A potent folklore of botanical plant materials against insect pests together with their preparations and applications

Muhammad Sarwar

Nuclear Institute for Agriculture & Biology (NIAB), Faisalabad, Punjab, Pakistan. E-mail: drmsarwar64@yahoo.com.

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Insect pests generally attack fruits, vegetables and crops in every season, cause severe damage to the plants and ultimately inflict high economic loss to farmers. Doubtlessly, the yield is the ultimate goal of the farmers, and therefore, the quantity and quality of the harvested farm produce depends primarily on the insect pests infestation levels along with some other factors. Pesticide applications (both synthetic and botanical) have been reported to control insect infestations and increase the yield of crop to a reasonable level. Conventional insecticides possess inherent toxicities that endanger the health of the farm operators, consumers and the environment. As a result, botanical pesticides are encouraged over broad-spectrum conventional pesticides. They affect only target pest and closely related organisms, effective in very small quantities, decompose quickly, and provide the residue free food and a safe environment to live. Since there is paucity of documented information on the use of plant extract mixtures in pest control, this article is aimed at assessing the efficacy of plant extracts for managing insect pests of plants. Plant based insecticides induce not only acute toxicity to insects, but also deterrence and repellence which may contribute to overall efficacy against some pests that cause great economic losses at the pre and post-harvest stages of the crop production. Aside this, the use of the plant products is cost effective, nontoxic to natural enemies and environmental safety is guaranteed. The information contained in the manuscript indicates that the botanical insecticide formulations have the potential to be developed as commercial products to incorporate in integrated pest management programs.

Key words: Insect pests, plant extracts, synergism, pest management, biopesticides.

INTRODUCTION

The fruits, vegetables and crops are attacked by a number of insect pests in every season, and cause severe damage to the food production. Insect pests generally attack plants because of the liking for food and to complete their life cycle on the host. They damage and use every part of the plant and ultimately results to a great economic loss to the farmers. Pesticide applications are frequently used to control insect infestations and increase the yield of crop to a reasonable level. The misuse and excessive use of synthetic insecticides may cause some undesirable effects not only to the agricultural ecosystem, but also to human health due to insecticide residue in food. Insecticide residue in agricultural products particularly in fruits, vegetables and crop products is a growing concern for producers, traders, and consumers in many parts of the world (Sarwar, 2016 a; 2016 b; 2016 c; 2016 d; 2016 e). The response of the insects to different levels of organic pesticide concentrations can be associated with the ability of each concentration to withstand photodecomposition of the extracts. Another important aspect in the application of organic insecticide formulations is to focus on their compatibility with other integrated pest management strategies. But sometimes, results indicate that the efficacy of an organic insecticide is low as compared with synthetic insecticide. This may be due to the fact that the active ingredient in synthetic insecticide is more environmentally stable than any known organic insecticide (Sarwar, 2014; Khalid et al., 2015; Sarwar, 2016 f; Sarwar and Sattar, 2016). Conventional insecticides possess inherent toxicities that endanger the health of the farm operators, consumers
and the environmental negative effects on human health leading to resurgence in interest in botanical insecticides because of their minimal costs and ecological side effects. Most of insecticidal compounds fall within four main classes- organophosphates, organochlorines, carbamates and pyrethroids. As a result of the problems of pesticide resistance and negative effects on non-target organisms including man and the environment, organochlorine has been reportedly banned in some countries. Insecticide residue in agricultural products particularly in vegetables and fruits products is a growing concern for producers, traders, and consumers in many parts of the world. This resuscitated the idea of botanical insecticide as a promising alternative to pest control. Botanical insecticides are naturally occurring chemicals extracted derived from plants. Botanical insecticides, which are plant extracts, as active components are safer as well as environmentally friendlier than synthetic insecticides. Botanical insecticides are naturally occurring chemicals which break down readily in the soil and not stored in plant or animal tissue. Often their effects are not long lasting as those of synthetic pesticides as these degrade readily (Isman, 2008; Ahmad et al., 2011; Sarwar, 2012; Sarwar, 2016 g; 2016 h). It has been found that botanical insecticides are safe to natural enemies and integration of biopesticides with natural enemies have a good impact on crop yield parameters (Shabozoi et al., 2011).

Toxicity of plant based insecticides to insect pests

Plant based insecticides induce not only acute toxicity to pests, but also deterrence and repellence which may contribute to overall efficacy against some pests that cause great economic losses at the pre- as well as post-harvest stages of the crop production, and transmit diseases to animals and humans. Botanical insecticides are generally pest specific and relatively harmless to non-target organisms. They are biodegradable and harmless to the environment, and also, the possibility of insect developing resistance to botanical insecticide is less likely (Isman and Akhtar, 2007). Botanical extracts induce insecticidal activity, repellence to pests, antifeedant effects and insect growth regulation, toxicity to nematodes, mites and other pests, as well as antifungal, antiviral and antibacterial properties against pathogens (Prakash and Rao, 1997; Sarwar, 2013). When incorporated in integrated pest management programs or used in rotation or in combination with other insecticides, botanical pesticides can greatly decrease the use of conventional pesticides, potentially lessen the overall quantities applied and possibly mitigating or delaying the development of resistance in pest populations (Sarwar, 2016 i; 2016 j). Extracts (aqueous, water or chemical-extracts or oil) of some plant materials are toxic to some species of insect pests of crops or others are less toxic. These extracts with lethal activity on insects may be applied sole or in mixtures with less toxic plant extracts to ascertain their complimentary or synergistic attributes in the management of crop pests (Hanem, 2012; Sarwar and Salman, 2015 a).

Plant based insecticides have been used for many centuries among limited resources farmers in developing countries to control insect pests of both field crops and stored produce, but their potential is initially limited and ignored. Nicotine, rotenone and pyrethrum are common among farmers to use to some extent for storage pests control and other pests in green houses. Although, the use of rotenone and nicotine appears to be waning, pyrethrum and neem are well established commercially, and pesticides based on plant essential oils have recently entered the marketplace (Schmutterer, 1981). Some of these plant species possess one or more useful properties such as repellency, antifeedant, fast knock down, flushing action, biodegradability, broad-spectrum of activity and the ability to reduce insect resistance (Olalfe et al., 1987). Extracts of chilli pepper (Capsicum annuum L.), in mixture with garlic (Allium sativum L.), onion (Allium cepa L.), bulbs extracts and lemon grass (Cymbopogon citratus Staph.), leaf extract are found very effective against some leaf eating insect pests of crops. Some farmers have been reported using a mixture of Derris roots, seeds of Jatropha curcas and Barringtonia asiatica to control Leptocorisa acuta on rice (Stoll, 1988).

Several field trials have been conducted in various cropping seasons under irrigated and rain fed conditions globally. Today, Insect Pest management (IPM) has to face up to the economical and ecological consequences of the use of pest control measures. Fifty years of sustained struggle against harmful insects using synthetic and oil-derivative molecules has produced secondary effects (mammalian toxicity, insect resistance and ecological hazards). The diversification of the approaches inherent in IPM is necessary for better environmental protection. Among the alternative strategies, the use of plants and insecticidal allelochemicals appear to be promising. Aromatic and medicinal plants and their essential oils are among the most efficient botanicals and their activities are manifold. They induce fumigant and topical toxicity as well as antifeedant or repellent effects. They are toxic to adults, but also inhibit their reproduction. Although, mechanism depends on phytochemical patterns and are not yet well known, this widespread range of activities is continuously being considered for both industrial and household uses, and
essential oils are presently regarded as a new class of ecological products for controlling of insect pests (Catherine, 1997).

Several authors have reported the potential of some of the plant species evaluated in the studies as biopesticides against several species of crop pests. The mixtures of Neem and Eucalyptus leaf extracts with extracts of other plant species was investigated for efficacy in the management of two major post flowering insect pests [legume pod borer, Maruca (testulalis) vitrata (Geyer) and Clavigralla tomentosicollis Stal.] of cowpea. The results revealed that the seasonal mean number of M. vitrata, was reduced (< 1.0/ flower and /or pod) on fields sprayed with leaf extracts of Neem (Azadirachta indica) + Lemongrass (Cymbopogon citratus), Neem + African curry (Murraya koenigii), Neem + Tomato (Solanum lycopersicum), Neem + Bitter leaf (Vernonia amygdalina), and Eucalyptus (Eucalyptus globulus) + African Bush tea (Aspalathus linearis). Pod sucking bugs (dominated by C. tomentosicollis) numbers were suppressed (< 1.5/ plant) on plants treated with leaf extracts of Neem + African curry, Neem + Lemon grass, Neem + Tomato, Neem + Bitter leaf, and Eucalyptus + African Bush tea. These extracts mixtures caused great reductions in pod damage per plant and ensured higher grain yield compared with the unsprayed plants during the two years of investigation (Oparaee et al., 2005 a) Studies were conducted to evaluate the efficacy and synergistic activity of extracts mixtures from herbal landraces in reducing pest numbers on cowpea plants and ensuring high yield of grains. The extracts mixed in a ratio of 10:10% w/ w included; cashew (Anacardium occidentale) nutshell + garlic bulb, cashew nutshell + African pepper and garlic bulb + chilli pepper. The results indicated that all the herbal extract mixtures reduced the numbers of the tested insect pests (legume flower bud thrips, legume pod borer larvae and pod sucking bugs) and pod damage as well as increased grain yields by 4-5 times compared to the untreated control in the two years of investigation. The synergistic advantage of mixing two different plant species in botanical formulations could play a key role in the renewed effort to control pests of agricultural crops using biopesticides (Oparaee et al., 2005 b).

A field application of two botanical insecticide formulations was conducted on cabbage crops to assess the effectiveness of these formulations in reducing two major cabbage insect pest populations. The efficacy of two botanical insecticide formulations, mixtures of Piper retrofractum (Piperaceae) and Annona squamosa (Annonaceae) (RS) extracts, and Aglaia odorata (Meliaceae) and A. squamosa (OS) extracts at 0.05% and 0.1% was compared to a synthetic pyrethroid, deltamethrin at 0.04% and a microbial insecticide, Bacillus thuringiensis at 0.15%. The applications of both RS and OS formulations decreased the population of Crocidoloma pavonana (F.) (Lepidoptera: Pyralidae) and Plutella xylostella (L.) (Lepidoptera: Yponomeutidae), and the treatments of RS and OS at 0.1% was more effective than synthetic insecticide. The applications of RS and OS did not affect the performance of insect pest natural enemies (Alao and Abiodun, AT. 2011). Field experiments to evaluate the effectiveness of two plant extracts Tephrosia vogelii and Petiveria alliacea applied as insecticides singly and as a mixture in a ratio of 1:1 against three major insect pests Maruca vitrata (Tab), Megalurothrips sjostedti (Try) and Ripotortus dentipes (Fab) was conducted. Unsprayed and synthetic insecticide (Decis) treated plants were included for comparison on cowpea (Vigna unguiculata (L) Walp). Application of the extracts irrespective of concentrations, significantly suppressed insect pest population, reduced pod damage and increased grain quality compared with control. However, the mixture of the extracts at 20% concentration competed favorably with synthetic insecticide (Decis). The result further demonstrated that the effectiveness of the extracts as insecticide was dose-dependent (Dadang and Prijono, 2011).

Preparation of botanical formulations

Fresh leaves or roots of the plant species are harvested at full maturity in order to prepare extracts from each of them. Five hundred grams (500 g) each of fresh leaves or roots are crushed separately in a mortar with pestle. The crushed plant parts are put in a separate plastic buckets containing one liter of water. These are allowed to settle overnight and the aqueous suspension is filtered through muslin cloth. The filtrate, then, is served as stock solution for the experiment. The extract from each plant is diluted to various (5, 10 and 20%) concentrations meaning that 5, 10 and 20% each is collected separately from 1000 ml of the stock solution. However, 5% is equivalent to 50 ml, 10% is equivalent to 100 ml while 20% is 250 ml of the stock solution. For comparison, each of the concentrations of synthetic and botanical insecticides is diluted with 1000 ml of water to achieve the same spray volume (Sarwar, 2015 a).

Preparation of extract formulations

Plant materials are cut and then ground using a mill to yield uniform size of powder. The powder of plant species is soaked in methanol (1: 10 w/ v) for 48 hours. Each plant extract solution is filtered with filter paper
Application of treatments

Application of treatments can be done on a weekly basis by spraying each crop very early in the morning using appropriate concentration of the extracts or the synthetic insecticide. The treatment applications can commence about 30-35 days after crop planting. The early morning application can prevent the photo-decomposition of the extracts. However, treatment can also be applied two weeks after crop planting to prevent pre-flowering insect pests (Sarwar, 2015 b).

The complementary roles played by individual plant species used for the extract mixtures in reducing pest numbers and increasing grain yields on sprayed plants suggest the future direction of new formulations of biopesticides in the management of field pests of crops on farms owned by resource limited farmers in low input agriculture characterizing in the developing countries. Among the six rotenoids which occur naturally from T. vogelii, rotenone has been found to be the most insecticidal agent which acts as either a contact or stomach poison (Schmutterer, 1990). Also, Dibenzylthiourea isolated from P. allicea is reported to be an insecticidal compound (Masingh and Williams, 1998). Moreover, the formulations should contain two or more plant extracts to make the formulation more efficient in using plant materials, more economic in extract and formulation preparations, and more effective in toxicity and slow down the development of insect resistance (Dadang and Ohsawa, 2008). This suggests that the plants used as insecticide effectively reduce the level of insect infestations and consequently lead to high yield.

It is important to note that natural pesticidal products are available as an alternative to synthetic chemical formulations, but they are not necessarily less toxic to humans. Some of the most deadly, fast acting toxins and potent carcinogens occur naturally. Several of the botanical pesticides are very toxic to fish and other cold-blooded creatures and should be treated with care. Protective clothing should be worn when spraying, even though their toxicity is normally low to warm-blooded animals. Botanical insecticides break down readily in soil and are not stored in plant or animal tissue. Often, their effects are not as long lasting as those of synthetic pesticides and some of these products may be very difficult to find. Further studies are required to find out the effects of these plant materials and others on insect pests of other cultivated crops and testing their appropriate spraying regimes for effectiveness. This review might be helpful to provide information about traditional botanicals as well as the newer botanicals, their effectiveness, uses, safety, commercialization and future trends of plant-based insecticides (Sarwar, 2015 c; 2015 d).

Conclusion

The results of this investigation show that botanical mixtures could form the basis for a successful formulation and commercialization of biopesticides in developing countries, where low input agriculture is in vogue. Botanical insecticides are desirable alternatives to synthetic chemical insecticides for controlling insect pests. In certain countries, these plants are readily available in large quantities in the local markets during the whole year for farmers use to protect their crops. Since the materials are used as extracts for the treatment of various upsets, they are safe, cheap, easily biodegradable and technologically and environmentally friendly. They could provide valuable alternatives to the synthetic insecticides in the management of pre or post flowering insect pests of plants in limited resources farmer’s farms. They are best suited for use in organic food production in industrialized countries to play a much greater role as a new class of eco-friendly products for controlling pests. However, these plants could be effectively used in developing countries especially in poverty ridden societies. Additionally, rural communities in developing countries could benefit financially by becoming involved in the cultivation and extraction of plants to produce botanical insecticides. Moreover, indigenous knowledge often extends beyond the potential efficacy of endemic plants as crop protectants to include their toxicity to users. Further studies are required to ascertain their optimum mixture levels and spraying schedules for optimum grain yield.

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