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Botanical Pesticides: Use of Plants in Pest Management

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Abstract: **Plants play a vital role in human life since the beginning of life on earth. Plants are not only directly used as a feed and fodder for humans and animals but are also used as drugs, food additives, pesticides, in flavor and fragrances and dye and pigments. The plants produce compounds for their growth and development and also produce secondary metabolites which provide additional properties to plants. These secondary metabolites produced by plant are responsible for these activities. Plants as a whole or in extracts/fractions form have been used as pesticides for protection of plants since thousands of years. Pyrethrum, neem, rotenone are such plants which has been used in many cultures and traditions for crop protection since ages and hold relevance in today's world as well. The plant extracts contain secondary metabolites which provide protection to plants against pests by either causing mortality of pests or act as repellent to them. They can also impact pests by causing anti-feedancy, toxicity, alters insects behavior during oviposition and mating and inhibition of progeny emergence in pests. Essential oils isolated from the plants have also pesticidal properties. Lemongrass essential oil, Citronella essential oils, Tea tree essential oils and Oregano essential oils are the commonly used essential oils against the pests. In this review, botanical pesticides are discussed and their role in pest management and their advantageous over synthetic pesticides in terms of biodegradability, posing no or low risk to humans, environment and non-target organisms. Also, the future of botanical pesticides is discussed where they can be an alternative to synthetic pesticides if more research is done on their stability, efficacy, safety, modes of action, cost reduction is done.**

Indexed Terms- **Botanical pesticides, plant extracts, secondary metabolites, essential oils**

I. INTRODUCTION

Plants have played an essential role in human life since time immemorial. Plant as whole or extracts have been used as herbal drugs since ages. Plant produces essential compounds required for their growth and development and they also produce vast variety of secondary metabolites for additional purposes [1]. These secondary metabolites are bioactive compounds which possesses broad activities towards human, bacterial, fungal, viral, protozoan and insect cells as well as these plays a vital role in interactions with other organisms [2]. Herbal drugs extracted from plants have been used by humans for treatment of variety of diseases [3]. As per a report of WHO, herbal drugs derived from plants are used for various ailments by around 80 % population of developing countries in world [4]. Various plants such as Phyllanthus emblica have been traditionally used and have found to be effective against various diseases such as malaria, diabetes, hepatitis B etc as found in a recent study also [5]. The herbal medicines in combination with western medicines are also found to be effective in rate and improvement of symptoms in COVID-19 disease [6]. As per a recent study, it was found that traditional Chinese medicine (herbs) may have the potential to constrain the infection of coronavirus in human population [7].

Many secondary metabolites produced by plants have pesticidal activity as well as repellent and antifeedant activity. Because of this pesticidal activity, plants can be considered to be used as botanical pesticides. Since the time the need of crop protection aroused thousands of years ago, at the same time the origin of use of plant secondary metabolites as insecticides can be considered [8]. The plants have been used as whole, plant parts and plant extracts since time immemorial in various culture and tradition across the world [9]. The extracts isolated from the plants can act as repellents to many insect's species, can reduce the feeding capacity and fecundity in insects, can be anti-ovipositional, fitness reducing properties in insects and have insect growth regulatory (IGR) properties [10] [11] [12]. Plant based insecticides which are traditionally used since ages in the world are pyrethrum, neem, rotenone and sabadilla [9].

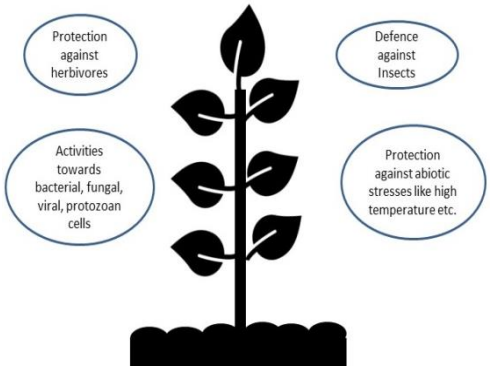

Figure 1: Functions of secondary metabolites produced by plants.

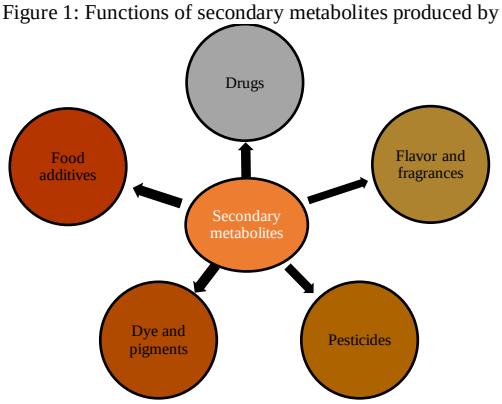

Figure 2: Economic importance of Plant secondary metabolites.

II. IMPACT OF SYNTHETIC PESTICIDES IN PEST MANAGEMENT

Synthetic pesticides have benefitted tremendously not only agriculture sector but also by its use in forestry and control of vector-borne diseases. The use of pesticides not only prevent crops from the damage from the pests by thereby improving productivity, also prevent reduction in crop yield, vector borne disease control such as malaria, quality of food etc. The estimated use of insecticide in India is 76% and globally is 44% [13]. Continuous use of pesticides by humans over the time has caused various health issues to human and a negative impact on the environment. Use of synthetic pesticides can result in various health hazards in humans and other life forms and non-target organisms [14]. Not only this, but synthetic pesticides also cause various effects to the environment like surface and ground water contamination, changing soil fertility by degrading beneficial microorganisms as well as air contamination, soil contamination and affect non-target plants [15]. The use of synthetic pesticides causes pesticidal occupational poisoning to farmworkers, applicators and even consumers. Another problem which is arising with the use of synthetic pesticides over the years is emergence of pesticide resistant pests [16]. An alternate to the synthetic pesticides can be Botanical pesticides which are isolated from the plants. The concept of Botanical pesticides can be traced back to 400 B.C where the plant extracts have been used to protect plants from the pests [17].

III. BOTANICAL PESTICIDES IN PEST MANAGEMENT

More than 2400 different plants have been documented for their pesticidal activities [18]. Botanical insecticides can be crude plant extracts or dried and grounded plant materials, or essential oils isolated from the plants which are used for pest management in plants [19]. This protective action against pests is due to secondary metabolites produced by plants. These secondary metabolites include alkaloids, steroids, phenols, flavonoids, non-protein amino acids, quinones, tanins, terpenoids, glycosides, glucosinolates etc. Different parts of the plants such as leaves, stems, barks, flowers, fruits, seeds, cloves, rhizomes are used to prepare botanical pesticides. The mode of action of most of the plants, their extracts and essential oils are by repelling, oviposition deterrence, feeding deterrence as well as interfering with physiological activities of pests and can be toxic and lethal as well to them [20].

A. Plant extracts/fractions

Azadirachta indica known as Neem has been used as an insecticide since hundreds of years. Neem-based products have been widely used in agricultural sector and in vector borne disease control such as malaria, dengue, and chikungunya in various parts of the tropical world [21]. Insecticidal activity of Azadirachta indica can majorly be attributed to the component azadirachtin present in it and it is present prominently in neem oil which is obtained from the seed kernels of the neem plant [22]. Bark, leaves, flower, seeds of neem plant contain bioactive components which have anticancer, antifertility, antimicrobial, anti-inflammatory, insecticidal, immunomodulatory activities [23]. The extracts act on insects by repellency, antifeedant effect, ovipositional, antifertility, insect growth regulatory (IGR) and changes the biological fitness of insects [12]. Many neem products are commercially available and used by the farmers for protection of crops.

Other successful examples of biopesticides are Pyrethrum isolated from Tanacetum cinerariifolium and Artemisia annua (sweet wormwood) and are considered safe insecticides [24]. Tanacetum cinerariifolium, also known as Dalmatian pyrethrum, is endemic to the east Adriatic coast but is grown worldwide. Pyrethrin is the bioactive component present in pyrethrum which has very high efficiency against variety of pests and does not cause any or minor ill effects on human health and environment [25] [26]. Pyrethrin acts as contact poison, has neurotoxicant effects on insect pests and it blocks voltage-gated sodium channels in nerve axons. This causes paralysis in insects leading to their death. At lower concentrations, Pyrethrin acts as a repellent. Extracts from Ryania speciosa acts against variety of pests including codling moth (Cydia pomonella L.), citrus thrips (Scirtothrips citri), Corn earworm (Helicoverpazea Boddie), European corn borer (Ostrinia nubilalis Hübner), caterpillars (Lepidoptera), and leaf eating beetles such as green beetles (Colaspis favosa) [27].

TABLE 1: PLANT EXTRACTS AND THEIR EFFECTS ON TARGET PESTS.

Source Plant of extracts	Effect on insects	Target Pest	Ref.
Tanacetum cinerariifolium (Dalmatian pyrethrum)	Neurotoxicant effects on insect pests, cause paralysis leading to mortality	Mosquitoes (Culicidae), sawfly larvae, caterpillars, leafhoppers, aphids and beetles etc	[28]
Azadirachta indica (Neem)	Repellency, antifeedant effect, ovipositional, antifertility, insect growth regulatory (IGR) and changes the biological fitness of insects	Insects of Lepidoptera, Diptera, Coleoptera, Homoptera and Hemiptera orders	[12]
Ryania speciosa	Mortality	Codling moth (*Cydia pomonella L.*), citrus thrips (*Scirtothrips citri*), Corn earworm *(Helicoverpazea Boddie*), European corn borer (*Ostrinia nubilalis Hübner*), caterpillars (Lepidoptera), and leaf eating beetles such as green beetles (*Colaspis favosa*)	[27]
Allium sativum (Garlic)	Repellence, toxicity, antifertility and mortality	Red flour beetle (*Tribolium castaneum*)	[29]

Curcuma longa (Turmeric)	Repellence, toxicity, antifertility and mortality	Red flour beetle (*Tribolium castaneum*)	[29]
Abies balsamea	Repellence	Asian citrus psyllid (*Diaphorina citri*)	[30]
Cinnamomum cassia	Mortality	Cigarette beetle *(L. serricorne)*	[31]
Nicotiana tabacum	Oviposition deterrence	Oriental fruit moth (*Grapholita molesta)*	[32]

B. Plant essential oils

Essential oils extracted from many medicinal plants have great potential to be insecticidal [33]. Essential oils and their components extracted from plant source cause toxic effects in insects via contact, ingestion, or fumigation. Various studies have shown the insecticidal activities of the essential oils extracted from the plants belonging to Apiaceae, Asteraceae, Lamiaceae, Laureaceae, Myrtaceae and Rutaceae families. Essential oils from different plants can destroy and kill insect's species at their egg and larvae stage or at an adult stage as well as they can be antifeedant and repellent to them [11] [34]. Essential oils can change the feeding behavior of insects thus causing mortality and also it alters insect's behavior during oviposition and mating.

TABLE 2: ESSENTIAL OILS AND TARGET PESTS

Source Plant	Target Pest	Ref.
Mentha species (Volatile oils)	Red flour beetle (*Tribolium castaneum*) and Cowpea weevel (*Callosobruchus maculates Fabricius*)	[38]
Cymbopogon nardus (L.) Rendle (Citronella essential oils)	Mosquito	[9]
Eucalyptus globulus (Tasmanian blue gum essential oil)	Housefly (*Musca domestica L)*	[39]
Anethum graveolens L. (Dill essential oils)	Cabbage root flies (*Phorbia brassicae Bch.*)	[40]
Melaleuca alternifoliatea (Tea tree essential oil)	Greenhouse whitefly *(Trialeurodes vaporariorum)*	[41]
Origanum onites L. (Oregano essential oils)	Mediterranean flour moth *(Ephestia kuehniella)* and Indianmeal moth *(Plodia interpunctella)*	[42]

IV. CONCLUSION AND FUTURE PROSPECT

Synthetic pesticides are considered an easy, fast and reasonable solution for protecting plants from the pests. They are easy to formulate, manufacture, readily available, have longer shelf life and simple to apply. Plants hold a great value in the pest management as synthetic pesticides has many drawbacks including development of pesticides resistant pests, pesticidal occupational poisoning, non-biodegradability etc. Synthetic pesticides are also posing a substantial risk to environment by contaminating soil, water and air. They also affect the non-target organisms such as plants, beneficial insects, aquatic animals such as fishes, birds, beneficial soil microorganisms, earthworms etc. Botanical pesticides in comparison to synthetic pesticides are less harmful and have low or no effect on non-target organisms. Also, they pose no or negligible hazard to the environment as they do not hoard in soil, air or water and they are biodegradable in nature.

Sufficient knowledge and commercial products of few botanical pesticides are available such as of Neem and pyrethrum. But intensive research in the field of development of botanical pesticides is required so that the plants with bioactive components can be identified and used for crop protection. New plants need to be identified for the bioactive components and more research is required to be done on existing known plants with bioactive components. Efficacy, safety and modes of action need to be established of bioactive components. Nanotechnology can be combined with the bioactive components to improve stability. Botanical pesticides are biodegradable but one of the major problems associated with them is that they have short shelf life. So, more research is required for development of bioactive formulations with more shelf life and efficacy. Another factor is of cost of botanical pesticides as extraction and purification may cost high. Inexpensive solvents should be used for extraction and purification of botanical pesticides. This process can reduce the cost of production so that even small-scale farmers can manage to use the botanical pesticides. Plants grown locally to an area should be tested for the pesticidal properties which can further decrease the cost. Integrated pest management program can be very beneficial to the farmers. Botanical pesticides have a very positive future in crop protection and it is expectant to eliminate the risk of using synthetic pesticide to user, consumer and environment.

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