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Comparative Studies of Commercial Insecticides and Bio-pesticides

Nisha Mohideen, Mohd Hashim Khan and Karthikeyan Ramalingam*

Department of Biotechnology, Saveetha Medical College and Hospital, Tamil Nadu, India

***Corresponding author:** Karthikeyan Ramalingam, Departmentof Biotechnology, B.S. Abdur Rahman Crescent Institute of Science and Technology, GST Road, Chennai, Tamil Nadu, India Tel: Phone: +91 44 22759223; E-mail: karthikeyan.sls@crescent.education

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Abstract

Insecticides and pesticides act as a broad spectrum for pests and are particularly harmful to birds and humans in many circumstances. Most harmful insecticides have been banned in various countries because of its high toxicity, but are still available in developing countries like India. There have been many deaths recorded because of these chemicals and other insecticides. So it is high time that we shift to safe alternates for the pesticides. So, an alternative nanoemulsion formulation synthesized from bio products can be used instead of the toxic insecticide. A nanoemulsion refers to a colloidal system consisting mainly of aqueous phase- water, a surfactant for stability, and oil of choice. Number of studies has been conducted confirming the antimicrobial and insecticidal activities of different nanoemulsions. The LC 50 value can be found using the acute toxicity test. The soil and leaf parts of the plant that has been exposed to the test materials can be subjected to residual analysis test .This review is written to demonstrate the toxic effects of the insecticides on various non-target organisms such as aquatic life and the soil microbes and to provide a possible harmless green alternate in the form of nanoemulsions and other bio-pesticides.

Keywords Insecticides; Nanoemulsion; Bio-alternative; Acute toxicity studies; Residual analysis test

Introduction

Insecticides in Agriculture

Since the time when people synthesized and used it in the field, the insecticides have been provided significant importance in plant disease control and enhancement in crop yield. Agrochemical industry is a huge field and usually deals with production and distribution of pesticides and fertilizers for various purposes. Yet, pesticide use is associated with many unfavorable effects. Residues have been found in many food crops and it has proven to be highly carcinogenic. It also kills beneficial organisms like fishes, microbes and non target plants. In Brazil, contamination of water with pesticides have been stated as the major threat to fish population and the productivity has also been decreased considerably [1]. It is also responsible for some serious ground water and soil contamination. For example, Monocrotophos is an organophosphate insecticide that was widely used as an insecticide in agriculture. But recently, its use has been banned in most developed countries due to its high toxicity levels and its effects on various organisms [2]. So, it is essential to devise other substances that have the same pesticide effects but without any effect on the environment. There are other options such as bio-pesticides. In olden China, Greece and India, plant derivatives were used as insecticides. Presently there are three major bio products used to control insects namely neem, essential oils and pyrethrum. Pyrethrum is obtained from oleoresin which is extracted from the flowers of the daisy, *Tanacetum cinerariaefolium* after drying it. Then the flowers are powdered and extracted with a non- polar solvent such as hexane. After this solvent is removed, it produces an orange liquid that contains the major active components. The insecticidal activity of the pyrethrin is known by a swift knockdown effect, predominantly in insects that fly, and other than that by convulsions and hyperactivity in many insects. Such symptoms occur due to the toxic action of the pyrethrins which affects the neuro systems which blocks voltage-gated sodium channels in nerve axons. Neem oil is produced by cold pressing the seeds, and is efficient against soft body insects. It has also been proven to efficient against phytopathogens. Azadirachtin acts in two ways on the insects. In the physiological level, it blocks the production and discharge of the molting hormones (ecdysones) from the prothoracic gland, which leads to unfinished ecdysis in immature insects. In grown insects (females), a parallel means of action leads to sterility [3].

Oils as insecticides

Essential oil has noteworthy effects on a large range of insects that attack grains in storage, which acts either through ingestion or by contact. In addition, they also show fumigant effect, repellent effect and anti-feedant effect. They can also be considered as practical tools to handle fungal and bacterial plant pathogens, including microbial populations in stored products [4]. There are various compounds in the essential oils that are responsible for their insecticidal activity like phenols, alcohols, terpenes, ketones, esters, etc. [5]. Pesticidal behavior of *Rosmarinus officinalis, Lavandula hybrida and Eucalyptus globules* oils and their 16 other chemical constituents were studied and they all showed efficacy against both female and male adults of *A.obtectus* [6]. Similarly various essential oils have been studied for their insecticidal and pesticidal activity against various pests and insects. In spite of these exclusive characteristics, insecticides from essential oil also have a few cons like limited water solubility, poor physical stability, quickly degrading, and raw material shortage from which they are produced. These restrictions make their application practically hard to attain [7].

Nanotechnology in insecticides

The study which focuses of particles with even one dimension in the size range of 10-100 nm is called nanotechnology. As the ratio of surface area to volume increases, the particle size decreases, and their chemical, physical and biological properties of the particles vary in comparison with their bulk counterparts [8]. A fine approach to overcome the drawbacks in normal essential oils is by the incorporation of nanotechnology. Nanoemulsions are useful to improve various aspects of the essential oils like diffusion in water, physical stability and bioavailability, limited toxicity of non-target organisms and less irritation [9]. Application of nanotechnology may increase the taste, texture, and stability characteristics of food [10].

One of the capable oils with insecticidal activity is the castor oil obtained from castor seeds. These are the seeds of the *Ricinus communis* plant. It is a species of perennial plant in the Euphorbiaceae family. The seeds contain between 40%-60% oil that is loaded with triglycerides, primarily ricinolein. Ricin present in the seeds is a water-soluble toxin. It is also present throughout the other parts of the plant in small quantities. This ricin may be held responsible for the insecticidal and larvicidal properties of the oil nanoemulsion. Larvicidal activities of the castor oil nanoemulsion against malaria vector *Anopheles culicifacies* have already been demonstrated. The experiment was conducted to check the insecticidal efficiency of both castor oil bulk and nanoemulsion. It was concluded that castor oil nanoemulsion can be used as a harmless and effective alternative and it was very effective than the bulk castor oil [11]. Other nanoemulsions prepared from certain other oils have also proved to be good substitute to pesticides and insecticides. Nanoemulsions were also prepared from eucalyptus oil (Eucalyptus globulus) for the control of *Tribolium castaneum*, a secondary pest of stored grains which has also been proved to be quite effective [12].

Plants have been accepted as a good resource of insecticidal activity, as they have their own defense mechanisms in case of insect attack. But, several bio products with insecticidal activity have less water solubility. To overcome this, nanotechnology has emerged as a fine alternative. So, plant based nanoemulsion was prepared using plant extracts such as *Manilkara subsericea*. It was observed that the insecticidal activities were very good and were safe for the non target organisms. There were also no toxic components in the formulation which makes it considerably more desirable [13].

The red flour beetle, *Tribolium castaneum* is a vital pest of stocked products. To overcome this, study was conducted to produce a nanoemulsion from the essential oil of *Pimpinella anisum L*. that contains approximately 81.2% of (E)-anethole. This improved the stability of the active components and enhanced its effects on the pests [14].

Acute toxicity studies

Acute toxicity studies are done to determine the short-range adverse effects of a drug when administered in a single dose or in multiple doses during a short phase such as 24-72 hrs. The aquatic ecosystem is presently under peril by the use of synthetic pesticides for human benefits and thus causes towering risk to non-target organisms. Organisms like fishes are affected by pesticides that pollute the natural water by the water from agricultural runoff. A study using *Cyprinus carpio* was conducted to demonstrate the difference between bio-pesticides named neem gold and two commercial pesticides-monocrotophos and permethrin. By the obtained LC 50 values and the physical signs exhibited by the fishes, it can be seen that the usage of bio pesticide for the control of pests in fields is safe and more environmentally benefitting than toxic pesticides. Along with the LC50 value, other teratogenic and developmental effects such as hatching and overall mortality are also observed, other physical altercations such as disrupted eye development and pigmentation, erratic swimming, hyper excitation and loss of equilibrium are also studied in an acute toxicity study. Acute toxicity studies are conducted in various model organisms such as mice, rats, rabbits, guinea pigs, etc. [15].

Zebrafish as a model

Danio rerio, the zebra fish is a well known vertebrate model organism for the studies regarding diseases and development. It is being gradually used more for pre-clinical studies and toxicological studies due to various favorable traits. They are cost effective and exhibit a high fecundity rate. Also, many zebrafish models mimic diseases observed in humans both phenotypically and genetically. The zebrafish and human genomes are 70% similar. The major physiological and developmental processes associated with many of the major organ systems, such as the cardiovascular system and the nervous system are quite comparable to humans. Zebrafish eggs grow externally, which makes them simple to control and be suitable to high throughput applications. Due to the transparency of the developing zebra fish, discriminating analysis that includes fluorescent markers are also possible. The rapid development of the zebra fish is also well established. This makes them suitable to a broad variety of toxicology studies all through their life span. An important benefit of using zebrafishes is that nanoparticles can be administered in different routes, which may include injecting into eggs or on specific sites on adults or embryos or can also be administered via the water or food [16]. A study was conducted to demonstrate acute toxicity testing of synthesized pyrazoline derivatives in adult zebrafishes and in zebrafish embryos. The LC 50 values of the derivatives were calculated, as well as the abnormal changes in the fishes was observed over a period of 96 hrs. This study established that the zebrafish was a viable model for determining compounds toxicity [17].

Residual analysis test

Water contamination by pesticides is a widely known aggravating problem. Twenty-three pesticides, which included 17 herbicides, were found in waterways in the puget sound basin [18]. Pesticides can affect the surface water by the runoff from treated plants and soil. It was found that pesticides were identified in all samples collected from rivers that were used for both urban purposes and agricultural purposes and most of them being from urban use samples, it was concluded that this may pose a serious health hazard to the people using the water. Pesticides can be classified into: (1) Hydrophobic and bio-accumulable pesticides that can vigorously bind to soil. Pesticides which show signs of such activities comprise the endosulfan, organochlorine DDT, endrin and their TPs. Even though many of these pesticides are prohibited in agriculture nowadays, their residues are still there. (2) Polar pesticides mainly consist of herbicides, but they also comprise fungicides and certain organophosphorus insecticides. They can be washed away either by leaching or runoff, thus eventually contaminating the drinking water supply of the population. Still effects of many insecticides have not been studied, showing that the need of the hour is to conduct residual test to find out the possible ways by which the insecticides are affecting the soil microorganisms, ground water and other natural sources of nutrients [19].

Pesticides fate after application to fruits and vegetables

According to OECD guidelines, fate means the outline of circulation of an agent in an system, organism, compartment or sub population of concern as a result of transformation, transport, or degradation. The pesticide may enter the plant through their cuticle and root surfaces. It may thus either enter the plant transport system or remain on the surface. If they remain on the surface, they can undergo one of the three processes-volatilization, photolysis and microbial degradation. Volatilization usually occurs at once after using the pesticide in the farm. The progression depends on the vapour pressure of the specific pesticide. Increased vapour pressure means the pesticide volatiles rapidly whereas low vapour pressure volatiles much slower. The volatilization rate is proportional to the natural factors such as temperature and speed of wind. High wind speed and high temperature causes the pesticide to undergo volatilization much rapidly. Photolysis happens when molecules of the pesticide take up energy directly from the sunlight, thus ending in their break down. Some pesticides are broken down by the third method-microbial metabolism. Microbes can sometimes utilize pesticides for their nutrients. Thus, they can break them into carbon dioxide and other components. As the natural chemicals and synthetic pesticides have a very different chemical structure, microbes cannot usually break them down completely but alter the chemicals at their reactive sites. Those products that are produced may end up being more or less toxic than the starting substance. It is concluded that under ordinary conditions, volatilization is the major process that degrades the pesticides [20].

Alternates for chemical insecticides-plant based insecticides

Melia volkensii

These varieties of plants grow at fair elevations east African nations and other places like Kenya. Initially, a fruit extract obtained from these plants were documented to have insecticidal properties against certain locusts [21]. Later, it was shown to have action against large range of pests and insects [22]. Almost 8 limonoids were isolated from these fruits. When an experiment was conducted to prove the larval growth inhibitor effect and antifeedant effect, it worked against both *Trichoplusia ni*, the cabbage looper and *Pseudaletia unipuncta*, armyworm [23]. Major constituent of these species that showed highly effective insecticidal action was volkensin. This fast-developing species begins to fruit within 5 years and produces fruit almost round the year, making it suitable for daily usage in east Africa [24]. On the other hand, the intricate chemistry involved and shortage of appropriate toxicological data about the plants make it almost implausible to be used in highly developed countries where its approval may require a lot of clear data.

Figure 1: A) Melia volkensii **B)** Chemical structure of volkensin.

Melia azedarach

It is normally known as the chinaberry tree and is indigenous to eastern Asia. It has been widely cultivated throughout the subtropics and tropics. The fruit extracts obtained from *M. azedarach* have been proved to have insecticidal activities, in par with neem [25]. But, usage of these extracts in crops has been avoided due to the presence of toxins such as limonoids, meliatoxins that may be toxic to mammals. On the other hand, plants grown in Argentina didn't show toxicity while tested with rats, and also contained meliartenin, a limonoid that showed insecticidal and anti feedant effects and thus can be used in crops without any harm [26]. A broad variety of bioactive limonoids such as meliacarpins, volkensin and salannin have been found in the seeds of this tree [27]. The most prominent constituent is toosendanin, which occurs in the bark of this tree at high concentrations such as 0.5%. In China, an extract comprising of Toosendanin, obtained from the bark is refined and used as a bio-insecticide. That extract contains certain analogues of toosendanin that have insecticidal effects against many insects [28].

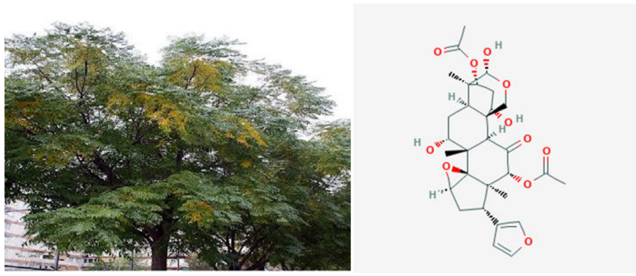

Figure 2: A) Melia Azedarach **B)** Chemical Structure of Toosendanin.

Azadirachta excelsa

The insecticidal activity of *A. excelsa* was first reported by the extracts obtained from the seeds of these plants. It acts by attacking the insect growth regulatory systems which was primarily done by an limonoid, marrangin, which was an analogue of azadirchtin [29]. Some other active limonoids have also been isolated from these plants. When the timber of a species was randomly screened in Malaysia, it proved to have very high insecticidal activity. It was found due to the presence of azadirachtin and its some other analogues. This timber was later realized to be *A. excelsa*. As they proved to have insecticidal effects, they have been widely planted all over Malaysia, and even a patent was issued for its effects against insects [30].

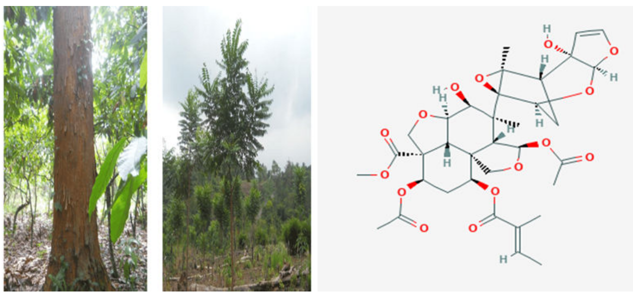

Figure 3: **A)** Azadirachta Excels **B)** Chemical structure of marrangin.

Trichilia Americana

Certain species of *T. Americana* in Costa Rica showed inhibitory effects against a particular species of army worm-*Spodoptera litura* [31]. Methanolic extracts of these species significantly prolonged pupal and larval development. It was later confirmed that it was primarily due to feeding inhibition caused in the insects. Neither injecting it directly nor topically administrating caused any toxicity. When normal diet without the extracts was given, they grew normally [32]. During an experiment, when cabbages were sprayed with 0.5% of methanolic extracts of this plant, it was safe from armyworms for almost 24 hours [33]. But, the active component was not able to be isolated successfully, even when bio assays such as fractionation, or HPLC were done. It was difficult to comprehend as these plants proved to be chemically complex and usually the active constituents were present in very low quantities. In case of future biological studies, and phytochemical investigation, this species have great scope to be used as an alternate as an insecticide.

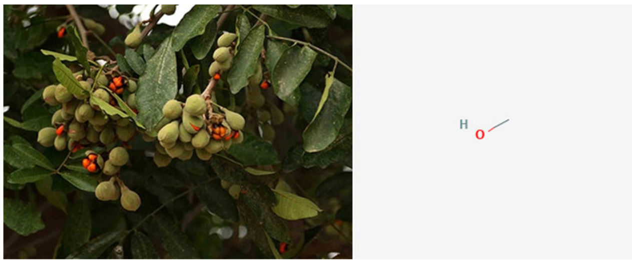

Figure 4: A) Trichilia Americana **B)** Chemical Structure of Methanol.

Role and growth of bio-pesticides in future

Organic production of bio-pesticides is on the rise by 15% per annum in western countries. The significance of bio-insecticides shall be well recognized in growing countries, where farmers are unable to afford synthetic insecticides. Even if they are affordable to farmers via govt loans and subsidies, restricted literacy and absence of proper protective equipment finally results in thousands of unintentional poisonings yearly [34].

Bio-pesticides are getting worldwide importance as a cautious approach to handle pest populations such as weeds, plant pathogens and insects while causing low risk to both people and the nature. Developmental experimentation in production, formulation and delivery may deeply play a role in commercialization of bio-pesticides. Increased research is required towards combining biological agents into normal production systems, and in improving the potential of growing countries to produce and apply bio-pesticides on their own. The commercial investors should be educated on the pros of using bio pesticide, thus encouraging them to conduct programs like public funded donations for improving the bio pesticide usage in the particular region. It is crucial to maintain the value and efficiency of bio-pesticides in the growing countries at a much lower cost than the developed countries. Thus, research on diverse features of bio-pesticides covering the current status, constraints, and prospects towards their efficient consumption for the advantage of human kind are currently in progress [35].With the help of nanotechnology, in future it can be expected that there will be a great improvement in the agricultural field with the involvement of bio-pesticides.

Conclusion

In present world, almost everything is made from chemicals. But it is not healthy to intake anything that has been exposed to too much chemical. Already, chemicals have been incorporated into foods as flavouring agents and preservatives. Moreover, if the crops in the field are also exposed to chemical pesticides, then we cannot even imagine the amount of harmful chemicals that we are consuming daily in the name of food. Even though there is comparatively less possibility to reduce the chemicals after harvesting the crops, the usage of chemical insecticides can be reduced in the previous stage. Worldwide there are numerous problems persistent due to the usage of harmful insecticides. Non target organisms such as fishes, beneficial microorganisms have been affected a lot. To prevent all these side effects, bio-pesticides prepared from natural products should be used. It can either be produced by incorporating the science of nanotechnology and producing insecticides in the form of nanoemulsions or usage of plant derived chemicals for insecticidal purposes. The best plant sources of insecticides include *Azadirachta indica*, *A. excelsa*, *Melia azaderach*, etc. Although the efficiency may be comparatively less than chemical insecticides, need of the hour is to shift to harmless, less toxic natural insecticides keeping in mind the well being of humans and the environment. With further research and improvements, the efficacy of bio-pesticides can be made equal to that of the chemical insecticides.

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