USE OF PLANT EXTRACTS AS AN ENVIRONMENTALLY FRIENDLY INSECT PEST MANAGEMENT METHOD

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Abstract

The use of natural insecticides from plant extracts, as safe insecticides are well known since ancient and has enormous intuitive appeal. The unique properties of the toxic principles from the plants with pest-control properties are as repellents, antifeedants, oviposition deterrents, and insect growth regulators. Otherwise, natural insecticides are low cost, local availability, safe to the environment and non target organisms and compatible with the agroecosystem. Use of synthetic insecticides can cause the development of insect resistance, resurgence, secondary pests and environmental contamination. Also, use of plant extracts as natural insecticides emphasizes their great potential value in crop pest management.

Key words: plant extracts, integrated pest management, preservation of biodiversity

Introduction

The application of insecticides is currently the common method to control or eradicate pest animals and plants. Many insecticides have non-specific properties, i.e. they do not kill the targets, but also affect other organisms, non-vertebrates and vertebrates to a varying degree. The damage to these non-target organisms may be reflected by sub-lethal, physiological or behavioral effects, direct mortality, long-term population reduction, or in the case of persistent insecticides as a result of bioaccumulation within the ecosystematic food web as a whole. Insecticides are never target specific and the aerial dispersion of insecticide over thousands of square kilometers must be regarded as potentially hazardous to man and environment (Müller 1990, Arinafril 2000, Arinafril and Müller 2001, Arinafril *et al*., 2001).

Plants are the richest source of organic chemicals on earth. Such antifeedants act at low concentrations and are perceived by specialized deterrent receptors or by their modifying effect on normal chemosensory input. In some cases, habituation to the presence of antifeedants occurs. Although only about 10.000 secondary plant metabolites have been chemically defined, it is estimated that the total number of plant chemicals may amount to 100.000 or more. The current use of antifeedants as dependable crop protection under field conditions is still limited. Moreover, in most cases no natural compounds are involved, but synthetic organometal compounds. Although the prospects of preventing insect infestations by using natural feeding inhibitors hold some promises, this method appears to be still in its infancy. Its further development requires much more fundamental knowledge about insect feeding behavior and its chemosensory basis, and the converted efforts by organic chemists to identify natural plant substances and to develop procedures for large scale isolation or synthesis of active compounds (Schoonhoven 1982, (Chiu 1985, Klocke 1987, Arnason *et al*. 1989, Schmutterer 1995, and Arinafril 1999).

History

It is well known that some insecticides of plant origin have been in use before the time of the Romans, e.g. pyrethrum, obtained from the flower heads of *Chrysanthemum cinerariifolium* (= *C. cineariafolium*) was already known during the time of the Persian King Darius the Great (521 - 486 B. C.) (Schmutterer 1995). By 1828 pyrethrum was being processed for commercial insect control, and by 1939 imports of pyrethrum into the United States reached a peak of 13.5 million pounds. Use of natural product declined in the early 1950's because of the advent of synthetic pyrethroids analogs, e.g. allethrins, which were both more stable and more effective in the field (Klocke 1987).

Some of these extracts have yielded compounds useful as sources (e.g. pyrethrins, rotenoids and alkaloids), others as models (pyrethrins, physostigmine) of commercial insecticides. Recent technological advances which facilitate the isolation and identification of the bioactive constituents of plants should ensure the continued usefulness of plant compounds in commercial insect control, both as sources and models of new insect control agents and also as components in host plant resistance (Steets 1976, and Klocke 1987). They were largely abandoned during the era of synthetic pesticides, but now the study of natural pesticides contributes novel approaches in control strategies for pests. Botanical pesticides are plant natural products that belong to the group of so-called secondary metabolites, which includes thousands of alkaloids, terpenoids, phenolics and minor secondary chemicals. These substances have no known function in photosynthesis, growth, or other basic aspects of plant physiology, however, their biological activity with insects, nematodes and phytopathogenic fungi among other organisms (Schmutterer 1988, 1995, and Jacobson 1989).

Pyrethrum powders were first used around 1800 and by 1951 their usage was world wide. Pyrethrum concentrations may be prepared from the ground flowers by extracting with petroleum ether, acetone, glacial acetic acid, ethylene dichloride or methanol (Matsumura, 1985). Rotenone and rotenoids have long been used as insecticides and piscicides (fish poisons). By the early 1950's more than 7 million pounds of leguminosae roots (e.g. *Derris*, *Lonchocarpus* and *Tephrosia* spp.) containing these insecticides were imported annually into the United States (Klocke 1987, and Grainge *et al*. 1984).

Plants with Pest-Control Properties

Many other plants are presently investigated for the presence of feeding inhibiting compounds and many crude plant extracts are tested on a few notoriously devastating insect species (Jacobson 1978, and Reed *et al*. 1981). Interest in naturally occurring pesticides has enjoyed a renaissance during the past 20 years. Such materials as pyrethrum and rotenone have long been known, but their uses suffered a decline following the discovery of inorganic and organic molecules with lower costs, greater toxicity and more durability to effects such as weathering. Now chemists working in conjunction with pest control scientist have opened a whole panoply of new materials for experimentation and possible use including insect growth regulators, receptors, and feeding agents, such as microbial insecticides and plant growth regulators like plant hormones, secondary plant products and allelopathic agents. Chemists have synthesized pyrethroids so that we can choose between natural and synthetic versions of these naturally occurring pesticides (Perkins, 1985, and Claßen 1987).

Feeding activity includes taking the first bite, swallowing and continuous feeding. It has been suggested that *suppressants* suppress biting activity and that *deterrents* prevent the insect from further feeding. Since it is often unknown which phase of feeding is interrupted, many authors use *antifeedants* and *feeding deterrents* synonymously for substances which when contacted prevent or interrupt feeding activity. Occasionally the term *rejectant* is used which does not necessitate discrimination between suppressants and deterrents. The term “repellent” should not be used in this context since it includes an oriented locomotion away from the source of stimulus (Schoonhoven 1982, Blaney *et al*. 1995, and Schmutterer 1995)

Chemical interactions between plants and insects are also associated with secondary plant substances, which are of little or no nutritional value. These substances influence various physiological processing resulting in growth inhibition, retardation of development of general toxicity (Slàma 1969). The search for new insect control substances of plant origin has recently attracted great interest throughout the world. During the last 25 years intensive and pioneering research on neem and its derivatives has established the potential role of botanicals in the field of antifeedants, repellents, toxicants and growth regulators. Feeding deterrence acts immediately and protects the specific plants (Islam 1986).

Chemical inhibition of feeding has been studied in detail for only a few insect species, but inhibitory chemicals play a considerable part in host plant selection by a wide range of phytophagous insects from several orders. Many different chemicals are involved, some of them amongst the normal constituents of plants. A few have a general effect, preventing feeding by all the insects, which have so far been tested, but the majority are effective only against some species (Chapman 1974).

Certain plants contain substances with insect hormone like activity. These hormone analogues may influence insect-plant interactions like some other factors such as nutritional requirements, chemoreception, and toxicity. Experimental evidence indicates that an external supply of the hormonal substances, which comes from the plant without respect to the physiological control mechanisms, disturbs the precise synchronization of insect development and leads to the appearance of malformed creatures unable to survive and reproduce (Sláma 1969). The secondary compounds of plants may protect them against phytophagous insects either by preventing feeding or by poisoning and rapidly disabling those insects, which do feed. The same compound may act in either of these ways with different insect species Such feeding deterrence and or growth regulation may be correlated with the magnitude of biochemical changes in the test species (Jacobson *et al*. 1978, and Blaney *et al*. 1990).

The active constituents of the extract are collectively referred to as pyrethrins, which can give rise to confusion, as two specific constituents are known as pyrethrin I and pyrethrin II. There are six active constituents of pyrethrum extracts. These are esters of two carboxylicacids, chrysanthemic acid, and pyrethric acid, and three cyclo-pentenolones (known collectively as rethrins), pyrethrolone, cinerolone, and jasmolone. Synthetic pyrethroids are now replacing the conventional insecticides. These insecticides, which are a synthesized version of the extract of the pyrethrum flower, are much more attractive biologically than the traditional insecticides. The pyrethroids are found to be very specific for killing insects and apparently exhibit no negative effects on plants, livestock or humans. Another apparent benefit is that there is no resistance to these compounds accumulated in the insects (Mandava 1985, Saxena 1987, and Kubo 1993). Superior plants have developed through time, many different compounds which play crucial role in their defense mechanisms against pest attack and which are broadly speaking classified as secondary metabolites (Steets 1976, Stein and Klingauf 1990, and Schmutterer 1995).

Effectiveness of Plant Extracts as Botanical Insecticide

Substances of plant origin, as alternative of the conventional chemical insecticides, have recently attracted great interest throughout the world (Dimetry *et al*. 1996). There is no doubt that many plant secondary metabolites affect insect behavior, development and reproduction. Identifying theses substances is an important first step in understanding the effects of plants on insect life at the molecular level. Besides benefits to basic science, accumulation of this knowledge may provide us with a more rational and scientific approach to insect pest control. Plant defenses to insect attack usually involve diverse secondary metabolites (Kubo 1993).

Antifeedants are the chemical substances which when perceived, reduce or prevent insect feeding. Consequently, growth, development, survival, and reproduction are adversely affected. They are generally pest-specific and therefore harmless to non-target organisms. Because of their biodegradable nature and relative safety to beneficial organisms in the environment, research on the biological activity and chemistry of antifeedants has been emphasized. Programs have been launched in several countries for developing feeding deterrent known to occur naturally in some plants (Fraenkel 1959, and Saxena 1987).

Inhibitory chemicals may be applied to plants in the same way as insecticides, their advantage being that the parasite or predator complex of species not feeding directly on the plant will be unharmed. An alternative approach is to breed resistant varieties of plants by selecting for inhibitory attributes. Although many varieties of crops are known which are insect resistant, the basis of the resistance is generally unknown. A more through understanding of the mechanisms involved in inhibition of feeding by chemicals would enable a more logical approach to be made to the development of resistant plants (Chapman 1974, Schwinger 1985 , and Dreyer 1986). The naturally occurring pesticides appear to have a prominent role for the development of future commercial pesticides not only for agricultural crop productivity but also for the safety of the environment and public health. They are produced by plants, insects, and several microorganisms, which utilize them for survival and maintenance of defense mechanisms, as well as for growth and development (Mandava 1985). The chemical composition of plants is of fundamental significance in their acceptance or rejection as food by insects. This is true with regard both to make selection between different plant species and to selection between the different parts of plant. In many cases feeding inhibitors are of primary importance in determining which plants are eaten and it is recognized that the use of chemicals, which inhibit feeding, is considerable potential value in crop production (Jermy 1965; and Munakata 1970).

In the 1990’s consumer demand is placing pressure on pest control specialist, as well as greenhouse and row crop growers to use “natural” or “green” pest control agents. For developing countries, botanical pest control products could address the problem of pest resistance to synthetic insecticides through their alternatives of action and product an opportunity to develop a value added product based on local natural resources (Grainge *et al*. 1984, Arnason *et al*. 1992, and Arinafril 1999). However, there are various impediments to the control of pest insects using environmentally sound practices. For example, methods that might be considered organic (biocontrol and or natural products) are often low in efficacy and therefore not practical. Also, some pesticide manufactures may attempt to market relatively persistent traditional synthetic chemical agents in their formulations through the use of "green" terminology (Ewete 1996, and Arinafril 1997).

There are however, some highly effective natural plant products with potential for use as pest control agents that possess the desirable characteristics of low mammalian toxicity, rapid biodegradability and soft modes of action such as behavioral deterrence against insects (Arnason *et al*. 1992). Several plant extracts and / or their isolated active compounds have exhibited enormous potential as acute or chronic insecticides, insect growth regulators, or antifeedants against a variety of insects. Several of the compounds, especially those produced by crop plants and other organisms, are consumed by humans and livestock, and yet appear to have no detrimental effects. They appear to be safe and will not contaminate the environment. Hence the public and the regulatory agencies will readily accept them for use as pest control. These natural compounds occur in nature only in trace amounts and require very low dosage for pesticide use. (Mandava 1985, Jacobson 1989, Schmutterer 1990, 1995, and Arinafril 1997).

Nowadays botanicals are being frequently recommended for plant protection particularly in subsistence crops in Third World countries. However, the effect of these preparations is often times not fully known. In recent years increasing attention has been paid again to traditional practices of plant protection in small farmer's holdings in developing countries. Besides cultural practices, especially plant extracts for pest control are regaining interest. The efforts to encourage this kind of self-sufficiency are often hampered by the fact that such traditional methods lack in a scientific basis. This often leads to wrong appraisals and thus to failures (Hassanali and Iwande 1989, Jacobson 1989, Stein and Klingauf 1990, and Downum *et al*. 1993). In recent years there has been increased interest in the use of natural compounds for pest control. With so vast a variety of compounds it may be expected that they affect various functions both in the organisms producing them and in those feeding on such plants. It is well known that secondary plant metabolites may act as kairomones, allomones, stimulants or deterrents of feeding and oviposition, antifeedants, insecticides and insect hormones. However, the investigations in this field are fragmentary and many compounds may posses still other, so far unknown biological qualities (Swain 1977, Alkofahi 1989, and Berenbaum 1989).

Insect growth regulators, including analogs and antagonists of endogenous hormones, have also been identified in plants. Prominent among these are the analogs of two insect hormones (Juvenile Hormone or JH and molting hormone) and the antagonist for JH. The possible consequences of antihormonal action on insect development have been calculated on the basis of the available information concerning the function of the neuroendocrine system. Hormonal inhibition, as revealed by some final developmental consequences, may be imposed at different points of neuroendocrine action chain (Sláma 1969, Claßen 1987, and Klocke 1987).

Neem as Potential Botanical Pesticide

The most important plant that posses pesticidal effect is the Neem Tree (*Azadirachta indica* A. JUSS.). This species is native to the tropical and some parts of the subtropical belt of the earth. This means, it is distributed mainly in developing countries and for the farmers it is easy and not expensive to prepare extracts with insecticidal activity. Various parts of the neem tree have long been used in India for their reputed medicinal or insecticidal. Furthermore, neem oil is used on a small industrial scale for soap production. At the beginning of this century the neem tree was introduced to many other tropical countries, especially in Africa. Here, many of its properties are still unknown and it is mostly used for firewood and as a shade tree. Recalling the insecticidal properties of neem, researchers began programs in the early sixties to identify the active principles and to screen insect species against which they can work. The results to date indicate that there are several active compounds, which are mostly concentrated in the seeds. Some of them inhibit larval development and reduce female fertility in various insect species by blocking insect hormones. Others act as repellents or antifeedants (Jacobson *et al*. 1978, Jacobson 1989, Downum *et al*. 1993, and Schmutterer 1995)

Many investigations have been carried out in isolation, identification and screening to find out the active principle. The most important active ingredient is azadirachtin. Azadirachtin, a triterpenoid, may be one of the more promising botanical substances for use in insect control. Neem extracts containing azadirachtin and the related triterpene limonoids, salannin and meliantriol, are readily available at low cost from this widely distributed tree. Neem extracts are known to have antifeedants or growth reducing activity to over 400 species of insects (Butterworth and Morgan 1971, and Arnason *et al*. 1985).

Azadirachtin and azadirachtin-containing neem-seed extracts cause various effects in insects. They act as antifeedants, growth regulators and sterilants. The effect upon insect development in most important from the viewpoint of practical insect pest control. (Steets 1976, Feuerhake 1985, Schwinger 1985, Dreyer 1986, and Schmutterer, 1988).

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