13

Bioactive Natural Products from Sapindaceae Deterrent and Toxic Metabolites Against Insects

Martina Díaz and Carmen Rossini
Laboratorio de Ecología Química, Facultad de Química, Universidad de la República, Uruguay

1. Introduction

The Sapindaceae (soapberry family) is a family of flowering plants with about 2000 species occurring from temperate to tropical regions throughout the world. Members of this family have been widely studied for their pharmacological activities; being *Paullinia* and *Dodonaea* good examples of genera containing species with these properties. Besides, the family includes many species with economically valuable tropical fruits, and wood (Rodriguez 1958), as well as many genera with reported anti-insect activity.

Antioxidant, anti-inflammatory and anti-diabetic properties are the pharmacological activities most commonly described for this family (Sofidiya et al. 2008; Simpson et al. 2010; Veeramani et al. 2010; Muthukumran et al. 2011). These activities are in some cases accounted for isolated phenolic compounds such as prenylated flavonoids (Niu et al. 2010), but in many cases, it is still unknown which are the active principles. Indeed, there are many studies of complex mixtures (crude aqueous or ethanolic extracts) from different species in which several other pharmacological activities have been described without characterization of the active compounds [*e.g.* antimigrane (Arulmozhi et al. 2005), anti-ulcerogenic (Dharmani et al. 2005), antimalarial (Waako et al. 2005), anti-microbial (Getie et al. 2003)].

Phytochemical studies on Sapindaceae species are abundant and various kinds of natural products have been isolated and elucidated. Examples of these are flavonoids from *Dodonaea* spp. (Getie et al. 2002; Wollenweber & Roitman 2007) and *Koelreuteria* spp. (Mahmoud et al. 2001), linear triterpenes from *Cupaniopsis* spp. (Bousserouel et al. 2005) and caffeine, xanthenes and cathequines from *Paullinia* spp. (Benlekehal et al. 2001; Sousa et al. 2009). All these compounds are naturally occurring in almost every plant family, however, the Sapindaceae do produce an unusual group of secondary metabolites: the cyanolipids (Avato et al. 2005). Eventhough these compounds exhibit a potential health hazard for humans and animals, for the plants, cyanolipids may have a protective physiological role. However, not many investigations have been developed involving the study of the ecological interactions among the plants producing them and other sympatric organisms. On the other hand, the toxicity of these cyanocompounds might be a potential source of pesticides. Indeed, not only cyanocompounds, but also a wide range of species of Sapindaceae have been tested on their anti-insect activity. Several extracts, fractions or pure compounds of different phenological stages, have been tested against diverse species of lepidopterans, dipterans and coleopterans of major importance in agriculture as well as in veterinary and medical applications. Examples of this include the larvicidal activity of *Magonia pubescens* against *Aedes aegypti*

(Diptera: Culicidae) (Arruda et al. 2003a,b); the toxicity of *Sapindus* spp. against *Sitophilus oryzae* (Coleoptera: Curculionidae) (Zidan et al. 1993; Rahman et al. 2007); and the toxicity of *Dodonaea* spp. against *Spodoptera* spp. (Lepidoptera: Noctuidae) (Abdel et al. 1995; El-Din & El-Gengaihi 2000; Deepa & Remadevi 2007; Malarvannan et al. 2008). The activity against different pest models of extracts from various South American species within the Sapindaceae was recently described. These species included *Allophylus edulis*, *Dodonaea viscosa* and *Serjania meridionalis*, from which isolated metabolites with anti-insect capacities have not yet been described (Castillo et al. 2009). This chapter will examine the available information on extracts and secondary metabolites from Sapindaceae focused on their defensive role for the plant against herbivory; and consequently this appraisal will also present a compilation of potential anti-insect agents from Sapindaceae.

2. Sapindaceae: its anti-insect potential

Anti-insect activity has been described in at least 15 of the 202 genera (Anonymous 2011) belonging to this family. Among these findings, the cases in which the bioactive compounds were isolated represent the least. It has been in general tested the activity of aqueous or ethanolic extracts from different organs and from plants of different phenological stages against a variety of insect targets using different bioassay designs. As a consequence, different modes of action have been described. Extracts have revealed to be potentially deterrent agents, growth inhibitors and even toxic agents against different genera of insects. The following appraisal comprises the main Sapindaceae genera from which extracts or isolated compounds with anti-insect activity have been described.

2.1 *Sapindus*

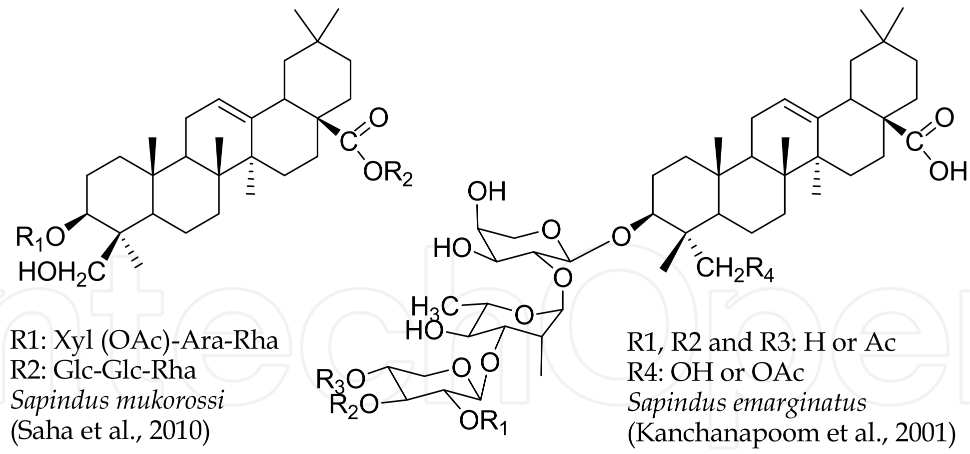
A vast number of species showing great potential as anti-insect agents belong to this genus. *Sapindus saponaria*, a tree widely distributed in Central and South America, is also frequently used as ornamental (Lorenzi 2004). Brazilian people commonly prepare homemade soap from this tree; and use its seeds to make handcrafts. Its wood is broadly used in construction. Its fruits and roots are popularly used as painkillers, astringents, expectorants and diuretics (Ferreira Barreto et al. 2006). Besides, its medicinal potential as healing and anti thrombotic agents has been studied. Research on that area has revealed that flavonoids in the leaf extracts are responsible for those activities (Meyer Albiero et al. 2002). On the other hand, much research has been devoted to the anti-insect capacity of extracts from different organs of this plant. Boiça Junior et al (2005), on their search for activity against larvae of the cabbage pest *Plutella xylostella* (Lepidoptera: Plutellidae) investigated eighteen plant species from a variety of families, finding that aqueous leaf extract of *S. saponaria* was one of the most active products. The extract produced 100 % of mortality in tests where the larvae were offered cabbage foliage disks coated with the extracts to be evaluated as a sole food (Boiça Junior et al. 2005). In another study, the aqueous fruit extract of this tree showed deterrent properties against another cabbage pest, *Ascia monuste orseis* (Lepidoptera: Pieridae). In this case the activity was comparable to that showed by aqueous extracts of the neem tree, *Azadirachta indica*, the newest botanical pesticide in the market (Isman et al. 1996; Medeiros et al. 2007). The aqueous seeds´ extracts were evaluated against another lepidopteran, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), showing strong effect on larvae development and midgut trypsin activity (dos Santos et al. 2008). Not only against lepidopterans has this tree revealed anti-insect potential, but also against other insect orders.

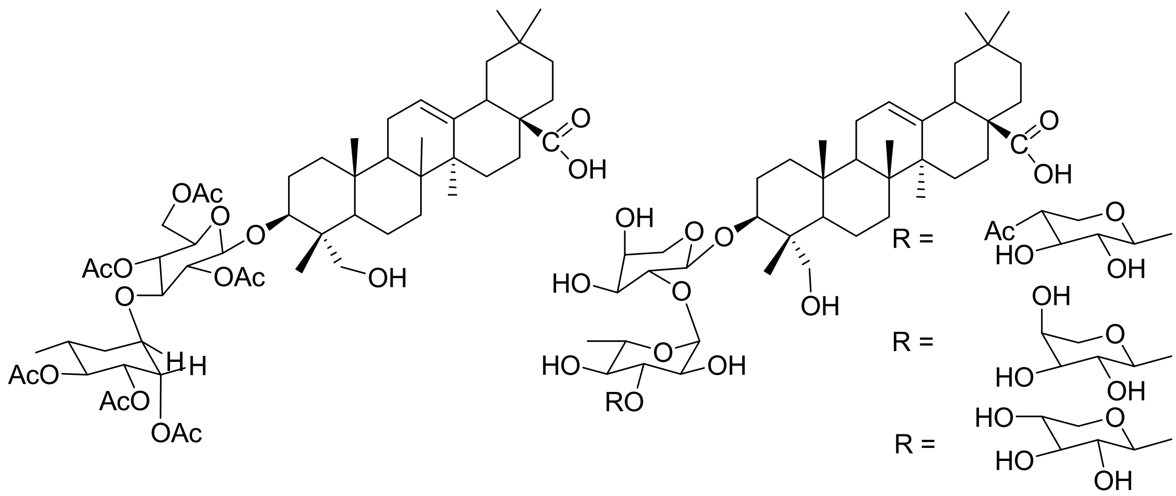
For instance, a saponin extract from fruits from this species showed toxicity against adults of the greenhouse whitefly *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae) (Porras & Lopez-Avila 2009); and complete ethanolic extracts from fruits have shown larvicidal and morphological alterations effects on the mosquito *Aedes aegypti* (Diptera: Culicidae) (Ferreira Barreto et al. 2006). Some other saponins presenting other kinds of biological activity, isolated from the fruits of this species, are shown in Figure 1 (Lemos et al. 1992; Ribeiro et al. 1995).

Sapindus emarginatus, another tree from this genus, widely distributed in India, has also demonstrated larvicidal activity of its fruit extract against three important vector mosquitoes: *A. aegypti*, *Anopheles stephensi* and *Culex quimquefasciatus* (Diptera: Culicidae) (Koodalingam et al. 2009). Later, this group has also investigated the impact of the extracts on the activity of mosquito phosphatases and esterases to gain an insight into the extent of disturbance in metabolic homeostasis inflicted upon exposure to the extract (Koodalingam et al. 2011). Previous reports on this species have shown that the pericarps contain triterpene saponins (Figure 1), which are commonly used as antifertility, antipruritic and anti-inflammatory agents in traditional Indian and Thai medicine (Jain 1976; Kanchanapoom et al. 2001). Perhaps, anti insect activity may be due to saponins in this plant similarly to the case of *Sapindus saponaria* (Porras et al. 2009).

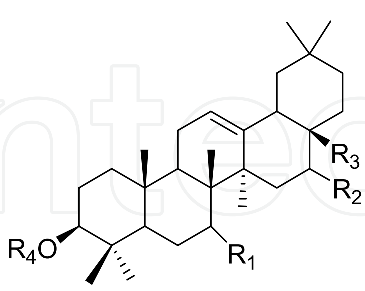
Activity of members of this genus against other insect orders, further than dipterans and lepidopterans, has also been evaluated, including coleoptera and lice. That is the case of the extract from *Sapindus trifoliatus* fruit cortex which showed activity against the red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) (Mukherjee & Joseph 2000). In this case, weight gain was significantly reduced when larvae were fed on diets including the extract at different doses; and females topically treated -upon emergence- with the extract laid fewer viable eggs. (Mukherjee & Joseph 2001). Another ethanolic fruit extracts, in this case from *Sapindus mukorossi*, also showed anti coleopteran activity against another pest of stored grains, *Sitophilus oryzae* (Coleoptera: Curculionidae) and also against *Pediculus humanus* (Phthiraptera: Pediculidae) (Rahman et al. 2007). Finally, from the methanolic extract of fruits of this species triterpenic saponins (Figure 1) have also been isolated and these natural products demonstrated their potential as growth regulators and antifeedants against *Spodoptera littura* (Lepidoptera: Noctuidae), both as glycosides and as free genines (Saha et al. 2009). In this particular study, it was verified that upon hydrolysis of the saponins, the growth regulatory activity was improved, whereas very little difference was found in regard to the antifeedant activity.

All in all, the genus *Sapindus* contains a variety of species which have been studied on their activity for some insects from different orders. In spite of the fact that not many reports do exist on the action of isolated compounds, the previous ethnobotanical uses of *Sapindus* spp. and the isolation of some active saponins from this genus, may suggest that this group of secondary metabolites might be related to the anti-insect activity. Saponins -glycosides of sapogenins containing a monosaccharide or a polysaccharide unit- reduce the surface tension becoming biological detergents. They are widely distributed secondary plant metabolites, found among almost 100 plant families (Bruneton 1995). Being effective defences for some insects (Plasman et al. 2001; Prieto et al. 2007), saponins have been implied in mechanisms of plant resistance against potential herbivores (Nielsen et al. 2010). The genus *Sapindus*, rich in this kind of compounds, may therefore be promissory raw material to develop plant pest control products. Further information can be found at recent works reviewing saponins from *Sapindus* spp. and their activity (Pelegrini et al. 2008; Sharma et al. 2011).





Sapindus saponaria (Ribeiro et al, 1995; Lemos et al, 1992)



	R1	R2	R3	R4
1	H	H	CH_2OH	-Xyl (2)Glc, (3)Ara
2	H	H	CH_2OH	-Glc (2)Glc, (3)Ara
3	H	H	CH_2OH	-Xyl (3)-Glc (6)-Ac
4	α-OCH_3	H	CH_2OH	-Glc (2)Glc, (3)Ara
5	H	β-OH	CH_3	-Xyl (2)Glc, (3)Ara
6	H	β-OH	CH_3	-Glc (2)Glc, (3)Ara

Nepheliosides **1-6** *Nephelium lappaceum* (Ito et al., 2003)

Fig. 1. Saponins isolated from *Sapindus* and *Nephelium* spp.

2.2 *Dodonaea*

From this genus, there are two species to which almost all research has been devoted: *Dodonaea angustifolia* and *Dodonaea viscosa*. These two species are considered by some taxonomists to be synonymous, while others recognize *D. angustifolia* as a sub-species of *D. viscosa* (cited in Omosa et al. 2010). *D. angustifolia* is widely distributed in Australia, Africa, Asia and South America; and it has been employed until present days in traditional medicine all over the world. It is traditionally used as analgesic, laxative, antipyretic, and to treat rheumatism, eczema, and skin ailments (Malarvannan et al. 2009; Omosa et al. 2010). *Dodonaea viscosa* is a shrub, rarely a small tree, widely distributed in tropical and subtropical areas of both hemispheres. It is used in folk medicine as a febrifuge, a diaphoretic drug, and also for the treatment of rheumatism, gout, inflammations, swelling and pain (Niu et al. 2010).

Anti-insect activity has been described for extracts from both plant species mostly against lepidopterans (Malarvannan & Subashini 2007; Malarvannan et al. 2008; 2009; Sharaby et al. 2009). For instance, extracts of leaves of *D. angustifolia* (obtained with hexane, petroleum ether, chloroform, acetone and water) were tested in field bioassays, showing to be effective biocontrol agents for the larvae of *Earias vitella* (Lepidoptera: Noctuidae) (Malarvannan et al. 2007). Besides, those extracts also showed ovicidal activity against *Helicoverpa armigera* (Lepidoptera: Noctuidae) (Malarvanan 2003). However, while in the case of extracts from different organs (fruits, leaves and twigs) of *D. viscosa* coming from Uruguay, none of these products proved to be active against the polyphagous *Spodoptera littoralis* (Lepidoptera: Noctuidae) (Castillo et al. 2009), insects from other orders were deterred by *D. viscosa* extracts. Interestingly, while extracts from leaves and twigs exhibited good activity against aphids (*Rhopalosiphum padi* and *Myzus persicae*) and a coleopteran (*Epilachna paenulata*), they were innocuous to beneficial insects (*Apis mellifera*) (Castillo et al. 2009). This selectivity makes *D. viscosa* a good candidate from which to develop botanical pesticides. Another independent study also showed a strong contact activity of the seed extracts against the coleopteran, *S. oryzae* (Zhao et al. 2006).

D. angustifolia is known to contain essential oils, flavonoids, terpenoids, phenols, coumarins, sterols and unidentified alcohols (Malarvannan et al. 2008). Meanwhile several flavonoids, diterpenoid acids and saponins have been isolated from *D. viscosa* (Niu et al. 2010). However, the chemical basis for the pesticide and antifeedant activities remains unclear as tests on individual compounds have not been performed. Nevertheless, a series of clerodane diterpenoids (Figure 2) and prenylated flavonoids (Figure 3) were isolated from the aerial parts of *D. viscosa* from China, having them not shown larvicidal activity against two mosquito species tested (Niu et al. 2010), however the authors stated that previous studies showed activity of these clerodanes against two lepidopterans (*Plutella xylostella* and *Pieris rapae*) and against the coleopteran *Sitophilus oryzae*.

At the same time, an investigation on this family of compounds from *D. angustifolia* from Kenya showed that the extracts from the leaf surface of this plant is composed mainly by clerodanes (Figure 2) and also by methylated flavones and flavonols (Figure 3) (Omosa et al.). Clerodanes isolated from *D. viscosa* and *D. angustifolia* belong to the *neo*-clerodane group. As it is well known, these secondary metabolites have a structure based on the carbon skeleton and absolute stereochemistry of clerodin (Klein Gebbinck et al. 2002) isolated first from *Clerodendron infortunatum* (Lamiaceae) (Banerjee 1936). This large group of plant secondary metabolites have been described mainly from Lamiaceae and Asteraceae, and they have exhibited a wide range of anti-insect properties as it has been reviewed

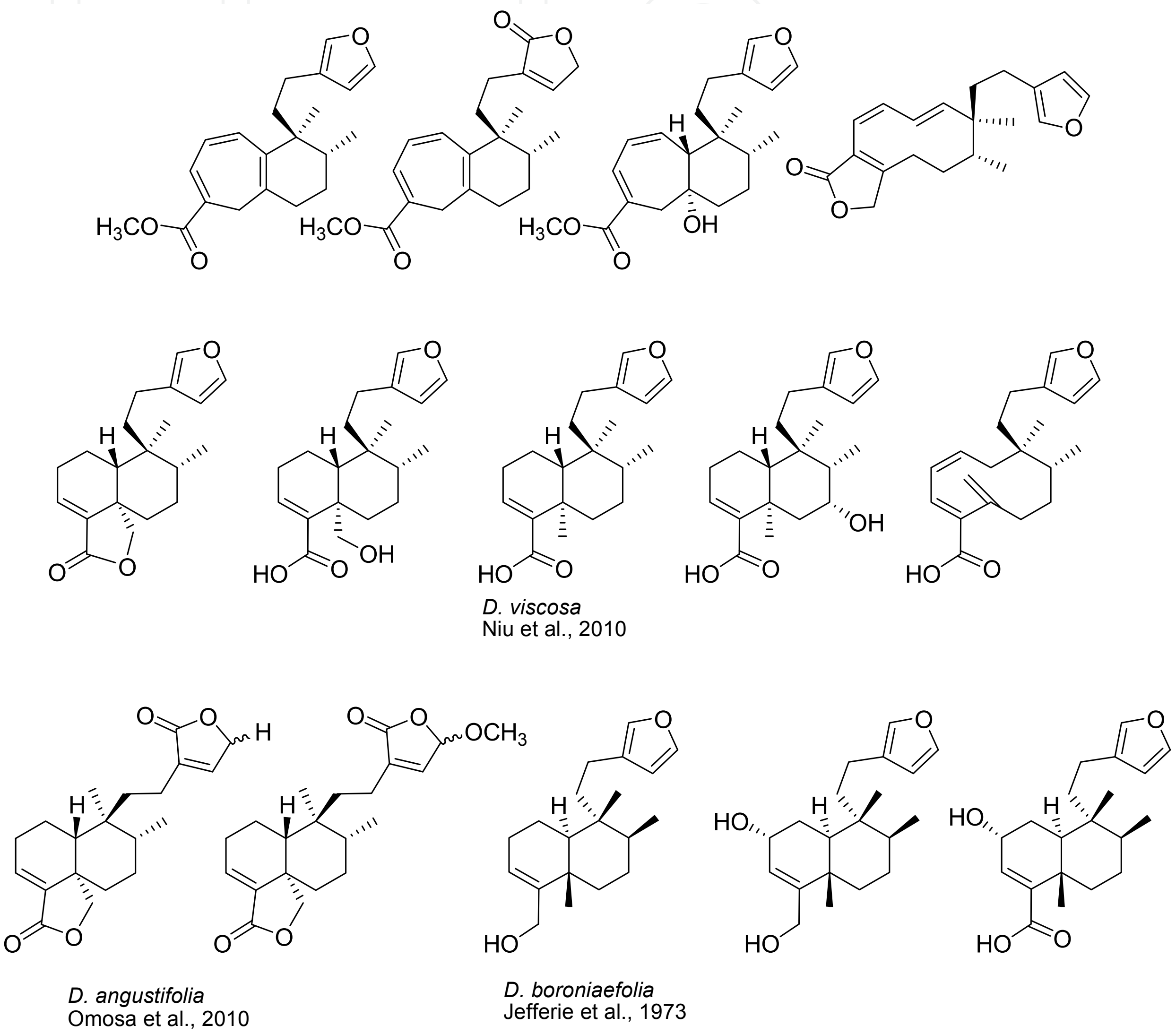
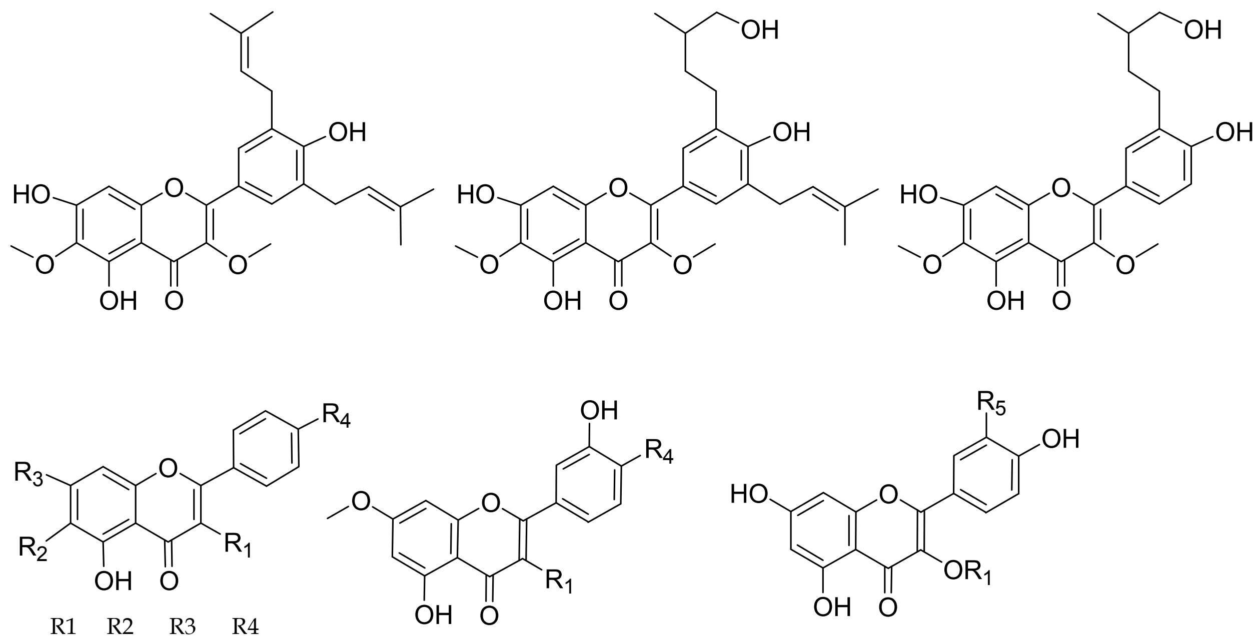


Fig. 2. Clerodanes from *Dodonaea* spp. Structures shown were isolated from *D. viscosa* (Niu et al. 2010) with the exception of the indicated ones.

previously (Klein Gebbinck et al. 2002; Sosa & Tonn 2008). Worth to be noticed, an earlier work by Jefferies et al. (1973) reported the occurrence of various diterpenes in another species, *Dodonaea boroniaefolia*, of the opposite configuration in the main skeleton (Figure 3), that is *ent*-clerodanes.



	R1	R2	R3	R4
1	OH	H	OH	OMe
2	OMe	OMe	OH	OH
3	OMe	OMe	OH	OMe
4	OMe	H	OMe	OMe
5	OH	H	OH	OH
6	OMe	H	OMe	OMe
7	OH	OMe	OMe	OMe
8	OH	H	OMe	OMe
9	OMe	H	OMe	OH
10	OMe	OMe	OMe	OH

	R1	R4
11	OH	OH
12	OMe	OMe

	R1	R5	
13	H	H	kaempferol
14	glucosyl	H	kaempferol 3-*O*-β-D-glucoside
15	galactosyl	H	kaempferol 3-*O*-β-D-galactoside
16	rhamnosyl	H	kaempferol 3-*O*-β-L-rhamnoside
17	rhamnoglucosyl	H	kaempferol 3-*O*-rhamnoglucoside
18	glucosyl	OH	quercetin 3-*O*-β-D-glucoside
19	rhamnosyl	OH	quercetin 3-*O*-β-L-rhamnoside
20	rhamnoglucosyl	OH	quercetin 3-*O*-rhamnoglucoside

Fig. 3. Flavonoids from *Dodonaea* spp. (Niu et al. 2010; Omosa et al. 2010; Teffo et al. 2010).

2.3 *Magonia and Paullinia species*

Paullinia spp. is one of the few purine alkaloid-containing genera used to prepare stimulant drinks worldwide (Weckerle et al. 2003). *Paullinia clavigera* grows in primary forests and shores of the South American Amazonic aquatic ecosystems, and it has been studied mostly in Perú for the control of different insect pests (cited in Pérez et al. 2010). The toxicity of aqueous extracts of lianas from this species against larvae of *Anopheles benarrochi (*Diptera: Culicidae) (Pérez & Iannacone 2004) and afterwards the mortality and repellence of such extracts against larvae of *Rhynchophorus palmarum* (Coleoptera: Curculionidae) (Pérez & Iannacone 2006) were tested. Besides, the activity of aqueous extracts against *Eupalamides cyparissias* (Lepidoptera: Castniidae), and the activity of hydroalcoholic extracts against *Tuthillia cognata* (Hemiptera: Psyllidae) (Pérez et al. 2008) were also reported, showing the potential of this vegetal species as a biocontrol agent against different insect orders. However, it is still unclear which compounds are responsible for the anti-insect effects of *P. clavigera*. Flavonoids, phenols, triterpenes and saponins were detected in a phytochemical study in extracts from the stem cortex of *P. clavigera.* (Pérez et al. 2010); and other species from the same genus (*P. cururu*) contain saponins, tannins and polyphenols (Wilbert & Haiek 1991).

Magonia pubescens, widely distributed in the Brazilian Cerrado, is commonly used in the construction industry. It has been mostly studied for its larvicidal activity against *A. aegypti* (Arruda et al. 2003; da Silva et al. 2003; Rodrigues et al. 2006). In this case, one of the most active fractions from the ethanolic extract of stem barks was shown to be rich in tannins, and specially in a proanthocyanidin (catequic tannin which structure is shown in Figure 4) (Silva et al. 2004). Tannins are largely distributed in nature, usually being the active principles of plants used in traditional medicine. Condensed tannins have a great ability to interact with metallic ions and macromolecules and to form soluble complexes with electron-donor groups such as the ones found in alkaloids and proteins. That may be one of the reasons explaining their toxicity against different organisms, including insects, fungi and bacteria. Morphological alterations caused by this active fraction on the epithelium of the midgut of larvae of *A. aegypti* resembled the ones recorded for tannic acid (Rey et al. 1999). In a side note, it is worth to notice that this vegetal species has also demonstrated potential on its ethanolic extract of stem barks, as acaricide against the larvae of the common cattle tick, *Rhipicephalus (Boophilus) sanguineus* (Acari: Ixodidae) (Fernandes et al. 2008).

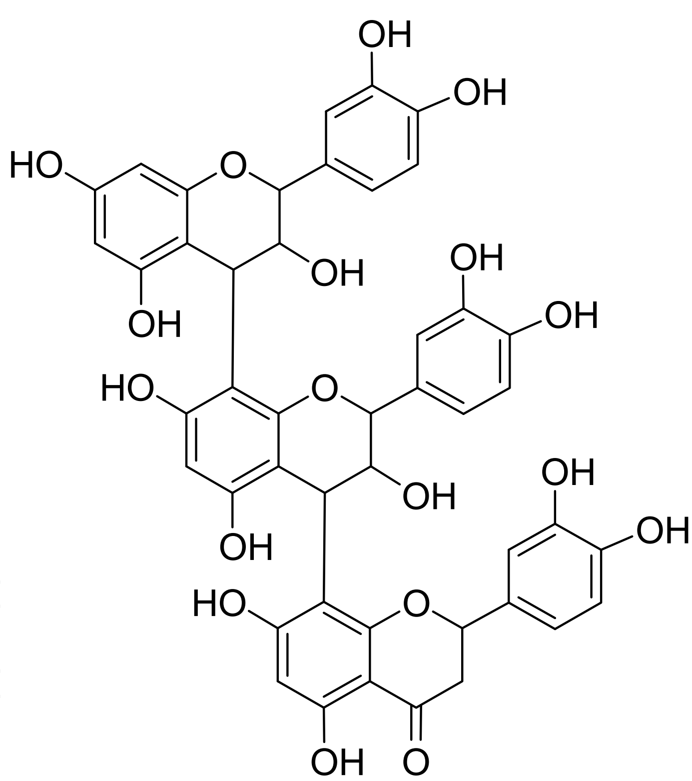


Fig. 4. Catequic tannin with larvicidal activity against *A. aegypti* isolated from *Magonia pubescens* (Silva et al. 2004).

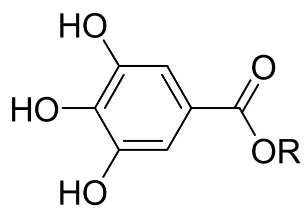
2.4 Miscellaneous

Talisia esculenta, locally known as pitomba occurs in northern and northeastern Brazil. Its fruits are edible to humans and birds which disperse the seeds. However, popular information also mentions that chickens die after ingesting the fruit (cited in Macedo et al.

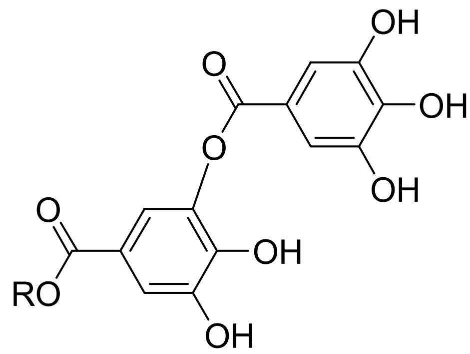
2002). *Koelreuteria paniculata* is popularly grown as an ornamental tree in temperate regions all across the world (Kamala-Kannan et al. 2009). From these two species of Sapindaceae, lectins have been isolated from their seeds (Macedo et al. 2002; Macedo et al. 2003). Lectins from *T. esculenta* inhibited larval growth of two bruchids *(Callobroschus maculatus* and *Zabrotes subfasciatus*) (Macedo et al. 2002). And in the case of *K. paniculata*, lectins not only showed insecticide activity against *C. maculatus* but also against *Anagasta kuehniella* (Lepidoptera: Pyralidae) (Macedo et al. 2003). Plant lectins are a large group of proteins defined as ''plant proteins that possess at least one non-catalytic domain that binds reversibly to a specific mono- or oligosaccharide'' (Peumans & Van Damme 1995). Plant lectines have been implied in many ecological roles, being their action as defences against insects one of the latest described (Murdock & Shade 2002; Van Damme et al. 2008). Their mechanisms of action as anti-insect agents are yet poorly understood, with many emerging hypotheses proposed (Van Damme et al. 2008). According to Macedo et al. (2003), the action of *K. paniculata* lectins on *C. maculatus* and *A. kuehniella* larvae may involve *(1) binding to glycoconjugates on the surface of epithelial cells along the digestive tract, (2) binding to glycosylated digestive enzymes, thereby inhibiting their activity, and (3) binding to the chitin component of the peritrophic membrane (or equivalent structures) in the insect midgut*. Finally, regarding *T. esculenta*, its aqueous seeds extracts were studied on its effect on *S. frugiperda* larvae which development was negatively affected, but the activity of the midgut trypsin was not inhibited (dos Santos et al. 2008).

The red maple, *Acer rubrum*, is another Sapindaceae from which bioactive compounds have been isolated. This prominent maple occurs in hardwood forests, being avoided by several potential sympatric consumers [for instance, larvae of *Malacossoma disstria* (Lepidoptera: Lasiocampidae), and the North American beavers, *Castor canadensis*] (Abou-Zaid et al. 2001). The main constituents of an aqueous leaf extract have been phytochemically characterized as ellagic acid, gallate derivatives (structures **1-7** in Figure 5) and glycosides of flavonoids (quercetin and structures **13-20** in Figure 3). When these compounds were tested by themselves against *M. disstria* larvae, it was found that all gallate derivatives exhibited deterrent activity, but not the flavonoids. Among gallate derivatives, compounds **2** and **4-7** in Figure 5 were the five most active compounds. Perhaps in this case, the feeding deterrence effect of the extracts may be traced to the galloyl moiety in its secondary metabolites.

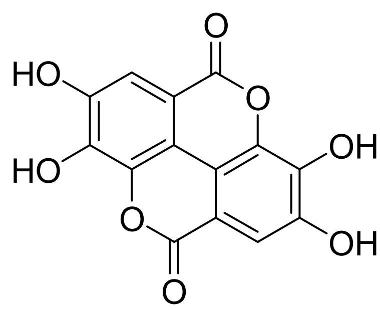
Blighia sapida, commonly known as Ackee, is an evergreen tree, native from West African wild forests. In the late 18th century, the plant was introduced in Jamaica, where nowadays its fruit has been adopted as the national fruit (cited in Gaillard et al. 2011). Its bark is used as fish poison and also in folk medicine in the treatment of malaria, ulcers, back aches and headaches (Kayode 2006). The plant contains triterpenic and steroidal saponins, alkaloids, polyphenols and aminoacidic secondary metabolites (Mazzola et al. 2011). By ingestion, the unripe fruits can cause vomiting and circulatory collapse in humans due to the presence of hypoglycin-A (seeds and flesh) and hypoglycin-B (seeds) (Figure 6) (Hassall et al. 1954; Hassall & Reyle 1955; Gaillard et al. 2011). Acetone and ethanolic extracts of the fruits showed repellent properties against stored-product pests, namely, *C. maculatus*, *Cryptolestes ferrugineus* (Coleoptera: Cucujidae), and *Sitophilus zeamais* (Coleoptera: Curculionidae) (Khan & Gumbs 2003). Furthermore, ethanol, acetone, hexane, methanol, chloroform, and water extracts from the seeds were evaluated on their repellence against *T. castaneum,* demonstrating the aqueous extract to be the most active (Khan et al. 2002).



1 R = H Gallic acid
2 R = Me Methyl gallate
3 R = Et Ethyl gallate
4 R = β-D-Glc 1-*O*-Galloyl-b-D-glucosa
5 R = α-L-Rha 1-*O*-Galloyl-a-L-rhamnose

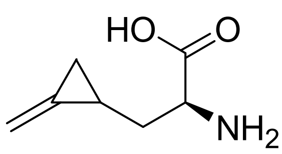


6 R = OH *m*-Digallate
7 R = OC_2O_5 Ethyl *m*-digallate

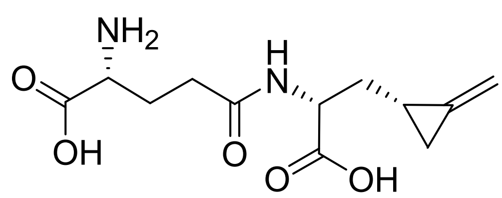


8 ellagic acid

Fig. 5. Ellagic acid and gallate derivatives isolated from *A. rubrum.* (Abou-Zaid et al. 2001).



Hypoglycin-A



Hypoglycin-B

Fig. 6. Hypoglycins isolated from the fruits of *B. sapida.*

Serjania lethalis is another species that has been studied in its anti-insect activity. The ethanolic stem bark extract showed larvicidal activity against *A. aegypti* (Rodrigues et al. 2006). In this study the active compounds were not identified. However, the presence in this species of tannins, flavonoids and of saponins (serjanosides) has been reported (Teixeira et al. 1984; de Sousa Araújo et al. 2008). *S. meridionalis,* a species phytochemically not described, exhibited deterrent activity against *E. paenulata* and *M. persicae* (Hemiptera: Aphididae) when its ethanolic leaf extracts were assayed. Disappointingly, this extract was also toxic against beneficial insects (honey bees) (Castillo et al. 2009).

From the genus *Nephelium*, the species *N. lappaceum* is commonly known for its edible fruit "rambutan". It is native from Southeast Asia where the fruits are an important commercial crop (Palanisamy et al. 2008). These fruits have shown potential on its ethanol seed extract, against *S. oryzae*, revealing to reduce esterase and glutathione-S-transferase activities from such insect (Bullangpoti et al. 2004). *N. maingayi,* native from Malasya and Indonesia, has also edible fruits and it has not been studied in its anti-insect activity. However, six saponins, namely, nepheliosides **1-6** (Figure 1) were isolated from a chloroform extract of its bark exhibiting cytotoxic activity when evaluated against a panel of human cancer cell lines (Ito et al. 2004).

3. Cyanocompounds

As stated, Sapindaceae are rich –in their seeds- in toxic cyanolipids (Figure 8), *e.g.* fatty acid esters of α- and γ- hydroxynitriles (Mikolajczak 1977; Seigler 1991). Although, some works report the occurrence of cyanolipids also in members of the Hippocastanaceae (Mikolajczak 1977; Bjarnholt & Møller 2008) and the Boraginaceae (Mikolajczak et al. 1969; Seigler et al. 1970), it appears that later investigations have confirmed that these metabolites are characteristic only of the Sapindaceae (Seigler 1976; Avato et al. 2005). The cyanolipids are usually extracted in the seed oils where the amounts vary broadly within the species (Dinesh & Hasan; Selmar et al. 1990; Hasan et al. 1994; Ucciani et al. 1994; Hasan & Roomi 1996; Sarita et al. 2002; Avato et al. 2005; Avato et al. 2006), ranging from only 3% in *Paullinia cupana var. sorbilis* (Guarana) (Avato et al. 2003), to 58% in *Schleichera trijuga* (Mikolajczak & Smith 1971).

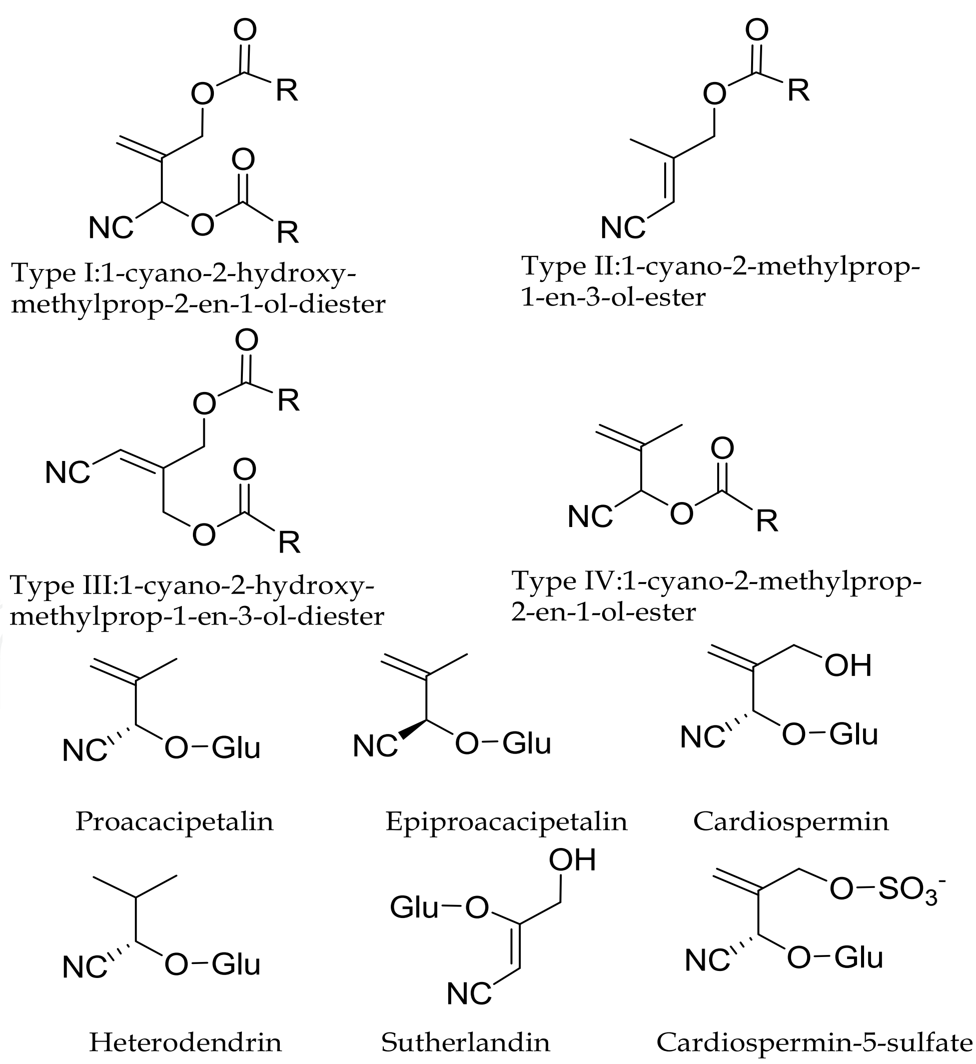


Fig. 8. Cyanolipids and glucosinolates from Sapindaceae.

Cyanolipids present in Sapindaceae belong to four types (Figure 8) which do not occur in all species. Although there is some controversy in the literature, it seems that each species has only one or two types of cyanolipids, but not all of them. The fatty acid moieties in cyanolipids vary within the species. In most of the studies, cyanolipids are esterified mostly by only one or two fatty acids. Eicosanoic acid (20:0) and eicosenoic acid (20:1 *n-9*) are present in high proportion in many species (Aichholz et al. 1997). In the genus *Paullinia*, the rare fatty acids paullinic acid (*Z*-13-eicosenoic acid) and cis-vaccenic acid (*Z*-11-octadecenoic acid) are ubiquitous constituents (Seigler 1974; Spitzer 1995; Spitzer 1996; Lago et al. 2000; Avato et al. 2003). Other fatty acids found go from dodecanoic (12:0) to docosanoic acids (22:0) (Mikolajczak et al. 1970a; 1970b; 1971; Aichholz et al. 1997; Avato et al. 2003).
Besides lipid derivatives, other cyanocompounds (the corresponding glycosides and salts) have also been isolated from aerial parts (Seigler et al. 1974; Bjarnholt et al. 2008) or roots of different species (Kumar et al. 2011). For example, cardiospermin (Figure 8) has been isolated from some species -and has been shown to be the responsible of the anxiolytic effects of ethanolic root extract from *Cardiospermum halicacabum* (Kumar et al. 2011); and in the particular case of *Cardiospermum grandiflorum* the corresponding sulphate-containing cyanogenic glucoside of cardiospermin was described (Hubel & Nahrstedt 1979).
Only cyanolipids of the type I and IV are cyanogenetic (Avato et al. 2005). Therefore cyanolipids do not work for all species as defensive compounds producing HCN. When HCN can be formed, its production works similarly to the one from glycosinolates, with a previous step of hydrolysis of the ester moieties catalyzed by estearases (Figure 9) (Wink et al. 1997). Cyanolipids can effectively work as plant defences, as it has been shown that their enzymatic breakdown produces the α-hydroxynitriles, from which HCN is released in a similar way than the one from glycosinolates (Wink et al. 1997). Moreover, it has been shown that *in vivo* HCN is produced upon wounding by herbivores (Selmar et al. 1990). Besides, as any plant defence, these defensive metabolites have been overcome in their original function by herbivores. In that sense it is well known that some Heteroptera (*Leptocorus* and *Jadera* spp.) not only are specialists on Sapindaceae, but are also able to sequester cyanolipids as such from their food plants, and biotransform them to the glycosylated derivatives (Braekman et al. 1982; Aldrich et al. 1990). Moreover, such acquisition of cyanocompounds from their host renders these gregarious, aposematic insects unpalatable to a variety of predators (Aldrich et al. 1990).

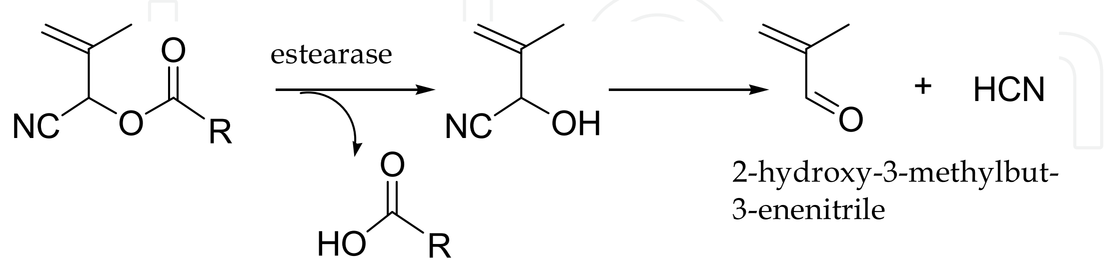


Fig. 9. Hydrolysis of cyanolipids to produce HCN (Wink et al. 1997).

Cyanolipids have been investigated in their potential as control agents for insects. In that sense, insect repellent and insecticidal properties of some of these products have been described. For instance, when adults of the red flour beetles, *Tribolium castaneum,* were exposed to seed oils from two species of *Cardiospermum* (*C. canescens* and *C. belicacabum*), the beetles preferred the arena zones where no oil was applied (Khan et al. 1983). However this repellency effect seems not to be a general pattern as in a pitfall trap bioassay, oils reach in cyanolipids stimulated aggregation in the cases of the saw toothed grain beetle, *Oryzaephilus surinamensis*, and of the rice weevil, *Sitophilus oryzae* (Mikolajczak et al. 1984). In this later work, when tested separately the four classes of cyanolipids (Figure 8) lost their repellent activity, suggesting synergism among them for this action. When the effect of cyanolipids was tested in a contact bioassay, only the ones belonging to classes I and IV showed a paralyzing effect against the saw toothed grain beetle, *Oryzaephilus surinamensis*. Eventhough one may be tempted to correlate this effect with the capacity of producing HCN by the pure compound tested, the conclusion is not again a general one since these cyanolipids did not have any effect on three other beetles (Mikolajczak et al. 1984). Finally, the European corn borer, *Ostrinia nubilalis*, was affected in its metamorphosis when cyanolipids of the classes II and IV were incorporated in its diet (Mikolajczak et al. 1984). On the whole, even though non- glycoside cyanogens were described in Sapindaceae as early as in the 1920` (cited by Mikolajczak et al. 1969), not many studies have been carried out in regard of either their ecological role as plant defences, or their potential as biopesticides. Although in the last case one can envisioned that cyanolipids of the classes I and IV will not be selective –because HCN is generated-, there is a chance that cyanolipids of the classes II and III may have some interest in this regard.

4. Conclusion

The family Sapindaceae includes many edible species, *e.g.* ackee, rambutan, longan and lychee (fruits from *Blighia sapida, Litchi chinensis*, *Nephelium lappaceum*, *Dimocarpus longan* respectively), which are widely consumed mainly in Asia and Australia (Diczbalis 2008; Vichitrananda & Somsri 2008; Diczbalis et al. 2010). Nevertheless, some species in this family produce in different phenological stages (including fruits in some cases) bioactive compounds with medicinal or toxicological properties. With reference to insect toxicity, up to now most of the studies carried out have found activity against species in the orders Lepidoptera and Diptera (mosquitoes). However, these results may be an artefact of the biodetection itself, as much of the research focuses on chewing armyworms and borers of economically significance, and on mosquitoes as important vectors of human diseases. In addition, products from Sapindaceae have revealed differential activity on insect targets from different orders, and even from the same order (Mikolajczak et al. 1984; Khan et al. 2002; Castillo et al. 2009); and have demonstrated selectivity when their activity was checked against beneficial insects while some other products have not (Castillo et al. 2009). These findings emphasise the need for widening the spectrum of biodetectors used in the tests.

The Sapindaceae are well characterized for the presence in their seeds of toxic cyanolipids, and the occurrence of this group of secondary metabolites seems to be restricted to this family. However, it is difficult to foresee that the Sapindaceae will find their way into the development of botanicals based on their unique cyanogens due to the intrinsic general toxicity of these compounds.

This family takes its name from the soapberry tree *Sapindus saponaria* (Emanuel & Benkeblia 2011), mostly known for being rich in saponins. Those chemical constituents provide its extracts with tensoactive properties, having been widely used not only as a source of soap but also for the application of its biological effects in medicine as well as in pest control. Indeed, the tensoactivity has been a property that has found application in pest control as shown by the fact that soaps are probably among the oldest insecticides in use (Silva et al. 2007).

Many other bioactive compounds belonging to different chemical groups have also been isolated from members of this family. For instance, from species studied for their anti insect activity, it has been reported the occurrence of clerodane diterpenoids and prenylated flavonoids (*Dodonaea* spp.); flavonols, phenols and triterpenes (*Paullinia* spp.); tannins (*M. pubescens*); lectins (*Talisia esculenta)*; gallic acid, gallates and derivatives (*Acer rubrum*). Being confirmed in some cases that those compounds are the responsible for the activities found. Among these secondary metabolites, probably the ones with the strongest potential as anti-insect agents are the clerodanes. Eventhough the main sources of these diterpenes are species from Asteraceae and Lamiaceae, the Sapindaceae are showing to be also a good resource of them. So far, different studies have shown the antifeedant capability of clerodanes against many insects, including species from Lepidoptera, Coleoptera, and Orthoptera (Klein Gebbinck et al. 2002; Sosa et al. 2008).

All in all, the family Sapindaceae, which members are widely distributed in every continent and have been used since early days for different purposes –taking advantage of their medicinal and toxicological properties-, seems to be a promissory source of bioactive compounds to be used as biological control agents. However more extensive studies, not only on more species not yet prospected, but also concerning more diverse targets are still needed.

5. Acknowledgments

We acknowledge financial support from the following agencies: OPCW (research grant L/ICA/ICB/111817/06); TWAS (research grant Nº 05-318); and LATU (Laboratorio Tecnológico de Uruguay), Facultad de Química (Universidad de la República) and Agencia Nacional de Investigación e Innovación (ANII, Uruguay) for doctoral fellowships to MD. Finally, we would like to thank the editors of this book for their kind invitation to participate in this endeavour.

6. References

Abdel, A., Shadia & Omer, E. A. (1995). Bio-evaluation of *Dodonaea viscosa* L. Jacq. extracts on the cotton leafworm, *Spodoptera littoralis* (Boisd.) as indicated by life table parameters. *Annals of Agricultural Science (Cairo)* Vol. 40, 2, pp. 891-900

Abou-Zaid, M. M., Helson, B. V., Nozzolillo, C. & Arnason, J. T. (2001). Ethyl m-digallate from red maple, *Acer rubrum* L., as the major resistance factor to forest tent caterpillar, *Malacosoma disstria* Hbn. *Journal of Chemical Ecology* Vol. 27, 12, pp. 2517-2527

Aichholz, R., Spitzer, V. & Lorbeer, E. (1997). Analysis of cyanolipids and triacylglycerols from sapindaceae seed oils with high-temperature gas chromatography and high-temperature gas chromatography chemical ionization mass spectrometry. *Journal of Chromatography A* Vol. 787, 1-2, pp. 181-194

Aldrich, J. R., Carroll, S. P., Lusby, W. R., Thompson, M. J., Kochansky, J. P. & Waters, R. M. (1990). Sapindaceae, cyanolipids, and bugs. *Journal of Chemical Ecology* Vol. 16, 1, pp. 199-210

Anonymous (2011). Germplasm Resources Information Network - (GRIN) National Germplasm Resources Laboratory, Beltsville, Maryland. In: *USDA, ARS, National*

Genetic Resources Program, 11 July 2011, Available from: http://www.ars-grin.gov/cgi-bin/npgs/html/gnlist.pl?999

Arruda, W., Cavasin Oliveira, G. M. & Garcia da Silva, I. (2003a). Morphological alterations of *Aedes aegypti* larvae exposed to *Magonia pubescens* extract. *Entomologia y Vectores* Vol. 10, 1, pp. 47-60

Arruda, W., Oliveira, G. M. C. & da Silva, I. G. (2003b). Toxicity of the ethanol extract of *Magonia pubescens* on larvae *Aedes aegypti*. *Revista da Sociedade Brasileira de Medicina Tropical* Vol. 36, 1, pp. 17-25

Arulmozhi, D. K., Veeranjaneyulu, A., Bodhankar, S. L. & Arora, S. K. (2005). Pharmacological studies of the aqueous extract of *Sapindus trifoliatus* on central nervous system: possible antimigraine mechanisms. *Journal of Ethnopharmacology* Vol. 97, 3, pp. 491-496

Avato, P., Pesante, M. A., Fanizzi, F. P. & Santos, C. A. D. (2003). Seed oil composition of *Paullinia cupana* var. *sorbilis* (Mart.) Ducke. *Lipids* Vol. 38, 7, pp. 773-780

Avato, P., Rosito, I., Papadia, P. & Fanizzi, F. P. (2005). Cyanolipid-rich seed oils from *Allophylus natalensis* and *A. dregeanus*. *Lipids* Vol. 40, 10, pp. 1051-1056

Avato, P., Rosito, I., Papadia, P. & Fanizzi, F. P. (2006). Characterization of seed oil components from *Nephelium lappaceum* L. *Natural Product Communications* Vol. 1, 9, pp. 751-755

Banerjee, H. N. (1936). Clerodin from *Clerodendron infortunatum*. *Science and Culture* Vol. 2, pp. 163

Benlekehal, H., Clotteau, M., Dornier, M. & Reynes, M. (2001). An Amazonian product particularly rich in caffeine: the seed of guarana [*Paullinia cupana* H.B.K. var. *sorbilis* (Mart.) Ducke]. *Fruits (Paris)* Vol. 56, 6, pp. 423-435

Bjarnholt, N. & Møller, B. L. (2008). Hydroxynitrile glucosides. *Phytochemistry* Vol. 69, 10, pp. 1947-1961

Boiça Junior, A. L., Medeiros, C. A. M., Torres, A. L. & Chagas Filho, N. R. (2005). Effect of plant aqueous extracts on the development of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), on collard greens. *Arquivos do Instituto Biologico Sao Paulo* Vol. 72, 1, pp. 45-50

Bousserouel, H., Litaudon, M., Morleo, B., Martin, M. T., Thoison, O., Nosjean, O., Boutin, J. A., Renard, P. & Sevenet, T. (2005). New biologically active linear triterpenes from the bark of three Newcaledonian *Cupaniopsis* species. *Tetrahedron* Vol. 61, 4, pp. 845-851

Braekman, J. C., Daloze, D. & Pasteels, J. M. (1982). Cyanogenic and other glucosides in a neo-guinean bug *Leptocoris isolata*: Possible precursors in its host-plant. *Biochemical Systematics and Ecology* Vol. 10, 4, pp. 355-364

Bruneton, J. (1995). Pharmacognosy, phytochemistry, medicinal plants. Paris, Lavoisier Publishing: 538-544

Bullangpoti, V., Visetson, S., Milne, J. & Pornbanlualap, S. (2004). Effects of Mangosteen's peels and rambutan's seeds on toxicity, esterase and glutathione-S-transferase in rice weevil (*Sitophilus oryzae* L.). *Kasetsart Journal, Natural Sciences* Vol. 38, 5, Supplement, pp. 84-89

Castillo, L., Gonzalez-Coloma, A., Gonzalez, A., Diaz, M., Alonso-Paz, E., Bassagoda, M. J. & Rossini, C. (2009). Screening of Uruguayan plants for deterrent activity against insects. *Industrial Crops and Products* Vol. 29, 1, pp. 235-240 da Silva, I. G., Guimaraes, V. P., Lima, C. G., da Silva, H. H. G., Elias, C. N., Mady, C. M., da Mota e Silva, V. V., de Paiva Nery, A., da Rocha, K. R., Rocha, C. & Isac, E. (2003). Larvicide and toxic effect of the ethanol crude extract of the stem coat of *Magonia pubescens* towards *Aedes aegypt* in laboratory. *Revista de Patologia Tropical* Vol. 32, 1, pp. 73-86

de Sousa Araújo, T. A., Alencar, N. L., de Amorim, E. L. C. & de Albuquerque, U. P. (2008). A new approach to study medicinal plants with tannins and flavonoids contents from the local knowledge. *Journal of Ethnopharmacology* Vol. 120, 1, pp. 72-80

Deepa, B. & Remadevi, O. K. (2007). Contact toxicity of the leaf extracts of *Dodonaea viscosa* (Sapindaceae) to *Spodoptera litura* (Fab.). *Hexapoda* Vol. 14, 1, pp. 66-67

Dharmani, P., Mishra, P. K., Maurya, R., Chauhan, V. S. & Palit, G. (2005). *Allophylus serratus*: A plant with potential anti-ulcerogenic activity. *Journal of Ethnopharmacology* Vol. 99, 3, pp. 361-366

Diczbalis, Y., Nicholls, B., Groves, I. & Lake, K. (2010). Sapindaceae production and research in Australia. *Acta Horticulturae* Vol. 863, pp. 49-58

Diczbalis, Y. A. (2008). Nutrition management of tropical fruits grown in north Queensland, Australia. *Acta Horticulturae* Vol. 772, pp. 375-379

Dinesh, K. & Hasan, S. Q. Cyanolipids in sapindaceous seed oils. *Asian Journal of Chemistry* Vol. 23, 6, pp. 2589-2591

dos Santos, W. L., Freire, M. D. M., Bogorni, P. C., Vendramim, J. D. & Macedo, M. L. R. (2008). Effect of the aqueous extracts of the seeds of *Talisia esculenta* and *Sapindus saponaria* on fall armyworm. *Brazilian Archives of Biology and Technology* Vol. 51, 2, pp. 373-383

El-Din, M. M. & El-Gengaihi, S. E. (2000). Joint action of some botanical extracts against the Egyptian cotton leafworm *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae). *Egyptian Journal of Biological Pest Control* Vol. 10, 1/2, pp. 51-56

Emanuel, M. A. & Benkeblia, N. (2011). Processing of ackee fruit (*Blighia sapida* L.): present and future perspectives. *Acta Horticulturae* Vol. 894, pp. 211-213

Fernandes, F. F., D'Alessandro, W. B. & Freitas, E. P. S. (2008). Toxicity of extract of *Magonia pubescens* (Sapindales : Sapindaceae) St. Hil. to control the Brown Dog tick, *Rhipicephalus sanguineus* (Latreille) (Acari : Ixodidae). *Neotropical Entomology* Vol. 37, 2, pp. 205-208

Ferreira Barreto, C., Cavasin, G. M., Garcia da Silva, H. H. & Garcia da Silva, I. (2006). Study of the morphohistological modifications in larvae of *Aedes aegypti* (Diptera, Culicidae) submitted to the pure ethanolic extract of *Sapindus saponaria* Lin. (Sapindaceae). *Revista de Patologia Tropical* Vol. 35, 1, pp. 37-57

Gaillard, Y., Carlier, J., Berscht, M., Mazoyer, C., Bevalot, F., Guitton, J. & Fanton, L. (2011). Fatal intoxication due to ackee (*Blighia sapida*) in Suriname and French Guyana. GC-MS detection and quantification of hypoglycin-A. *Forensic Science International* Vol. 206, 1-3, pp. e103-e107

Getie, M., Gebre-Mariam, T., Rietz, R., Hohne, C., Huschka, C., Schmidtke, M., Abate, A. & Neubert, R. H. H. (2003). Evaluation of the anti-microbial and anti-inflammatory activities of the medicinal plants *Dodonaea viscosa*, *Rumex nervosus* and *Rumex abyssinicus*. *Fitoterapia* Vol. 74, 1-2, pp. 139-143

Getie, M., Gebre-Mariam, T., Rietz, R. & Neubert, R. H. H. (2002). Evaluation of the release profiles of flavonoids from topical formulations of the crude extract of the leaves of *Dodonaea viscosa* (Sapindaceae). *Pharmazie* Vol. 57, 5, pp. 320-322

Hasan, S. Q. & Roomi, Y. A. (1996). Cyanolipids in *Sapindus trifoliatus* seed oil. *Journal of the Oil Technologists' Association of India* Vol. 28, 1, pp. 23, 25

Hasan, S. Q., Roomi, Y. A. & Chitra, N. (1994). Reinvestigation of seed oil of *Sapindus saponaria* for its cyanolipid content. *Journal of the Oil Technologists' Association of India* Vol. 26, 3, pp. 77-79

Hassall, C. H. & Reyle, K. (1955). Hypoglycin-A and Hypoglycin-B, two biologically active polypeptides from *Blighia sapida*. *Biochemical Journal* Vol. 60, 1-4, pp. 334-339

Hassall, C. H., Reyle, K. & Feng, P. (1954). Hypoglycin A,B: Biologically active polypeptides from *Blighia sapida*. *Nature* Vol. 173, 4399, pp. 356-357

Hubel, W. & Nahrstedt, A. (1979). Cardiosperminsulfate - sulfur-containing cyanogenic glucoside from *Cardiospermum grandiflorum*. *Tetrahedron Letters* Vol. 20, 45, pp. 4395-4396

Isman, M., Matsuura, H., MacKinnon, S., Durst, T., Towers, G. & Arnason, J. (1996). Phytochemistry of the Meliaceae. *Recent Advances on Phytochemistry* Vol. 30, pp. 155-178

Ito, A., Chai, H. B., Kardono, L. B. S., Setowati, F. M., Afriastini, J. J., Riswan, S., Farnsworth, N. R., Cordell, G. A., Pezzuto, J. M., Swanson, S. M. & Kinghorn, A. D. (2004). Saponins from the bark of *Nephelium maingayi*. *Journal of Natural Products* Vol. 67, 2, pp. 201-205

Jain, S. C. (1976). Isolation of flavonoids from soapnut, *Sapindus emarginatus* Vahl. *Indian Journal of Pharmacy* Vol. 38, 6, pp. 141-142

Jefferie, P. R., Knox, J. R. & Scaf, B. (1973). Structure elucidation of some ent-clerodane diterpenes from *Dodonaea boroniaefolia* and *Cyanostegia angustifolia*. *Australian Journal of Chemistry* Vol. 26, 10, pp. 2199-2211

Kamala-Kannan, S., Park, S. M., Oh, B. T., Kim, H. M. & Lee, K. J. (2009). First report of aster yellows phytoplasma in Goldenrain tree (*Koelreuteria paniculata*) in Korea. *Journal of Phytopathology* Vol. 158, 3, pp. 197-199

Kanchanapoom, T., Kasai, R. & Yamasaki, K. (2001). Acetylated triterpene saponins from the Thai medicinal plant, *Sapindus emarginatus*. *Chemical & Pharmaceutical Bulletin* Vol. 49, 9, pp. 1195-1197

Kayode, J. (2006). Conservation of indigenous medicinal botanicals in Ekiti State, Nigeria. *Journal of Zhejiang University SCIENCE B* Vol. 7, 9, pp. 713-718

Khan, A. & Gumbs, F. A. (2003). Repellent effect of ackee (*Blighia sapida* Koenig) component fruit parts against stored-product insect pests. *Tropical Agriculture* Vol. 80, 1, pp. 19-27

Khan, A., Gumbs, F. A. & Persad, A. (2002). Pesticidal bioactivity of ackee (*Blighia sapida* Koenig) against three stored-product insect pests. *Tropical Agriculture* Vol. 79, 4, pp. 217-223

Khan, M. W. Y., Ahmad, F., Ahmad, I. & Osman, S. M. (1983). Nonedible Seed Oils as Insect Repellent. *Journal of the American Oil Chemists Society* Vol. 60, 5, pp. 949-950

Klein Gebbinck, E. A., Jansen, B. J. M. & de Groot, A. (2002). Insect antifeedant activity of clerodane diterpenes and related model compounds. *Phytochemistry* Vol. 61, 7, pp. 737-770

Koodalingam, A., Mullainadhan, P. & Arumugam, M. (2009). Antimosquito activity of aqueous kernel extract of soapnut *Sapindus emarginatus*: impact on various developmental stages of three vector mosquito species and nontarget aquatic insects. *Parasitology Research* Vol. 105, 5, pp. 1425-1434

Koodalingam, A., Mullainadhan, P. & Arumugam, M. (2011). Effects of extract of soapnut Sapindus emarginatus on esterases and phosphatases of the vector mosquito, *Aedes aegypti* (Diptera: Culicidae). *Acta Tropica* Vol. 118, 1, pp. 27-36

Kumar, R., Murugananthan, G., Nandakumar, K. & Talwar, S. (2011). Isolation of anxiolytic principle from ethanolic root extract of *Cardiospermum halicacabum*. *Phytomedicine* Vol. 18, 2-3, pp. 219-223

Lago, R. C. A., Simoni, M. d. L. P. S. C. & Pinto, A. d. C. (2000). On the occurrence of cyanolipids in *Paullinia carpopodea* Cambess and *P. cupana* Kunth seed oils. *Acta Amazonica* Vol. 30, 1, pp. 101-105

Lemos, T. L. G., Mendes, A. L., Sousa, M. P. & Braz-Filho, R. (1992). New saponin from *Sapindus saponaria*. *Fitoterapia* Vol. 63, 6, pp. 515-517

Lorenzi, H. (2004). Arvores brasileiras. Manual de identificaçao e cultivo de plantas arvoreas nativas do Brasil. Piracicaba: Plantarum

Macedo, M. L. R., Damico, D. C. S., Freire, M. D., Toyama, M. H., Marangoni, S. & Novello, J. C. (2003). Purification and characterization of an N-acetylglucosamine-binding lectin from *Koelreuteria paniculata* seeds and its effect on the larval development of *Callosobruchus maculatus* (Coleoptera: Bruchidae) and *Anagasta kuehniella* (Lepidoptera: Pyralidae). *Journal of Agricultural and Food Chemistry* Vol. 51, 10, pp. 2980-2986

Macedo, M. L. R., Freire, M. D. M., Novello, J. C. & Marangoni, S. (2002). *Talisia esculenta* lectin and larval development of *Callosobruchus maculatus* and *Zabrotes subfasciatus* (Coleoptera : Bruchidae). *Biochimica et Biophysica Acta* Vol. 1571, 2, pp. 83-88

Mahmoud, I., Moharram, F. A., Marzouk, M. S., Soliman, H. S. M. & El-Dib, R. A. (2001). Two new flavonol glycosides from leaves of *Koelreuteria paniculata*. *Pharmazie* Vol. 56, 7, pp. 580-582

Malarvannan, S., Giridharan, R., Sekar, S., Prabavathy, V. R. & Nair, S. (2009). Ovicidal activity of crude extracts of few traditional plants against *Helicoverpa armigera* (Hubner) (Noctuidae: Lepidoptera). *Journal of Biopesticides* Vol. 2, 1, pp. 64-71

Malarvannan, S., Kumar, S. S., Prabavathy, V. R. & Sudha, N. (2008). Individual and synergistic effects of leaf powder of few medicinal plants against American bollworm, *Helicoverpa armigera* (Hubner) (Noctuidae: Lepidoptera). *Asian Journal of Experimental Sciences* Vol. 22, 1, pp. 79-88

Malarvannan, S., Sekar, S., Prabavathy, V. R. & Sudha, N. (2008). Individual and synergistic efficacy of leaf powder of *Argemone mexicana* against tobacco caterpillar, *Spodoptera litura* Fab, (Noctuidae: Lepidoptera). *Emerging trends of researches in insect pest management and environmental safety, Volume I* Vol., pp. 155-164

Malarvannan, S. & Subashini, H. D. (2007). Efficacy of *Dodonaea angustifolia* crude extracts against spotted bollworm, *Earias vitella* (Fab.) (Lepidoptera: Noctuidae). *Journal of Entomology* Vol. 4, 3, pp. 243-247

Mazzola, E. P., Parkinson, A., Kennelly, E. J., Coxon, B., Einbond, L. S. & Freedberg, D. I. (2011). Utility of coupled-HSQC experiments in the intact structural elucidation of three complex saponins from *Blighia sapida*. *Carbohydrate Research* Vol. 346, 6, pp. 759-768

Medeiros, C. A. M., Boica Junior, A. L. & Angelini, M. R. (2007). Sub-lethal effect of aqueous vegetals extracts of *Azadirachta indica* A. Juss. and *Sapindus saponaria* L. against the biology of *Ascia monuste orseis* at kale. *Boletin de Sanidad Vegetal, Plagas* Vol. 33, 1, pp. 27-34

Meyer Albiero, A. L., Aboin Sertié, J. A. & Bacchi, E. M. (2002). Antiulcer activity of *Sapindus saponaria* L. in the rat. *Journal of Ethnopharmacology* Vol. 82, 1, pp. 41-44

Mikolajczak, K. L. (1977). Cyanolipids. *Progress in the chemistry of fats and other lipids* Vol. 15, 2, pp. 97-130

Mikolajczak, K. L., Madrigal, R. V., Smith, C. R. & Reed, D. K. (1984). Insecticidal effects of cyanolipids on three species of stored product insects, European Corn Borer (Lepidoptera: Pyralidae) Larvae, and Striped Cucumber Beetle (Coleoptera: Chrysomelidae) *Journal of Economic Entomology* Vol. 77, 5, pp. 1144-1148

Mikolajczak, K. L., Seigler, D. S., Smith Jr, C. R., Wolff, I. A. & Bates, R. B. (1969). A cyanogenetic lipid from *Cordia verbenacea* DC. Seed oil. *4* Vol. 6, 617-619,

Mikolajczak, K. L. & Smith, C. R. (1971). Cyanolipids of kusum (*Schleichera trijuga*) seed oil. *Lipids* Vol. 6, 5, pp. 349-&

Mikolajczak, K. L., Smith, C. R. & Tjarks, L. W. (1970). Cyanolipids of *Cardiospermum halicacabum* L and other sapindaceous seed oils. *Lipids* Vol. 5, 10, pp. 812-&

Mikolajczak, K. L., Smith, C. R. & Tjarks, L. W. (1970). Cyanolipids of *Koelreuteria paniculata* Laxm. seed oil. *Lipids* Vol. 5, 8, pp. 672-&

Mukherjee, S. N. & Joseph, M. (2000). Medicinal plant extracts influence insect growth and reproduction: A case study. *Journal of Medicinal and Aromatic Plant Sciences* Vol. 22-23, 4A-1A, pp. 154-158

Mukherjee, S. N. & Joseph, M. (2001). Medicinal plant extracts influence insect growth and reproduction: a case study. *Journal of Medicinal and Aromatic Plant Sciences* Vol. 22/23, 4A/1A, pp. 154-158

Murdock, L. L. & Shade, R. E. (2002). Lectins and protease inhibitors as plant defenses against insects. *Journal of Agriculture and Food Chemistry* Vol. 50, pp. 6605–6611

Muthukumran, P., Begumand, V. H. & Kalaiarasan, P. (2011). Antidiabetic activity of *Dodonaea viscosa* (L) leaf extracts. *International Journal of PharmTech Research* Vol. 3, 1, pp. 136-139

Nielsen, N. J., Nielsen, J. & Staerk, D. (2010). New resistance-correlated saponins from the insect-resistant crucifer *Barbarea vulgaris*. *Journal of Agrulture and Food Chemistry* Vol. 58, pp. 5509-5514

Niu, H. M., Zeng, D. Q., Long, C. L., Peng, Y. H., Wang, Y. H., Luo, J. F., Wang, H. S., Shi, Y. N., Tang, G. H. & Zhao, F. W. (2010). Clerodane diterpenoids and prenylated flavonoids from *Dodonaea viscosa*. *Journal of Asian Natural Products Research* Vol. 12, 1, pp. 7-14

Omosa, L. K., Midiwo, J. O., Derese, S., Yenesew, A., Peter, M. G. & Heydenreich, M. (2010). neo-Clerodane diterpenoids from the leaf exudate of *Dodonaea angustifolia*. *Phytochemistry Letters* Vol. 3, 4, pp. 217-220

Palanisamy, U., Cheng, H. M., Masilamani, T., Subramaniam, T., Ling, L. T. & Radhakrishnan, A. K. (2008). Rind of the rambutan, *Nephelium lappaceum*, a potential source of natural antioxidants. *Food Chemistry* Vol. 109, 1, pp. 54-63

Pelegrini, D. D., Tsuzuki, J. K., Amado, C. A. B., Cortez, D. A. G. & Ferreira, I. C. P. (2008). Biological activity and isolated compounds in *Sapindus saponaria* L. and other plants of the genus *Sapindus*. *Latin American Journal of Pharmacy* Vol. 27, 6, pp. 922-927

Pérez, D. & Iannacone, J. (2004). Insecticidal effect of *Paullinia clavigera* var. bullata simpson (Sapindaceae) and *Tradescantia zebrina* Hort. ex Bosse (Commelinaceae) in the control of *Anopheles benarrochi* Gabaldon, main vector of malaria in ucayali, Peru *Ecología Aplicada* Vol. 3, pp. 64-72

Pérez, D., Iannacone, J. & Pinedo, H. (2010). Toxicological effect from the stem cortex of the amazonic plant soapberry *Paullinia clavigera* (Sapindaceae) upon three arthropods. *Ciencia E Investigacion Agraria* Vol. 37, 3, pp. 133-143

Pérez, D., Iannacone, J. & Tueros, A. (2008). Toxicity of *Paullinia clavigera* schltdl. (Sapindaceae) and *Chondrodendron tomentosum* ruiz et pav. (Menispermaceae) on jumping lice of camu camu *Tuthillia cognata* (Hemiptera: Psyllidae). *Gayana Botanica* Vol. 65, 2, pp. 145-152

Pérez, D. D. & Iannacone, O. J. (2006). Effectiveness of botanical extracts from ten plants on mortality and larval repellency of *Rhynchophorus palmarum* L., an insect pest of the Peach palm *Bactris gasipaes* Kunth in Amazonian Peru. *Agricultura Tecnica* Vol. 66, 1, pp. 21-30

Peumans, W. J. & Van Damme, E. J. M. (1995). Lectins as plant defense proteins. *Plant Physiology* Vol. 109, pp. 347-352

Plasman, V., Plehiers, M., Braekman, J., Daloze, D., De Biseau, J. & Pasteels, J. (2001). Chemical defense in *Platyphora kollari* Baly and *Leptinotarsa behrensi* Harold (Coleoptera: Chrysomelidae). Hypotheses on the origin and evolution of leaf beetles toxins. *Chemoecology* Vol. 11, pp. 107-112

Porras, M. F. & Lopez-Avila, A. (2009). Effect of extracts from *Sapindus saponaria* on the glasshouse whitefly *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae). *Revista Colombiana De Entomologia* Vol. 35, 1, pp. 7-11

Prieto, J. M., Schaffner, U., Barker, A., Braca, A., Siciliano, T. & Boevé, J. L. (2007). Sequestration of furostanol saponins by *Monophadnus* sawfly larvae. *Journal of Chemical Ecology* Vol. 33, 513-524,

Rahman, S. S., Rahman, M. M., Begum, S. A., Khan, M. M. R. & Bhuiyan, M. M. H. (2007). Investigation of *Sapindus mukorossi* extracts for repellency, insecticidal activity and plant growth regulatory effect. *Journal of Applied Sciences Research* Vol., February, pp. 95-101

Rey, D., Pautou, M.-P. & Meyran, J.-C. (1999). Histopathological effects of tannic acid on the midgut epithelium of some aquatic Diptera larvae. *Journal of Invertebrate Pathology* Vol. 73, 2, pp. 173-181

Ribeiro, A., Zani, C. L., Alves, T. M. D., Mendes, N. M., Hamburger, M. & Hostettmann, K. (1995). Molluscicidal saponins from the pericarp of *Sapindus saponaria*. *International Journal of Pharmacognosy* Vol. 33, 3, pp. 177-180

Rodrigues, A. M. S., De Paula, J. E., Degallier, N., Molez, J. F. & Espindola, L. S. (2006). Larvicidal activity of some Cerrado plant extracts against *Aedes aegypti*. *Journal of the American Mosquito Control Association* Vol. 22, 2, pp. 314-317

Rodriguez, E. M. (1958). The wood of Argentine Sapindaceae. Structure, characteristics, and applications. *Rev Fac Agron Y Vet [Buenos Aires]* Vol. 14, (2), pp. 271-305

Saha, S., Walia, S., Kumar, J., Dhingra, S. & Parmar, B. S. (2009). Screening for feeding deterrent and insect growth regulatory activity of triterpenic saponins from *Diploknema butyracea* and *Sapindus mukorossi*. *Journal of Agricultural and Food Chemistry* Vol. 58, 1, pp. 434-440

Sarita, R., Geeta, N., Srivastava, V. K., Hasan, S. N. & Hasan, S. Q. (2002). Cyanolipids in *Sapindus obovatus* seed oil and reinvestigation of the seed oil of *Heliotropium indicum*, *H. eichwaldi* and *D. viscosa*. *Journal of the Oil Technologists' Association of India* Vol. 34, 2, pp. 69-71

Seigler, D. (1974). Determination of cyanolipids in seed oils of the Sapindaceae by means of their NMR spectra. *Phytochemistry* Vol. 13, 5, pp. 841-843

Seigler, D. S. (1976). Cyanolipids in *Cordia verbenacea*: A correction. *Biochemical Systematics and Ecology* Vol. 4, 4, pp. 235-236

Seigler, D. S. (1991). Cyanide and cyanogentic glycosides. In: *Herbivores: Their Interactions with Secondary Plant Metabolites*, Rosenthal, G. A. & Berembaum, M. R., pp. Academic Press San Diego, California

Seigler, D. S., Eggerding, C. & Butterfield, C. (1974). A new cyanogenic glycoside from *Cardiospermum hirsutum*. *Phytochemistry* Vol. 13, 10, pp. 2330-2332

Seigler, D. S., Mikolajczak, K. L., Smith Jr, C. R. & Wolff, I. A. (1970). Structure and reactions of a cyanogenetic lipid from *Cordia verbenacea* DC. seed oil. *Chemistry and Physics of Lipids* Vol. 4, pp. 147-161

Selmar, D., Grocholewski, S. & Seigler, D. S. (1990). Cyanogenic lipids: Utilization during seedling development of *Ungnadia speciosa*. *Plant Physiology* Vol. 93, 2, pp. 631-636

Sharaby, A., Abdel-Rahman, H. & Moawad, S. (2009). Biological effects of some natural and chemical compounds on the potato tuber moth, *Phthorimaea operculella* Zell. (Lepidoptera: Gelechiidae). *Saudi Journal of Biological Sciences* Vol. 16, 1, pp. 1-9

Sharma, A., Sati, S. C., Sati, O. P., Sati, D. M. & Kothiyal, S. K. (2011). Chemical constituents and Bioactivities of genus *Sapindus*. *International Journal of Research in Ayurveda & Pharmacy* Vol. 2, 2, pp. 403-409

Silva, H. H. G. d., Silva, I. G. d., dos Santos, R. M. G., Rodrigues Filho, E. & Elias, C. N. (2004). Larvicidal activity of tannins isolated of *Magonia pubescens* St. Hil. (Sapindaceae) against *Aedes aegypti* (Diptera, Culicidae). *Revista da Sociedade Brasileira de Medicina Tropical* Vol. 37, 5, pp. 396-9

Silva, T. M. S., Da Silva, T. G., Martins, R. M., Maia, G. L. A., Cabral, A. G. S., Camara, C. A., Agra, M. F. & Barbosa, J. M. (2007). Molluscicidal activities of six species of Bignoniaceae from north-eastern Brazil, as measured against *Biomphalaria glabrata* under laboratory conditions. *Annals of Tropical Medicine and Parasitology* Vol. 101, 4, pp. 359-365

Simpson, B., Claudie, D., Smith, N., Wang, J. P., McKinnon, R. & Semple, S. (2010). Evaluation of the anti-inflammatory properties of *Dodonaea polyandra*, a Kaanju traditional medicine. *Journal of Ethnopharmacology* Vol. 132, 1, pp. 340-343

Sofidiya, M. O., Jimoh, F. O., Aliero, A. A., Afolayan, A. J., Odukoya, O. A. & Familoni, O. B. (2008). Antioxidant and antibacterial properties of *Lecaniodiscus cupanioides*. *Research Journal of Microbiology* Vol. 3, 2, pp. 91-98

Sosa, M. E. & Tonn, C. E. (2008). Plant secondary metabolites from Argentinean semiarid lands: bioactivity against insects. *Phytchemical reviews* Vol. 7, 1, pp. 3-24

Sousa, S. A., Alves, S. F., de Paula, J. A. M., Fiuza, T. S., Paula, J. R. & Bara, M. T. F. (2009). Determination of tannins and methylxanthines in powdered guarana (*Paullinia cupana* Kunth, Sapindaceae) by high performance liquid chromatography. *Brazilian Journal of Pharmacognosy* Vol. 20, 6, pp. 866-870

Spitzer, V. (1995). GLC-MS analysis of the fatty-acids of the seed oil, triglycerides, and cyanolipid of *Paullinia elegans* (Sapindaceae): A rich source of cis-13-eicosenoic acid (paullinic acid). *Journal of High Resolution Chromatography* Vol. 18, 7, pp. 413-416

Spitzer, V. (1996). Fatty acid composition of some seed oils of the Sapindaceae. *Phytochemistry* Vol. 42, 5, pp. 1357-1360

Teffo, L. S., Aderogba, M. A. & Eloff, J. N. (2010). Antibacterial and antioxidant activities of four kaempferol methyl ethers isolated from *Dodonaea viscosa* Jacq. var. *angustifolia* leaf extracts. *South African Journal of Botany* Vol. 76, 1, pp. 25-29

Teixeira, J. R. M., Lapa, A. J., Souccar, C. & Valle, J. R. (1984). Timbós: ichthyotoxic plants used by brazilian indians. *Journal of Ethnopharmacology* Vol. 10, 3, pp. 311-318

Ucciani, E., Mallet, J. F. & Zahra, J. P. (1994). Cyanolipids and fattyacids of *Sapindus trifoliatus* (Sapindaceae) seed oil. *Fat Science Technology* Vol. 96, 2, pp. 69-71

Van Damme, E. J. M., Lannoo, N., Peumans, W. J. & Jean-Claude Kader and Michel, D. (2008). Plant Lectins. In: *Advances in Botanical Research*, pp. 107-209 Academic Press

Veeramani, C., Pushpavalli, G. & Pugalendi, K. V. (2010). In vivo antioxidant and hypolipidemic effect of *Cardiospermum halicacabum* leaf extract in streptozotocin-induced diabetic rats. *Journal of Basic and Clinical Physiology and Pharmacology* Vol. 21, 2, pp. 107-125

Vichitrananda, S. & Somsri, S. (2008). Tropical fruit production in Thailand. *Acta Horticulturae* Vol. 787, pp. 33-46

Waako, P. J., Gumede, B., Smith, P. & Folb, P. I. (2005). The in vitro and in vivo antimalarial activity of *Cardiospermum halicacabum* L. and *Momordica foetida* Schumch. et Thonn. *Journal of Ethnopharmacology* Vol. 99, 1, pp. 137-143

Weckerle, C. S., Stutz, M. A. & Baumann, T. W. (2003). Purine alkaloids in *Paullinia*. *Phytochemistry* Vol. 64, 3, pp. 735-742

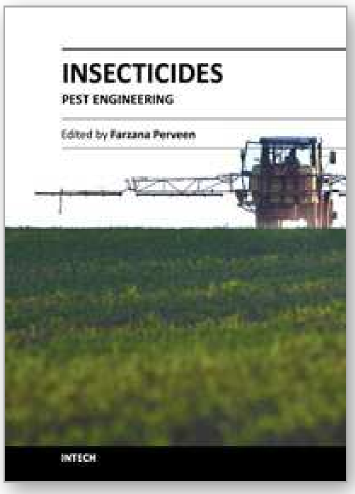
Wilbert, W. & Haiek, G. (1991). Phytochemical screening of a Warao pharmacopoeia employed to treat gastrointestinal disorders. *Journal of Ethnopharmacology* Vol. 34, 1, pp. 7-11

Wink, M., Dey, P. M. & Harborne, J. B. (1997). Special nitrogen metabolism. In: *Plant Biochemistry*, pp. 439-486 Academic Press London

Wollenweber, E. & Roitman, J. N. (2007). New reports on surface flavonoids from *Chamaebatiaria* (Rosaceae), *Dodonaea* (Sapindaceae), *Elsholtzia* (Lamiaceae), and *Silphium* (Asteraceae). *Natural Product Communications* Vol. 2, 4, pp. 385-389

Zhao, H., Qin, X. & Yang, M. (2006). Preliminary study contact toxicity of extracts from *Dodonaea viscosa* seed aganist *Sitophilus oryzae*. *Journal of Yunnan Agricultural University* Vol. 22, 6, pp. 942-944

Zidan, Z. H., Gomaa, A. A., Afifi, F. A., Fam, E. Z. & Ahmed, S. M. S. (1993). Bioresidual activity of certain plant extracts on some stored grain insects, in relation to seed viability. *Arab Universities Journal of Agricultural Sciences* Vol. 1, 1, pp. 113-123



Insecticides - Pest Engineering

Edited by Dr. Farzana Perveen

ISBN 978-953-307-895-3
Hard cover, 538 pages
Publisher InTech
Published online 15, February, 2012
Published in print edition February, 2012