Natural products: insecticidal and antimicrobial activity

N. Knaak*, **S.L.F. Wiest**, **W. Soares** and **L.M. Fiuza**

PPG Biologia, Laboratório de Microbiologia e Toxicologia/UNISINOS, Av. Unisinos, 950, São Leopoldo, RS, Brazil
* Corresponding author: email: neivaknaak@gmail.com

Plants, algae and micro-organisms are the major natural sources of substances insecticidal and antimicrobial, synthesized in response to the attack of insects or microorganisms. These features make the plants powerful sources of biocides, which are widely studied in agriculture, especially in prospecting of bactericides, fungicides and insecticides. The growing interest in phytotoxins is related to wide range of new sites of action in target organisms. In this case, even if they are not commercially available, may indicate paths for the synthesis of new products. This is important when considering the speed of development of resistance by insects and microorganisms to chemical insecticides often used as pest control agents. In this context, this paper aims to show data about the antimicrobial and insecticide effect of substances obtained from plants.

Keywords: Bioactive substances; vegetable proteins; biological activity; biological control

1. Introduction

The agriculture involves the cultivation of plants and other biological forms for the production of food, fiber and further products necessary for life. Its history and evolution are characterized by constant challenges which are related to restrictions on the expansion of land and increasing of its productivity - on the supply side - and with the attendance to the expansion of consumption - on the demand side [1].

In addition of meeting the growing global demand for food, the agriculture also faces increasing pressures about the reduction of their environmental impact, especially regarding the use of pesticides. Brazil, the largest consumer of pesticides in Latin America, uses for example 1.5 kg of active ingredient per hectare. The most of the scientific studies place these losses between 30% and 40% of the planted culture [2].

Thus the use of natural products for pest control has increased, since they are substances with fewer risks to human and environmental health and are comply with the increasing demand for healthy food products free of pesticide residues [3]. In Brazil, the use of plants with medicinal properties in the treatment of diseases was initially practiced by the natives, who transmitted their knowledge to the settlers of the country. So, the settlers expanded the medical use for the biological control of agricultural pests [4].

Secondary metabolites usually have complex structure, low molecular weight and marked biological activity. On the other hand, primary metabolites are present in low concentrations in certain plants groups [5]. Natural agents obtained from vegetables such as pyrethrum, rotenone and nicotine were very popular between the 1930s and the 1940s. In this context, Brazil was the major producer and exporter of these products, which present greater security in agricultural use and lower environmental impact [6; 7]. These features make the plants producing these products powerful sources of biocides, which are widely utilized in the prospecting of natural substances with bactericide, fungicide and insecticide activity [8]. The search for biopesticides has been highlighted after the discovery of the harmful effects of synthetic insecticides, such as DDT, to the ecosystems.

In this way, sustainable agriculture seeks to mobilize harmoniously all the available resources on the farm, in order to reduce the environmental impact and pollution, minimizing the foreign dependence on raw materials. Thus, it would be possible to achieve the optimization of the energy balance of production and produce cheaper and high-quality food to meet domestic needs and generating exportable surpluses.

2. Insecticidal activity

In recent years, there has been a major scientific breakthrough involving the exploration, characterization and elucidation of the mechanisms of action of natural substances, in order to obtain new compounds with biological activity for use in agriculture. Plants have their own defenses that protect them from the attack by phytophagous insects and herbivores predators. These defenses usually involve chemical substances of secondary metabolism, as phytotoxins or allelochemicals [9]. The secondary products have an important role in the adaptation of the plants to the environments since these molecules contribute to that the vegetables have a good interaction with the different ecosystems [10; 11].

The use of substances extracted from plants has numerous advantages when compared to the use of synthetic products: (i) natural substances are obtained from renewable resources and are rapidly degraded – i.e. not persist in the environment; (ii) the development of resistance to these substances - composed by the association of various active ingredients - is a slow process; (iii) these pesticides these pesticides are easily accessed and obtained by farmers and and don't leave residues in food; (iv) have a low production cost.

The secondary compounds of plant are usually classified according to their biosynthetic pathway [12]. The insecticidal components can be divided into the following groups: substances derived from chemical compounds (tannins, terpenoids, flavonoids, alkaloids, quinones, limonoids and phenols); molecules produced from the processing of proteins (chitinases, lectins, α-amylase inhibitors and protease inhibitors) and volatile plant compounds such as essential oils [13]. The plant defense proteins most studied are lectins, protease inhibitors, α-amylase inhibitors, ribosomes inactivating proteins (RIPs) and storage proteins (vicilins) [14]. In this case, the plants can be used in developing safe methods applied in the control of insects. The mode of action can be presented in different ways: toxicity, delayed development, inhibition of feeding, deterrence, reduced fecundity and fertility.

In Microbiology and Toxicology Laboratory, located in UNISINOS (University of the Vale do Rio do Sinos, Rio Grande do Sul, Brazil), was evaluated the potential insecticide of extracts, decoctions and essential oils of medicinal plants as *Zingiber officinale*, *Artemisia absinthium*, *Cymbopogon citratus* and *Tanacetum vulgare*, to the control of *Anticarsia gemmatalis* (Lepidoptera: Noctuidae), the main soybean pest. The extracts were obtained by maceration of the plant tissue with liquid nitrogen and prepared with sterile distilled water, at 4° C, in the ratio 1:10. Essential oils and decoctions (aqueous phase) were obtained from medicinal plants by hydrodistillation technique, and the essential oils were diluted to 8%. In the bioassays were applied 10 µL of each treatment, on sections of soybean leaves, arranged on acrylic mini-plates containing moistened filter paper, where thirty larvae of the 2st instar of *A. gemmatalis* were individualized (Figure 1). In the control group, the treatments were replaced by sterile distilled water. The tests were kept under controlled conditions and the mortality was assessed at second, fifth and seventh days after treatment application, and then corrected by Abbott's formula.

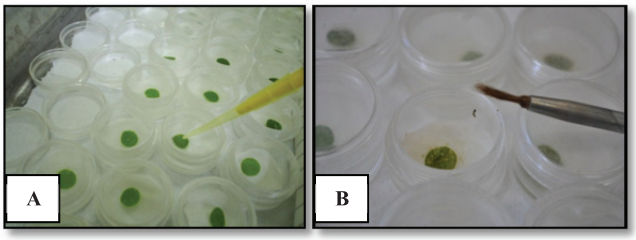

Fig. 1 a) Acrylic mini-plates containing moistened filter paper, with sections of soybean leaves, used in bioassays; b) larvae of the 2st instar of *Anticarsia gemmatalis* being deposited with a brush in acrylic mini-plates.

In the analysis of results, was obtained the Corrected Mortality (CM) of 90% for *A. gemmatalis* larvae treated with 8% of the essential oils of *Z. officinale* and *C. citratus*, and with the decoction of *C. citratus*. In larvae treated with the essential oil of *T. vulgare* the CM was 47%. In the other treatments the CM was less than 15%. These results show the potential application of essential oils and their by-products in the management of *A. gemmatalis*, ensuring greater safety, selectivity and biodegradability in the environment.

The Medial Lethal Concentration (LC_{50}) of the essential oils of *Eucalyptus citriodora* and *Origanum vulgare* in 1st instar larvae of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) was also assessed. This polyphagous insect occurs in major crops, such as rice. The oil was obtained by hydrodistillation and to the tests were used ninety larvae of *S. frugiperda* per treatment. The larvae were arranged on acrylic mini-plates containing moistened filter paper, with a section of soybean leave, where 10 µL of the treatments were applied. Six concentrations of the essential oil of eucalyptus: 8; 6; 5; 2; 0.8 and 0.5%, plus the control (acetone), were tested. The experiments were developed under controlled conditions (25° C, 12 hour photophase and 70% Relative Humidity), and the mortality was evaluated until the seventh day after the application of the treatment. The CM was determined by Abbott's formula, and the LC_{50} was obtained by Probit's analysis. In the data analysis, was obtained the CM of 93% for *S. frugiperda* larvae treated with the highest concentration of essential oil of *E. citriodora*, and the LC_{50} was estimated in 0,31 $\mu L/cm^2$. The essential oil of *O. vulgare* revealed a LC_{50} of 0,22 $\mu L/cm^2$ for *S. frugiperda* larvae. These data indicate the potential for future field trials and subsequent indication to compose Integrated Pest Management programs.

For the evaluation of sublethal effects of the by-product of *Malva* sp. and *Z. officinale*, in the *S. frugiperda* control, the decoctions were obtained through the technique of hydrodistillation, used to obtain the essential oils of these plants. The assays were performed as described above, and the sublethal effects observed were: duration of larval and pupal stage, size and weight of pupae, sex ratio and fertility of postures. The data were submitted to variance analysis and the averages compared by Tukey at 5% probability. The results of the lethality of *S. frugiperda* were corresponding to 5 and 24% of MC for treatments with decoctions of *Malva* sp. and *Z. officinale*, respectively. About the sublethal effects, evaluated over the life cycle, there was no significant difference ($p < 0.05$) in the size and weight of pupae, and in the larval and pupal period, when compared to the control. The proportion of males and females (1:1) was similar for both treatments ($p < 0.05$). When evaluated fertility in *S. frugiperda* adults, were found that in the treatment with hidrolact of *Z. officinale*, 81% of the eggs were infertile, while the decoction treatment *Malva* spp. did not differ from control ($p < 0.05$). Many times the lethal effects are not the primary objective to control the target pest, because they require higher doses and, therefore, of a large amount of raw material. Thus, the decoction of *Z. officinale* may be indicated for the control of *S. frugiperda* because it reduces the population growth of the pest, affecting the fertility of adults.

One way to increase the effectiveness of natural compounds is their use in conjunction with chemical insecticides or other biological control agents, such as Gram-positive bacterium *Bacillus thuringiensis*. This interaction relies on the principle that conventional insecticide or biocontrol agents act as insect stressors, leading to acquisition or activation of infectious diseases, making it more susceptible to the *B. thuringiensis* toxins [15]. The compatibility with other biological insecticides or natural agents of control is important in developing strategies that utilize entomopathogen in Integrated Pest Management programs [16]. In these cases, it is essential to study the potential interactions, mainly to make viable its use in economic terms and also to assess its impact on the environment [15].

Thus, tests were performed to evaluate the interaction of essential oils from *Z. officinale*, *Malva* sp., *A. absinthium*, *T. vulgare*, *C. citratus*, *Ruta graveolens* and *Mentha* sp., with *B. thuringiensis* subsp. *aizawai* (*Bta*) and *B. thuringiensis* subsp. *Kurstaki* (*Btk*), to the *S. frugiperda* control. The growth of the *Bta* and *Btk* isolates, originating from the commercial products Xentari® and Dipel®, respectively, was carried in glucose usual medium for 48 hours, at 28 ± 2° C and 180 rpm. Then, the material was centrifuged to eliminate the culture medium and bacterial suspensions were standardized to bioassays at a concentration of 1.10^9 cels./mL. The essential oils of medicinal plants were diluted in acetone (2%).

The thirty-two treatments with larvae of the 1st instar of *S. frugiperda* were: (a) acetone, (b) *Bta*, (c) *Btk*, (d) 2% of essential oil from *Z. officinale*, (e) 2% of essential oil from *Malva* sp., (f) 2% of essential oil from *A. absinthium*, (g) 2% of essential oil from *T. vulgare*, (h) 2% of essential oil from *C. citratus*, (i) 2% of essential oil from *R. graveolens*, (j) 2% of essential oil from *Mentha* sp., (k) *Bta* + *Z. officinale* (1:1), (l) *Bta* + *Malva* sp. (1:1), (m) *Bta* + *A. absinthium* (1:1), (n) *Bta* + *T. vulgare* (1:1), (o) *Bta* + *C. citratus* (1:1), (p) *Bta* + *Malva* sp. (1:1), (q) *Bta* + *Ruta graveolens* (1:1), (r) *Bta* + *Mentha* sp. (1:1), (s) *Btk* + *Z. officinale* (1:1), (t) *Btk* + *Malva* sp. (1:1), (u) *Btk* + *A. absinthium* (1:1), (v) *Btk* + *T. vulgare* (1:1), (w) *Btk* + *C. citratus* (1:1), (x) *Btk* + *Malva* sp. (1:1), (y) *Btk* + *Ruta graveolens* (1:1), (z) *Btk* + *Mentha* sp. (1:1). The bioassays were performed in two batches containing sixteen treatments. In the treatments, were applied 10 µL of products in sections of rice leaves (1 cm diameter) arranged on acrylic mini-plates containing moistened filter paper, where thirty caterpillars were individualized. For each test, three repetitions were performed, totalling 2.880 caterpillars assessed in tests of interactions. In the control, the volume of the treatments of the suspensions (10 µl) was replaced by acetone. The assays were maintained in an acclimatized chamber at 25° C, 70% Relative Humidity, with a 12 hour photophase. Mortality was assessed at 2, 5 and 7 days after treatment application, and then corrected by the Abbott's formula [17]. The mortality values were submitted to ANOVA and Tukey test ($p<0.05$) to compare the averages. To assess the degree of interaction between entomopathogen it was used the following terminology [15]:

1 - Independent Synergism: is a system where the two components act independently, without interference between them. The mortality (%) resulting from this synergy can be expressed as: $A_{1+2} = A_1 + A_2(1- A_1/100)$, where: A_1 and A_2 correspond to mortality caused by agents 1 and 2, respectively.

2 - Additional synergy: it is a system with two effective components that together produce a greater effect than the sum of the independent effects ($A_{1+2} > A_1 + A_2$).

3 – Sub additive synergism: is a system where the two components acting together produce a greater effect than the independent synergism, but less than the sum of the two individual effects.

4 - Additive effect: it is a system where the two components acting together produce a slight increase in its effect, for the performance of individual components, but not enough to be considered synergism.

5 - Antagonism: is a system where the interaction of elements produces a smaller effect than their individual performances. In this case, the interaction is considered negative, while the other four examples mentioned above, is considered positive.

In the study of the interaction between the products of the entomopathogen *B. thuringiensis* and the essential oils was found antagonism when applied *Bta* x *T. vulgare*, *A. absinthium*, *Z. officinale* and *C. citratus*, as well as *Btk* x *Malva* sp. and *T. vulgare* (Table 1). The inhibition of the action of *B. thuringiensis* can be due to decreased intake of the treatment, or by competition between the essential oils and the microorganism by the host. [18]. This type of effect is common when agents of different natures interact [19].

Table 1 Data from the interaction of *Bacillus thuringiensis* subsp. *aizawai* (*Bta*) and *B. thuringiensis* subsp. *kurstaki* (*Btk*) with the essential oil (2%) from *Malva* spp., *Mentha* spp., *Cymbopogon citratus*, *Zenziber officinale*, *Artemisia absinthium*, *Tanacetum vulgare* and *Ruta graveolens* to larvae of the 2st instar of *Spodoptera frugiperda*.

Treatments	MC (%)	*Bta* MC (%)	Type of interaction	*Btk* MC (%)	Type of interaction
Ruta graveolens	17b	77e	Sub additive synergism	64d	Additional synergy
Malva sp.	1a	80e	Sub additive synergism	38c	Antagonism
Tanacetum vulgare	18b	64d	Antagonism	39c	Antagonism
Artemisia absinthium	3a	51d	Antagonism	58d	Additional synergy
Zenziber officinale	39c	56d	Antagonism	61d	Sub additive synergism
Cymbopogon citratus	31c	61d	Antagonism	60d	Sub additive synergism
Mentha sp.	22b	81e	Sub additive synergism	67e	Additional synergy
B. thuringiensis aizawai			69e		
B. thuringiensis kurstaki			40c		
Control			0a		

Means followed by same letter do not differ significantly by Tukey test at 5% probability. CM = Corrected mortality.

The antagonism, according to [15], can have various causes such as: (i) small doses of a given insecticide can have repellent effect or may decrease insect activity, thus the insect does not come into contact with lethal amounts of pesticide or pathogen; (ii) the pathogen may have ability to metabolically degrade the pesticide molecule, preventing or decreasing its action on the insects; (iii) the use of sub-lethal dose of insecticide can produce an increase in metabolic rates and a consequent increase in the immune response to the pathogen.

B. thuringiensis acts through ingestion and has its action initially restricted to the insect's digestive tract. However, through the mechanism of action triggered by Cry toxins, toxins and enzymes spread by the insect's body, causing sepsis [18; 20]. At that time, occurs competition with secondary compounds present in the essential oils tested in this study.

In studies with extract of the leaves and the volatile oil from *Taxodium distichum* and *Boswella carterri*, in combination with *B. thuringiensis* and the fungi *Beauveria bassiana*, for the control of stored product pests, Sabbour [21], there was a reduction significant value in the LC_{50}. According Novan [22], the use of plant extracts reduces the insect feeding due to the presence of allelochemicals, which optimizes the insecticidal activity of the organism, resulting in a higher mortality rate. Thus, the plant extracts appropriately selected and in appropriate concentrations, may be used in combination with entomopathogens to obtain additive or synergistic effects in the control of pests [23].

Knaak et al. [24] evaluated the effect of the interaction of various plant extracts with Xentari® in the midgut of *S. frugiperda*, demonstrating that the pathological effects of *Z. officinale*, *M. silvestris*, *R. graveolens* and *Baccharis genistelloides* were more intense when compared to *Petiveria alliacea* and *C. citratus* extracts, which showed a positive interaction with Xentari®, accelerating the process of destruction of intestinal cells, which represents a reduction in lethal time of *S. frugiperda*. In this study, was observed the synergistic interaction between *Bta* with essential oils from *Malva* sp., *R. graveolens* and *Mentha* sp. (Table 1), demonstrating that both the extract, such as oil plants, stimulate the action of the pathogen. Thuse, *Btk* obtained a synergistic effect with *R. graveolens*, *A. absinthium*, *Z. officinale*, *Cymbopogon citratus* and *Mentha* sp.

3. Antimicrobial activity

The natural antimicrobial compounds capable to inhibit the growth of microorganisms, including bacteria, viruses and fungi, are a new way to ensure a healthy feeding, since it maintains unchanged the quality of food. Plants can co-evolve with microorganisms and insects, and are natural sources of insecticides and antimicrobial substances which may be synthesized in response to attacks by such organisms. The use of plant extracts, including allelochemicals compounds, such as essential oils, were used in the antimicrobial control, before the advent of synthetic organic substances [25]. In nature, the most plants are resistant to different pathogens and this resistance may be related to the natural synthesis of insecticides and fungicides [26].

The isolated compounds of plants are substances whose chemical structure, with rare exceptions, has major difference compared to antibiotics derivatives of microorganisms. These antimicrobial agents isolated from superior plants may act by regulating the intermediary metabolism, by enabling or blocking the enzymatic reactions, determining the occurrence of the synthesis in molecular or ribosomal level. In addition, antimicrobial agents may alter membrane structures [27].

The fungicide effect from plant extracts of *Symphytum officinale*, *R. graveolens* and *P. Alliacea* was valued to determine the potential application in control of the plant pathogens *Bipolaris oryzae* and *Gerlachia oryzae*, important pests of irrigated rice. The aqueous extracts of medicinal plants have been obtained by maceration with liquid nitrogen, and then dialyzed in retention 3 kDa-membrane. To determine the antifungal activity of plant extracts methods of Kirby-Bauer and incubation were used. Protein concentrations of plant extracts was estimated by Bradford‘s method and the protein profile was assessed on SDS-PAGE (15%). Data relating to mycelial growth of *G. oryzae* (Table 2), after the treatment with plant extracts, indicated that *R. graveolens* did not differ significantly (p<0.05) of the control group. On the other hand, the other treatments resulted in the inhibition of mycelial growth of *G. oryzae*, which was maintained until the 14th day after the treatment application (DAT). When evaluated the Colony Forming Units (CFU), it was observed that none of the treatments differed significantly from control. The aqueous extracts of *R. graveolens* and *P. alliacea* caused a reduction in the number of conidia, but it was not found any difference in the UFC's number, compared to control. The results for the treatments with plant extracts on *B. oryzae* showed that only the *S. officinale* extract inhibited the vegetative growth of the fungus, when compared to control. In the evaluation of CFU's of *B. oryzae* (Table 2) it was observed that all treatments, except *Cymbopogon citratus* extract, were significantly different from control (p<0.05). In contrast, *R. graveolens* extract stimulated the production of conidia. From the protein profile analysis was noting that the extracts of *A. graveolens*, *S. officinale* and *P. alliaceae* had estimated polypeptide fragments between 30 and 50 kDa.

Table 2 Average diameters of the colonies, halos of inhibition of growth, colony forming units (CFU's) and number of conidia of fungi *Gerlachia oryzae* and *Bipolaris oryzae* submitted to treatments with medicinal plan extracts.

Treatments	***G. oryzae***				***B. oryzae***			
	7DAT mm*	**14DAT mm***	**CFU**	**Conidia Nºx10^5**	**7DAT mm***	**14DAT mm***	**CFU**	**Conidia Nºx10^5**
Ruta graveolens	9b	9b	423c	1,63b	9a	9^a	365b	279c
Symphytum officinale	9b	9b	207a	91d	9a	9^a	300a	404d
Petiveria alliacea	1,77a	1,41a	384b	0,98a	9a	9^a	456b	162b
Control (PBS)	9b	9b	339b	26,28c	9a	9^a	660c	121a

Means followed by same letter in the column do not differ significantly by Tukey test at 5% probability. DAT = day after the treatments application, CFU = colony forming units, * inhibition halo of mycelial growth.

Tanacetum vulgare extract, when evaluated in the maximum concentration (822 µg/mL), on the fungus *B. oryzae*, inhibits sporulation (2A), because it was statistically different (p<0.05) from control. Thus, there was antagonistic effect on the biological activity of the extract.

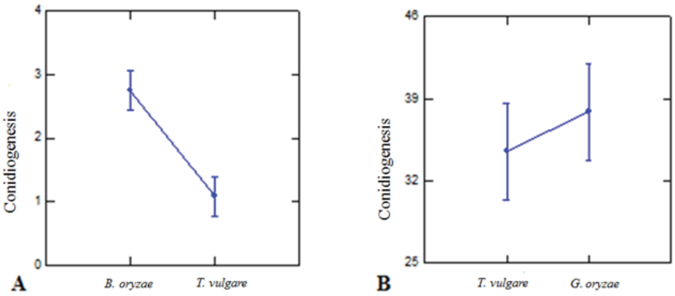

Fig. 2 Average conidiogenesis of pathogenic fungi: a) *Bipolaris oryzae* (3BCX) and b) *Gerlachia oryzae* (FAEM01), after incubation with the maximum concentration of *Tanacetum vulgare* extract.

On the other hand, *G. oryzae* incubated with *T. vulgare* was statistically similar to the control (Fig.1b), so there was no inhibition of conidiogenesis. When measuring the CFU's production, it was found that the T. vulgare extract resulted in an average of 392 CFU and the control produced an average of CFU 220. Thus, the extract resulted in an increase in the number of colonies *G. oryzae*, showing a synergistic effect. The data reveal that toxins present in *T. vulgare* can produce antagonistic effect on fungus *B. oryzae*.

Considering the number of different groups of chemical compounds present in the plants, it is very likely that their antifungal activity is not attributable to a specific mechanism, but to existence of multiple targets in cells, causing changes in the cytoplasmic membrane, active transport and coagulation of the cellular content. Not all of these mechanisms reach separate targets, may occur in signaling reactions or in chain [28]. Even if the individual interaction of a secondary metabolite can be weak and unspecific, the sum of all interactions can lead to a substantial effect [29].

4. Biotechnology

Since the emergence and development of agriculture, in the early days of mankind, were made biotechnological practices, which facilitated access to food. This procedure initiated the selection of best grains and plants, more productive and palatable. This period took millions of years of selection of our species *Homo sapiens* than, to seek more knowledge, succeeded in conquering our planet. However, all this has a cost and today we have the need to develop and increase our production, always thinking about sustainable process [30].

According to Boaretto [31], FAO data show statistics that currently our food production and consumption is balanced, but with a population of 7 billion - it is estimated that by 2050 would be around 9 billion - it is essential to increase around 70% of food production. Therefore, in this millennium, we have as challenge overcome human population pressure without causing major environmental impacts, using the productive areas with raw materials bio-leveraged primarily for food and feed. According Pimm [32] are produced annually 132 billion tons of biomass for human consumption or not, but unfortunately, much is wasted - about almost 60%. So, what to do for the population in the future has sufficient and quality food? What is the role of science today to ensure human life tomorrow?

For this, the food should be nutritious and produced in sufficient quantities giving security guarantees to the consumer. This should be implemented via specific legislation which reduces the use of chemicals until their elimination altogether in agricultural production. At the same time, we need healthy food production policies with bioactive compounds, promoting preventive increasing population immunization, avoiding the appearance of certain diseases [31].

According Mendonça [33], a need exists for highly productive organisms that may address several problems associated with limited resources. This limitation can be caused by: (i) soil depletion; (ii) lack of water; (iii) low occurrence of nutrients in the soil and (iv) climatic imbalances. All these factors can cause high losses in productivity, which tend to worsen over the years. For this reason, there is a greater incentive for development of biotechnology agro-productive and of the agro-ecology, so that farmers undertake the management of its natural resources and continue to be competitive in this capitalist world.

Agro-ecology is based on high-quality biological production, which aims to minimize operating costs and impacts caused by the saturation of agricultural land, maintaining biodiversity and supplying to society necessary raw materials for bioenergy, biochemical and feed [33]. Therefore, to ensure competitiveness and sustainability of production in the face of climate change and to the biotic and abiotic stress in cultivars, the use of the agro-ecology coupled with biotechnological knowledge is very important.

Currently, biotechnological advances are usually associated with the development of techniques that maximize the use of raw materials. In this context, plant biotechnology has evolved in many ways as the production of biofertilizers and biopesticides, promoting essential conditions for agro-ecological process. The report of the International Service for the Acquisition of Agri-Solutions (2010), shows that Brazil grew about 22 million hectares of transgenic plants and became the second largest producer, in a universe twenty five producing countries [34]. This is related to economic benefits obtained that reached US$ 18.8 billion in sixteen years of use of biotechnology in agriculture - 81% were with producers and 19% with industry [35].

In a competitive agriculture, biotechnological cultivars developed by RT-PCR and ELISA techniques, form potentiated lineages derived from inoculations of nucleic acid sequences in the biosynthetic route of the organism. The biotechnology program of micropropagation, which enables the development of seedlings via gene sprouts, also strengthens the process of multiplication and plant cloning [36]. It is also important to note that, for plants, in addition to the characterization of small molecules and proteins, there are other macromolecules like cellulose and lignin, which should be analyzed within the genomic approach. The metabolic profile (metabolomics) is not only of interest for functional genomics, but also for several other important situations, as in the application of that knowledge in the production of transgenic safe to human health. The chemistry of natural products, in the post-genomic era, remains an essential tool for understanding of the cellular metabolic mechanisms and its functions. This also applies to substances are not involved in the basic metabolic processes of the cell, but which account for signaling, adaptation, pollination and defense [37].

Therefore, the agricultural sector must establish integration between the agro-ecology program and the biotechnology, increasing the public-private partnerships and academic research, based on technologies applied in agricultural production, thus generating business opportunities through the science and the agribusiness.

5. Conclusions

The richness and structural complexity of natural products offer an endless substrate for the search of bioactive substances of agronomic interest and in food preservation. The different selective pressures imposed by different evolutionary scenarios led to the production of the huge variability and structural complexity of these substances. The growing interest in phytotoxins is related to wide range of new sites of action in target organisms. In this case, even if they are not commercially available, may indicate paths for the synthesis of new products. This is important when considering the speed with which insects and microorganisms have developed resistance to chemicals commonly used target species control agents.

Studies about the use of plant products in agriculture involve the social, economic and environmental aspects. Plant products are biodegradable, but this feature limits the control of certain pests, by having little residual effect, leading to the need for new applications. The exploitation of plants should be made in such a way that allows the preservation and conservation of the species. To ensure the success of the use of botanical insecticides, all aspects must be considered from the survey and the evaluation of wild species to the mapping of the active ingredients and of their concentrations in the different plant parts.

Acknowledgements The support by FAPERGS and CNPq is gratefully acknowledged.

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