REVIEW ON AGRICULTURAL INSECT PESTS CONTROL USING ENTOMOPATHOGENIC FUNGUS *BEAUVERIA BASSIANA*

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Abstract

Beauveria bassiana **Balsamo (Vuillemin) plays an important role in controlling insect pests both in the greenhouse and open field production. Selection of strains that are host specific is key to improve infectivity and to protect the non-target insects. Recent advances in production, formulation, and application of** ***B. bassiana*** **has resulted in the development of improved myco-insecticide products, and registration of several new products. In addition, many countries have developed commercial products that are available in the market for use. Commercial production for this fungus as a biopesticide has been successful but environmental factors such as high temperatures and low humidity among other factors have limited its success in field conditions. The development of oil formulation and UV protectants on commercial products are currently in use and have overcome this challenge. Greenhouse production has had some cases of success but cases of low persistence for long periods has been a limitation. There is need to improve its application such the use of endophytes since this fungus is endophytic in most agricultural crops. For future research, improvements are needed in the research methods, mass production, formulation and the application techniques. This paper reviews studies done using** ***B. bassiana*** **as biopesticide and endophyte on several crops for insect pest control.**

Key words: Biological control, food production, mycoinsecticides, biopesticides

Introduction

Agricultural insect pests are a major threat to global food production. As the world population increases there is need for more food especially in the developing countries. Majority of farmers in sub-Saharan Africa are small-scale farmers and commonly use the cultural methods of intercropping, mixed farming and crop rotation to manage these pests. Other methods commonly used include good husbandry practices such as weeding and removing the debris, manuring and mulching which produce vigorous plants that have improved pest tolerance. The use of clean planting stock, sanitation and crop rotation are also universally advocated to reduce the pest status of many pests (Compendium, 2004).

The increase in population has necessitated seeking for alternative methods e.g. the use of pesticides to manage insect pests. Pesticides are effective and fast acting and increase food production (Mengech et al., 1995). The indiscriminate use of pesticides has however resulted in the development of resistance in insect pests against the insecticides, adverse ecological events affecting beneficial fauna and accumulation of residues in the environment (Gold and Merriaen, 2000; Nankinga et al., 1998). Pesticide use is also hazardous to consumers since residues may be found in food and the safety of individuals handling them is also compromised (Mengech et al., 1995). High costs also limit their utilization as control methods (Allard *et al.,* 1991; Nankinga *et al.,* 1994). There is need therefore to develop safer and cheaper control alternatives that can be used to complement existing ones (Nankinga et al., 1998).

Biological control includes use of natural enemies and microbial control. Natural enemies such as arthropod predators, parasitoids and entomogenous nematodes have been used to control pests. The use of predators like the predatory mite *Phytoseiulus persimilis* has been used to control red spider mites in greenhouses on roses and other crops especially at low pest populations (Gerson et al., 2003). This is mainly due to the low food requirements by the predatory mites and fast development to the egg laying stage (Gerlach and Şengonca, 1985).

The predatory larvae of the Javanese rhagionid fly, *Chrysophilus ferruginosus*, attacks *Cosmopolites sordidus* larvae in the laboratory, but not in the field due to environmental conditions. In harvested pseudostems, *Dactylosternum abdominale* reduced the multiplication of *C. sordidus* by 40-90% at different predator population densities, and *Thyreocephalus interocularis* reduced it by 42% (Hasyim and Gold, 1998). In crop production the parasitoid *Ceranisus femoratus* was found successful in control of *Megalurothrips sjostedti* in cowpeas (Neuenschwander and Markham, 2001).

The potential use of entomopathogenic nematodes for biological control has been well demonstrated (Lunau et al., 1993). The nematode genera that are commonly utilized include *Steinernema* and *Heterorhabditis*. These genera have a wide host range especially of lepidopteran, dipteran and coleopteran pests of commercial crops (Burnell and Stock, 2000) and have the ability to kill the hosts rapidly. They have an advantage over fungi especially for pests like banana weevil since they are able to actively seek their host in response to a CO_2 gradient and thus able to find the larvae within the tunnels provided they can withstand the pH changes (Lunau et al., 1993).

Microbial control of insects has focused on fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* among others which have been used successfully in the laboratory, screen house experiments and in commercial field. These fungal species that infect insects are commonly known as entomopathogens. Many are common natural enemies of agricultural pests (Roberts and St Leger, 2004), and occur naturally. They are wide spread in many parts of the world, with low to no mammalian toxicity (Goettel et al., 2005).

Beauveria bassiana when used as biocontrol agent has several advantages; it infects all the developmental stages of their hosts, have a broad host range and present no health hazard to man or other vertebrates as well as the natural enemy complex. However, the use of fungi has challenges such as: difficulty in developing a correct formulation state of for use in field conditions because of sensitivity of fungal spores to desiccation and UV radiation. In addition inoculum are affected by environmental factors such as temperature and water availability so it is difficult to predict the success of pathogenicity (Deacon, 1981). This paper reviews the biological control using *Beauveria bassiana* to control of insect pests as a bio pesticide and an endophyte, in addition it will identify some studies done on several crops.

Beauveria bassiana as a biopesticide

Beauveria bassiana is an entomopathogenic fungi used to control insect pests and arachnids for many years (Meyling and Eilenberg, 2007). It belongs to the Division Deuteromycotina (Fungi imperfect) within the class Hyphomycetes. The genus *Beauveria* contains several species which include: *bassiana, brongniartii, tenella, amorpha* and *velata* (Goettel and Jaronski, 1997). They produce asexually and are distinguished by the morphological and the developmental features of the spore bearing structures.

Mostly *B. bassiana* occurs naturally in soil , insects and plant residues; It is also well-known for the production of secondary metabolites (White Jr et al., 2003) some of which have antibiotic properties while others have virulence factors facilitating the ability of the fungus to colonize an insect pest (Strasser et al., 2000). Toxins produced by isolates of *B. bassiana* include beauvericin, bassinolide, beauvolide, beauvirolide , oosporein , bassianin and tellinin (Gupta et al., 1991). It's infection is unique in that it does not need to be eaten by the insect or enter through an opening e.g. wound but it is capable of entering the insect directly through the cuticle by production of enzymes or other secondary metabolites (Boucias et al., 1988).

Studies on *Beauveria bassiana* have been done in various parts of the world under laboratory, field and screen house experiments (Faria and Wraight, 2001). Inoculation has generally focused on several techniques which include seed coating, soil drenching, substrate inoculum, stem injection, or foliar spray (Tefera and Vidal, 2009). Foliar spray is mostly deployed in one or more inundative applications of large numbers of aerial conidia in dry or liquid formulations. Spores/conidia can stay for a very long time but the frequent sub culturing was found to lower its virulence.

Dispersal and infection is by conidia, which germinate and penetrate the insect cuticle or gut wall (Deacon, 1981). The spores then germinate and grow directly through the cuticle to the inner body of their host. The fungus proliferates throughout the insect's body producing toxins, mycosis and draining the insect of nutrients, eventually killing it. After the insect dies, the fungus produces an antibiotic (oosporein) that enables it to outcompete intestinal bacteria. Eventually the entire body cavity of the insect becomes filled with mycelia (Gold and Merriaen, 2000). The chlamydospores produced after death of the host, can maintain the fungus in a viable state within the host cadaver. These spores subsequently germinate to form emergent hyphae that sporulate on the surface of the host to produce new external infective spores (Deacon, 1981; Ferron, 1978), which can reinfect another host.

Behavioral changes have also been observed during the period of lethal infection for example female carrot flies, *Psila rosae,* infected with *E. muscae* do not lay their eggs near carrot plants as healthy ones do reducing chances for egg survival. Ants change their normal route to avoid contact with other ants or they climb elevated locations just before dying (Hajek and St. Leger, 1994).

Beauveria bassiana has also been used in the control of *Dendrolimus* species, the Pine Moth in Pine forests in China. The fungus is locally propagated cheaply on a bran or peat substrate and is applied by air or by ground equipment as a spray or dust (Xiao et al., 2012). In another study Bing and Lewis (1992b) researched on *B. bassiana* to control *O. nubilalis* activity at different stages in corn development, application of the fungus was applied to corn as a foliar application of a granular formulation and also through injection of a conidial suspension at the whorl stage of development and results indicated that there was less damage of the European corn borer(Bing and Lewis, 1992).

As a biopesticide, *Beauveria bassiana* offers an environmentally safe control measure against insect pests. Most studies done have found that this fungus attacks mostly lepidopteran and coleopteran pests, without affecting natural enemies, hence it can be integrated with other biological control agents in the management of pests(Kaaya and Hassan, 2000).

The major limitation of using *B. bassiana* as a biopesticide in the field has been limited by abiotic and biotic factors (Fuxa and Richter, 2004; Hallsworth and Magan, 1999). Environmental factors such as relative humidity, soil moisture and composition, temperature, and sunlight greatly influence it's efficacy and persistence in the field (Lingg and Donaldson, 1981). Currently though oil formulations have been used to solve this limitation due to a better adhesion and spreading of the formulation on the lipophilic cuticle than for conidia formulated in water(Inglis et al., 1996).

The components of the oil fungus formulation in relation to the insect need to be carefully studied to achieve good results (Bateman et al., 1993; Luz and Batagin, 2005). In addition, field application has also been constrained by high costs of inoculum production and application in comparison to establishing the fungus within the plant. There is therefore need to develop an economical and effective delivery system that overcomes field application such as the use of endophytes.

Beauveria bassiana as an endophyte

The term endophyte refers to interior colonization of plants by micro-organisms mostly bacteria and fungi that live most of their life inside of the plant tissues without eliciting any pathogenic symptoms to host plants (Faeth and Fagan, 2002). Endophytes of *Beauveria bassiana* are protected from the harsh environmental conditions which limit their virulence and persistence (Card et al., 2016) . In most studies done no adverse effects reported in its association with the host plant and therefore it is safe for human consumption (Lewis et al., 2001).

B. bassiana occurs naturally as an endophyte in some plants such as corn, cotton, jimson weed, stinging nettle, and hawthorn (Jones, 1994; Meyling and Eilenberg, 2006). *Beauveria bassiana* can however also be artificially introduced into plants using several techniques and the endophytic colonization is associated with insect control (Bing and Lewis, 1991, 1992; Posada and Vega, 2005; Quesada-Moraga et al., 2006). These fungi can be isolated using the plating techniques on selective media (Doberski and Tribe, 1980).

Studies have demonstrated that endophytic *B. bassiana*, can be established in several crops (Vega et al., 2008), they include ironwood (Bills and Polishook, 1991), Jimsonweed, potato (Jones, 1994), maize (Wagner and Lewis, 2000), cacao (Posada and Vega, 2005) , date palm (Gómez-Vidal et al., 2006), opium poppy (Quesada-Moraga et al., 2006), banana (Akello et al., 2007), coffee (Posada et al., 2007), sorghum (Tefera and Vidal, 2009), wheat, cotton, tomato, bean, pumpkin (Gurulingappa et al., 2010), jute (Biswas et al., 2012), *Theobroma gileri* (Evans et al., 2003), *Carpinus caroliniana* (Bills and Polishook, 1991), tomato (Powell et al., 2009), in seeds and needles of *Pinus monticola* (Ganley and Newcombe, 2006) and radiate pine (Brownbridge et al., 2012).

Endophytic colonization by *B. bassiana* reduces damages caused by several pest insects which include; European corn borer (*Ostrinia nubilalis*) and maize stem borers (*Sesamia calamistis)* in maize (Bing and Lewis, 1991; Cherry et al., 2004; Lewis et al., 2001), Tomato fruitworm (*Helicoverpa zea)* in tomato (Powell et al., 2009), Banana weevil (*Cosmopolites sordidus*) in banana (Akello et al., 2008), stem gall wasp *Iraella luteipes* in opium poppy (Quesada-Moraga et al., 2006), Cotton aphid, *Aphis gossypii* in cotton (Gurulingappa et al., 2010), stem weevil, *Apion corchori* in white jute (Biswas et al., 2012), and Pea leafminer *Liriomyza huidobrensis* in faba bean and Phaseolus vulgaris (Akutse et al., 2013).

In most studies done insects recovered from endophytic plants only show a few cases of mycosis (Akello et al., 2008; Powell et al., 2009; Vidal and Jaber, 2015). The mechanisms involved in the control of insect pests in most cases are unclear to most authors (Vidal and Jaber, 2015), but they speculate several metabolites are produced by endophytic *B. bassiana* that aid in insect control. These metabolites may aid in parasitism of insects in cases where they are produced but are not required since some isolates do not produce them.

Conclusion

B. bassiana when used as a biocontrol agent against insect pests is a sustainable way to avoid relying on chemical pesticides commonly used by most farmers in Africa. There is need to search for isolates that give good results both in the green house and in field conditions. Application methods can also be improved e.g. oil formulations, combining foliar sprays or drenching to give better results. In summary the focus in insect pest control should be on the use of biological control to support agro-ecosystems and give sustainable solutions through the use of entomopathogens especially as endophytes.

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