C, Borkosky SA, Asakawa Y, Bardón A (2009) Molluscicidal phloroglucinols from the fern *Elaphoglossum piloselloides*. J Nat Prod 72:787–790. https://doi.org/10.1021/np800724h

Sparg SG, van Staden J, Jäger AK (2000) Efficiency of traditionally used South African plants against schistosomiasis. J Ethnopharmacol 73:209–214. https://doi.org/10.1016/S0378-8741(00)00310-X

Sparg SG, Light ME, van Staden J (2004) Biological activities and distribution of plant saponins. J Ethnopharmacol 94:219–243. https://doi.org/10.1016/j.jep.2004.05.016

Steinmann P, Keiser J, Bos R et al (2006) Schistosomiasis and water resources development: systematic review, meta-analysis, and estimates of people at risk. Lancet Infect Dis 6:411–425. https://doi.org/10.1016/S1473-3099(06)70521-7

Suleiman MHA (2015) An ethnobotanical survey of medicinal plants used by communities of Northern Kordofan region, Sudan. J Ethnopharmacol 176:232–242. https://doi.org/10.1016/j.jep.2015.10.039

Talaat M, Evans DB (2000) The costs and coverage of a strategy to control schistosomiasis morbidity in nonenrolled school-age children in Egypt. Trans R Soc Trop Med Hyg 94:449–454. https://doi.org/10.1016/S0035-9203(00)90137-8

Tefera A, Belay T, Bajiro M (2020) Epidemiology of *Schistosoma mansoni* infection and associated risk factors among school children attending primary schools nearby rivers in Jimma town, an urban setting, Southwest Ethiopia. Plos One 15:e0228007

Thiilborg ST, Christensen SB, Cornett C et al (1993) Molluscicidal saponins from *Phytolacca dodecandra*. Phytochemistry 32:1167–1171. https://doi.org/10.1016/S0031-9422(00)95085-4

Thiilborg ST, Brøgger Christensen S, Cornett C et al (1994) Molluscicidal saponins from a zimbabwean strain of *Phytolacca dodecandra*. Phytochemistry 36:753–759. https://doi.org/10.1016/S0031-9422(00)89811-8

Treyvaud V, Marston A, Dyatmiko W, Hostettmann K (2000) Molluscicidal saponins from *Phytolacca icosandra*. Phytochemistry 55:603–609. https://doi.org/10.1016/S0031-9422(00)00233-8

Truiti MCT, Ferreira ICP, Zamuner MLM et al (2005) Antiprotozoal and molluscicidal activities of five Brazilian plants. Brazilian J Med Biol Res 38:1873–1878

Tulp M, Bohlin L (2004) Unconventional natural sources for future drug discovery. Drug Discov Today 9:450–458. https://doi.org/10.1016/S1359-6446(04)03066-1

Utzinger J, Raso G, Brooker S et al (2009) Schistosomiasis and neglected tropical diseases: towards integrated and sustainable control and a word of caution. Parasitology 136:1859–1874. https://doi.org/10.1017/S0031182009991600

Utzinger J, N'Goran EK, Caffrey CR, Keiser J (2011) From innovation to application: social–ecological context, diagnostics, drugs and integrated control of schistosomiasis. Acta Trop 120:S121–S137. https://doi.org/10.1016/j.actatropica.2010.08.020

Vieira PC, Kubo I (1990) Molluscicidal quinoline alkaloids from *Galipea bracteata*. Phytochemistry 29:813–815. https://doi.org/10.1016/0031-9422(90)80024-B

Vieira PC, Kubo I, Kujime H et al (1992) Molluscicidal acridone alkaloids from *Angostura paniculata*: isolation, structures, and synthesis. J Nat Prod 55:1112–1117. https://doi.org/10.1021/np50086a012

Walz Y, Wegmann M, Dech S et al (2015) Risk profiling of schistosomiasis using remote sensing: approaches, challenges and outlook. Parasit Vectors 8:163. https://doi.org/10.1186/s13071-015-0732-6

Wang L-D, Chen H-G, Guo J-G et al (2009) A strategy to control transmission of *Schistosoma japonicum* in China. N Engl J Med 360:121–128. https://doi.org/10.1056/NEJMoa0800135

Wang W, Wang L, Liang Y-S (2012) Susceptibility or resistance of praziquantel in human schistosomiasis: a review. Parasitol Res 111:1871–1877. https://doi.org/10.1007/s00436-012-3151-z

Wang W, Mao Q, Yao J et al (2018) Discovery of the pyridylphenylureas as novel molluscicides against the invasive snail *Biomphalaria straminea*, intermediate host of *Schistosoma mansoni*. Parasit Vectors 11:291. https://doi.org/10.1186/s13071-018-2868-7

Wanyonyi AW, Chhabra SC, Mkoji G et al (2002) Bioactive steroidal alkaloid glycosides from *Solanum aculeastrum*. Phytochemistry 59:79–84. https://doi.org/10.1016/S0031-9422(01)00424-1

Wanyonyi AW, Chhabra SC, Mkoji G et al (2003) Molluscicidal and antimicrobial activity of *Solanum aculeastrum*. Fitoterapia 74:298–301. https://doi.org/10.1016/S0367-326X(03)00030-3

Wei FH, Xu XJ, Liu JB et al (2002) Toxicology of a potential molluscicide derived from the plant *Solanum xanthocarpum*: a preliminary study. Ann Trop Med Parasitol 96:325–331. https://doi.org/10.1179/000349802125000727

WHO (2012) Schistosomiasis: population requiring preventive chemotherapy and number of people treated in 2010. Wkly Epidemiol Rec Relev Épidémiologique Hebd 87:37–44

Wright WH (1972) A consideration of economic impact of schistosomiasis. Bull World Health Org 47:559–565

Xing Y, Yao J, Qu G et al (2021) Evaluation of the molluscicidal activities of arylpyrrole on *Oncomelania hupensis*, the intermediate host of *Schistosoma japonicum*. PeerJ 9:1–17. https://doi.org/10.7717/peerj.12209

Yadav SC, Jagannadham MV (2008) Physiological changes and molluscicidal effects of crude latex and Milin on *Biomphalaria glabrata*. Chemosphere 71:1295–1300. https://doi.org/10.1016/j.chemosphere.2007.11.068

Yadav RP, Singh A (2011) Efficacy of Euphorbia hirta latex as plant derived molluscicides against freshwater snails. Rev Inst Med Trop Sao Paulo 53:101–106

Yang X, Chen S, Zhang R et al (2006) Study on molluscicidal active components of petrol ether extract of *Ginkgo sarcotestas*. Chin J Zoonoses 22:961

Yang X, Chen S, Xia L, Chen J (2008) Molluscicidal activity against *Oncomelania hupensis* of *Ginkgo biloba*. Fitoterapia 79:250–254. https://doi.org/10.1016/j.fitote.2007.11.030

Yousif F, Hifnawy MS, Soliman G et al (2007) Large-scale in vitro. Screening of Egyptian native and cultivated plants for schistosomicidal activity. Pharm Biol 45:501–510. https://doi.org/10.1080/13880200701389425

Zacchino S, Rodríguez G, Pezzenati G et al (1997) In vitro evaluation of antifungal properties of 8.O.4'-neolignans. J Nat Prod 60:659–662. https://doi.org/10.1021/np9605504

Zani CL, Marston A, Hamburger M, Hostettmann K (1993) Molluscicidal milliamines from *Euphorbia milii* var. *hislopii*. Phytochemistry 34:89–95. https://doi.org/10.1016/S0031-9422(00)90788-X

Zheng L, Deng L, Zhong Y et al (2021) Molluscicides against the snail-intermediate host of *Schistosoma*: a review. Springer, Berlin Heidelberg

Zhou Y, Chen Y, Jiang Q (2021) History of human schistosomiasis (bilharziasis) in China: from discovery to elimination. Acta Parasitol 66:760–769. https://doi.org/10.1007/s11686-021-00357-9

Zoni AC, Catalá L, Ault SK (2016) Schistosomiasis prevalence and intensity of infection in Latin America and the Caribbean countries, 1942–2014: a systematic review in the context of a regional elimination goal. PLoS Negl Trop Dis 10:e0004493