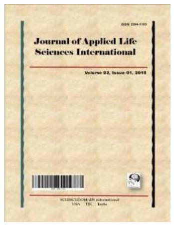

Journal of Applied Life Sciences International

12(1): 1-10, 2017; Article no.JALSI.32503
ISSN: 2394-1103

Botanical Pesticides in Management of Common Bean Pests: Importance and Possibilities for Adoption by Small-scale Farmers in Africa

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Authors' contributions

This work was carried out in collaboration between all authors. Author AOK wrote the manuscript. Authors PAN and ERM reviewed the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JALSI/2017/32503
Editor(s):
(1) Dr. Vasil Simeonov, Laboratory of Chemometrics and Environmetrics, University of Sofia "St. Kliment Okhridski", Bulgaria.
Reviewers:
(1) Eline Meulenberg, Netherlands.
(2) Joao Batista Fernandes, Federal University of Sao Carlos, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/19502

Mini-review Article

Received 28th February 2017
Accepted 31st May 2017
Published 13th June 2017

ABSTRACT

Botanical Pesticides (BPs) have been cited and are used as alternative to synthetic pesticides in agricultural systems worldwide. The BPs are believed to be safe to the environment and are used in pest control to avoid pesticidal pollution, which is a universal problem. In this review, authors provide comprehensive information on the use of BPs in management of common bean pests in Africa. This piece of literature is useful due to major negative side effects to the environment as well as human health arising from synthetic chemicals. It is due to this reason that the authors composed this review to provide insights on potentiality of the BPs in Africa. Generally, it is believed that majority of Africans, feel that BPs are their heritage, thus any technology derived from the BPs is likely to be highly adopted. This review highlights importance, preparation and different methods of applying the BPs so that farmers and other users of this document can easily understand quick methods of using BPs as alternative to synthetic pesticides in combating common bean pests in Africa. Furthermore, areas for future research have been highlighted to establish the need of moving the BPs industry forward for pest management in common bean and other crops in Africa.

Keywords: Botanical pesticides; common bean pests; common bean.

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1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the most important protein-source grain legume for direct consumption in the world [1]. Worldwide production exceeds 23 million Metric tonnes (MT) of which 7 million MT are produced in Africa and Latin America. It is recognized as the second most important source of human dietary protein and the third most important source of calories and consumed by almost everyone both vegetarian and non-vegetarian in Africa. In the Eastern and Southern Africa the consumption exceeds 50 kg per person per year [2,3,4,5]. Despite this big consumption, common bean production in Africa is threatened by a number of constraints especially insect pests and diseases. Control of these constrains is currently considered difficult due to costs and risks on health and environment associated with synthetic pesticides in crop pest management in Africa. This review highlights an alternative option of using botanical pesticides (BPs) in managing common bean pests in Africa. BPs are naturally occurring chemical compounds extracted or derived from plants to manage field and storage crop pests [6]. For thousands of years, empirical knowledge of the use of BPs for pest control provided means for crop protection in different parts of the world before the development of synthetic insecticide [7,8]. Some examples of useful plant products used as source of BPs include rotenone [9], neem [10,11,12,13], sabadilla [14,15,16] and pyrethrin [8,17]. In other areas such as Northern America and Europe, the use of BPs dates as early as 1800s [14]. In these continents, the BPs were widely used to protect field crops and stored products until early 1940s to the 1950s when they were abandoned in the industrialized countries' agriculture due to development of synthetic insecticides [18]. Later on in the 1990s, use of BPs aroused due to numerous negative side effects of synthetic pesticides which were noticed, including the development of pest resistance, pesticide food contamination, environmental pollution problems, the disruption of natural balance, toxicity to non-target organisms and the most important negative impact on human health [8,19,20]. These effects pushed researchers and the community to explore the BPs throughout the world. The BPs have been reported to have ability to protect field and stored commodities or to repel various pests from human habitations [21,22]. Different studies have shown that the biological activity of botanical pesticides is significantly depending on the species of plants, plant parts used for the preparation of the extracts, the physiological state of the part used the extraction solvent and the insect species under study [23].

The BPs can easily degrade in the environment, and they are easily available, less toxic to human and non-targeted organisms and are compatible with different human cultures [8,24,25]. Studies have shown that, plants are very good source of crop protectants against pests [26]. In countries like Benin, BPs such as pyrethrins and neem extracts are used to control cotton bollworm and in Uganda extracts from marigold (*Tagetes spp*) are used against bruchid beetles of cowpeas [27]. In other parts such as West Africa, some plant species such as bushmints (*Hyptis suaveolens*) have been used for the control of pink stalk borer (*Sesamia calamistis*) on maize. Lantana (*Lantana camara*, African nutmeg (*Monodora myristica*) and *Enu-opiri* (*Euphorbia lateriflora*, Schum and Thonner) are also reported to be effective against common bean weevil and maize weevil [28]. With these few described examples, it seems interestingly that, the BPs can be used intensively in a number of crop systems, particularly in Africa.

In a study by Kamatenesi et al. [29], a number of plants such as chill pepper (*Capsicum frutescens),* African marigold (*Tagetes spp,)* cultivated tobacco (*Nicotiana tabacum), Cypressus spp.,* fish bean *(Tephrosia vogelii),* neem *(Azadirachta indica),* banana (*Musa spp), Eucalyptus spp and Carica papaya* have been identified to have strong anti-insect properties and thus they are being used for pest management by the subsistence farmers in countries around Lake Victoria.

In Africa, several studies have shown that the BPs are effective in controlling field insect pest of common beans. For instance, Paul, [30] reported insecticidal properties of neem (*Azadirachta Indica* L.), worm seed (*Chenopodium ambrosioides* L.), cypress (*Cupressus lucitanica*) and marigold (*Tagetes minuta* L.) in management of important field and storage insect pest of common beans particularly, Ootheca (*Ootheca bennigseni*) and common bean weevil (*Acanthoscilides obtectus)*. Recent studies by Mpumi et al. [24], Mkindi et al. [31], Mwanauta et al. [32] reported toxicity, potentiality and effectiveness of BPs particularly *Tephrosia vogelii, Venonia amygdalina, Tithonia diversifolia* and *Lantana camara* in managing both field and storage insect pests of major economic importance i.e. Common bean stem maggot (*Ophiomyia phaseoli*), Ootheca (*Ootheca bennigseni*) and Aphids (*Aphis fabae*) in common beans production in Tanzania. Other BPs reported to have a strong anti-insecticidal properties include *Grewia similis*, *K. schum* and *Echnops hispidu*s, Fresen [34]. Several authors have described some BPs such as *Tagetes minuta (Mexican marigold*) and *Boscia anguitifolia* (Agahini) to be effective against a number of pests of economic importance in common beans (Table 1). Chemical compositions of some BPs described in this review are as shown in Table 2.

Although beneficial effects of the BPs have been reported [31,32], limited information is available on the importance of BPs in the control of common bean pests in Africa. Understanding the role of these BPs will improve their application by common beans farmers and encourage more research in the areas of BPs, thus contributing positively to sustainable management of common bean pests in Africa.

Table 1. Some botanicals pesticides commonly used to control common beans pests in different countries

SN	Common bean disease/ Common bean insect pest	BPs used	Country	Reference
1	Aphids, bruchid beetle	*Targetes minuta*	Uganda	[27]
2	Pink stalk borer	*Hyptis suaveolens, Lantana camara*	West Africa	[28]
3	Anthracnose, common bean leaf spot	*Targetes minuta*	Kenya & Tanzania	[33]
4	Common bean rust fungus	*Boscia angustifolia* *Zanthoxylum chalybeum*	Kenya	[56] [57]
5	Urdcommon bean Leaf Crickle Virus (ULCV)	*Mirabilis jalapa, Datura metel, Catharanthus*	India	[58]
6	Common bean Common Mosaic Virus	*Nicotiana tabacum* L. *Azadirachta Indica, Allium sativum* L.	Bangladesh	[59]
7	Sclerotium root rot	*Azadirachta indica*	Uganda	[60]
8	Cotton bollworm	Pyrethrin, *Azadirachta indica*	Benin, India, United States	[61]
9	Grasshoppers, armyworms Aphids, cabbage loppers	Sabadila	South America	[62,63]
10	Potato aphids, onion thrips, corn earworm	*Ryania speciose*	India, united States	[64]
11	Aphid, thrips, caterpillar	Nicotine	Mexico	[65]

Table 2. Composition of selected commonly botanical pesticides in majority of African countries

SN	BPs	Chemical composition	Reference
1.	Fish bean, *Tephrosia vogelii*	complex mixture of rotenoid, sesquisterpene, lignin, rotenone, tephrosin and deguaelin	[66]. [67]
2.	Neem, *Azadirachta indica*	Azadirachtin	[68].
3.	Lantana, *Lantana camara* L	oxo-triterpenic acid e.g. Pomolic acid, lantanolic acid, lantoic acid, camarin, lantacin, camarinin, and ursolic acid	[69,70]
4.	Pyrethrum, *Chrysanthemum cinerariaefolium*	chrysanthemic acid and three esters of pyrethric acid	[71,72,73]
5.	Mexican sunflower, *Tithonia diversifolia*	diter-penoids, flavonoids, sesquiterpene lactones	[74,75]
6.	Bitter leaf, *Vernonia amygdalina*	Vernodalin, Vernodalol and Epivernodalol	[76]
7.	Pignut, *Hyptis suaveolens*	Alkalloids, tannins, phenols, flavonoids, saponins	[77]

2. IMPORTANCE OF BPs IN ENVIRONMENTAL PROTECTION AND BIODIVERSITY CONSERVATION IN AFRICA

The BPs are believed to be very important for environmental and biodiversity conservation [6]. The active component in BPs are non-persistent with many being UV labile and others are broken down through oxidation or by microorganisms hence presenting lower risks to human, and environments [6,34]. The BPs can maintain biological diversity of natural enemies, lower impact to beneficial insects such as pollinators, and this makes them alternative to synthetic pesticides in pests' control [6]. Contrary to the BPs, synthetic pesticides pose adverse effect of persistent organic pollutants (POPs) on the environment, human health and non-targeted microorganisms. These POPs do not degrade easy, but remain intact in the environment for long period of time and they disperse easily across a wide geographic area, retain their toxicity and have a tendency to accumulate in the fatty tissue of different organisms comprising the biodiversity [25,35]. Use of BPs will assist majority of common bean farmers who lack or who are unable to comply with safety information on use of the synthetic pesticides in pest control in Africa. The BPs are easily available, lower in cost compared to synthetic pesticides, accessible and can be renewed sustainably as botanicals can be grown, multiplied and easily shared within local communities.

3. PREPARATION AND APPLICATION METHOD OF BPs

Most BPs can be prepared in different forms such as powder, liquid formulation including water extract, crude oil extract, ethanol extract, aqueous extract or commercial formulation. In this section the most common methods of preparation have been discussed.

3.1 Powder Formulation and Mode of Application

To prepare powder formulation, plant materials are collected; either sun dried or oven dried and then pulverized into fine powder using pestle and mortar or electric mill. The materials are then sieved with a fine mesh (0.25 mm diameter sieve) [36,37,38,39]. For field application, the powder can be spread out by hand (broadcasting) over the field crops in a manner similar to fertilizer application or they can be applied at planting time along with the basal fertilizer application and work into the soil or applied around the growing plants by ring method or side banding. One of commonly used BPs in this form is the neem leaves [40]. The application rate of powder formulation ranges from 1-20 g/kg of the produce, but does not usually exceed 2% of the weight of produce [41,42,43]. For instance, BPs such as neem dust can be used as soil amendments at 100 - 2000 kg/ha for the management of soil borne pests [43]. For storage of product, the powder is applied directly over the produces and mixed thoroughly before storage [36;44,45].

3.2 Oil Formulation and Mode of Application

A crude extract of oil is extracted from seeds by pounding them lightly in a motor to obtain the kernels after removal of the outer cover [36]. The kernels are ground into a paste, transferred to a pot and briefly heated, then small amount of water is added followed by boiling [39]. The mixture is then allowed to cool. When the content has cooled down, the oil on top of the mixture is collected ready for application [37]. To apply the oil for controlling insect or disease causing pathogens in the field, oil extract at 0.25 - 3% (high volume spray) or about 3 L/ha (low volume spray) can be applied by using conventional knapsack, ULV or hand sprayers [36;44;43]. Otherwise the broom sprinkling method can be used where a long broom or leaf branch is dipped into desired concentration of the extract and sprinkling it on the crops [46]. The application is usually repeated at 10 days intervals. To apply the oil extract in the storage of seeds the application rate of 2.5 - 5ml/kg seeds is recommended [36;43].

3.3 Aqueous Formulation and Mode of Application

Using neem plant materials as example, aqueous formulation can be extracted by using water as a solvent. The aqueous neem solution can be obtained by pressing out fresh juice and diluting it in water at 10%-50% (v/v) concentrations or through maceration (that is immersing in water for prolonged periods). It can also be obtained by infusion (the immersion of plants in already boiled water for prolonged periods) [37,39,47]. Immersion of the plant extracts in water for longer period improves the efficacy of the neem aqueous extracts [48]. The mode of application is as described under the oil formulation and mode of application section (3.2).

3.4 Commercial Formulation

Schmutterer [49] reported that, bioactive components in plants are usually extracted in 95% ethanol, using chromatographic techniques, which include open column chromatography, flash chromatography, thin layer or vacuum liquid chromatography on silica gel and liquid chromatography. The extraction can be done in laboratories or in a small-scale industry using standard protocols [50]. The mode of application of commercial formulations is based on the manufacturer's recommendations.

4. HOST-BPs-PEST INTERACTION

There seems to exist some mechanisms that aid the pest to allocate its host. An illustration showing how the BPs interacts with host and pest is shown in Fig. 1. In this interaction, the pest receives signals (essential oil/chemical communication) released by a host plant and when it reaches the plant surface, it tries to start infesting. If the BPs are applied they can either kill the pest, interfere with insect physiology and development, repel it from the surface or elicit the plant to develop induced systemic resistance (ISR) [51]. If that happens, the plant will not be injured thus no negative economic effect. In the situation where application of BPs has no action on pest, colonisation of plant by the pest can occur, leading to economical injury of the plant.

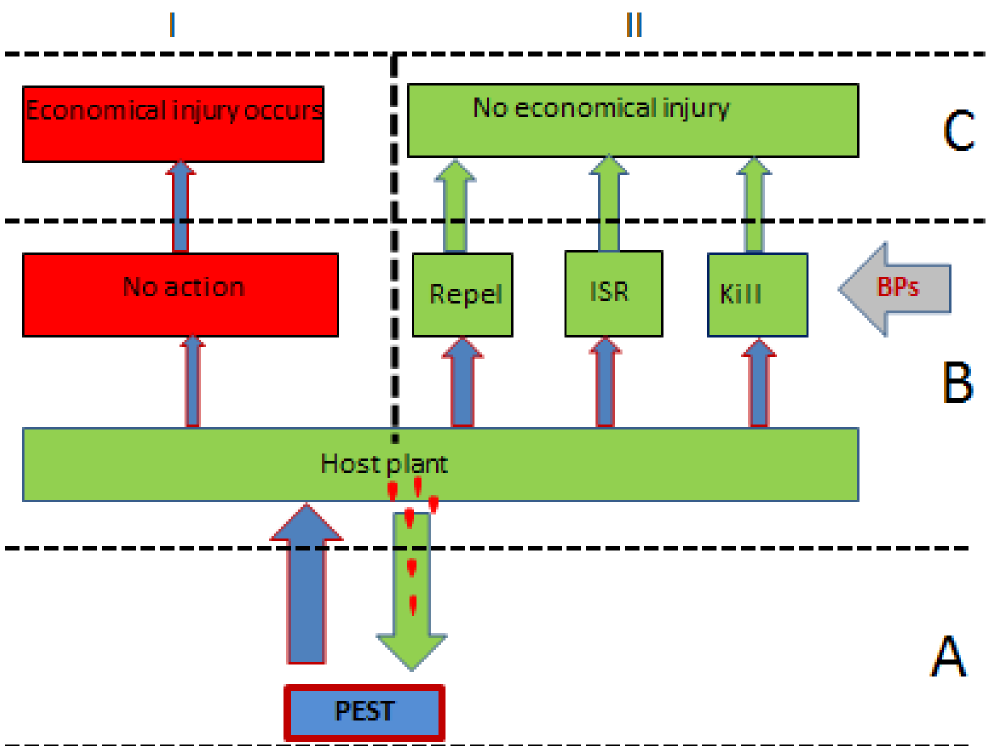

Fig. 1. A model describes how botanical pesticides (BPs) interact with the host and pest. In stage A, the pest receives signals (essential oil/chemical communication) released by a host plant and moves towards the host plant. In stage B, the pest reaches the plant surface and when BPs are applied at this stage, the BP can either kill the pest, elicit the plant to develop induced systemic resistance (ISR) or repel the pest. If that happens, the plant will not be colonised by the pest thus no economic injury (part II C). In the situation where application of BPs has no action on pest in stage B (I), the pest will colonise the plant leading to economical injury of the plant (part I C)

5. BPs AVAILABILITY AND ADOPTION IN AFRICA

BPs plants are widely distributed across many countries in Africa. Some most common PBs in Africa are as shown in Table 2. Between 1994 and 2012; about 59 plant species were reported to have pest control properties in six African countries namely Ghana, Kenya, Malawi, Tanzania, Zambia and Zimbabwe [6]. There exists evidence that, farmers feel that BPs is their heritage thus any technologies that can be developed from the BPs can easily be adopted. For instance, Minja et al. [52] reported that over 80% of the farmers in Malawi, Tanzania, and Uganda exclusively employ traditional methods that included BPs use in pest management. In another study by Cobbinah et al. [53] in Northern Ghana, 90% of farmers regularly use BPs in pest control. In other countries outside Africa, report by Isman [15], Thacker [54] and Ware [55] show that China, Egypt, Greece and India have been using the BPs for the past two millennia. With this evidence on use of BPs not only in Africa but also elsewhere globally, it is undoubtedly convincing that the BPs are indeed worthy for consideration, exploration and use for sustainable insect pest control in many crop systems including common bean. Thus, we hereby and doubtlessly declare the potentiality of BPs adoption by small-scale farmers in common bean pest management. In line with this recommendation, there is need to create awareness and avail BPs information so that communities, specifically common bean growers can maximize crop productivity resulting from BPs for sustainable pest control in Africa.

6. CONCLUSION

In this review, the potential of using the BPs for insect pest control in common bean has been described. We have shown that the BPs are a possible way forward in pest control since they are considered safe to the environment. Generally, authors have shown that majority of Africans, feel that BPs are their heritage, thus any technology derived from the BPs is likely to be highly adopted. Highlights on importance, preparation and different methods of applying the BPs have been described so that farmers and other users of this document can easily understand and use BPs as alternative to synthetic pesticides in combating common bean pests in Africa.

7. FURTHER RESEARCH AREAS

Much that BPs are potential for pest control in common beans, there is need to establish safer levels of applications, storability and identification and how to handle or manage the active ingredients in the same way that synthetic pesticides are handled. There is need to increase research efforts on multiplication of some BPs plants to avoid over exploitation from the environment and developing commercial products out of the most effective BPs. All these require intensive research.

ACKNOWLEDGEMENTS

Authors acknowledge the Nelson Mandela African Institution of Science and Technology Library for providing access to literature used in developing this review.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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