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# Amazon Piperaceae with Potential Insecticide Use

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## ABSTRACT

*The Amazon rainforest is a potential source of essential oils, such as those found in the family Piperaceae, to which the species known as long pepper and pepper jack belong. The genus Piper comprises around 700 species, among the 140-300 species that are part of the rainforest flora of the Amazon region. The literature describes the composition of its essential oils, with various biological activities such as larvicide, antimicrobial, and antioxidant activities, among others. The use of essential oils as a future alternative to insecticides is a field that is growing, and this chapter presents a literature review of studies focusing on Amazonian Piperaceae essential oils that have potential insecticide use. The species Piper aduncum L., P. callosum, P. divaricatum, P. hispidinervum, P. hostimannianum, P. humaytanum, P. marginatum, P. nigrum L., and P. tuberculatum, have shown excellent results in studies to evaluate their potential as plants with biological activities that can be used to control pests that cause damage to agricultural crops, or to human health. The essential oil of P. aduncum is the one that has been most widely studied for its potential as an insecticide, showing effectiveness in the control of various species of agricultural pests in Brazil e.g., Cerotoma tingomarianus Bechyné, Tenebrio molitor L., Solenopsis saevissima. The Reports in the literature on the essential oils of Piperaceae demonstrate their ability to inhibit or delay insect maturation, reducing reproductive capacity, and causing death by starvation or direct toxicity. The main constituents present in the composition of the essential oils are phenylpropanoids,*

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*monoterpenes and sesquiterpenes, such as eugenol, safrole, α-humulene, β-caryophyllene, β-farnesene, and α-bisabolol. The wide biological diversity, largely unexplored, especially in tropical regions like the Amazon rainforest, holds great potential for research into new products that could replace conventional insecticides, or be used as part of synergistic formulations in the efforts to control insect resistance to these products.*

***Keywords:*** Amazon rainforest, *Piperaceae*, Essential oils, Insecticide use.

## Introduction

Angiosperms first appeared 90 million to 130 million years ago, with approximately 500,000 species (Castro *et al.*, 2004). In Brazil, there are thought to be around 200,000 species (Labandeira *et al.*, 1994). Of this total, at least 80,000 species grow in the Amazon rainforest (Pletsch and Santana, 1995).

The diversity of the flora is directly related to the structural diversity of secondary metabolites produced, which are currently estimated more than 200,000 compounds (phenolics in general, isoprenoids, alkaloids, and polyketides, among others) (Dixon, 2001).

The family Piperaceae is thought one of the most primitive of the angiosperms, and can be considered a "fossil plant" (Taylor and Hickey, 1992). A biogeographical analysis of the distribution of species of *Piper* on the North and South American continents revealed three distinct regions of occurrence: Amazon, Central America and Mexico, and the Atlantic forest (Jamarillo and Marquis, 2004).

The secondary metabolism of this family is presented as one of the most versatile of the botanical families known. The metabolites accumulated by species of Piperaceae are characterized by being derived from mixed biosynthesis (shikimate/acetate), resulting in the production of aromatic amides or aromatic compounds, essentially phenylpropanoids, of the lignan and neolignan types, and the occurrence of terpenoids, flavonoids and other classes of natural products with biological activity (Alécio *et al.*, 1997; Gottlieb *et al.*, 1995; Parmar *et al.*, 1997).

Estimates suggest that under normal development, 20 per cent of the carbon fixed by the plants flows to the shikimic acid pathway (Sangwan *et al.*, 2001), hence the importance, to the plant, of the compounds produced in this metabolic pathway.

The Piperaceae family comprises 12 genera, with about 2000 species. Of these, the bioactivity of the compounds has only been evaluated for only ten percent (Andrade *et al.*, 2009). In Brazil, 700 species have been reported for the genus *Piper*, of which between 140 and 300 are presumed to be part of the Amazon flora (Yuncker, 1972, 1973; Jaramillo and Manos, 2001).

The diversity of *Piper* can be explained by its unique adaptation to the natural habitat. The highest number of species is found in tropical rainforests. They are pioneer species, and then used in disturbed areas for their regeneration (Andrade *et al.*, 2009).

The aim of this study was to point out, by means of the currently available knowledge, the potential of Piperaceae species that occur naturally in the Amazon, as a source of promising compounds for pest control.

## Materials and Methods

We performed a literature search using the databases SCOPUS, ISI, PubMed, SCIELO, and search tools available on the Internet. Search keywords such as "Piperaceae", "Piper oil" and "insecticide" were used, plus the names of the main chemical classes present in *Piper*, in various combinations or alone.

The constituents of essential oils and plant extracts from the Piperaceae family presented in the study "Chemical Variability in essential oils of Piper species in the Amazon" (Andrade *et al.*, 2009) were used as reference. The study was conducted with 230 specimens of Piperaceae, representing 53 plant species collected in the Brazilian states of the Amazon region, including Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Roraima and Tocantins.

To indicate the potential of the species, the research started with the premise that secondary metabolites, such as most monoterpenes, sesquiterpenes, phenylpropanoids and some amides, present biological interference on insects. The metabolites considered were obtained from essential oils and methanol, ethanol and dichloromethanic extracts, pondering the accumulated knowledge for each type of product.

The prevalence of the chemical compounds monoterpenes, phenylpropanoids and sesquiterpenes for all species was defined by the greater percentage of occurrence in the oils, and in some cases, these were attributed to more than one compound, since that the presence of those compounds in the sample differ from minor values than 50 per cent of highest value observed.

## Results and Discussion

The family Piperaceae comprises one of the most important plant families in the Amazon rainforest. Most species of this genus are used in traditional and popular medicine, prompting interest in their chemical constitutions, especially the minor components contained in the plants. The phenylpropanoid compounds produced by plants of the genus *Piper* are largely responsible for the biological activity of some species of the Amazon, such as apiol, dillapiole, myristicin, elemicin, eugenol, methyl eugenol, and safrole ethyl piperonyl ketone, all of which have been found in essential oils of species previously studied (Dyer and Palmer, 2004).

The studies are subdivided into the major classes found in the chemical composition of essential oils and the activities of these insecticides.

### Essential Oils

The formation of essential oils, and their secretory structures, are primitive traits in plants, followed by the trend to replace the oil by other metabolites (Gottlieb and Salatino, 1987). These anatomical structures have evolved from oleiferous cells, secretory cavities and channels and glandular hairs. These structures characterize evolutionary lineages of angiosperms, and their occurrence, along with the storage and volatility of the oil, are important characteristics that define an essential oil. Volatilized plant substances can penetrate insects when the plant is injured, altering the hormonal balance of these insects resulting in a more sophisticated defense mechanism (Gottlieb and Salatino, 1987).

The constituents of essential oils are classified as terpenoids (most constituencies are synthesized in the chloroplast and cytoplasm) and phenylpropanoids (synthesized via shikimate). Although phenylpropanoids are not very common constituents in essential oils, some species, such as *Piper* genus, contain significant proportions of these compounds (Deschamps and Biasi, 2009).

## Phenylpropanoids

The deamination of phenylalanine to cinnamic acid, and it transformation into lignoids (flavonoids in condensed tannins, cinnamyl alcohols in lignins), was the crucial determining biochemical phenomenon in the colonization of the land by plants. Phenylpropanoids exert pronounced biological actions in animals (Gottlieb and Salatino, 1987). The primary structures of phenylpropanoids found in Piperaceae species are shown in Figure 20.1.

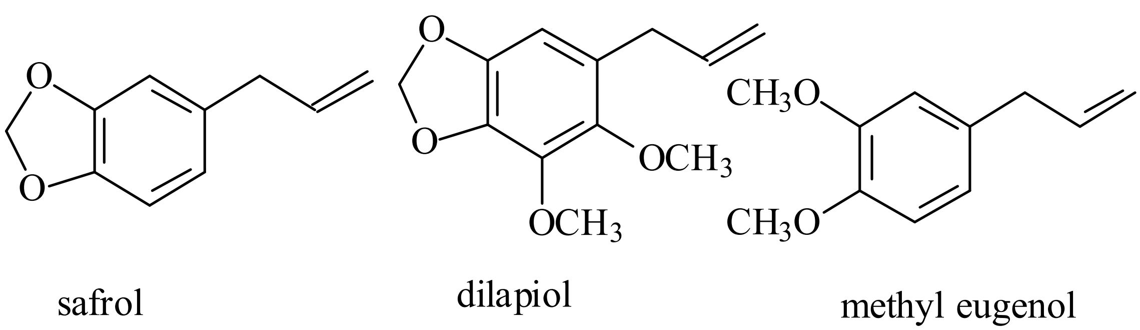



**Figure 20.1**: Examples of phenylpropanoids found in Piperaceae species.

A differentiated group of phenylpropanoids is lignans, which encompass a broad spectrum of structural models and molecular sizes. They are found in various parts of the plant (stem, rhizome, roots, seeds, oils, resins, flowers, leaves and bark) and their amounts vary depending, on the tissues and the species (Davin and Lewis, 1998).

The functions of lignans are related primarily to plant defense, and their formation is constitutive or stress-induced; their deposits contribute to the durability, color and quality of plant tissue (Burlat *et al.,* 2001). This component is also attributed with antioxidant, antiherbivore, bactericide, fungicide, ad antiviral functions, and phytotoxicity to other plant species (Chu *et al.,* 1993). There is evidence that the accumulation of lignans in damaged sites inhibit the enzymes secreted by fungi, preventing the lignan from breaking down (Ward, 1997).

Lignins and lignans are accumulated in the same tissue; lignin give rigidity to the tissue, while lignan protects the plant against microorganisms (Davin Lewis, 1998).

The binding of lignans to the methylenedioxyphenyl group is a characteristic of Piperaceae, and they are considered important cytochrome P450-dependent monooxygenase inhibitors, used as synergists of natural insecticides (Murkerjee *et al.*, 1979; Bernard *et al.*, 1990). Synthetic derivatives of the chemical group showed synergistic effect for carbamate insecticides (Wilkinson *et al.*, 1966), and also act alone as an insecticide (Star, 2005).

## Terpenoids

Terpenes have an important ecological role by acting as internal and external messengers, functioning as allelopathic agents, insect repellent, or to insect attractant, to promote plant pollination (Harrewijan *et al.*, 2001). There is evidence that its biosynthesis is induced by insect feeding, probably through oral secretion from the individuals (Paré and Tumlinson, 1997).

Terpenes can be classified according to the number of C5 units: monoterpenes, C10, sesquiterpenes, C15; diterpenes, C20; sesquiterpenes, C25, triterpenes, C30, and tetraterpenes, C40 (Castro *et al.*, 2004).

The insecticidal action of mono and sesquiterpenes appears to be related to the inhibition of acetylcholinesterase. The majority of studies report that the higher terpenoids act by inhibiting or retarding growth, damaging the insect maturation, reducing its the reproductive capacity, and suppressing the appetite, which may lead to death of the insect by starvation or direct toxicity (Viegas Júnior, 2003).

The majority of monoterpenes are volatile, and are the basic constituent of aromatic oils (essential oils or essences). Some are precursors of a special class of substances, iridoids and secoiridoids, others as structural units of some types of complex alkaloids (Castro *et al.*, 2004).

Some sesquiterpenes are present in various essential oils, such as $\alpha$-humulene, $\beta$-caryophyllene, $\beta$-farnesene and $\alpha$-bisabolol. The chemical structure of some constituents of the essential oils is found in Figure 20.1. Other more complex and more functionalized sesquiterpenes have an ecological function, or are active constituents of some medicinal plants such as sesquiterpene lactones (Castro *et al.*, 2004).

## Amides

Based on the report of Parmar *et al*. (1997), 145 different amides had been isolated from plants of the Piperaceae family, this number can now be assumed to be over 300, though no references have been found to support this.

Piperine (Figure 20.3) was the first amide to be isolated from the fruit of the *Piper* species, and its chemical constituents have widely investigated, including the unsaturated lipophilic amides, considered as precursor metabolites in the synthesis of various other amide analogs. Besides being the major group of plant metabolites, these are primarily responsible for the insecticidal activity, Parmar *et al*. (1997).

The insecticidal action of the amide piperine, derived from *Piper nigrum* L, was proven in 1924 (Su, 1977). It is considered a metabolite precursor of the synthesis of

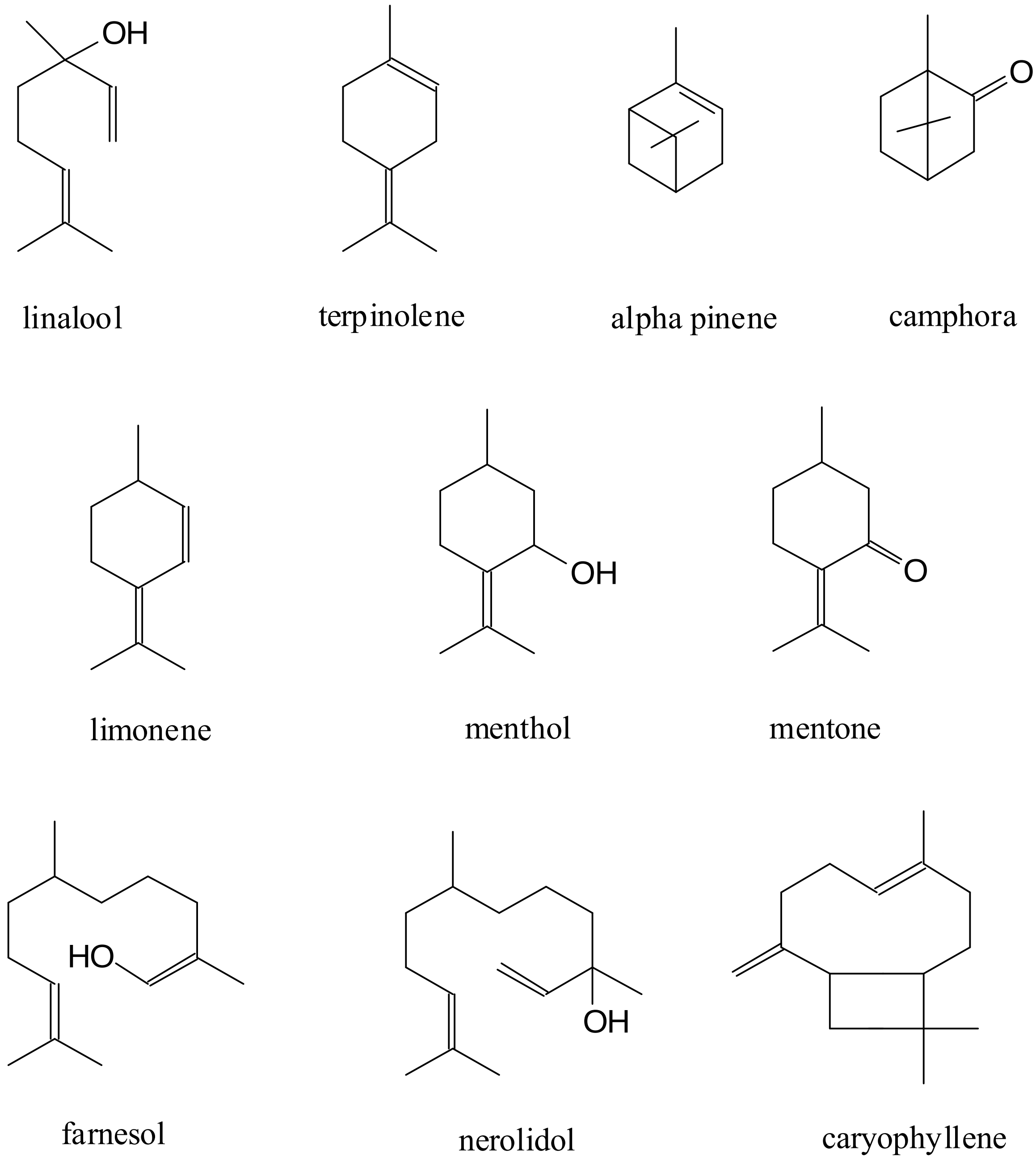
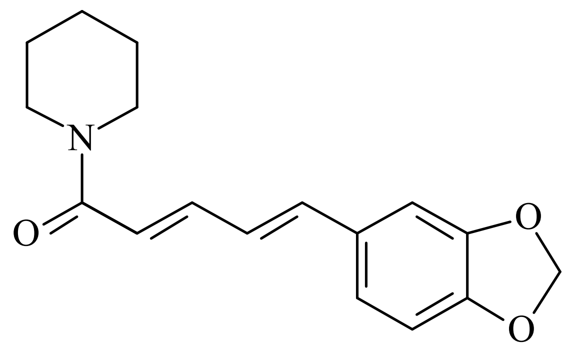



**Figure 20.2**: Examples of monoterpenes and sesquiterpenes.

several other amide analogs. In general, amides have insecticidal neurophysiological action (Scott *et al.*, 2008).

Plants of the Piperaceae family constitute a source of long chain unsaturated isobutylamides with insecticidal properties, like piperine (Strunz and Finlay, 1994). Estrela *et al*. (2005) investigated the piperine amide analogs with the N-hexyl, N-isopropyl, and N-isopentyl groups bound to isopentyl (3,4-methylenedioxyphenyl) amide. They observed that these amides caused high toxicity to the caterpillar *S. frugiperda*, causing mortality and deformities involved in its vital activities.




piperine

**Figure 20.3**: Isolated amide from species of the genus *Piper*.

It can be inferred that the presence of the methylenedioxyphenyl bound to some amide groups confers stability to the molecule, and removing this radical, according in Elliott *et al*. (1987), practically nullifies the insecticidal action of the amide.

This was evidenced by the work of Scott *et al*. (2002), who demonstrated that piperamides are bifunctional when combined with the molecule methylenedioxyphenyl, acting as neurotoxin and cytochrome P450 enzyme inhibitor. This chemical characteristic is common in plants of *Piper*, and it is considered a defense strategy of the plant, against herbivores (Navickiene *et al.,* 2006).

Of the 53 Piperaceae species evaluated, 45 (84.9 per cent) presented sesquiterpenes as the predominant compounds, followed by 17 others (32.7 per cent) with a predominance of monoterpenes, and of these, 15 species presented sesquiterpenes as the second most predominant compounds. Only five species (9.4 per cent) were predominant in the phenylpropanoid in essential oil, and only in *P. marginatum* and *P. millegranum* were predominant together with monoterpenes, sesquiterpenes and phenylpropanoids (Table 20.1).

The effectiveness of essential oils for the control of at least one species of insect that is harmful to crops or human health was demonstrated for only seven *Piper* species (13.2 per cent): *P. aduncum* L., *P. callosum*, *P. divaricatum*, *P. hispidinervum*, *P. hostimannianum*, *P. humaytanun* and *P. marginatum*.

The essential oil of *P. aduncum* is the most widely studied oil in terms of insecticidal properties, and has efficacy in the control of the crop pests: *C. tingomarianus* Bechyné, *Tenebrio molitor* L, 1758 (Fazolin *et al.,* 2005 and Fazolin *et al.,* 2007), *Sitophilus zeamais* Mots., 1865 (Star *et al.,* 2006), *Solenopsis saevissima* Smith 1855 (Souto 2005), all of which are present in Brazil. *Choristoneura rosaceana* (Harris) an important polyphagous pest in North America and Europe was also controlled by *P. aduncum* oil (Laroque *et al.,* 1999). Moreover, it was also found to controls insect vectors of human diseases: *Anopheles marajoara* (Galvão and Damasceno, 1942) and *Aedes aegypti* L (Souto, 2005). Its insecticidal action is related to the wealth of lignans associated with dillapiole, a phenylpropanoid that in this association, inhibits reactions of the cytochrome P450 monooxygenase (Murkerjee *et al.,* 1979; Bernard *et al.,* 1990). Bernard *et al*. (1995) argue that this compound alters the detoxification capacity of insects,

**Table 20.1**: Piper species occurring in the Amazon and quantification of the compounds of essential oils with potential insecticide use.

| *Piper Species of Amazon* | *Number of Specimens* | *Monoterpenes (Per cent)* | *Sesquiter-penes (Per cent)* | *Phenylpro-panoids (Per cent)* | *Species of Insects Controlled* |
|---|---|---|---|---|---|
| *Piperaduncum L.* | 21 | | | 97.0 | *C. tingomarianus; T. molitor; S. zeamais; Anopheles marajoara; A. aegypti; S. saevissima; Choristoneura rosaceana* |
| *Piper alatipentiolatum* Yuncker | 3 | | 99.8 | | |
| *Piper amapaense* Yuncker | 1 | | 96.9 | | |
| *Piper anonifolium* Kunth | 8* | 81.8 | 75.5 | | |
| *Piper aramanum* C.DC. | 2 | | 84.7 | | |
| *Piper arboreum* Aubl. Vr. *Arboreum* | 8 | | 99.8 | | |
| *Piper baccans* (Miq.) C.DC. | 2 | | 82.9 | | |
| *Piper bartlingianum* (Miq.) C.DC. | 2 | | 98.3 | | |
| *Piper brachypetiolatum* Yuncker | 1 | | 79.5 | | |
| *Piper brasiliense* C.DC. | 1 | | 75.3 | | |
| *Piper brevesanum* Yuncker | 1 | | 96.4 | | |
| *Piper callosum* Ruiz and Pav. | 8 | | | 83.9 | *Anopheles marajoara; Aedes aegypti; S. saevissima* |
| *Piper carniconnectivum* C.DC. | 6 | | 97.7 | | |
| *Piper cernnum* Vell. | 1 | 39.6 | | 45.0 | |
| *Piper colubrinum* (Link ex Kunth) Link ex C.DC. | 3* | 71.1 | 96.6 | | |
| *Piper crassinervium* Kunth | 1 | | 70.2 | | |
| *Piper cyrtopodon* (Miq.) C.DC. | 7 | | 81.1 | | |
| *Piper dactylostigmum* Kunth | 1 | | 87.9 | | |
| *Piper demeraenum* (Miq.) C.DC. | 4 | 96 | | | |

*Contd...*

**Table 20.1**–*Contd...*

| *Piper Species of Amazon* | *Number of Specimens* | *Monoterpenes (Per cent)* | *Sesquiter-penes (Per cent)* | *Phenylpro-panoids (Per cent)* | *Species of Insects Controlled* |
|---|---|---|---|---|---|
| *Piper dilatatum* Rich. | 10 | | 94.8 | | |
| *Piper divaricatum* G. Mey | 11 | | | 92.1 | *Anopheles marajoara; A. aegypti; S. saevissima* |
| *Piper duckei* C.DC. | 2 | | 98.8 | | |
| *Piper durilignum* | 1 | | 98.6 | | |
| *Piper erectipilum* | 1 | | 67.9 | | |
| *Piper* glandu*losissimum* | 7 | | 84.1 | | |
| *Piper gurupanum* | 2 | | 100.0 | | |
| *Piper hispidinervum* C.DC. | 12 | | | 97.3 | *T. molitor; S. zeamais* |
| *Piper hispidum* Sw. | 12* | 83.6 | 97.9 | | |
| *Piper hostmannianum* (Miq.) C.DC. | 8* | 62.1 | 78.8 | | *A. aegypti* |
| *Piper humaytanum* Yuncker | 5 | | 87.4 | | *A. aegypti* |
| *Piper kegelianum* (Miq.) C.DC. | 1 | 86.2 | 83.0 | | |
| *Piper klotzschianum* (Kunth) C.DC. | 1 | 82.6 | | | |
| *Piper krukoffii* Yuncker | 1 | | | 83.3 | |
| *Piper macedoi* Yuncker | 2* | 53.2 | 33.9 | | |
| *Piper manausense* Yuncker | 4 | | 77.0 | | |
| *Piper marginatum* sensu lato | 26* | 58.9 | 87.9 | 91.4 | *A. aegypti; Anopheles marajoara; S. saevissima* |
| *Piper marstersianum* C.DC. | 1 | | 91.8 | | |
| *Piper millegranum* Yuncker | 4* | 43.8 | 73.3 | 45.7 | |

*Contd...*

**Table 20.1**–*Contd...*

| *Piper Species of Amazon* | *Number of Specimens* | *Monoterpenes (Per cent)* | *Sesquiter-penes (Per cent)* | *Phenylpro-panoids (Per cent)* | *Species of Insects Controlled* |
|---|---|---|---|---|---|
| *Piper montealegreanum* Yuncker | 1 | 31.8 | 67.8 | | |
| *Piper nigrispicum* C.DC. | 1 | | 96.7 | | |
| *Piper ottonoides* Yuncker | 1 | | 94.8 | | |
| *Piper ovatilimbum* C.DC. | 1 | | 89.2 | | |
| *Piper pellitum* C.DC. | 1 | 25.7 | 61.3 | | |
| *Piper peltatum* (L.) Miq. | 5 | | 96.2 | | |
| *Piper piresii* Yuncker | 1 | | 97.6 | | |
| *Piper plurinervosum* Yuncker | 1 | 42.6 | 54.6 | | |
| *Piper reticulatum* L. | 2 | | 60.5 | | |
| *Piper schwackei* C.DC. | 8 | | 98.9 | | |
| *Piper trichocarpum* C.DC. | 2 | | 72.7 | | |
| *Piper tuberculatum* Jacq.*Var. Tuberculatum* | 11 | 83.8 | 69.9 | | |
| *Piper utinganum* Yuncker | 1 | | 95.2 | | |
| *Piper vitaceum* Yuncker | 1 | 49.6 | 43.6 | | |
| *Piper wachenheimii* Trel. | 1 | 60.5 | 36.8 | | |

Adapted from Andrade *et al.* (2009).

–* Predominant compounds in two different specimens within the same species.

which are poisoned with compounds present in the food that would normally be eliminated gradually.

This phenomenon is of interest due the fact that in coevolution between herbivores and plants, the selection of individuals of both plant and animal species occurs, depending on the ability to adapt and survive in this chemical struggle. Thus, the mode of action of dillapiole is altering the capacity of the insect, through the loss of chemical adaptation, developed over time, this capacity returning to the primitive stages of protection.

In addition to the insect species mentioned above, the essential oils of *P. hostimannianum*, *P. humaytanun* and *P. marginatum* are also effective against *A. aegypty*, an important vector of the dengue fever virus (Mitchell *et al.,* 2007).

Of the 53 species occurring in the Amazon, only *P. tuberculatum* had isolated that amides that showed insecticidal action; pelitorin and 4.5 dihydro piperlonguminine (Table 20.2). These amides were effective in the control of important pests of soybean *Anticarsia gemmatalis* Hueb., 1818 and sugar cane, *Diatraea sacharallis* (Fabr, 1794) (Navickiene, 2007). The extracts of this Piperaceae also presented insecticide activity against *A. aegypti* (Pohlit *et al.,* 2004) (methanol and aqueous extracts), *Diatraea sacharallis* (methanol, ethanol and dichloromethanol extracts) (Soberon *et al.,* 2006) and *Ostrinia nubilalis* (Hübner) (ethanol extract) (Bernard *et al.,* 1995), the latter being an important polyphagous pest distributed throughout Europe, Asia, Africa, North America.

Aqueous extracts of *P. aduncum* also presented efficient control of *Aetalion reticulatum* (L., 1767) (Smith *et al.,* 2007), known as the "cricket of the orchards," and a widespread pest in Brazil.

Based on the above, it is clear that there is need for further research with Amazonian Piperaceae, in order to evaluate its potential insecticide use. Considering an estimated incidence of approximately 250 species of Piperaceae in the Amazon, only 27.2 per cent (53 species) have been investigated for their chemical constituents, and only 6 (2.4 per cent) of them have had some kind of assessment for their insecticide potential, whether through the use of essential oils, extracts or isolation products, or synthesis of amides.

Considering the wealth of insecticidal compounds of these Amazonian *Piper* species, as demonstrated by Andrade *et al*. (2009) (Tables 1 and 2), mainly present in essential oils rich in mono- and sesquiterpenes and phenylpropanoids, it can be concluded that there is much still to be investigated.

If the objective assessment of the insecticide potential is made on the basis of the predominance of phenylpropanoids, at least three species should be further investigated: *P. cernnum*, *P. Kukroffii* and *P. millegranum*, whose specimens showed 45.0 per cent, 83.3 per cent and 45.7 per cent of that compound, respectively (Table 20.1). It is noteworthy that in the case of occurrence of levels near 45 per cent phenylpropanoids, this is ordinarily associated with the occurrence of terpenoids in high proportions, which can increase the potential for insecticide use these species of Piperaceae.

**Table 20.2**: Piper species that occur in the Amazon and quantification of extracts or isolated compounds with potential insecticide use.

| *Piper Species of Amazon* | *Isolated Amides with Insecticide Activity* | *Species of Insects Controlled* | *Types of Extracts Evaluated as Insecticide* | *Species of Insects Controlled* |
|---|---|---|---|---|
| *Piper aduncum* L. | | | 1-Metanol; 2- Aqueous; 3- Etanol | *A.aegypti* (*1 and 2*); *Aetalion sp.* (*2*); *O. nubilalis* (*3*) |
| *Piper tuberculatum* Jacq. Var. tuberculatum | Pelitorin and 4,5-dihydro piperlonguminine | *A.gemmatalis; D. sacharallis* | 1-Metanol; 2- Aqueous; 3- Etanol;4- Dichlorome-thanol | *A.aegypti* (*1 and 2*); *O. nubilalis.* (*3*); *Diatraea sacharallis* (*1,3, and 4*) |

Adapted from Andrade *et al*. (2009).

Also, considering the wealth of phenylpropanoids in the essential oils of eight species (Table 20.1), there is a need to evaluate the potential use as a synergistic when combined with conventional insecticides. This may attract the interest of the agrochemical industry to promote a more economically advantageous substitute for piperonyl butoxide, which is produced from safrole (*P. hispidinervum*) and is currently the most widely used synergistic in insecticides worldwide.

Of the 53 species of *Piper* evaluated by Andrade *et al*. (2009), 45 (84.9 per cent) species, rich in terpenoids (Table 20.1), have not been evaluated for their insecticide potential. This opens a vast prospect of bioprospecting essential oils that can be used for insect pest control.

With the rapid growth in demand for products of organic origin, and that are compatible for use in subsistence farming, the potential insecticide use of essential oils and extracts of Piperaceae may justify greater investment in research with plants of the Amazon.

There is a visible lack of information on the insecticidal activity of the different extraction methods and amides isolated from 53 species evaluated in this study, with only two species–*P. aduncum* and *P. tuberculatum*–presenting results that indicate the potential use of these substances (Table 20.1). Regarding the isolation of amides with insecticidal activity, *P. tuberculatum* was the only species studied, resulting in the isolation of pelitorine and 4.5 diidropiperlonguminine with marked insecticidal activity. Bernard *et al*. (1995) considers that the isobutylamides from *Piper*, because they contain nitrogen atoms with simple and low molecular weight, could theoretically be biosynthesized with low production costs.

In terms of the simplicity of obtaining some types of extracts, mainly aqueous and alcoholic, these have higher possibilities for use, but the limitation to their successful use is the lack of knowledge of their components and guarantee of homogeneity of the product.

Besides furthering phytochemical knowledge of Piperaceae, there is still much to be done to domesticate species of commercial interest, as well as improving and adapting the industrial process of hydrodistillation. In relation to the spray application of essential oils of *Piper* in particular, evaluations of the phytotoxic effect of lethal concentrations to the pests in certain plant species should be observed.

Consumer concerns over the environment, food quality and side effects of synthetic insecticides have led researchers to test alternative forms of pest control. Research into alternatives to synthetic chemical insecticides is very important, not only for controlling insect pest infestations, but also for safeguarding consumers' health against toxic residues (Sriranjini and Rajendran, 2008).

Recent works have reported high insecticide capacity of oils of the *Piper* species. Coitinho *et al*. (2010) evaluated the persistence of essential oils and of the compound eugenol in corn seeds infested with maize weevil, *Sitophilus zeamais*. The results of this study indicate that of the seven essential oils tested, the essential oil of *P. marginatum* was more persistent on maize grain for 120 days of storage, with better results than the standard eugenol.

Essential oil of *P. hispidinervum* showed insecticidal activity against *Macrosiphum euphorbiae* (Thomas) (Hemiptera: Aphididae) on rose bushes (Smith *et al.*, 2012).

## Conclusion

Based on this literature review, it is concluded that several compounds present in *Piper* species have bioactivity in insects that cause diseases in plants and animals, enabling the use of the isolates and extracts or oils from these plants as alternatives to synthetic chemical insecticides for the control of pest infestations, minimizing the issue of toxic residues and lowering production costs. However, further research is needed to evaluate the chemical composition of oils and extracts of a wider range of Amazonian *Piper* species, and to evaluate their activity and isolated compounds in the control of insects that are harmful to agriculture or human and animal health.

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