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Medicinal and Aromatic Plants: A Major Source of Green Pesticides/Risk-Reduced Pesticides

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Introduction

Pesticides are chemical substances, even defined as poisons targeted to kill harmful insect pests [1]. Developing countries consider them as powerful weapons in order to enhance crop yields and to reduce the vector-borne disease burden. However, the indiscriminate and haphazard usage of pesticides poses serious negative public health impacts and adverse environmental hazard too [2,3]. It has been estimated that about 2.5 million tons of pesticides are used on crops each year and the worldwide damage caused by pesticides reaches $100 billion annually [4].

Pesticide and Global Public Health

Insect-transmitted diseases are major causes of morbidity and mortality in many tropical and subtropical countries [5], accounting for nearly 17% of the estimated global burden of infectious diseases [6]. Pesticide-based vector control interventions serve as the mainstay to minimize the vector-borne disease burden [7], by managing vector populations to reduce/interrupt the transmission of disease [8]. However, the indiscriminate and injudicious use of pesticides has led to the widespread development of resistance. The rise in the number of insecticide-resistant arthropods of public health importance has been observed from 2 to 150 in 1946-1980 while 198 in 1990. Some species have also become resistant to multiple insecticides, making their control by chemical methods to be extremely difficult and expensive [6].

Indoor residual spraying (IRS) is one of the most effective interventions, which involves applying, long-lasting insecticide to the inside walls of houses and other structures where people sleep [8]. Although, occupational insecticidal poisoning (OIP) is a global phenomenon, more commonly prevalent among spray-men that can be a threatening to the indoor residual spray men's health. Their frequent insecticide exposure is a matter of grave concern too which could impair their health as well as occupational competence [7]. In addition, application of conventional insecticides into the mosquitoes breeding sites may lead to adverse side effects in the aquatic ecosystem. Therefore, innovative vector control strategies like use of phytochemicals as alternative sources of insecticidal/larvicidal agents in the fight against the vector-borne diseases has become inevitable [5].

Pesticide and Agriculture Sector

In the developing countries nearly 80% of the people directly or indirectly engaged in the agriculture sector and, it is estimated that nearly 3 million farmworkers experience severe pesticides poisoning, resulting to about 18,000 deaths; while about 25 million workers suffer from mild pesticide poisoning each year [9,10]. Therefore, pesticidal occupational poisoning is a growing concern in the resource-constrained settings. Persistent pesticides are highly toxic, causing an array of diverse effects, notably death, diseases and birth defects among human and animals. Specific effect can include cancer, allergies and hypersensitivity, damage to the central and peripheral nervous systems, reproductive disorders, and disruption of the immune system [11].

Pesticide and Environmental Pollution

Besides, pesticide use raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% herbicides reach a destination other than their target species, present in air, water and soil. Pesticides are one of the causes of water pollution; some are persistent organic pollutants contributing to soil contamination [12]. Due to misuse and overuse of pesticides, presence of pesticide residues in foods, fruits, vegetables and even in mother's milk creates an alarm on human health [13]. Therefore, looking for alternative plant-based pesticides could be a possible and viable solution to address this catastrophe which could serve as potent "***Ecofriendly-agrochemicals***" [14].

Over the centuries, even before the advent of modern synthetic pesticides our ancestors completely depended on the usage of plant-derived products as pesticidal agent against various insects. At the moment, due to high cost and resistance development of the synthetic insecticides, a revived interest has been observed to exploit the pest control potentialities of various plants [15]. As a result, it is the hour to launch extensive search to explore ecofriendly biological materials for control of insect pests, and we are all just around the corner to reinstate the ubiquitous chemical of concern by plant-based products in the insect control [16].

Green Pesticides: An Age-old Practice and a Rekindle Hopes

Green pesticides, also called ecological pesticides, are pesticides derived from organic sources which are considered environmentally friendly and causing less harm to human and animal health, and to habitats and the ecosystem [17]. The green pesticides can contribute to reduce the pest population and increase food production. They are more compatible with the environment components than synthetic pesticides [18].

To the present concept of green pesticides, some rational attempts have been made to include substances such as plant extracts, hormones, pheromones and toxins from organic origin and also to encompass many aspects of pest control such as microbial, entomophagous

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nematodes, plant-derived pesticides, secondary metabolites from microorganisms, pheromones and genes used to transform crops, in order to express resistance to pests. Even the extremely biodegradable synthetic and semisynthetic products in pest management, has been considered to constitute the umbrella of green pesticides [19-21]. Some botanicals or their derivatives such as pyrethrum-based products have made an impact in crop protection and this has rekindled hopes for the resurgence of plant-derived pesticides that are traditionally used and produced by farmers in developing countries where these botanicals are locally readily available and they appear to be quite safe and promising [22].

Significance of Green Pesticides

Over the past 50 years, more than 2000 plant species belonging to different families and genera have been reported to contain potential toxic principles. The botanicals are broad spectrum in pest control, safe to apply, unique in action, and can be easily processed and applied. Plants contain a large number of secondary metabolites and those categorized under terpenoids, alkaloids, glycosides, phenols, tannins etc. play a major role in plant defense and cause behavioural and physiological effects on insects [23]. Complex mixtures of lethal and sub-lethal phytochemicals in botanicals often offer multi-factorial selective pressures that retard the development of resistance in pests [24]. Besides, increased demand for more sustainable agricultural practices and organic products serve as impetus to resort to risk-reduced/green pesticides [25].

Many plant essential oils show a broad spectrum of activity against pest insects and plant pathogenic fungi ranging from insecticidal, antifeedant, repellent, oviposition deterrent, growth regulatory and antivector activities. Recent investigations indicate that some chemical constituents of these oils interfere with the octopaminergic nervous system in insects. As this target site is not shared with mammals, most essential oil chemicals are relatively non-toxic to mammals and fish in toxicological tests, and meet the criteria for "reduced risk" pesticides [4]. The stimulation of the octopaminergic nervous system of invertebrates is a proven strategy for the control of important pest species [26].

Green pesticides prove effective in agricultural situations, particularly for organic food production. Further, while resistance development continues to be an issue for many synthetic pesticides, it is likely that resistance will develop more slowly to essential-oil-based pesticides owing to the complex mixtures of constituents that characterize many of these oils. Ultimately, it is in developing countries which are rich in endemic plant biodiversity that these green pesticides may ultimately have their greatest impact in future integrated pest management (IPM) programmes due to their safety to non-target organisms and the environment [4]. In general, as the reduced-risk of pesticides are often accessible, affordable, user and eco-friendly they become more attractive alternative pesticides to resource-poor and organic farmers in developing nations.

Indeed, natural pesticides can be very toxic for certain species, but not for the environment as a whole as other species can digest them without any problem and they do not accumulate in the environment or food chain [27]. Pyrethrins break down quickly and are one of the least poisonous insecticides to mammals and this is why even today millions of bed nets are treated with several potential pyrethroids in order to save millions of malaria related mortality in the tropical and subtropical countries of the world.

Perspective and Key Challenges for Green Pesticides

Although, the usage of plant-based pesticides is a part of tradition and culture in the developing countries, over the past three decades there is a tremendous dedication and commitment to develop a plant-based ideal pesticides or green pesticides by various researchers. As a result we have evaluated over thousands of plants as potential pest control agents in terms of insecticidal, antifeedant, repellent, oviposition deterrent, growth regulatory and antivector activities. However, only a few plant-derived botanicals have demonstrated their broad effectiveness against various insects like neem, lemon grass, etc.

Neem-based products have been demonstrated as a natural insect repellent and insecticide over hundred insect pests. They are extensively used in agricultural practices and in vector control, in many parts of the tropical world [28]. The azadirachtin content of neem oil is positively correlated with its effect against insects [29]. The active components exhibit actions against insects that can be grouped into six categories: antifeedency, growth regulation, fecundity suppression, sterilization, oviposition repellency or attraction, and changes in biological fitness [14].

Neem tops the list of 2,400 plant species that are reported to have pesticidal properties and is regarded as the most reliable source of eco-friendly bio-pesticide. Neem is also used as a bio-control agent to control many plant diseases [30]. Neem is observed to have dual advantages; (1) insect pests cannot easily develop resistance due to it is complex chemical constituents nature and (2) it also proves a low toxicity to beneficial organisms, animals and humans. In many parts of the world since time immemorial people are administering neem wood and non-wood products (flowers, fruits, seeds, leaves, bark, oil and gum) which are well known for their omnipotent usage and therapeutic values [14].

Globally, *Cymbopogon citratus* or lemongrass is well-known due to its invincible nature and an infinite number of phytotherapeutic applications and potentialities [31]. Methanol leaf extracts of *C. citratus* has been screened for larvicidal activity against *Anopheles arabiensis*. The investigation establishes that *C. citratus* extracts could serve as a potent mosquito larvicidal agent against *An. arabiensis* [5]. Sukumar et al. [32] reported that *C. citratus* causes significant growth inhibition and mortality in later developmental stages of *Aedes aegypti*. *C. citratus* essential oil has also shown toxicity against *Culex quinquefasciatus* larvae with a LC_{50} value of 24 mg/l [33].

At the moment, the people are appreciating and insinuating the use of plant-based botanicals as pest control agents to control insect vectors and pests. It has ceased the tendency of heavy reliance on chemical insecticides to reduce negative impacts to human health and the environment. In general, many people believe that plant-based pesticides are safer in terms of user and eco-friendly nature. However, we should also be aware of the fact that some of the botanicals are known to cause serious adverse effect when misused, particularly at a higher dose. Therefore, they should be handled with great caution like their commercial counterparts.

Nevertheless, majority of the green pesticides are relatively less harmful than modern synthetic chemical pesticides and that can be as potent as chemical pesticides. Therefore, there is an enduring demand for developing new pest control tools in terms of green pesticides/reduced-risk of pesticides by means of unique novel modes of action. It is quite important and imperative to identify ideal sustainable agriculture strategies and one must follow the aspects [2,3,18]; (1)

enhance the crop yields by reducing crop losses by proper usage of green pesticides, (2) minimizing the conventional pesticide usage, (3) avoiding the accumulation of pesticide residues, (4) increasing farmer's income and enhancing environmental health.

Insecticide resistance management (IRM) to pests in the urban environment has a 20-year history. In addition, promotion of alternative pest control strategies such as application of biopesticides and integrated pesticide management (IPM) is apparently inevitable. It shall further reduce the heavy reliance of chemical pesticides as well as their adverse impact on human health and environment [14]. In general, green pesticides are target-specific and can be non-toxic. However, the following issues have to be considered in order to formulate novel potential green pesticides/reduced-risk pesticides in the near future;

- In the recent years many plant species are reported for their insecticidal properties; however it necessitates a well-advanced technological drive.
- There is a need for strong, committed, inter and multi-disciplinary experts team consist of entomologist, ethnobotanist, expert in phytochemisty, microbiologist and eco-toxicologist, to progress from active ingredient to agricultural and *commercial product* lines.
- It also demands a strong as well as long-lasting joint-venture between the scientific laboratories and the pesticide manufacturers.

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