

REVIEW ARTICLE

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Biological control chance and limitation within integrated pest management program in Afghanistan

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Abstract

Integrated pest management (IPM) has recognized as a sustainable method for pest prevention, monitoring, and control. The purpose of this review article focused on biological control potential and challenges in Afghanistan. Biological control is beginning to increase in Afghanistan, in large part due to the establishment of graduate studies in entomology in 2008. Afghan farmers have restricted knowledge about agrochemicals and mostly use a few conventional chemical pesticides and fertilizers. The development and registration of biological agents as an alternative is a more recent movement. Only a single parasitoid agent and three microbial products were registered or pending registration for commercial use on various crops. Products based on *Trichogramma brassicae* (Bezdenko 1968) for lepidopteran pests, *Trichoderma viride* against soil-borne pathogens including *Rhizoctonia solani*, *Macrophomina phaseolina*, and *Fusarium* species are most widely spread. Also, *T. viride*, *Cydia pomonella granulovirus*, and *Helicoverpa zea nucleopolyhedrovirus* registered in 2015. Pesticide registration is the responsibility of the Afghan Ministry of Agriculture, Irrigation and Livestock, with the assistance of the Pesticides Division of Plant Protection and Quarantine Department in coordination with the Ministry of Public Health. The pesticide management board of the National Environmental Protection Agency has not yet signed the membership of the World Trade Organization (WTO) or the International Plant Protection Convention (IPPC). Currently, only one foreign company, the National Horticulture and Livestock Project (NHLP), produces microbial pesticides. However, it promised that two more other companies, the Center for Agricultural Bioscience International and the Afghanistan Agriculture Inputs Projects, will start production shortly. This is a review of the brief history of biological control of pests, with a view on current challenges of pest control practices as well the status of the market and the registration procedures for biocontrol agents, along with challenges and opportunities for the development of biocontrol in Afghanistan.

Keywords: Biocontrol control, Microbial pesticides, Biopesticides, Registration, Afghanistan

Background

Afghanistan is a landlocked country located in the northern and eastern hemispheres, bordered by Iran, Pakistan, Turkmenistan, and Tajikistan, with an area of 653,000 sq. Km. The climate is arid continental. Most of Afghanistan is covered by mountain ranges, the most famous of which is the Hindukush (Sharifi 2013).

Only 3.3 million ha (5.1%) of the country is irrigated and intensively farmed; another 4.5 million ha (7%) is rain-fed, and 29.2 million hectares (45%) is rangeland. The remaining 42.9% is not arable comprised of urban areas, barren land, and the rocky regions of the mountains (ICARDA 2005) (Fig. 1).

Two farming systems practice in the country including sedentary and nomadic (FAO 2011). In the sedentary, mixed crop-livestock system, even the most sedentary of farmers tend to have some livestock because of the need for plowing and transport. The nomadic system takes its name from the livestock

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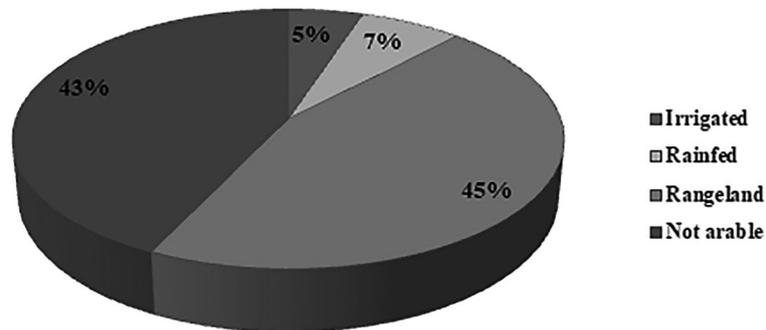


Fig. 1 Percentage of all agricultural and non-agricultural areas of Afghanistan

owners, called “Kuchi” (from ‘kock’ meaning migratory), which rear mostly sheep and goats (Afghan national development strategy 2008).

The main crop and essential food staple are wheat, accounting for 70% of total cereal consumption and grown on 57% of cultivated land. The country is no longer food self-sufficient and must import wheat to meet food demands. Other significant crops include corn and barley, which may use as livestock feed. Fodder crops, such as alfalfa, Persian clover, and other clovers used for hay, make up 10% of the cultivated areas (ICARDA 2005; Sharifi and Sharifi 2016). Minor crops include chickpea, cotton, potatoes, gardens, and orchards (always irrigated) that contribute to vegetables, fruits, and nuts (NHLP 2012).

There is an increasing demand for food self-sufficiency, as well as the ever-greater need for feed, fiber, biofuel, and other bio-products to meet a growing population. A key challenge for the current crop production system is yield loss from pests. In a country-wide study, Bhattacharyya and Pujari (2014) estimated that 6% of cereals and pulses (beans), 10% of oilseeds, 18% of fruits, and 13% of vegetable loss due to pests’ activity during harvesting, handling, and storage. Concurrently, many traditional chemical pesticides used to combat plant pests have withdrawn from use (Damalas and Eleftherohorinos 2011; Williams et al. 2013).

Plant protection in Afghanistan is based predominantly on the use of conventional (synthetic) chemical pesticides (Habibi 2012; Rahimi 2011). The concern is growing, however, regarding the negative impact of chemical pesticides on human, animal, and environmental health (Kumar 2015). The development of alternative plant protection approaches such as Integrated Pest Management (IPM) has been encouraged to address these concerns (FAO and WHO 2017).

Biological control using natural enemies through classical, augmentative, and conservation strategies is a crucial IPM tool offering a more environmentally benign alternative to chemical pesticides (Messing and Brodeur 2018; Kumar et al. 2018). The global biopesticide market

in 2013 estimated at \$3 billion. This level represents a mere 5% of the total crop protection market but has predicted to grow 50% to more than \$4.5 billion by 2023 as biopesticides play a more significant role as replacements in reducing over reliance on chemicals (Damalas and Koutroub 2018). The increasing popularity of biopesticides is due to their higher target specificity and, therefore, safety for non-target organisms (Kumar et al. 2018). Greater appreciation of biopesticides as a component of IPM programs led to a similar increase in their use in Afghanistan (NHLP Report 2018).

Historical view

IPM

From 1992 and particularly in the period 1992–94 and after 2001 with the establishment of an Afghan interim government, FAO has implemented emergency plant protection projects in the north of the country based on the use of pesticides, especially regarding locusts, sunn pest, Colorado potato beetle, and melon fly (Stride et al. 2003). In the provinces where these insects are endemic, these problems have often become political issues. In those provinces, the provincial authorities have applied pressure on “Ministry of Agriculture, Irrigation and Livestock: MAIL” for immediate action, which led to access use of chemical pesticides as the quick and handiest action. In June 2008, under the Horticulture and Livestock Project (HLP), FAO invited the national coordinator an Iranian IPM program based on participatory Farmer Field Schools (FFS) (FAO 2013). This new approach has received the attention of the HLP management team, and that consultant was allowed to conduct many training courses for mores farmers (FAO 2003–2018). However, in November 2008, due to funding problems, the donor (the World Bank) decided that IPM-FFS would no longer fund under HLP. In July 2008, the government of Afghanistan, in collaboration with the U.N., launched its joint emergency appeal in response to the humanitarian crisis faced by the poorest segment of the population as a result of drought and rise

in world market prices of essential staple foods. Under this appeal, FAO submitted a concept note “Promotion of Integrated pest management in Afghanistan.” The concept of IPM is still relatively new in Afghanistan, and there is always a limited understanding of the idea of IPM and its transform to practical use by farmers in different cropping systems (FAO 2013).

Biological control

Arthropod biocontrol programs have a short history in Afghanistan. The first importation of a biocontrol agent occurred at 2008, when the parasitoid, *Trichogramma brassicae* (Bezdenko 1968), was imported from Pakistan by the Aga Khan Foundation for the management of lepidopteran pests, mainly for codling moth, *Cydia pomonella* (Linnaeus 1758), a pest of fruit trees. Due to problems such as lack of specialists and security problems, this advance is not developed extensively and deployed in a limited number of provinces, including Badakhshan, Takhar, Baghlan, and Samangan. Since 2008, *T. brassicae* released annually as an inundative product in more than 287,900 Tricho-card for 2698 hectares of cultivated land and gardens by the Aga Khan Foundation (AKF 2017).

In 2014, the NHLP started the production of biological control agents in Afghanistan. NHLP established an equipped laboratory in Kabul with the cooperation of the center for Agricultural Bioscience International (CABI). The NHLP subsequently established laboratories in several additional provinces, including Nangarhar, Takhar, and Mazar-e Sharif. These laboratories have focused on the mass rearing of *T. brassicae*, as well as *Trichoderma viride* (Pers 1794), *Cydia pomonella granulovirus* (CpGV), and *Helicoverpa zea* nucleopolyhedrovirus (HzNPV) for the control of multiple plant pests and pathogens (Table 1) (NHLP 2018). Therefore, in 2018, 2341 Tricho-card were used in 2341 hectares of cultivated land and gardens by NHLP.

Traditional pest management against some common pests

Cereal crop

Afghan farmers in different locations use various conventional methods for the control of locusts (*Dociosaurus moroccanus* (Thunberg 1815), *Calliptamus italicus* (Linnaeus 1758), *Schistocerca gregaria* (Forsk. 1775), and *Melanoplus differentialis* (Thomas 1865) (Stride et al. 2003). Therefore, some methods including beating or trampling on the hopper, digging up egg capsules or plowing fields with egg pods, scattering straw over roosting sites, and then burning it, making noise to prevent swarm form set in the fields, and early seeding are used usually (FAO 2013). Due to little knowledge about pesticide side effects and particularly the risks associated with their use and little understanding of the agro-ecology of the crops,

there is no any effective traditional method for use against the sunn pest, *Eurygaster integriceps* (Puton 1881), and the unique way is application of different chemical pesticides (FAO 2003–2018; Rahimi 2015; Habibi 2011; Sidiqi 1985).

Orchards

Application of lime sulfur is the main current control tactic of powdery mildew, which causes with species of Erysiphales, especially *Podosphaera xanthii* (Junell 1966) and Pseudococcid species of Hemiptera in grape. The first use of sulfur dust is 2 weeks after bud burst and then apply with 15 days intervals to protect new growth at least three times. Another issue is the control of anthracnose with spot spraying of copper fungicide in April. This method is an effective way to manage fungal agents of anthracnose from the genus of *Colletotrichum*. Mechanical control of *Tibicen* sp. and white grub species including *Polyphylla fulla* (Linnaeus 1758), *P. adspersa* (Motschulsky 1854), and *P. ollivieri* (Castelnau 1840) are from other issues with significant impact on those pest densities which encouraged and corresponded methods developed accordingly (NHLP 2018). Diverse varieties of pomegranates provided significant contributors to Afghan agriculture.

The main concern for the pomegranate of the country is the larval stage of the Carob moth, *Ectomyelois ceratoniae* (Zeller 1839), which causes injury to the fruit via the calyx at the flowering stage. The biology of the moth in the pomegranate poorly understood. The Afghan farmers apply orchard sanitation to reduce the number of infested fruits in the orchard to decrease the upcoming pest density. Moreover, mechanical control can also employ as a plug of mud placed in the calyx of the very young fruit, which acts as a physical barrier and prevents the larvae from entering (FAO 2013). Another control measure is the application of mineral oils. A dormant spray of winter oil is a routine method to reduce overwintering populations of pests as sedentary stages or eggs, particularly aphids, scales, and mites (FAO 2003–2018). Besides the insect pests, there is a high incidence of bacterial canker and gummosis in almond and apricot trees. Copper has some impact in slowing the development of the disease. A dormant spray of copper (Bordeaux mixture) applied on the trees and Bordeaux paste is applied directly to lesions and pruning cuts. The copper spray also offers some protection against the causal agent of shot hole disease coryneum blight, *Wilsonomyces carpophilus* (Lev.) Adaskaveg, Ogawa, and Butler.

Vegetables

The trench method is another tactic for applying against the Colorado potato beetle, *Leptinotarsa decemlineata* (Say 1824) (CPB), which mainly used in the small

Table 1 Available biological agents reported by the National Horticulture and Livestock Project for use in Afghanistan (NHLP Report 2018)

No	Province	District	Agent	Target
1	Kabul	Mirbachakot	<i>Trichoderma viride</i> HzNPV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i>
2	"	Shakar dara	<i>Trichoderma viride</i> CpGV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Cydia pomonella</i>
3	"	Qarabagh	<i>Trichoderma viride</i> HzNPV and CpGV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i> and <i>Cydia pomonella</i>
4	"	Char asia	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
5	"	Dah sabz	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
6	"	Sorobi	<i>T. viride</i> HzNPV and CpGV	Soil-borne diseases including <i>Rhizoctonia solani</i> (Kühn) Moore 1987, <i>Macrophomina phaseolina</i> (Tassi) Goid 1947), and <i>Fusarium</i> species <i>Helicoverpa zea</i> (Boddie 1850) and <i>Cydia pomonella</i>
7	"	Paghman	<i>T. viride</i> HzNPV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i>
8	"	Guldara	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
9	"	Farza	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
10	Parwan	Center	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
11	wardak	Center	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
12	Kapisa	center	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
13	panjshir	Center	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
14	Nengarhar	Jalal abad	<i>T. viride</i> HzNPV and CpGV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i> and <i>Cydia pomonella</i>
15	"	Shiwa	<i>T. viride</i> HzNPV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i>
16	"	khogyani	<i>T. viride</i> HzNPV	Soil-borne diseases and <i>Helicoverpa</i> <i>Helicoverpa zea</i>
17	"	Sorkhroad	<i>T. viride</i> HzNPV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i>
18	Lakhman	Center	<i>T. viride</i> HzNPV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i>
19	"	Mahterlam	<i>T. viride</i> HzNPV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i>
20	Konar	Center	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
21	Baghlan	Center	<i>T. viride</i> HzNPV	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species <i>Helicoverpa zea</i>
22	Herat	Center	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species
23	Mazar	Center	<i>T. viride</i>	Soil-borne diseases including <i>Rhizoctonia solani</i> , <i>Macrophomina phaseolina</i> , and <i>Fusarium</i> species

acreage of the country. In areas where close rotations used or potatoes are grown adjacent to last year's potato fields, this method may help to alleviate first-generation CPB damage. Using the flamer is another method for controlling CPB (FAO 2013).

Main available methods for the control of melon fly, *Myiopardalis pardalina* (Bigot 1891), are plant rotation, early planting, food baiting, pupal collecting from the soil, collection, and destruction of infested fruits. Also, the method of smoke with animal stools before sunrise and after the sunset and primarily covering the fruit with muslin cloths bags (30 × 35 cm) have provided an efficient management program of this tephritid fly during the last years (Stonehouse et al. 2006; Farman Ullah et al. 2015).

Inventory of bio-pesticides used in agriculture

Application and usage of the natural enemies as a core feature of organic production have a strong influence in compelling agricultural industries, especially those who export their products towards non-chemical production (Glare et al. 2012; Damalas and Koutroub 2018; Pandey and Seto 2015; Gadad and Hegde 2014). Demand for organic production, which showed global expansion this decade (Hattinga et al. 2018; Ghasemi 2016), creates new opportunities for biocontrol agents. Consequently, multinational agrochemical inputs have actively purchased bio-pesticide companies over the past years (Arthurs and Dara 2018). If this shift is accurate, then growth in the

biopesticide market seems sure to continue (Hattinga et al. 2018; Gupta and Dikshit 2010; Sheridan et al. 2014).

Before 2014, there was non-significant literature on biological control or available biopesticides in Afghanistan. From 2014 to 2018, three types of biopesticide agents introduced by NHLP rapidly expanded. In 2018, NHLP distributed 2137 kg of *Trichoderma viride* (Pers 1794), over 2137 ha, 538.5 L of *Helicoverpa zea* nucleopolyhedrovirus over 1077 ha, and 12.5 L of *Cydia pomonella granulovirus* over 25 ha (Figs. 2 and 3).

Commercial suppliers of pesticides and biopesticide products

The Afghan government is likely to continue to impose stringent safety standards on conventional chemical pesticides, which will improve opportunities for the introduction and expansion of biopesticides. This plan must come concurrently with generating a greater understanding of the adverse side effects of chemical pesticides, the emergence of a new pest or secondary pest outbreak, and the significant role of their natural enemies. This further information will provide fresh insights into the ecological interactions of pests and natural enemies, leading to improved biopesticide efficacy and acceptance (Sharifi and Sharifi 2016).

Before 2009, there were no legal instruments for pesticide companies to regulate their product registration, import, distribution, and application in Afghanistan. The

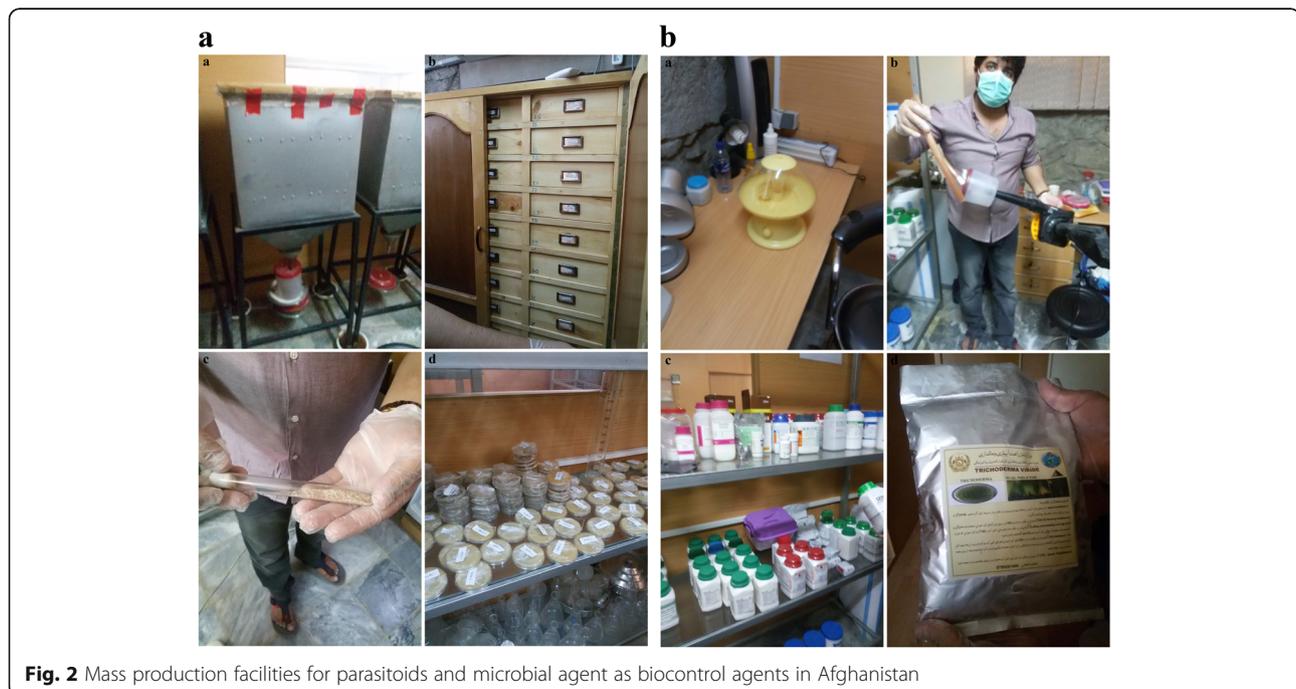
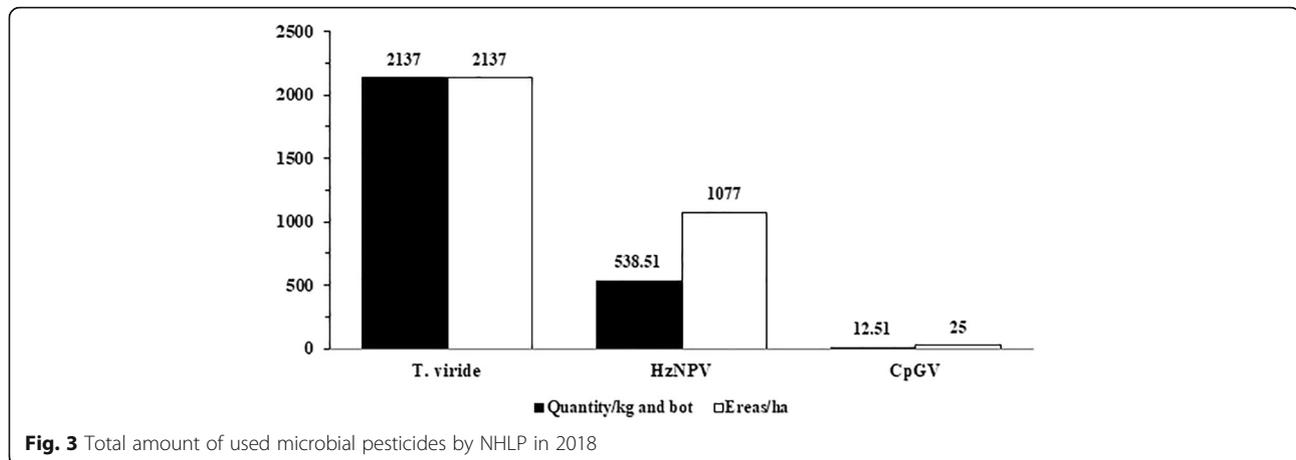


Fig. 2 Mass production facilities for parasitoids and microbial agent as biocontrol agents in Afghanistan



government, with the assistance of USAID, provided an initial pesticide law in 2015 about control the production, import, transport, maintenance, distribution, and use of pesticides and also to prevent risks to human, animal, and plant health resulting from the use of pesticides. There is no explanation about the future of biocontrol agents in this law. It includes some generally recommended items in terms of use and selection of pesticides (USAID 2016).

Responsibility for pesticide registration rests with the Afghani Ministry of Agriculture, Irrigation, and Livestock, with the assistance of the Pesticides Division of the Plant Protection and Quarantine Department. This agency maintains the pesticide registry, receives registration applications, prepares applications, and submits them for approval to the Board of Pesticides (AAIP 2011).

The main goal of registration is ensuring the effectiveness of pesticide products for their proposed use as well as a fair market for pesticide product manufacturers, importers, and distributors (Wyckhuys 2013; Kumar and Singh 2015). The legislation is a critical mechanism to achieve this goal by regulating the production, import, transport, storage, sale, use, and disposal of chemical and biological pesticides.

An additional issue is the development and adoption of strategies for non-chemical pest management. The post-registration regulation of pesticides is the legal responsibility of the Ministry of Agriculture, Irrigation, and Livestock through the Plant Protection and Quarantine Department, in coordination with the Ministry of Public Health and the Pesticides Management Board of the National Environmental Protection Agency (AAIP, 2011). The rationale for post-registration activities is to provide a means of measuring the validity of predictions based on registration data regarding the efficacy, safety, and environmental effects of a pesticide. A list of biological control-based products currently registered in

Afghanistan (USAID 2016) shows that only one foreign company (NHLP) produces biopesticide products domestically (Table 1).

Product safety

According to the Ministry of Agriculture, Irrigation, and Livestock (MAIL 2017), registration dossiers must contain information on the active ingredient, formulation, metabolites, and/or degradation product pharmacology, toxicology, and environmental impact. If a product containing a new active ingredient which already registered by one or more of the USA, E.U., U.K., Japan, or Australia authorities, Afghan authorities may submit relevant toxicological risk assessment reports assembled by independent, accredited toxicologists in support of provisional registration.

Challenges

There are four major areas where the biological control pesticide market encounters challenges that require intensive development.

Regulatory issues

Registration is a universal and obligatory obstacle to the development of biopesticides as commercially available products. Complex bureaucracy and rigorous documentation requirements from the World Trade Organization limit the production and importation of biological control products (Srinivasan 2012). Efforts to simplify regulatory requirements for most biocontrol agents have been made based on lower social and environmental risks (Nawaz et al. 2016). This issue reduces the costs of toxicological testing and development time. Streamlining outdated registration processes to reflect the reduced risk of biopesticides would encourage the commercialization of a more extensive product range and crop profile for their use (Torres et al. 2014; Kalla et al. 2014). For example, entomopathogenic nematodes (EPNs) are low-risk biological

insecticides that are exempt from registration requirements in many countries, an outcome that has strongly and positively impacted their commercialization. In the USA, the EPA has exempted nematodes from any kind of registration. Still, in the EU, EPNs are regarded as macroorganisms by various authorities, which most of them consider EPNs safe. Even FAO put the EPNs in their documents (ISPM No. 3) as invertebrate biocontrol agents and not as microorganisms (biopesticides) (FAO 2005). Moreover, several countries have provided their acts about EPNs according to these guidelines (Ehlers 2005). The data requirements for registering *Bacillus thuringiensis* products should also simplify given this biopesticide extensively documented history of safety and efficacy.

There are additional ways the Afghani government might encourage the adoption of biopesticides. Most farmers are reluctant to change their current pest control practices, so guaranteeing minimum crop prices would reduce perceived risks and encourage more use of non-chemical alternatives (Cory and Franklin 2012).

The lack of transparent national certification systems for organic or chemical pesticide-free may reduce consumer confidence in this critical, high-value market. Most natural products export due to the superior revenue for organic products in foreign markets (Kledal et al. 2012). Addressing certification would provide a legal framework leading to the expansion of organic crop production and, therefore, biopesticide use. The United Nations' Food and Agriculture Organization addresses the global coordination of biopesticide regulations. Hopefully, these efforts will realize to provide a process for updating the biopesticide regulation policy in Afghanistan and many other countries (Karimi et al. 2018).

The Afghanistan government accepted and harmonized some national, regional, and international obligations relative to environmental management, including United Nations Convention to Combat Desertification (UNCCD), Vienna, Montreal, London, and Convention on Biological Diversity (UNCBD). However, there is no party or signatory to some of the critical international agreements, conventions and treaties like the Rotterdam Convention on the International Code of Conduct on the Distribution and Use of Pesticides on Prior Informed Consent (PIC), Stockholm, Kyoto and the Rio (AAIP, 2011).

Growers' needs

Because agricultural holdings in Afghanistan tend to be small and resource-poor, subsistence farmers still rely heavily on chemical pesticides. Growers are reluctant to replace chemical agents with more expensive biopesticides and less well-understood biological agents (Roberto and Parra, 2014). Most farmers have a limited understanding of biological control strategies. The government's lack of experience and implementation

support suggests that farmers require practical training in biocontrol delivered by outreach programs (Sharifi and Sharifi 2016). One outreach avenue is foreign companies that support training programs such as Farmer Field School to increase the flow of biocontrol information to Afghan farmers. The continuation of such on-farm programs emphasizing the integration and use of biological control will encourage the development of biopesticide markets in the country (USAID 2016).

Biopesticide manufacturer issues

A core challenge for biopesticide production in Afghanistan is a limited investment and technical expertise. While there are opportunities for foreign investment, the current security situation is a significant obstacle for specialists to contribute essential knowledge.

The International Biocontrol Manufacturer's Association (ibma-global.org) and the newly rebranded Biological Products Industry Alliance (bpia.org) represent the biological control industry broadly to promote biological control products in agriculture, horticulture, public health, and consumer education through outreach and advocacy activities. International policies presently provide Afghani companies with an opening to work with foreign investors and agencies. Eventually, there may be sufficient interest among producers and distributors to organize a trade association promoting biopesticides. Such an association could lobby for streamlined registration procedures and new government policies encouraging growers to adopt biocontrol and IPM practices. Over the last 5 years, foreign companies have supported the establishment of more than 564 ha of greenhouse crops in the 30 provinces, with growers receiving significant financial incentives to purchase and apply biological control agents (<http://mail.gov.af>).

Research limitations

The most fundamental problem for research in Afghanistan is security. Due to uncertain security, specialists cannot travel to most locations either to collect native specimens for mass rearing in the laboratory or outreach purposes. This issue similarly constrains foreign scientists hoping to assist in field aspects of research programs. Several companies are working on biopesticides, but their research efforts are limited (AAIP 2011). Also, there is little national funding for applied biological sciences. Less than 0.1% of gross domestic product currently allocated to research and development compared with $\geq 1\%$ in most industrialized countries. Under Afghani's "Comprehensive Plan for Science," however, up to 2% of the gross domestic product will be allocated to research and development by 2035 to stimulate industry-university research partnerships and products. Given these new opportunities, there is

real potential to integrate research and industry needs for the development of biological control products. The recommendations push firmly for expanding international training and cooperation. In this way, development international cooperation for joint research/education, including a national center of excellence that focuses on teaching, research, and outreach on biological alternatives to chemicals, has an invaluable role. A useful model could be the China Academy of Agricultural Sciences, which leveraged international collaborative learning and research opportunities to rapidly mature into a first-class scientific institute (USAID 2016). Similarly, the highly successful programs of state agricultural experiment stations in the USA could serve as a model for the development of outreach programs in Afghanistan.

The critical issue is rarely documented information about status of pests and their natural enemies as well as pollinators. Moreover, it is necessary to provide the list of invasive species and quarantine pests. These items could be research plans either for native researchers and academicians or international partners.

Conclusion and recommendations

Integrated pest management is a dynamic approach in which pesticides are essential tools for pest suppression. Nevertheless, pest management tools should be cost-effective and present minimal risk to human and desirable components of the environment (Kernasa et al. 2018), which provides an opening for biopesticide products. The use of biopesticides in Afghanistan remains stunted. Biological agents are currently not widely used because of government regulations and inadequate knowledge about their optimal use (Ansari and Butt 2013; Sharifi and Sharifi 2016). The availability of biopesticides has been at a disadvantage for many years, and it is unlikely that Afghani farmers will have any choice in the short-term but to continue their heavy reliance on widely available and inexpensive chemical pesticides. Extensive research, especially in the public sector, is a prerequisite if the country is to develop effective biopesticide-based IPM technologies. The private sector should help in a different way to develop a commercial venture of bio-pesticides so that these products can be available to growers (Wright et al. 2005; Sharif 2013).

Strict quality control measures should consider for commercially available bio-pesticides. Synthetic chemical pesticides should not be subsidized. Public-private institutes should initiate a massive public awareness campaign directed at growers and consumers on the harmful effects of chemical pesticides. Regional and international cooperation on biopesticide research and development should be enhanced. Since rural farmers in Afghanistan receive little agricultural education or training, universities, federal and state agencies, pesticide manufacturers, and

distributors should work with farmers and other stakeholders to improve their knowledge and acceptance of biopesticides (Woo et al. 2014). Some existing initiatives may play a role in the development, marketing, sale, and use of biocontrol pesticides. Examples include Farmer Field School programs and other outreach programs by pesticide suppliers who deal with farmers (Michaud 2002; Oerke 2006; Wyckhuys et al. 2013; Oreste et al. 2015). These programs provide opportunities to educate farmers about IPM and to differentiate between genuine and unregistered or fake biopesticides. Demonstration of successful microbial biopesticide technologies among more progressive farmers would enhance local adoption, as Afgan farmers use most biopesticides in semi- and peri-urban areas (Kaur and Kaur 2018).

In this way, a holistic and sustainable approach of biopesticide-based integrated pest management system for different crops should be undertaken, thus reducing pest management costs with minimal risk or hazard to humans and desirable components of their environment. In a broader view, the top required issues are social, economic, political, and security situations, which have to remain stable.

Finally, the essential points that the Ministry of Agriculture, Irrigation, and Livestock must pay attention to develop the use of biological control agents within IPM technologies are as follows:

- Study the definition and division of insect pest populations and their natural enemies on natural vegetation and wild plants.
- Survey and production of local natural enemies and their use in biological control, relying on the local strains of insect parasitoids and predators such as *Trichogramma* spp. in control invasive pests.
- Attention to the local strains of natural enemies as they are more efficient than the imported strains.
- Behavioral control using insect pheromones must be considered in integrated pest management programs in the country (insect monitoring, mass trapping, and mating disruption).
- Consider the other biorational tactics, including resistance traits of some crop varieties and also other naturally derived materials like particular botanical-based pesticides and their role in IPM programs.

Abbreviations

AKF: The Aga Khan Foundation; IPM: Integrated pest management; UNCCD: United Nations Convention to Combat Desertification; UNCBD: Vienna, Montreal, London and Convention on Biological Diversity; FAO: Food and agriculture organization; FFS: Farmer field school; NHLP: National Horticulture and Livestock Project; USAID: United States Agency for International Development; HLP: Housing, land, and property rights; MAIL: Ministry of Agriculture, Irrigation and Livestock; WTO: World Trade Organization; IPPC: International Plant Protection Convention; ICARDA: The International Center for Agricultural Research in the Dry Areas

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