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Research Article

"Botanical Pesticides in Modern Agriculture" A Review

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ABSTRACT

To protect crops from insect synthetic chemical pesticides are used continuously endangered pesticides resistance, pest resurgence, health issues, elimination of beneficial insects and environmental pollution. These negative effects led towards development of botanical insecticides which have gained more attention due to their safety for higher organism, natural population and environment concerns as well. Plant derivatives are employed globally in agriculture to combats harmful insect pest, diseases, weeds, nematodes and mites. Investigations on plants have been increased in the recent years to find out biologically active compounds which are compatible with other control methods. These botanical insecticides are acceptable by humans because of their least toxicity, safety for environment and naturally growing populations. Botanical extractives are potential source and important component of biopesticides which are helpful in replacing of harmful synthetic pesticides, reducing global warming and sudden climatic changes. This article suggested enhancing research on application and formulation of bioactive compound for increasing crop production on environment friendly basis. Moreover, all available plant based derivatives are not potentially used and few have got place in the world market. So, more research on natural assets as botanical insecticides, herbicides and fungicides is needed for better and improved grain production.

Keywords: Biopesticides. Botanical insecticides. Botanical herbicides. Botanical fungicides. Chemical pesticides

INTRODUCTION

Demand of biopesticides is increasing due to their safe profile, systemicity and biodegradability [1]. Approximately 69 botanical insecticidal products were registered and commercialized in the United States by early 2014 [2]. Pesticides are the most effective and efficient weapon that plays an important role against pest control, however unsystematic use of synthetic pesticides every year adversely affected human health, environmental concerns, non target species, pesticides resistance and pest resurgence etc. Therefore this comprehensive review described the use of botanical insecticides, herbicides and fungicides in agricultural protections. Almost 70000 pest species cause damage to agriculture globally including 9000 sporadic pest species caused about 70 % losses to agriculture that showed the compulsion of pesticides uses against these pest species. Normally synthetic based compounds are harmful while in contrast, plant based medicinal agents are usually free from side effects with least toxicity to plants and beneficial

organism [3]. However heavy reliance on synthetic chemicals for controlling pest population brought numerous problems like resistance races of target pest and non target pest resurgence. Besides environmental concerning issues, health hazardous problems and indiscriminate use of synthetic chemicals also cause elimination of beneficial organism [4; 5]. It was reported by [6] that no chemical pesticide has been formulated with different action mechanism for the last 20 years.

Traditionally farmers use biopesticides in variety of ways either directly or indirectly for pest management in field crops or storage products. The similar practices has adopted by farmers in India and other countries in the world [7]. Use of plant derived extracts in agriculture provide unique benefits to producers and consumers in different ways as they have less risk to humans, least residual effects in food stuff and short pre-harvest interval because of their quickly decomposable properties. Many of plant based products have strong pesticidal activity like quick and sturdy acting, causing deterring effect in insect feeding behavior, safe to beneficial insect and selective to non-target organism (Biopesticides Industry Alliance 2011).

As world population is increasing fastely and there is huge task to enhance food production with reducing insect pest infestation on sustainable basis to fulfill the increasing demand of food, however this task should be achieved with increasing biopesticides production which are good alternative of synthetic pesticides.

Botanicals as Insecticides

Plants are a God–given treasure to human beings; they produce a variety of secondary metabolites, i.e., alkaloids, flavonoids, steroids, glycosides, terpenoids, tannins, saponins, quinine, and phenols [8] and have the best curative potential of pharmaceutical medicines, biocides and biopesticides [9; 10]. Hence, divergent raw material is extracted and used for pesticides production in different parts of the world. According to World Health Organization (WHO) medicinal plants are those which contain substances that can be used for therapeutic purpose or for chemo-pharmaceutical semi synthesis.

Botanical pesticides extracted from *Sophora flavescens* is most widely used and registered as first rank among botanical pesticides in China and according to statics of 2015 there are about 70 manufacturers with 92 registration products (http://www.chinapesticide.gov.cn/hysj/index.jhtml). Pesticidal activity of *Sophora flavescens* is mainly due to presence of number of alkaloids such as sophocarpine matrine, cytisine and sophoridine [11;12]. Furthermore, with insecticidal (caterpillar, aphid and some other pest) and antimicrobial properties, antifeedants activity for plant growth regulation i.e. increase the fresh and dry weight of cucumber, stimulate the seedling growth and increase tomato production [13; 14].

Sabadilla lily, a tropical plant from which sabadilla is extracted, has been used against several pest by Indians, native Americans and Spanish. It is effective against leaf hoppers, caterpillars, bugs and thrips, cause the insect death by effecting and paralyzing nervous system [15]. *Quassia amara* also called as quassia or bitterwood is forest shrub has insecticidal properties and it showed antifeedants activity on Mahogany shoot borers and *H. grandella* larvae [16]. Ryanoids is well known botanical insecticides extracted from Ryania. Alkaloids from this plants are responsible for insecticidal properties with longer residual activity than other botanical extractives [17]. It is proved to be effective against European corn borer, corn earworms, citrus thrips and codling moth [18].

Barbasco (*Lonchocarpus utilis*) and derris (*Derris elliptica*) contain rotenone [15]. The roots of *D. elliptica* contain 5% rotenone [19] act as potential antifeedants with contact and stomach action against thrips, aphids, suckers and caterpillars causing sudden death [20]. Although it is environmental friendly and easily degradable in air, light and heat [21], however its use is partially

restricted in Austria, Switzerland, Spain and Italy [22].

Several plants contain phytochemicals which are isolated and characterized including grapes, apples, vegetables (Brocoli, Onion), spices (Turmeric), Beverages (Green Tea and red vine) and many other sources like weeds [23; 24]. Brazil is rich in biological diversity and usually accounts for 20% of whole world as a source of sustainable agriculture tools for bio-prospecting [25]. Chemical composition of plant based compound such as birch (*Betula* sp.) has been studied well by [26]. Similarly it was proved by [27] that birch oil is a good source to prevent crops and other food stuff from sucking molluscus species *Arianta arbustorum* and *Arion lusitancus*. It can also be applied on pots or fences by dusting or painting to prevent such pests. Meanwhile, botanically extracted compounds are most commonly used for wood preservation in different countries.

Botanical insecticides can effectively control pests so they are a good substitute of chemical insecticides that effect on biochemistry and physiology of insect pest [28-32]. [1] reported that several kind of plant species have been used for extraction of botanical pesticides which have already been established and accepted as potential plant protection products, meanwhile these phytoconstituents are potentially employed in agriculture for pest control. However, synthetic pesticides usually affect biochemical enzyme and nervous system of insect [33; 34].

Globally plant flora contain wide range and variety of free radical molecules such as vitamins, flavonoids, phenols and terpenoids rich in antioxidant activity, these radical molecules are effective tools for insect pest control in crops [35]. Phytochemicals constituents of several plants play an important role against pathogenic insect, protozoa, fungi and bacteria [36].

Plant extracts such as antimycin, hydramethylnon and rotenone inhibit electron transport chain where as surangin B can reduce ATP production in store grain pest [37]. [38] Reported that seed extract of *Citrus reticulate* can reduced the activity of *Culex quinguefasitus*. Aloe vera, datura, garlic, onion, ginger, and basil had larvicidal activity against *Culex quinquefasciatus* [39]. Similarly neem based bioinsecticides can prevent egg laying process of *Spodoptera exigua* [29]. Extracts of *Azadirachtina indica* is very effective botanical insecticides [40; 41]. Similarly plant extracted oils contain repellent, larvicidal and ovicidal properties against pests [28; 42]. [43] tested eight plants extract viz; neem, sweet sop, banyan, 5-leaved chaste tree, water pepper, crown flower, china box and oleander and reported that neem extract cause highest mortality against *Aleurodicus dispersus* after a short period with topical spray, while all other mixture of plant extract showed variable synergistic activity against said pest. Plant extracts can effectively suppress store grain pests and other insects such as *Nezera viridula* and *Psyttalia concolor* [30; 37; 44-46]. *Tabebuia* species have recorded insecticidal effect against several insect species [47]. *Cannabis sativa* (Marijuana) is a historical plant with curative potential and agrochemical properties. It has been used in folk medicines due to its phytochemical properties. It contains hemp of chemicals including canabinoid, phenolic and terpenes compound. Cannabis has been used for the ancient time in textile industry and also as herbal medicine [48; 49]. Different parts of this plant like stem axis, young and older leaves, uppermost nodes and flower contain phytochemical properties used in controlling several pest [50]. [48] Studied the detailed history of cannabis from Xinjiang-Uighur an Autonomous cold and old region of China and reported botanical evidence from wild cannabis plants. Chromatographic analysis of *C. sativa* L. represents the presence of cannabinol (CBN) which contained tetrahydrocannabinol (THC) a major component of phytocannabinol.

Parthenium hysterophorus contain parthenins reported to show insecticidal activity against termite and cockroaches [51]. Larvicidal activity against *Aedes aegypti* L. [52-54], cytotoxic

activity [54] acaricidal activity [55], production of xylanase [56], antioxidant activity [57; 58], skeletal muscle relaxant activity [59] and as pesticidal agent [51; 60].

Citrullus Colocynthis belongs to the family Cucurbitaceae mostly grown in desert areas has gained attention as a natural botanical insecticide; its insecticidal activity has been evaluated against several insect pests species [61]. Phytochemical properties of *C. colocynthis* was reported by [62] who stated antifeedant, deterrent, reducing fertility and growth regulating properties of insect species. *C. Colocynthis* exerts carcinogenic, antidiabetic, antibacterial, antioxidant, and toxic properties [63-66]. It is also used as herbal medicine as cathartic, vermifuse, furgatives, abortifacient and for the treatment of tumor, leukemia, jaundice, cancer, amerorrhea, fever and also has insect repellent activities [6; 67].

[68] extracted and tested phytoinsecticides and phytofungicides from nine plants. Extractive substance originated from natural and cultivated plants and these phytopreparations proved with insecticidal and fungicidal properties that caused limitations of pest populations under green houses, field and laboratory conditions. Similarly extract having fungicidal activity proved to be effective against downy mildew, grey mold, leaf mold, dry leaf spot and fusarium wilt on vegetables including sweet peppers, tomatoes and cucumbers. [69] reported the insecticidal properties of ginger, hail and shammar whom dried powder was tested against *Oryzaephilus surinamensis* a stored product pest. Ginger powder was proved to be most effective against *O. surinamensis* followed by hail and shammar. It was also concluded that ginger effect the body protein, hail effect polypeptide fraction and shammar lower molecular weight protein using Polyacrylamide gel electrophoresis technique (PAGE) for body proteins analysis.

[70] Described the potent activity of botanical extract i.e. Tobacco (*Nicotiana tabacum*), Hing (*Asafoetida*) and Neem seed extract and neem oil (*Azadirachta indica*) against sucking complex of cotton. Highest mortality was caused by neem seed extract, neem oil followed by tobacco and *asafoetida.* They suggested the application of botanical pesticides against sucking pest of cotton with an interval of 10 days. The effectiveness of botanical extracts of Neem, Tobacco and Datura against sucking pest i.e. whitefly, Jassid and mites of Brinjal was described by [71]. Among the tested plant extract neem was proved to be most effective against whitefly, Jassid and Mites followed by tobacco and Datura.

Botanicals used as Herbicide

Botanical herbicides are biodegradable like other biopesticides which play an important role for weed management. These bio-herbicides have potential to cause delaying growth in weeds through infection [72]. [73] Evaluated the allelopathic affect of different parts of *Kochia scoparia* aqueous extracts on flaxseed. Stem and leaf aqueous extracts have different degree of germination and seedling growth which increase with increasing concentration.

[74] reported that *Parthenium hysterophorus* extract contain herbicidal properties and used for controlling crops weeds. [75] applied extracts of several young plants (*Parthenium hysterophorus, Calotropis procera, Amaranthus viridis, Bergia capensis, Mikania micrantha, Cyperus difformis, Ageratum conyziode, Physalis minima, Echinochola colona*) and some parts of mature plants like (*Hibiscus subdariffa, Tectona grandis, Bambosa vulgaris, Cucumis sativus*) and proved as good alternatives of weed management in system intensification. In the meanwhile it was further reported by [76] that crop productivity can be increased by reducing weed losses to crops which can be managed easily and successfully by annual planning of weed seed on pre-emergence basis. Bash of these botanical herbicides including organic extract of Parthenium, Bamboo, Senji methi and teak were used either single or in combination with chemical herbicides give maximum mortality of weed seed 51.07-60.91% followed by botanicals mixture 40.57- 49.83%. [77] demonstrated that botanical aqueous extract

and dry powder of three plant species having known allelochemicals properties against germination seedling growth of *Sorghum bicolor* L. cultivars. Khella (*Ammi majus*) showed highest inhibition of seed germination (52.5%) followed by Ghobaish (*Guiera sengalensis*) and Safsaf (*Salix spp*.) 85.5% and 85.0% respectively. Among three plants species data on seedling and shoot growth Safsaf gave maximum reduction in shoot length followed by Khella and Ghobaish. However plant has phytoherbicide potential on germination and seedling growth of *S. bicolor*.

Allelochemicals are those which are produced by organisms that inhibit the growth, development and reproduction of other plants [78]. It was described by [79] that sorgoleone is hydrophobic compound produced by roots of *S. bicolor* inhibits the growth of other weeds when it was applied as wettable powder formulation. This can be used as safe and environmental friendly tool for weed management. [80] evaluated the allelopathic effect of sixteen plant parts (roots, stalk, leaves, bar and peel) against *Striga hermonthica* (Del.) a noxious weed of food crops pearl millet, maize and sorghum in sub-Saharan Africa. Aqueous extract of four plants decreased the germination of *Striga hermonthica* seed from 95.8 to 99.8%. However striga seed germination was strongly inhibited up to 76% when conditioned with water extract of seven other plant species. It was suggested that use of local plant extract could be a biological component of a striga weed management in Africa. Sunflower (*Helianthus annus* L.) contain allelopathic properties and phytotoxic effect against several weed species. Further [81] reported the efficacy of sunflower leaf extract on barnyardgrass a weed of rice crop. Leaf extract showed 80-100% inhibition of emergence of barnyardgrass and seedling growth when treated with concentration of 10-15% of its leaf extract has the ability to be applied as bioherbicides. Terpenoids, phenolic and flavonoids properties of sunflower was described by [82; 83]. These compounds have the potential to inhibit shoot and seedling growth by affecting the process of cell division and interfering with enzyme activity [84].

[85] investigated the herbicidal effect of eighteen plant species from Thailand against *Mimosa pigra* a common and serious weed growing in wetland of Thailand. Out of eighteen plants employed for test determinations, *Aglaia odorata* showed highest potential to inhibit germination, root and shoot growth followed by *Hydrocotyl umbellata*. Other physiological parameters like root and shoot length, fresh and dry weight calculated were lower than control treatment. [86] extracted citronellal and citronellol from essential oil of *Eucalyptus citriodora*. They drastically exhibited germination and seedling's growth of *S. arvensis*. 3 % oil application caused complete death of *S. oleraceus*, *S. arvensis*, and *A. fatua* while severe injuries were appeared on *X. strumarium*. Consclusively *E. citriodora* essential oil has the potential to be used as bioherbicide as an alternative of chemica weed control. Bioherbicidal effect of *Eucalyptus tereticornis* against a economically important weed *Echinochola crus-galli* L. of rice crop was explored by [87] who reported *Eucalyptus tereticornis* a tall and evergreen plant with heavy biomass contain essential oil. Physiological and biochemical parameters were analyzed after the treatment of *E. tereticornis* and observed that seed germination and shoot length reduced up to 60% and 29-44% with increasing concentration up to 250µg/ml respectively. Similarly chlorophyll, fresh and dry weight, carbohydrate and protein content were decreased in comparison to untreated plants. Reduction in contents may occur due to disturbance in metabolic activities. In recent years allelopathic control of weeds from crops has been developed and allelopathy in crop production and protection are successful examples like in Pakistan [88].

Mango (*Mangifera indica*) leaf extract is a source of botanical herbicides. Leaf extract of *Mangifera indica* contain several compound such as steroids, saponins, flavonoids and tennis which inhibit the

seed germination of *Cassia occidentalis* [89]. [90] reported the bioherbicidal potential of mango leaf extract against germination of *Cassia occidentalis*. Both dry and fresh leaf extract inhibit the germination and seedling growth of this plant. The degree of inhibition varied with increasing concentration. Due to strong inhibiting properties against germination and seedling growth *Mangifera indica* may considered as bioherbicidal source.

Botanicals used as Fungicides

Discovery and development of plant based fungicides is the need of time due to the increasing resistant of plant pathogen but very less botanical fungicides have been registered and commercialized to date, however many researchers isolated and characterized variety of plant derivatives.

Activity of *Cinnamomum osmophloeum* leaves essential oil was evaluated against wood decay fungi. It contains strongest antifungal activity against *Laetiporus sulphureus* and *Coriolus versicolor* [91]. Furthermore, [92] reported that antifungal activity of eugenol and cinnamaldehyd, bioactive compounds of *C. osmophloeum* exhibited strongest antifungal activity against tested fungi. *Macleaya cordata* is an oriental medicinal plant in China has insecticidal and antifungal activity. Alkaloids from these plants are responsible for effectiveness against plant microbial pathogen [93; 94].

[95] performed the screening of eight plants for their antifungal potency against Citrus blue mould. Methanolic, ethyl acetate, petroleum ether and chloroform were used for extraction to check their best antifungal activity. *Inula viscosa* extract with petroleum was recorded highest inhibition of disease. Similarly petroleum ether extract from *Asteriscus graveolens, Inula viscose, Thymus leptobotry, Bibonium odorum,* and *Anvillea radiata* and chloroform extract of *Anvillea radiate, Bibonium odorum* and *Hammada scoparia* presented highest inhibition zone of citrus blue mould. Further [95] used 50 aromatic and medicinal plants for finding richness of antifungal properties against *P. italicum*. In-vivo and in-vitro experiments showed antifungal activity of eight plants out of tested fifty plants. These plants found to be strong inhibitor of *P. italicum*. It was reported by [97] that *Parthenium hysterophorus* roots, leaves and stem possess antibacterial activity against *E. coli, Pseudomonos auriginosa, Lactobacillus sporogense* and *Staphylococcus aureus*. Roots extracts of this plant contain highest antimicrobial activity than stem against bacteria. [98; 99] reported a variety of beneficial aspects of *Parthenium hysterophorus* including anti-bacterial activity. [100] described that wood vinegar extracted from broad leaved trees and also from bamboo which is effective against sap staining fungus. Further antifungal effectiveness of wood vinegar was studied by [101] who reported that the efficiency depends upon the phenolic compound present in wood vinegar.

Moreover [102] tested five plants for their antifungal activity against *Penicillium digitatum* a causal organism of citrus green mould. Ethanolic extract of Chili (*Capsicum frutescence*), Neem (*Azadirachta indica*) and Pong-pong (*Cerbera odollam*) showed high antifungal effect on citrus green mould (*Penicillium digitatum*) followed by ginger (*Zingiber officinale*) and Lemmon grass (*Cymbopogon nardus*) which also contain toxic effect.

Different fungi cause economic losses to post harvested fruits, however [103] reported the antifungal activity of *E. cannabinum, C. ambrosioides, L. inermis, Z. officinale, E. citriodora, O. canum, P. persicae, O. sanctum, O. gratissimum* and *Z. cassumunar* that exhibit the growth of pathogen *Botrytis cinerea*. Twenty five plants were screened out and ten were found to contain antifungal activity. Three plants viz. *Zingiber officinale, Ocimum sanetum* and *Prunus persica* shows enhancement of shelf life for 6, 5 and 4 days respectively when applied on grapes and remains active for a long period of time i.e. 36, 24 and 48 months respectively.

[104] evaluated the antifungal activity of essential oils of Orange (*Citrus sinensis*), Basel (*Ocimum basilicum*), Mustard (*Brassica juncea* L.) and Lemon (*Citrus Medica)* against *Colletotrichum gloeosporioides* (Penz.) on mango fruits. Orange oil at all tested concentrations was proved as effective to reduce the fungal linear growth. Thus, various aspects of biopesticides covering the current status, constraints, prospects and regulatory network towards their effective utilization for the benefit of human kind need to be reviewed regularly.

CONCLUSION

The agrochemical industry focusing on naturally extracted insecticides, fungicides and herbicides. From the last few decades need of botanical pesticides blown up globally because of their less toxicity, target specific, safe for environment and beneficial natural enemies, so research on green chemicals is needed on scientific basis for better podium, but among currently used plant derivatives a few are registered as biopesticides. Hence, ecofriendly botanical pesticides are needed to be developed for the substitute of chemical pesticides. From above review it is concluded that botanical pesticides playing important role in crop protection but to accomplish the claim of ecofriendly green chemicals for agriculture system need more research to investigate new safe and cost effective botanicals with compatibility and adaptability.

Author contribution statement

All authors were involved in the writing and drafting of the manuscript. Mingshan Ji, Mazher Farid and Aatika Sikandar review and finalized the manuscript. All authors carefully read and approved the manuscript.

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Compliance with ethical standards

Conflict of interest

All authors declare no conflict of interest.

Ethical approval

This article does not contain any studies and reviews with human participants performed by any of the authors. All applicable guidelines for the care and use of animals were followed.

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