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FRASES

*Ninguno puede ser feliz si no se aprecia a sí mismo*

Jean Jacques Rousseau

*Aunque nadie justifique el desvarío, atrévete; Aunque el mundo te tilde de idealista, láncate; Aunque sean ilusiones vanas, muéstralas; Aunque ya no se use la poesía, ¡vívela!*

Anónimo

*La fama es la amada de todo corazón humano*

Charles Dickens

*Excusarse antes de ocasión es culparse*

Baltasar Gracián

*El valor, la buena conducta y la perseverancia conquistan a todo lo que se les pone por delante*

Anónimo

*Perdedor no es quien llega último sino quien no se atreve a competir*

Anónimo

*Una cosa es continuar la historia y otra repetirla*

Jacinto Benavente

*Nunca discutas con un tonto, la gente puede no notar la diferencia*

Ley de Murphy

ABSTRACT: This work reviews plant molluscicides and presents preliminary findings of a molluscicidal screening programme carried out on some South African candidate molluscicidal plants. The overall objective of studies on plant molluscicides is to complement methods for controlling snails acting as intermediate hosts of schistosomes. In the last two decades, plant molluscicides have received considerable attention in the search for cheaper, effective, environmentally-friendly alternatives to expensive, imported chemotherapeutic agents and synthetic molluscicides used in schistosomiasis control. Although molluscicidal screening programmes have been conducted in many African countries, only relatively little efforts have been made to identify South African plants which could be suitable for use locally as plant molluscicides. The attraction of a locally grown molluscicidal plant is based on the development of a philosophy of self-reliance and community participation. This approach is dependent on community recognition of the infection as a public health menace, and their acceptance of the proposed control measures. Schistosomiasis has been recognized as a primary health problem in KwaZulu-Natal Province of South Africa, especially among the people in the rural communities that depend on river-water for all their water requirements. Concerns for schistosomiasis in the Province have indeed been matched by a 75% prevalence of *Schistosoma haematobium* infection among children aged 6 to 16 years. Forty-one medicinal plants commonly used by traditional healers for the treatment of schistosomiasis in KwaZulu-Natal Province of South Africa were evaluated for molluscicidal activity according to

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WHO’s method, using niclosamide (Bayluscide®) as reference molluscicide for comparison. Adult Bulinus africanus and Biomphalaria pfeifferi were exposed to sublethal and lethal doses of crude, aqueous extracts of the Zulu antischistosomal plants for a period of 24 hours. Results obtained indicate that 14 (34%) of the 41 plants examined possess moderate to strong molluscicidal properties. Sublethal, toxic effects of the active plant extracts on the snails included retraction of the foot-sole and mobility, swelling of the cephalopedal mass, and haemorrhagic blistering in the subepithelium of the foot-sole, while administration of lethal doses resulted in cessation of mobility, severe swelling of the cephalopedal mass, increased mucous secretion, and haemorrhage. It is speculated that part of the molluscicidal actions of the active plant extracts could involve disruption of the snails’ foot-sole epithelium osmoregulatory physiology and enzyme-mediated pathways. However, osmolarity and electrolyte studies, as well as enzymatic, histochemical and biochemical studies are required to substantiate these possible modes of molluscicidal action of the South African candidate plant molluscicides. Treatment of schistosomiasis is based on chemotherapy with praziquantel, which is the currently available drug of choice for all forms of the disease. However, since resistance to praziquantel has been demonstrated in many schistosomiasis endemic areas of the world; of necessity is a holistic approach which should include not only reducing the disease burden in schistosomiasis-infected persons, but also measures interfering with the life-cycle of the parasite by eliminating the intermediate host snail vectors. Inexpensive, non-toxic, effective and readily-available alternative drugs from natural sources are certainly warranted.

**KEY WORDS:** Schistosomiasis; Molluscidal Plants; Snail Control; Molluscicide; Niclosamide.

**RESUMEN:** Este trabajo revisa las plantas medicinales molluscicidas y presenta resultados preliminares de los análisis de esta actividad del programa llevado a cabo con algunas plantas de Sudáfrica. El objetivo global de los estudios en estas plantas es complementar los métodos para controlar caracoles que actúan como los organizadores intermediarios de schistosomiasis. Las plantas han recibido una atención considerable en la búsqueda de alternativas más baratas, eficaces, medio ambientalmente-amistosas para los agentes químiotherapéuticos caros, importados y los molluscicidas sintéticos usados en el control de la schistosomiasis en las últimas dos décadas. Aunque los análisis molluscicidas de los programas han sido conducidos en muchos países africanos, han sido sólo esfuerzos relativamente pequeños para identificar plantas Sudaficana que podrían ser localmente conveniente para el uso como plantas molluscicidas. El interés por una planta con esta actividad a nivel local, esta basado en el desarrollo de una filosofía de máxima confianza y la participación de la comunidad. Este acercamiento es dependiente en el reconocimiento de la comunidad de la infección como una amenaza de salud pública, y su aceptación de las medidas de control propuestas. Schistosomiasis se ha reconocido como un problema de salud primario en la Provincia KwaZulu-Natal de Sudáfrica, sobre todo entre las personas en las comunidades rurales que dependen del agua del río para todas sus necesidades. Las preocupaciones para el schistosomiasis en la Provincia han sido analizadas debido a un predominio de un 75% de infección por Schistosoma haematobium entre los niños de edades entre 6 a 16 años. Se evaluaron 41 plantas medicinales normalmente usadas por los sanadores tradicionales para el tratamiento de schistosomiasis en la Provincia KwaZulu-Natal de Sudáfrica para la actividad molluscicidal según el Método de la OMS, mientras que usando el fármao niclosamide (Bayluscide®) como el molluscida de referencia para hacer la comparación. Bulinus africanus adulto y Biomphalaria pfeifferi fueron expuestos a dosis subletal y letales de extractos crudos, ácidos de las plantas de antischistosomal Zulu para un período de 24 horas. Los resultados obtenidos indican que 14 (34%) de las 41 plantas examinadas posee una propiedad moderada a las actividad molluscicidal. Dosis subletal, los efectos tóxicos de los extractos activos de la planta medicinal en los caracoles incluyeron retracción y movilidad de la del cuerpo del caracol, mientras la masa cefalopedal se inflamó, y produjo coágulos hemorragicos en el subepitelio del cuerpo del caracol, mientras la administración de dosis letales producía la cesación de movilidad, la hinchazón severa de la base ventral del cuerpo, secreción mucosa aumentada, y hemorragia. Se especula que parte de las acciones molluscicidal de los extractos activos pudiera involucrar disrupción del epitelio del cuerpo del caracol, de la fisiología osmoregulatoria de la zona epitelial del cuerpo del caracol y sendas enzima-mediadas. Sin embargo, el estudio de osmolaridad y del electrólito, así como enzimático, exigen histoquimicamente los estudios bioquímicos para probar estos posibles modos de acción molluscicida de las plantas medicinales estudiadas en Sudáfrica. El tratamiento de schistosomiasis es basado en la quimioterapia con praziquantel que es la droga actualmente-disponible de opción para todos los formularios de la enfermedad. Sin embargo, desde la resistencia al praziquantel se ha demostrado en muchos schistosomiasis, las áreas endémicas del mundo; por necesidad es un acercamiento holístico que debe incluir no sólo reduciendo la carga de la enfermedad en las personas schistosomiasis-infectadas, pero también medidas que interfieren con el ciclo de vida.
del parasito eliminando los intermediarios como el vector caracol. Barato, no-tóxico, se garantizan drogas de alternativa eficaces y prontamente-disponibles de las fuentes naturales ciertamente.

INTRODUCCIÓN

Schistosomiasis (sometimes called “bilharziasis”) is frequently referred to as the second most important parasitic disease after malaria among the infectious diseases of tropical and subtropical countries, and the third most prevalent parasitic disease in the world in terms of overall morbidity burden, socio-economic and public health importance, and human impact. It has been estimated that more than 200 million people in rural, agricultural and peri-urban areas of 74 tropical and subtropical countries of the world are infected with schistosomiasis, of whom 120 million are symptomatic and 20 million suffer severe consequences of the disease. An estimated 600 million other people are reported to be at risk of this nematode disease. In many countries, schistosomiasis affects a large proportion of under-17 children. For the control of the disease, a multifaceted approach is desirable, including control of the intermediate host snails.

Schistosomiasis is a parasitic disease caused by digenetic blood trematodes of the genus Schistosoma. Biologically, the flukes belong to the Phylum: Platyhelminthes; Class: Trematoda; Subclass: Digenea; Family: Schistosomatidae; and Genus: Schistosoma. The five most common species of schistosomes infecting man and causing human schistosomiasis are: (i) Schistosoma haematobium (which affects 54 countries in Africa and the Eastern Mediterranean, and causes urinary schistosomiasis), (ii) Schistosoma mansoni (which is responsible for African intestinal schistosomiasis), (iii) Schistosoma japonicum, (iv) Schistosoma mekongi (the two schistosomal species that cause intestinal schistosomiasis in Asia and the Pacific regions), and (v) Schistosoma intercalatum. Other species of Schistosoma which parasitize man and other mammals are Schistosoma mattheei and Schistosoma bovis. Like other digenetic trematodes, the schistosomes are equipped with suckers with which the worms attach themselves to the walls of the blood vessels in which they live.

The life-cycle of the trematodes that cause schistosomiasis in man is atypical of the other parasites of the Class Trematoda in that the worms are unisexual. Adult worms in humans reside in the mesenteric venules in various locations, which at times seem to be specific for each species. For instance, Schistosoma haematobium normally lives and mates in the veins of the urinary bladder of man (the only important definitive host), producing eggs with a terminal spine, which pass into the bladder wall and thence into the urine. When an egg is deposited into fresh water, it hatches within a few minutes to a miracidium, a highly motile larva which moves about in the water for about 24 hours with the aid of its cilia. It then seeks a suitable snail host. Once inside the soft tissues of a favourable snail host, the miracidium develops within 96 hours into a sporocyst. After 7 days, the sporocyst develops into cercaria, the final larval form. The cycle from snail penetration by the miracidium to the production of mature cercaria takes about 4 to 5 weeks for S. mansoni; 5 to 6 weeks for S. haematobium; and 7 weeks or more for S. japonicum. The infected snails are damaged in the process, and they die shortly after releasing the cercariae into water. The mature cercaria escapes from the daughter sporocyst and enters the water, swimming vigorously by means of its bifurcated tail. A snail can shed 500 – 3000 cercariae of S. haematobium or S. mansoni daily when in full production, but the figure for S. japonicum is much less (15 – 160), the snails being much smaller than those infected by the other species. Cercariae do not feed and their life-span is short, up to 48 hours. They are quickly killed at 50ºC and strong sunlight, and lack of oxygen is also lethal to them. A cercaria can penetrate the skin of a definitive host within a few minutes. In doing so it sheds its tail, and once in the definitive host’s tissues, it becomes a Schistosomulum. Within 24 hours, the schistosomulum enters the lymphatic or venous system of the host to be transported to the right heart and lungs. Some schistosomules pass into the mesenteric vessels and thence to the vessels of the liver. Some may pass directly through the diaphragm to the liver and the portal vessels. Growth takes place in the liver, and paired worms may be found after about 26 days following host skin’s penetration. Most worms leave the liver when they are sexually mature and have mated, and migrate to the veins of the vesical plexus (S. haematobium) or the mesenteric veins (S. mansoni, S. japonicum and S. intercalatum), where they begin to lay eggs. The period between skin penetration by the cercariae and egg-laying may be 30 – 40 days or more. The mated worms move as far as possible towards the fine terminal vessels, and the female worm then leaves the male, moving to the finest vessels, where she deposits her eggs, retracting after having done so. The eggs escape from the venules into the host’s tissues, those of S. haematobium largely into the wall of the bladder but occasionally into the wall of the lower bowel, those of S. mansoni, S. japonicum and S. intercalatum mainly into the wall of the lower bowel. Only about 50% of the eggs produced by the adult worms are passed out in the urine or stool. The remaining half (50%) stay in the body where they can scar and damage vital organs. The symptoms of the disease are caused by the body’s reaction to the worms’ eggs, and not by the worms themselves. Microscopic identification of schistosomal eggs in the stool or
urine of patients is the most practical method for the diagnosis of schistosomiasis. Stool examination should be performed when infection with *S. mansoni* or *S. japonicum* is suspected, and urine examination should be performed if *S. haematobium* is suspected. In addition to microscopy, ‘antibody detection’ can be used in the clinical management of recent infections and for epidemiological surveys. Some eggs of all *Schistosoma* species are also usually found in the genital tract, liver, lungs, central nervous system, and other organs. The eggs are generally responsible for the pathological effects of the disease, the symptoms of which depend upon the intensity of infection. The pathological stage may last for a long time, culminating in irreversible effects if not treated. In *Schistosoma haematobium*, the urinary system bears the heaviest pathological burden, and the symptoms vary greatly. In the early stages, there is often slight fever, with general weakness and prostration, but the most characteristic sign is haematuria with or without a sense of urinary irritation or pain. Systemic complications with evidence of hepatocellular damage, cough, myalgia, abdominal pain, skin rash, and so on, have been reported.

*Schistosoma mansoni* normally lives and mates in the superior mesenteric veins of man, producing eggs with a lateral spine which pass into the wall of the large intestine and lower ileum, and thence into the faeces. *Schistosoma japonicum* normally lives and mates in the inferior mesenteric veins of man, producing eggs which pass into the bowel wall and thence into the faeces. Although *Schistosoma haematobium* most often occurs in the venous plexus of the bladder, it can also be found in the rectal venules. The female worms of the parasites (size 7–20 mm) deposit eggs in the intestinal or bladder small venules. *Schistosoma intercalatum* is a parasite of the *S. haematobium* complex, producing characteristic eggs with a terminal spine, but found exclusively in faeces. It lives and mates in the mesenteric-portal venous system. The eggs of *Schistosoma mattheei*, a parasite of sheep and cattle which affects man in South Africa, is also found in both urine and faeces.

Strains of *schistosoma spp.* which infect man vary widely in their ability to infect passive intermediate snail hosts. Some schistosomes readily infect snails of one geographical area and not of the other. *Schistosoma haematobium* is transmitted by snails of the genus *Bulinus*, while *Schistosoma mansoni* is transmitted by snails of the genus *Biomphalaria*. While snails of *Oncomelania spp.* transmit *Schistosoma japonicum*, snails of *Lythoglyphopsis spp.* transmit *Schistosoma mekongi*.

Schistosomiasis in all its forms, is a rural disease, and depends on a variety of other factors. These factors include contamination of fresh water with human urine or faeces containing schistosomal eggs; the presence in the water of snails capable of infection by miracidia from those eggs, and capable of producing cercariae infective to man. Water temperature, rate of flow, acidity or alkalinity, and content of organic matter conducive to snail growth are also important. Furthermore, human contact with water containing living cercariae by bathing, wading, washing, swimming in, or drinking it is a crucial factor. Infection is strongly influenced by social and religious practices in relation to contact with water.

Schistosomiasis has a long history. As early as 1050 BC, Egyptian pharaohs wrote about urinary bladder disturbances. Schistosomal ova were found in the cirrhotic liver of an Egyptian mummy around 1200 BC. Historically, it was generally thought that the old papyrus records from Egypt indicate that schistosomiasis (bilharziasis) was common around 2000 BC with the hieroglyph for the widely spread “aaa disease” being interpreted as “haematuria”. Egypt was the centre for much of the early work on schistosomiasis. The disease was certainly endemic there in ancient times, but there are now doubts as to the veracity of the traditional interpretation of hieroglyphs in Egyptian papyri and paintings thought to mean haematuria, its treatment and prevention. However, epidemiological studies on schistosomiasis began in the middle of the 19th century both in Egypt and Japan. ‘Asiatic schistosomiasis’, as it later became known, was described from Katayama in Japan in 1847. The original description of ‘Asiatic schistosomiasis’ was given by Fujii in 1847. Pruritic papules on the legs of persons working in flooded rice fields constitute the dominant feature of the disease that affected all age groups. Abdominal upsets were common, and when symptoms continued, the typical stages of what we now know as ‘hepatosplenic schistosomiasis’ developed — and there was no effective treatment. According to legend, the disease started after a ship sank near Kata Mountain (Katayama) in a bay that was eventually reclaimed from the sea (1). What became known as ‘Katayama disease’ was later recognized in other parts of Japan, and studied independently in each locality of the country. The causative parasite, *Schistosoma japonicum*, was not identified until early 20th century, but unraveling the life-cycle of the fluke took only a few years, being aided by the use of domestic animals as alternative hosts to man, in transmission experiments.

Theodore Bilharz [1825 – 1862], a German scientist, pathologist and medical doctor, identified the cause of ‘African schistosomiasis’ at Kasr El-Eini Hospital in Cairo in 1852 (2, 3). However, the transmission picture in ‘African schistosomiasis’ was complicated by the fact that two species of worms were involved, each using a different genus of snail intermediate host, but apparently without alternative hosts to man. Between 1851 and 1853, in a series of autopsies, Bilharz found trematode blood flukes with separate male and female adult worms, in the bladder wall and...
in the mesenteric veins. Bilharz noted that the female worms from the bladder wall contained an abundance of eggs compared with those from the mesenteric veins. Although Bilharz had partly solved the problem of the disease that was to subsequently bear his name – he had at least identified the cause – the failure to incriminate the two species of worm laid the foundations for a future scientific controversy that was to make and break reputations half a century later (1).

The life-cycle of the parasites remained a mystery for more than 60 years, during which time numerous preparations from the pharmacopoeia of the day were tried in the search for a cure. Leiper (4,5), an English scientist, and Leiper and Atkinson (6) discovered the intermediate snail hosts for *S. haematobium* and *S. mansoni*. At about the time that Leiper discovered the life-cycle of *Schistosoma haematobium*, confirmed the existence of the long suspected *Schistosoma mansoni* and discovered its life-cycle, a highly effective treatment, antimony potassium tartrate (or tartar emetic), was found. Tartar emetic brought hope where there had been none, and laid the foundations for rational control of the disease (1). In Sudan, it was used in a preventive control programme to stop bilharziasis invading the Gezira Irrigation Scheme, and in Egypt, it was used for morbidity control. Combined with mollusciciding, tartar emetic provided the means for the first transmission control study which took place in Dakhla Oasis (1). Hopes that the disease could be controlled easily faded rapidly, and it must be admitted that even if we now have a better understanding of what is required for control in different epidemiological situations, effective implementation is still often a problem.

Schistosomes that cause human schistosomiasis enter the body through skin contact with infected fresh water in which snails that carry the schistosomes live. This occurs mainly among people who drink the water or use it for washing, bathing, swimming or work activities such as fishing, rice cultivation, or irrigation. However, rural–urban migration is also introducing the disease into peri-urban areas in Africa and North-East Brazil, while refugee movements are spreading the disease in Somalia and Cambodia. More tourists are now contracting schistosomiasis with the rise in “off-track” tourism, at times with severe acute infection and unusual sequelae including paralysis of the legs (1). Although many infections are asymptomatic, acute schistosomiasis (“Katayama fever”) may occur a few weeks after the initial infection, especially by *S. mansoni* and *S. japonicum*. Manifestations of acute schistosomiasis include fever, cough, abdominal pain, diarrhoea, hepato-splenomegaly, itching and eosinophilia. Continuing infection may cause granulomatous reactions and fibrosis in the affected organs, which may result in manifestations that include: colonic polyposis with bloody diarrhoea (*Schistosoma mansoni* mostly); portal hypertension with haematemesis and splenomegaly (*Schistosoma mansoni*, *S. japonicum*); cystitis and urethritis with haematuria (*S. haematobium*) which can progress to bladder cancer; pulmonary hypertension (*S. mansoni*, *S. japonicum*, and more rarely, *S. haematobium*); glomerulonephritis; and central nervous system lesions. Within few to several weeks, worms grow inside the blood vessels of the infected person/s, and the adult female worms produce eggs. Some of these eggs travel to the bladder or intestines, and are passed out of the body with urine or stool.

The socio-economic and health effects of schistosomiasis cannot be underestimated. School performance and growth patterns of infected children are retarded, although the effects are 90% reversible on average with treatment. In Egypt, Sudan and North-East Brazil, the work capacity of rural inhabitants is severely reduced due to weakness and lethargy caused by the disease. Urinary schistosomiasis causes a specific type of bladder cancer, and it has been established that in some parts of Africa, the incidence of bladder cancer linked with schistosomiasis is 32 times higher than that of simple bladder cancer in the USA and Europe (7).

Despite more than half a century of international research on schistosomiasis control, this disease is still a public health menace in many developing countries, especially in Africa, Asia and South America. Chemotherapy and transmission reduction via intermediate host snail eradication are the two main tools in the control of schistosomiasis. Control of the intermediate snail host is still considered the most important means of schistosomiasis control where the water volume per head of human population at risk of infection is small (8). However, safe and effective drugs are now available for the treatment of schistosomiasis. Schistosomicides such as antimonials were introduced as the drugs of choice, and they continued to be used as such until the early 1960s. The antimonials were administered intravenously. However, the severe side-effects of the antimonials made their application difficult and adversely affected their use in large-scale chemotherapy campaign. The antimonials were, therefore, replaced by hycanthone and lucanthone which were administered intramuscularly. These drugs produced side-effects such as hepatotoxicity and gastrointestinal disturbances, and were consequently withdrawn. It was then decided that the alternative was to produce synthetic drugs that could be administered orally. Nitazoxanide, oxamniquine and metrifonate were consequently introduced as schistosomical agents, while drugs like oltipraz and amostranate were still at clinical trial phase. Therapeutic doses of drugs like hycanthone, nitazoxanide and amostranate were found to cause
many major side-effects and were, therefore, considered unsafe. The introduction of relatively safe, effective, broad-spectrum oral anthelmintic agent, praziquantel, constituted a significant landmark in the chemotherapeutic control of schistosomiasis. To date, praziquantel is the drug of choice for infections caused by all species of Schistosoma. Oxamniquine has also been used effectively in treating infections caused by S. mansoni in some cases where praziquantel is less effective. Studies have also shown that metrifonate is as effective as praziquantel in treating S. haematobium and S. mansoni infections. Because praziquantel is effective even in treating advanced hepatosplenic schistosomiasis, with fewer side-effects, the drug is currently the drug of choice for the treatment of any kind of schistosomiasis. Its only limitation is the cost which restricts its use in many developing countries. With the introduction of praziquantel, there has been a shift away from transmission control to the control of severe morbidity. However, despite the effectiveness of praziquantel, there is a high re-infectivity rate in endemic areas even after mass treatment. Repeated treatment will, therefore, be necessary, although it has not been established what would be a suitable interval between such treatments. Furthermore, the cost of praziquantel remains prohibitive for mass control programmes in many schistosomiasis endemic areas of the world. Together with chemotherapy, molluscicides are widely considered to be an important tool of schistosomiasis control that can be used at selected transmission sites to achieve quick results. Measures such as improved sanitation and health education are likely to take longer time to affect the disease spread and prevalence. While effective and safe drugs for schistosomiasis mass chemotherapy campaign are being developed, problems of therapeutic failure and drug resistance are being reported in some developing countries of the world. Under these circumstances, alternative drugs must be found. Mass treatment, a crucial goal in the eventual control of schistosomiasis, awaits a well-tolerated and non-toxic drug that will ultimately prove to be effective where and when cure is definite and non-negotiable. However, treatment of this preventable disease must always be accompanied by good health education and hygiene practices.

Treatment of schistosomiasis is now simple, and control of the disease can protect millions of people in schistosomiasis-endemic areas of the world, especially in Africa, South America, China and Asia. Reducing the intensity of infection can ultimately reduce morbidity and mortality. For the control of schistosomiasis, multi-faceted approaches are desirable, including control of the intermediate host snails. At present, niclosamide (Bayluscide®, Bayer, Germany) is the only commercially-available molluscicide applied on a large scale (9, 10). However, this synthetic molluscicide tends to be generally biocidal, toxic to fish and microscopic aquatic animals, and affecting many of the plants in the snail habitat. Furthermore, the compound is often not affordable and/or available in many of the poor, schistosomiasis-endemic countries. The rising cost of proprietary molluscicides has stimulated a search for cheaper, natural compounds from plants. This strategy relies on the integration of snail control into the activities of self-help schemes and projects in rural areas. Moreover, the use of indigenous rather than imported materials is desirable, especially as strategies for schistosomiasis control programmes should be based on long-term operations (6). Although chemotherapy is one of the most valuable methods of controlling schistosomiasis, there is a pressing need for more selective and effective molluscicides for the control of snail vectors. Many plants have been screened for their intrinsic molluscidal properties in an attempt to find an affordable alternative to niclosamide. However, despite the discovery of several promising plant molluscicides, none of them has yet been used in schistosomiasis control campaigns. Plants with molluscidal activity may be exploited to contribute to schistosomiasis control, especially if they are already grown locally for other purposes. The use of plants with molluscidal properties is a simple, inexpensive and appropriate technology for the snail control. Since the discovery of active saponins in the berries of Phytolacca dodecandra (L’Herit), naturally occurring molluscicides are receiving considerable attention.

During the last few decades, plant molluscicides have received considerable attention in the search for cheaper alternatives to existing chemotherapeutic agents and synthetic molluscicides in schistosomiasis control. On the African continent, interest in plant molluscicides dates from the 1930s when Archibald (1933) (11) and Wager (1936) (12) advocated planting of the desert palm, Balanites aegyptiaca and B. maughamii, along the water courses of Sudan and South Africa, respectively. The laboratory and field trials of the two latter scientists indicated that the fruit of the plants which fell into the water prevented subsequent increase in snail population density. These encouraging findings prompted the introduction of Balanites aegyptiaca to Puerto Rico, where it was planted around Biomorphic glabrata-infested pools with apparently beneficial results. Mozley (1939) (13) considered B. aegyptiaca and two other saponin-containing plants, Sapindus saponaria, the berries of which were widely used in Africa and South America as a fish poison and soap, and Swartzia madagascariensis, a traditional African medicine and fish poison (12), to be among the most promising vegetable molluscicides. Using the berries of S. saponaria, Mozley (1939) (13) controlled a population of Bulinus africanus in a pond in Zanzibar.
In South America, preliminary studies by Luttermoser (1946) in Venezuela, and by Pinto and Almeida (1944) (14) in Brazil, showed that the berries of *S. saponaria* were lethal to numerous microscopic aquatic organisms, as well as to the host snails of *Schistosoma* and *Fasciola*. Synergistic effects were found between the extracts of *S. saponaria* and sodium pentachlorophenate. For many years that followed, neither of the plants, nor any of the several other ‘Old World’ fish poisons, was further exploited for the control of snail vectors. Indeed, not until the mid-1960s was the first plant, *Phytolacca dodecandra*, used for the control of schistosomiasis in an endemic focus in Ethiopia (15).

Encouraged and stimulated by these early studies, the search for plants with molluscicidal potential was intensified as exemplified by the extensive screening and general improvement of screening methods and techniques reported by various investigators worldwide (7). Amorin and Pessoa (1962) (16) randomly screened fresh materials of nine plants indigenous to Alagoas State of Brazil. Three of the plants, *Paullinia pinnata*, *Stenolobium velutinum* and *Piptadenia macrocarpa*, were found to be only mildly molluscicidal at 1000 ppm, probably due to the fresh and green states of the plants. Silva *et al.*, (1971) (17) screened another 30 species of plants indigenous to Brazil, four of which were toxic to *Biomphalaria straminea*, but only one, *Agonandra brasiliensis*, was molluscicidal at 100 ppm. Possible confinement of the active ingredient in the bark, which regenerates slowly, of *A. brasiliensis* and *Brysonium sericea* probably precludes their practical use for snail control. The bark of *Ziziphus undulata* was found to have no effect on the snails, but Barbosa and Mello (1969) (18) reported 30% mortality in *Biomphalaria glabrata* exposed to a 10-ppm water extract of *Z. jaqueiro*. In North-East Brazil, several studies have implicated many plants as potential molluscicides. However, fish and many other aquatic organisms succumbed to lower concentrations of the plant extracts than those required to kill the snails, and resistance of the plants to physio-chemical stress (sunlight, temperature variations, silt, pH, etc) remains to be studied before their suitability as plant molluscicides can be fully assessed (7).

As natural pesticides, plants have long held the interest of biologists wanting to control diseases such as schistosomiasis, fascioliasis, malaria, filariasis and dengue (19, 20, 21). Medina and Woodbury (1979) (22) tested all parts of 198 plants indigenous to Puerto Rico and two to the Dominican Republic. Water extracts of 30 species of the plants were found to be lethal to *Lymnaea cubensis* and *L. columnella* at 1000 ppm. For further screening, the plant products were oven-dried and tested as water extracts at 25, 100 and 1000 ppm. *Hedychium coronarium* yielded the most potent extract, while other species exhibited great variations in potencies, and highest toxicity levels were most often found in the flowers and leaves. Several species of *Solanum* are being cultivated for solasodine, a sapogenin used in the production of pharmaceutical steroids. Solasodine, and possibly solamargine, another glycoalkaloid in the fruit of *Solanum mammosum*, were significantly more toxic than the crude aqueous and methanolic extracts (Alzerreca *et al.*, 1981) (23). Although the small number of plant species tested by Medina and Woodbury (1979) (22) did not permit detailed comparisons between plant families, it was noted that the greatest proportion of molluscicidal plants found are from the families: Solanaceae, Phytolaccaceae, Fabaceae, Rubiaceae, and Euphorbiaceae. The toxicity of the two *Phytolacca* species tested against *Lymnaea spp.* corroborates the findings of several other investigators (24). The most extensive plant screening programme has been carried out in China, where nearly 600 indigenous plants have been tested for snail toxicity. Less than 20 species were mildly toxic at concentrations of 10 000 ppm and lower. No plant species has thus been considered to be cost-effective for large-scale use (25).

Twenty-three of the 181 methanolic extracts (12.7%) representing 106 plant species used in Nigerian herbal medicine, gave 100% kill against *Bulinus globosus* (26). They include the root of *Rauvolfia calphra*, the stem and root of *Bombax costatum*, the fruit of *Dialium guineense*, the root and stem of *Combretum spp.*, and the root of *Terminalia mollis*, the root of *Cryptogonone argenta*, the stem of *Acioa emenii* and *A. ruatissii*, the leaves of *Morinda lucida* and *Rothmania whitefieldii*, the leaves of *Xiris anceps*, and fruits of *Tetrapleura tetraptera*. Many plant species have undergone systematic field evaluation in other endemic areas of Africa. The most notable work has been carried out in Ethiopia on *Phytolacca dodecandra*. Other plant species being tested include: *Ambrosia maritima* (Egypt); *Anacardium occidentale* (Mozambique); *Swartzia madagascariensis* (Tanzania); *Croton machrostachys* and *Jatropha curcas* (Sudan) (7, 27, 28); and *Vernonia amygdalina*, *Terminalia brachystemma*, *Ricinus communis*, *Maytenus senegalensis*, *Abrus precatorius*, *Pterocarpus angolensis*, *Securidaca longipedunculata*, *Ozoroa insignis*, *Dicoma anomala*, *Ximenia caffra*, *Lannea edulis*, *Elephantorrhiza goetzii* (Zimbabwe) (29).

In South Africa, most rural and informal settlements rely heavily on natural water bodies for their domestic and recreational needs, and consequently, schistosomiasis is a major health problem in the country. Schistosomiasis is mainly endemic in, and restricted to, the eastern and northern regions of the country, namely: Mpumalanga, KwaZulu-Natal and Northern (Limpopo) Provinces. In these provinces, infection is characteristically associated with an...
absence of pipe-borne water, good recreation and sanitary facilities (28, 30).

It has been estimated that at least 40% of the school children in KwaZulu-Natal Province of South Africa are afflicted with schistosomiasis. Stopforth (1976) (31) recorded that 47 families at Adams Mission in KwaZulu-Natal considered schistosomiasis to be the most important childhood illness prevailing among children between 6 and 16 years old. The foci of endemic areas are, therefore, expected to be in rural areas. Generally, a national anti-schistosomiasis control programme has never operated in South Africa, and there is no National Control Programme to fund or initiate any control measures in the country. There is a high prevalence of the disease amongst the populace, especially among the children (32). Despite records in excess of 70% for large areas of the endemic region (28, 33, 34), schistosomiasis is not a notifiable disease in South Africa. Under these circumstances, of necessity is a holistic approach which should include not only chemotherapeutic measures, but also measures interfering with the lifecycle of the parasite by eliminating the intermediate host vector snails. The only commonly available synthetic molluscicide, niclosamide, is too expensive for most developing countries [including South Africa], which also experience transport, infrastructural and logistical problems in supplying molluscicides to remote areas and the necessary expertise to apply them (32). Therefore, there is a need to search for cost-effective alternatives from plant sources which can be simply prepared and applied safely by rural community members themselves. In Southern Africa, research into plant molluscicides have received considerable attention in the last two decades (28). The emphasis has been on the identification of cheap, effective and environmentally-acceptable plant products. This is particularly true for Africa where adoption of the Western Health Care System has resulted in an expensive, hospital-based, doctor-dependent, urban-biased health care system, which is economically beyond the reach of the rural people (35). The attraction of the use of indigenous molluscicidal plants lies not only in economic benefit, but also in the development of a philosophy of self-reliance in rural communities (28, 36). Plant material would be cultivated, harvested, processed and applied focally to human water contact points, using an appropriate form of technology (29). This is not an unrealistic goal, and indeed many plant species have undergone systematic field evaluation for snail vector control in other endemic parts of Africa. The success of such self-help programmes is, however, dependent on the support of the affected communities. Community willingness to participate, in turn, presupposes recognition of infection and its economic burden and effects as a public health problem (28, 37, 38, 39). The study of community beliefs and habits is vital because these intrinsic elements influence their health and determine their involvement in any intervention programme (40). Reports of research findings on plant molluscicides from various countries of Africa, Latin America, Asia and other parts of the world have permeated the medical literature. To date, however, only a few of such research reports have been documented for South African plant molluscicides. The core aim of the present study was to screen for molluscicidal activity, some of the South African medicinal plants commonly used in Zulu folk medicine for treating schistosomal infections and controlling intermediate snail hosts of schistosomiasis.

MATERIALS AND METHODS

PLANT MATERIAL: The plants examined in this study were selected on the basis of ethnopharmacological information indicating their medicinal uses in schistosomiasis control in endemic areas of KwaZulu-Natal Province of South Africa. Voucher specimens of the plants are kept at the Natal Provincial Herbarium in Durban. The plant species were collected locally from their natural habitat and identified (with reference to herbarium specimens) by the Taxonomist/Curator of the Department of Botany, University of Durban-Westville, Durban 4000, South Africa. The plant materials were sorted out into roots, stems, leaves, flowers, fruits and seeds, and shade-dried at room temperature.

PREPARATION OF PLANT EXTRACTS: One kilogramme (1 kg) each of the air-dried plant materials used (leaves, root- or stem-barks, fruits, and so on) was ground into fine particles with a Waring blender, and Soxhlet extracted twice, on each occasion with 2.5 litres of distilled water at room temperature for 24 hours with shaking. The combined aqueous extracts were filtered, concentrated to dryness in vacuo under reduced pressure in a rotary evaporator at 30 ± 1°C and freeze-dried, finally yielding powdery, crude aqueous extracts of the plant materials. Aliquot portions of the plant extract residues were weighed and dissolved in distilled water for use on each day of our molluscicidal screening tests. From the crude extracts, stock solutions of concentration series in gram per litre of water (1000 mg/l) were freshly prepared in distilled water. Different test dilute solutions, ranging from 10 to 1000 mg/l, (i.e., ppm) were prepared from the stock solutions, using deionized and dechlorinated water, to determine the LD_{50} and LD_{90} values.

TEST SNAILS: Species of intermediate snail hosts of urinary and intestinal schistosomiasis in KwaZulu-Natal Province of South Africa, *Bulinus africanus* and
**Biomphalaria pfeifferi**, were used in this study. Adult snails were collected from ponds and water courses in Randle Park, Overport in Durban, KwaZulu-Natal Province. The ponds had not been previously treated with molluscicides. Uninfected snails, that is, those that did not show patent trematode infections, were acclimatized in pond water to laboratory conditions for seven days before being used in our molluscicidal tests. Ten snails were then allocated to each of the groups and immersed in either untreated, dechlorinated tap water (control) or aqueous extract-treated dechlorinated water. Preparations of the plant extracts and toxicity test protocols were adapted from those described by Brackenbury and Appleton in 1997 (18, 19).

**MOLLUSCICIDAL ACTIVITY TESTS:** Molluscicidal evaluations of the plant extracts were performed according to WHO guidelines (WHO, 1965). Groups of 10 uninfected snails were placed in glass ‘tanks’ (containers) with some sand, snail food and 1000 ml of deionized and dechlorinated pond or tap water bubbled with atmospheric air. Tests were carried out at room temperature (26±1°C). In each set-up, the snails were prevented from crawling out of the glass container by means of a fine stainless steel mesh placed above the water surface. The test snails were challenged with various doses of the plant extracts (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 400, 800 and 1000 mg/l [ppm]). After 24 hours of exposure to the plant extracts, the snails were transferred to fresh dechlorinated and deionized water and maintained there for another 24 hours. Death of the snails was determined and confirmed by the absence of heartbeat and lack of reaction to irritation of the foot with a blunt wooden probe to elicit typical withdrawal movements. Control solutions were also made with deionized and dechlorinated tap water. Control experiments were performed with deionized and dechlorinated water alone (‘negative control’) or with niclosamide [Bayluscide®] (‘positive control’). Molluscicidal test with each plant extract dose was separately repeated three times. The snails were neither fed nor disturbed during the exposure and recovery periods. LD$_{50}$ and LD$_{90}$ (referring to the plant extract doses in ppm, that kill 50% and 90% of the test snails respectively) were determined by the method of Leitchfield and Wilcoxon (1949) (41) with 95% confidence limit. Plant extracts that caused no mortality at 1000 ppm were considered inactive and were not investigated further.

**RESULTS**

**BENCHSIDE OBSERVATIONS:** Each snail in the untreated water tanks (controls) initially withdrew into its shell, but resumed normal activity after about 45 minutes, moving around the container with its foot extended. When a mechanical stimulus was applied to the foot-sole, the snail immediately retracted into its shell. In the test snails, the toxic effects of the active plant extracts became evident. There was either a partial retraction (withdrawal response) in the partially dead snails, or no retraction at all (in the dead snails) to mechanical stimulation of the foot-sole with a blunt needle. There was a visible swelling of the cephalopedal mass. Development of haemorrhagic ‘blisters’ over the ventral surface of the foot-sole was also noted. High doses of the active plant extracts caused the cephalopedal mass of each snail to become severely swollen, turgid and failing to respond to mechanical stimulation with a blunt needle. Mucus secretion was observed over most of the foot.

**EXPERIMENTAL FINDINGS:** The 41 South African candidate molluscicidal plants examined (see Table 1) were claimed by Zulu traditional healers to be useful both as molluscicides in snail vector control and in the treatment of urinary and intestinal schistosomiasis. The plants are primarily used to treat haematuria caused by *Schistosoma haematobium* infection, and/or stomach troubles caused by *Schistosoma mansoni* infection. The results of our molluscicidal evaluation of the 41 plants examined are presented in Table 1.

### TABLE 1

<table>
<thead>
<tr>
<th>Family/Genus/Species</th>
<th>Parts commonly used by Traditional Healers</th>
<th>LD$_{50}$ values for the snails used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amaranthaceae</strong></td>
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<tr>
<td><em>Amaranthus spinosus</em></td>
<td>Aerial Parts/Leaves</td>
<td>400 – 800 ppm</td>
</tr>
<tr>
<td><em>Annona senegalensis</em></td>
<td>Aerial Parts/Leaves</td>
<td>100 – 200 ppm</td>
</tr>
<tr>
<td><strong>Apocynaceae</strong></td>
<td></td>
<td></td>
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<tr>
<td><em>Rauvolfia caffra</em></td>
<td>Barks/Leaves/Twigs</td>
<td>200 – 400 ppm</td>
</tr>
<tr>
<td><strong>Asparagaceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Asparagus racemosus</em></td>
<td>Aerial Parts/Leaves</td>
<td>400 – 800 ppm</td>
</tr>
</tbody>
</table>
### Asteraceae

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<tbody>
<tr>
<td>5.</td>
<td><strong>Berkheya speciosa</strong> (DC) O. Hoffm.</td>
<td>Barks/Leaves/Twigs</td>
</tr>
<tr>
<td>6.</td>
<td><strong>Vernonia amygdaлина DC.</strong></td>
<td>Barks/Leaves</td>
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### Balanitaceae

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<tbody>
<tr>
<td>7.</td>
<td><strong>Balanites maughami</strong> Sprague</td>
<td>Fruits/Leaves/Barks</td>
</tr>
<tr>
<td>8.</td>
<td><strong>Balanites aegyptiaca</strong> (Linn.) Delile</td>
<td>Fruits/Leaves/Barks</td>
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### Bignoniaceae

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<tbody>
<tr>
<td>9.</td>
<td><strong>Kigelia africana</strong> (Lamk.) Benth</td>
<td>Fruits/Seeds</td>
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### Cannellaceae

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<tbody>
<tr>
<td>10.</td>
<td><strong>Warburgia salutaris</strong> (Bertol. F.) Chiov.</td>
<td>Twigs/Leaves/Fruits</td>
</tr>
<tr>
<td>11.</td>
<td><strong>Warburgia ugandensis</strong> Sprague</td>
<td>Twigs/Leaves/Fruits</td>
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### Combretaceae

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<tbody>
<tr>
<td>12.</td>
<td><strong>Combretum imberbe</strong> Wawra</td>
<td>Barks/Twigs/Leaves</td>
</tr>
<tr>
<td>13.</td>
<td><strong>Combretum molle</strong> R. Br. ex G. Don</td>
<td>Barks/Twigs/Leaves</td>
</tr>
<tr>
<td>14.</td>
<td><strong>Combretum fragrans</strong> F. Hoffm</td>
<td>Barks/Twigs/Leaves</td>
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### Ebenaceae

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<tr>
<td>15.</td>
<td><strong>Eucllea natalensis</strong> A. DC.</td>
<td>Barks/Twigs/Leaves</td>
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### Euphorbiaceae

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<tbody>
<tr>
<td>16.</td>
<td><strong>Euphorbia cooperi</strong> N.E. Brown ex A. Berger</td>
<td>Twigs/Fruits/Seeds</td>
</tr>
<tr>
<td>17.</td>
<td><strong>Euphorbia tirucalli</strong> Linn.</td>
<td>Twigs/Fruits/Seeds</td>
</tr>
<tr>
<td>18.</td>
<td><strong>Jatropha curcas</strong> Linn.</td>
<td>Twigs/Fruits/Seeds</td>
</tr>
<tr>
<td>19.</td>
<td><strong>Ricinus communis</strong> Linn.</td>
<td>Twigs/Fruits/Seeds</td>
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### Fabaceae

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<tbody>
<tr>
<td>20.</td>
<td><strong>Spirostachys africana</strong> Sond.</td>
<td>Barks/Fruits/Seeds</td>
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### Fabaceae

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<tbody>
<tr>
<td>21.</td>
<td><strong>Acacia nilotica</strong> (Linn.) Delile</td>
<td>Barks/Leaves/Fruits</td>
</tr>
<tr>
<td>22.</td>
<td><strong>Dichrostachys cinerea</strong> Wight &amp; Arnott</td>
<td>Barks/Leaves/Fruits</td>
</tr>
<tr>
<td>23.</td>
<td><strong>Indigofera frutescens</strong> (Linn.) Mill</td>
<td>Barks/Leaves/Fruits</td>
</tr>
<tr>
<td>24.</td>
<td><strong>Sesbania sesban</strong> (Linn.) Merr.</td>
<td>Barks/Leaves/Fruits</td>
</tr>
<tr>
<td>25.</td>
<td><strong>Tephrosia diffusa</strong> (Linn.) Harv.</td>
<td>Barks/Leaves/Fruits</td>
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### Icacinaceae

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<tbody>
<tr>
<td>26.</td>
<td><strong>Apodytes dimidiata E. Meyer Ex. Arn. Subsp. dimidiata</strong></td>
<td>Barks/Leaves</td>
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### Lamiaeae

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<tbody>
<tr>
<td>27.</td>
<td><strong>Leonotis leonurus</strong> (Linn.) R. BR.</td>
<td>Aerial/Parts/Leaves</td>
</tr>
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### Lecythidaceae

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<tbody>
<tr>
<td>28.</td>
<td><strong>Barringtonia racemosa</strong> (Linn.) R. Br.</td>
<td>Fruits/Seeds</td>
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### Meliaceae

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<tbody>
<tr>
<td>29.</td>
<td><strong>Trichilia emetica</strong> Vahl</td>
<td>Roots/Leaves</td>
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### Olacaceae

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<tbody>
<tr>
<td>30.</td>
<td><strong>Ximenia americana</strong> Linn.</td>
<td>Barks/Leaves/Fruits</td>
</tr>
<tr>
<td>31.</td>
<td><strong>Ximenia caffra</strong> Sond.</td>
<td>Barks/Leaves/Fruits</td>
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### Phytolaccaceae

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<tbody>
<tr>
<td>32.</td>
<td><strong>Phytolacca dodecandra</strong> Linn.</td>
<td>Fruits/Leaves/Seeds</td>
</tr>
<tr>
<td>33.</td>
<td><strong>Phytolacca communis</strong> Linn.</td>
<td>Seeds</td>
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### Phytolaccaceae

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<tbody>
<tr>
<td>34.</td>
<td><strong>Phytolacca americana</strong> Linn.</td>
<td>Barks/Leaves</td>
</tr>
</tbody>
</table>
discoloration; Barks /Leaves

Octandra Linn. /Barks 100 ppm

Phytolacca americana /Barks 200 ppm

Polygalaceae

Securidaca longipedunculata Barks/Leaves 400 – 800 ppm

Rubiaceae

Gardenia thunbergia Aerial 50 – ppm

Oldenlandia corymbosa Parts/Leaves 400 ppm

Solanaceae

Solanum nigrum Linn. Parts/Leaves 100 – ppm

Solanum nodiflorum Jacq. Parts/Leaves 100 ppm

Withania somnifera Linn. Parts/Leaves 400 ppm

Positive Control

Niclosamide (Bayluscide®) Aqueous solution 0.20 – 0.8 ppm

KEY:

0.1 – 1.0 ppm = Very strong molluscicidal activity
50 – 100 ppm = Moderate to strong molluscicidal activity
100 – 200 ppm = Mild to moderate molluscicidal activity
200 – 400 ppm = Weak to mild molluscicidal activity
400 – 800 ppm = Very weak molluscicidal activity
≥ 1000 ppm = No molluscicidal activity (and therefore, rejected in this study).

Niclosamide (Bayluscide®), used as (‘positive control’) reference molluscicide, killed all the snails at a dose of 1 ppm. On the contrary, none of the snails (in the ‘negative control’) treated with deionized, dechlorinated water alone died.

DISCUSSION AND CONCLUSION

In Africa, some illnesses are regarded as uniquely African and, therefore, not treatable by Western medicine but by African indigenous remedies. Approximately 80% of the Black South Africans consult traditional healers as a first resort when ill (28, 42), and an estimated 75% of the world’s population relies on traditional remedies for their primary health care needs (28, 43, 44, 45). Home remedies and treatment from traditional doctors are affordable and readily accessible, although there is some doubt as to their success in curing schistosomiasis (28). However, the Zulus of South Africa do not regard indigenous and Western medicine as conflicting.

The use of plant molluscicides is culturally acceptable and certainly more accessible than Western antischistosomal drugs whose availability is limited by the cost and transport. The use of plant molluscicides at community level is imperative, and is in line with the suggestion of Straub and Walser (1992) (46) that rural health care needs to step beyond the facility- or provider-driven models in search of new solutions. Further evaluation of plant molluscicides and their potential value in rural South African communities is most certainly warranted (28). The problem that most researchers in the field of plant molluscicides continually encounter in dealing with crude plant extracts is the variability of the secondary metabolite content of the plant material. This variability may arise from a phenoplastic response to environmental conditions, and/or genetic control (32). However, previous studies in our laboratories and elsewhere have shown that potency levels of plant samples vary significantly according to season and geographical locations of the plants. Such unpredictable trends in the potency of plant molluscicides militates against their selection for control programmes (32). Another important criterion of a molluscicide is that it should retain its potency during dry storage, preferably for at least one year (47). This is generally the case for synthetic molluscicides but not so often for plant products whose shelf-life may vary from four months to five years (32, 48, 49, 50). Whether or not the plant materials examined in this study remain stable for a period of up to one year or more is not known. Storing plant molluscicides in aqueous solutions is not a practical consideration due to their rapid loss of potency (32, 48, 49, 50, 51). The stability of such solutions could possibly be extended by refrigeration (51), but for most rural communities in South Africa, electricity supplies and electrical appliances are generally not available or grossly inadequate.

The results obtained in this study are in consonance with the findings of earlier investigators from other parts of the world (e.g., 29, 52, 53), and indicate that 14 (34%) of the 41 Zulu medicinal plants examined in this study possess moderate to strong molluscicidal activity (see Table 1). The molluscicidal activity of most of the tested plant extracts is probably due to the presence of saponins. However, it has been established that not only saponins, but also some...
sesquiterpenes, chalcones and flavonol glycosides, as well as phorbol esters of various plants from diverse families, possess molluscicidal properties (52, 53, 54).

After exposure to the active plant extracts examined in the present study, the snails showed several behavioural responses, including the ‘distress syndrome’ described for other planorbid species by Harry and Aldrich (1963) (55); Sullivan and Cheng (1975) (56); Van Aardt and Coertze (1981) (57), Brackenbury and Appleton (1999) (31), indicative of intoxication. Swelling of the tissues was not restricted to the tentacles, but involved the whole cephalopedal mass. According to Brackenbury and Appleton (1999) (21), the inference from this observation is that the tissues of the cephalopedal mass had accumulated water, which caused haemorrhage at lethal concentrations of the active plant extracts. Nevertheless, the observations made in this study suggest that the toxic principles in the active plant extracts disrupted the permeability of the foot-sole surface epithelium by preventing its normal osmoregulatory function (21). The toxic effects of the sublethal doses of the plant extracts were, however, reversible after exposure if the snails were moved to toxic extract-free water for a recovery period. This observation is in agreement with the findings of Harry and Aldrich (1963) (55) and Van Aardt and Coertze (1981) (57) for Bulinus tropicus and Biomphalaria glabrata after exposure to copper. Exposure of the snails to the active plant extracts examined caused irreversible cellular damage to Bulinus africanus and Biomphalaria pfeifferi. According to Brackenbury and Appleton (1999) (21), the assumption that the molluscicidal actions of the active plant extracts was due to the disruption of the osmoregulatory physiology of the foot-sole epithelium could be supported by evidence of specific cellular injuries. Apart from disruption of the snail’s foot-sole epithelium osmoregulatory physiology, there is also the possibility that enzyme-mediated pathways of the snail are affected by the molluscicidal extracts (21). However, osmolality and electrolyte studies, as well as enzymatic, histochemical and biochemical studies are required to substantiate these possible modes of molluscicidal action of the plant molluscicides.

In many schistosomiasis-endemic countries of the world, pharmaco-chemical research on molluscicidal plants is now gaining the support of government and non-government institutions at a time when there is a slow growth in synthetic molluscicides. During the last 70 years, more than 1500 plant species have been screened, most of them superficially, for molluscicidal activities. The richness of the flora in most areas of the world where snail-transmitted diseases are endemic, probably suggests that many plants with molluscicidal properties remain to be discovered. Several promising plant molluscicides have been identified. Endod (Phytolacca dodecandra) in particular, compares fairly well with the major synthetic molluscicides in terms of potency, and has the advantage of yielding other products of pharmaceutical and industrial importance. The use of plant molluscicides may not only eliminate the economic burden of importing expensive synthetic molluscicides, but could also stimulate growth of small-scale industries in developing countries. More emphasis must, however, be placed on agronomic and organizational aspects, including community participation, if plant molluscicides are to be applied successfully in long-term and self-sustained snail control programmes (7).

Some of the major constraints limiting the use of plant molluscicides at present are lack of adequate information on their cost-effectiveness and chronic toxicity, and difficulties of developing viable snail control programmes in rural areas using local resources (7). In some communities, snail control has been traditionally carried out using imported synthetic chemicals, with little or no involvement of the local people, by health officials and technicians of central governments and international organizations. However, the use of local labour for cultivating, harvesting, processing and applying plant molluscicides, reduced transportation costs and new methods of screening and extracting the active compounds from the plants, can make local plant molluscicides more cost-effective. The extensive knowledge of local plants with toxic and medicinal properties which most of the rural people have acquired, together with new information on chemo-taxonomy, will permit focused screening of those plant families and genera that are most likely to contain species suitable for effective snail control. Although several investigators have successfully tested plant materials for molluscicidal activities using techniques commonly employed in phytochemical and pharmacological studies, more effective exchange of information is required to develop specific research methodologies and snail control strategies (7). In future, more attention must be paid to the development of simple, cheap and efficient extraction and application techniques amenable for use in rural communities. With community development and appropriate technology becoming important elements in most new national socio-economic plannings, many endemic countries of the world should now support the development and evaluation of plant molluscicides as a new tool in the implementation of locally and internally directed health improvement campaigns.
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REFERENCES


OTHER IMPORTANT REFERENCES


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FRASES

*Todo hombre no vive más que por lo que espera*
Giovanni Papini

*Ningún animal es más calamitoso que el hombre, Por la buena razón de que todos se satisfacen con los límites de su naturaleza, Mientras que sólo el hombre se desvive para sobrepasar los suyos*
Erasmio de Róterdam

*Nos interesan los demás cuando se interesan por nosotros*
Publio Siro

*Nunca hubo guerra buena ni paz mala*
Benjamín Franklin

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