Review of Literature
2. REVIEW OF LITERATURE

2.1. Phyllosphere microflora

The significance of phyllosphere microflora and the method used for leaf surface examination was extensively reviewed by Raimen (1961). Both pathogenic and saprophytic bacteria including nitrogen fixers, yeasts and fungi were isolated from the vegetative buds of tropical woody plants and some annuals (Leben, 1969; Davenport, 1970; Leben et al., 1970; Leben, 1971; Johan et al., 2001; Lindow and Brandl, 2003). Some plant pathogenic fungi had been reported to have their source of inoculam in the bud e.g. *Venturia inaequalis* (Preece, 1963) and *Tilletia caries* (Leben, 1971). Jones (1976) reported that both the nitrogen fixing and plant growth promoting phyllosphere bacteria have been present in many crops.

Influence of various insecticides on phyllosphere of rice crop was studied by Jayachandran and Chandramohan (1977). Impact of fungicides on potato phyllosphere was reported by Shukla and Mishra (1993), Shukla (2000). The effect of pollutants on the microbial ecosystem of leaves was reviewed extensively by Manning (1976), Dowding (1986), Fenn et al. (1989). Brighigna et al. (1997). Stadler and Muller (1996) reported the aphid honeydew and its effect on the phyllosphere microflora of *Picea abies* (Lin.). Mukerji and Rikhy (1980) worked on the microbial ecology of *Triticum aesticum* (Wheat) leaves. They found that different segments of the leaf lamina (apical, middle and basal) had different quantity and types of microorganisms. More than 85 different species of microorganism had been reported in the phyllosphere of rye, olive, sugar beet and wheat (Thompson et al. 1993; Loper and Lindow, 1994; Legard et al., 1994). Murty (1984) demonstrated that 1.6 to 3.2 kg nitrogen/ha\(^1\) was found in
Phyllophere of cotton during the entire growth period. Occurrence of nitrogen fixing *Pseudomonas* sp. in phylloplane of trees and nitrogen fixing *Bacillus polymyxa* and *B. macerans* in cotton phylloplane was reported by Jenni *et al.* (1989), Olieveira *et al.* (1993). Kaur *et al.* (2000) reported the natural occurrence of *Bacillus thuringiensis* in leguminous plants phylloplanes. They found that chickpea harboured the highest population of Bt followed by pigeonpea. Vigneshwaran and Natarajan (2003) isolated *B. macerans* from the cotton phylloplane and it's ability to fix nitrogen was studied by acetylene reduction assay. Michereff *et al.* (1994) isolated epiphytic bacteria from yam leaf by washing and serial dilution method. Other methods including fatty acid methyl ester (FAME), phospholipid fatty acid ester, (PLFA) Cot½ curve analysis and denaturing gradient gel electrophoresis (DGGE) had also been practiced to analyse microbial communities with or without culturing methods (Ching Hong Yang *et al.*, 2001). Hirane and Upper (2000) analysed the microbial communities with carbon source utilization patterns through BIOLOG microplates assay. The relative fitness of some human enteric pathogen in the phyllosphere has been studied by Cho *et al.* (1975), Ott *et al.* (2001), Balandrean *et al.* (2001). Ching Hong Yang *et al.* (2001) analysed phyllosphere communities of seven different plant species by culture dependent and independent methods such as gradient gel electrophoresis (DGGE) with 16S rRNA primers. The presence of methylotrophs and methanodrophs in woody plant tissues has been reported (http://www.ashukka/trped.com). Lactic acid bacteria have been reported from the phyllosphere of raised cultivars of legumes (http://www.scis.com).
2.2. Gut microflora

Cellulase activity of the intestinal tract of termites and woodrushes reported by Breznak (1982), Cruden and Markovetz (1987). Numerous investigations of the bacterial flora of insects gut and their significance was extensively reported elsewhere (Brooks, 1963; Hagen, 1966; Lysenko, 1985). Gut microflora of different insect order like Orthoptera (Hunt and Charnley, 1981), Lepidoptera (Sahayaraj and Mary Joseph, 2003) Diptera and Plcoptera (Findley et al., 1986), Isoptera (Smith and Douglas, 1987) Blattaria (Santo Domingo et al., 1988); Heteroptera (Sahayaraj, 2004) were recorded. Bignell (1982) reviewed in detail about the relation between structure and the microbial communities of insect gut. Dasch et al. (1984) reported the endosymbiont of insects. The contribution of endosymbionts and gut microbiota to the nutrition of the hosts have been extensively reviewed by Campbell (1989), Douglas (1992), Tanada and Kaya (1993). Mead et al. (1988) studied the gut microbial ecology of the colonized migratory grasshopper. Kaufman and Klug (1991) reported the contribution of hind gut bacteria to dietary carbohydrate utilization by crickets. Kane and Breznak (1991) reported the effect of host diet on the production of organic acid and methane by cockroach gut bacteria. Dillon and Charnley (1996) studied the colonization of the gut of germ free desert locusts Schistocerca gregaria by the bacterium Pantoea agglomerans. Cazemier et al. (1997) investigated the gut bacteria of 12 species of arthropods belonging to 7 orders by direct count using 4, 6 diamino phenyl indone staining method. Spiteller et al. (2000) reported the metabolic products of some lepidopteron gut bacteria are included in the synthesis of products that play a pivotal role in multitrophic interactions. They found such a interaction in Spodoptera litura lead to the suggestion that gut bacteria should be
included as another trophic level. Muraligopal et al. (2002) studied the microflora associated with coconut eriophyid mite with aim to isolate the putative pathogens. Pankaj et al. (2003) reported in detail about the gut bacterial flora of H. armigera. Sahayaraj and Mary Joseph (2003) reported the impact of NPV on gut bacteria of S. litura.

2.3. Entomopathogenic fungi

Entomopathogenic fungi are associated with insects living in diverse habitats including fresh water, soil and aerial habitat. These fungi are very specific to insects often to particular species and do not infect animals or plants. Fungal growth is favoured by moist condition but fungi also have resistant stages that maintain infection potential under dry condition. They have considerable epizootic potential and can spread quickly through an insect population and cause collapse. Several fungal species have potential as microbial insecticides and in some countries they are commercially available in formulations that can be applied using conventional spray equipment (Hoffmann and Frodsham, 1993). The entomopathogenic fungi are distributed in the following groups, namely, Mastigomycotina, Zygomycotina, Ascomycotina, Basidomycotina and Deuteromycotina. They have a wide host range belonging to Lepidoptera, Coleoptera, Hemiptera, Diptera and Hymenoptera (Tanada and Kaya, 1993; Padmaja, 2005).

Entomogenous and Zygomycetes principally belongs to the order Entomophthorales. Some species coming under the genera Entomophthora, Neozygites and Pandora have the ability to cause epizootics that decimate arthropod population. The insect hosts of these fungi occur in more than 32 families.
belonging to the orders *viz.* Homoptera, Diptera, Lepidoptera, Coleoptera and Hymenoptera (Pell *et al.*, 2001). *Entomophaga* sp. are the most common and widespread pathogen which mainly infect grosshoppers. Ramoska *et al.* (1988), Rameshiah (1968), Steinkraus *et al.* (1995) have isolated *Neozygites floridana* from *Aphis gossypii* Glover in India. Wilding (1981) reported that the application of *Entomophthora* sp. produced in vitro against aphids and mites on glasshouse plants resulted in 95% mortality within 24 hours suggesting the presence of fungal toxin.

2.3.1. Deuteromycete entomopathogenic fungi

Deuteromycotina (*fungi imperfect - Hyphomycetes*) most of the entomopathogenic fungi belongs to Deuteromycetes. About 30 genera have been reported to contain one or more species that infect insects. Imperfect fungi are mycelial fungi that reproduce by means of conidia that are generally produced on free or aggregated conidiophores on the substrate surface. Since these fungi lack apparently a sexual or perfect stage, they are known as imperfect fungi. They have been developing by parasexual reproduction in which nuclear fusion occur. The parasexual process provides a mechanism for genetic exchange among imperfect fungi. Fungi that produce conidia or more or less loose, cottony hyphae are often termed as hyphomycetes. Number of fungi belonging to this class causes muscardine diseases in insects (Humber, 1997). The term was first applied to the white muscardian of the silkworm caused by *Beauveria bassiana*. Other muscardine diseases associated with insects are the green muscardine caused by *Metarhizium anisopliae*, the red muscardine *Sorosporella uvella* and yellow muscardine by *Aspergillus flavus*. Jagtap (1958) reported that a heavy spare suspension of *M. anisopliae* killed 92 - 98 percent of adults and 90 - 95 percentage of nymphs of *Pyrilla perpusilla* Walker. Rao (1989) reported the
pathogenicity of *M. anisopliae* and *B. bassiana* to brown plant hoppers. Ranga Rao and Reddy (1997) first reported the occurrence of *M. anisopliae* in groundnut leaf miner (GLM) *Aproaerema modicella* (Devender). Alejandra et al. (1989) evaluated the comparative pathogenicity of *M. anisopliae*, *B. bassiana* and *Paecilomyces lilacinus* to adult sweet potato weevil *Cylas formicarius* (Fabricius). Pathogenicity of *M. anisopliae* was evaluated against different species of termites (Hanel and Watson, 1983; Sajap and Jang, 1990; Milner et al., 1998; Swaran and Varma, 2003). Biological control of *M. anisopliae* along with *Aspergillus regulosus* were evaluated against root mealy bug (Devasahayam and Abdulla Koya, 2000). Ambethgar (2003) evaluated the virulence of 22 indigenous isolates of entomopathogenic hypomycetes on cashew tree borer *Plodia dispar* (Lion). The fungus *Nomuraea rileyi* is pathogenic to economically important Lepidopteran pests such as tobacco caterpillar, *S. litura* (Vimala Devi et al., 1996; Venkatesan et al., 2000; Kulkarani and Lingappa, 2002) gram caterpillar, *H. armigera* (Gopalakrishnan and Narayanan, 1988).

2.3.2. *Beauveria bassiana* (Balsamo) Vuillemin

In France and Italy, the silk production was the most important economy during the 16th and 17th centuries. Heavy losses of larval silk worms due to "Muscardian" were experienced during those periods. In 1835, the Italian Scientist Agostino Bassi de Lodi (the "Father of insect pathology") reported that the silkworm disease was actually caused by a fungus that multiplied in and on the body of the insect. This was the first microorganism recognized as a contagious agent of animal disease. The fungus was later named as *Beauveria bassiana* in honor of it's discoverer. The very distinctive white mammies of affected caterpillars gave rise to the name muscardine.
Beauvaria bassiana is a common soil borne fungus that occurs worldwide and has been reported as a suppressive agent for several insect species (Bruce Wagner and Lewis, 2000; Gillespie, 1988). Easwaramoorthy and Santhanakishmi (1987) reported that B. bassiana caused 100% mortality of Chilo infuscatus larvae. The natural disease outbreak of B. bassiana on H. armigera was reported by Abbaiah et al. (1988). Alejandra et al. (1989) evaluated the biological control potential of four isolates of B. bassiana, M. anisopila and Paecilomyces lilacinus against sweet potato weevil Cylas formicarius (F.). Gopalakrishnan and Narayanan (1990) reported that Beauveria bassiana is highly effective against the different stages of Helicoverpa armigera. Rajagopal et al. (1988) reported the natural infection of A. modicella larvae of B. bassiana in Bangalore. It’s dose and mortality relationship on mango mealy bug Drosicha mangiferae was available in the literature (Masarrat Haseeb and Srivastava, 1998). Bing and Lewis (1993) studied the occurrence and virulence of this fungus in different tillage region in corn. Hafez et al. (1994) investigated the effect of B. bassiana on various developmental stages of the potato tuber moth Phthorimaea operculella (Seller). Lewis et al. (1996) reported the integrating effect of Bacillus thuringiensis and carbofurom with B. bassiana in corn against the larvae of the European corn borer. Application of B. bassiana at a concentration of $1.2 \times 10^8$ spores/ml of suspension reduced nearly 80% of the brown weevil Myllocerus aurolineatus Voes. (Wu et al., 1995). Jayanthi and Padmavathamma (1996a) reported that B. bassiana caused reduced pupation and higher pupal mortality in S. litura.
Adane et al. (1996) carried out a preliminary study on the use of *B. bassiana* to control the maize weevil *Sitophilus zeamais* (Motsch) under *in vitro* condition. *B. bassiana* induced natural epizootics in the rice leaf folder (*Crophalocrocis medinalis*) (Goence) a (Ambethgar, 1997). Many workers have extensively investigated about the usage of *B. bassiana* against the important coleopteran pests namely blister beetle, *Lytta nutali* (Miranpuri and Khachatourians, 1994) and *Coleomegilla maculata* (Coccinelid) (Todorova et al., 1996). Vandenberg et al. (1998) isolated *B. bassiana* from the diamond black moth *Plutella xylostella*. Pathogenicity of *B. bassiana* isolates on brinjal spotted beetle *Henosepilachna vigintioctopanctata* (Fabricius) was recorded by Padmaja and Gurvinder Kaur (1998). Sivasankaran et al. (1998) studied the influence of temperature and relative humidity on the growth, sporulation and pathogenicity of *B. bassiana*. Adhanan Negasi et al. (1998) evaluated the pathogenicity of *Beauveria bassiana*, *Paecilomyces farinosus* and *Verticillium lecanii* against the adults, eggs, first and third instar larvae of silverleaf whitefly, *Bemisia argentifoli* (Bellows & Perring). Kempraj and Gopalan (1999) conducted the pathogenicity of four species of entomogenous fungi against the soybean leaf miner, *A. modicella* and reported that *B. bassiana* was the most effective fungi than *M. anisopliae*. Hastuti et al. (1999) evaluated about the susceptibility of life stages of *Paropsis charydis*. Impact of soil spray of the entomopathogen *B. bassiana* and *M. anisopliae* on coffee berry borer adults *Hypothenemus hampei* (Ferrari) was studied (Bustillo et al., 1999). Grace (1991) Sajap and Jan (1990) and Jones et al. (1996) evaluated the pathogenicity of *B. bassiana* on termites.
Investigation on the effect of insecticides on the pathogenicity of *B. bassiana* and *M. anisopilae* against *Spodoptera litura* was undertaken by Dayakar *et al.* (2001). They observed that the combination of insecticides with *B. bassiana* showed 1.05 to 1.24 fold increase in virulence over the sole treatment. Hazarika and Puzari (2000) made an attempt to control the major tea pests. Fernandez *et al.* (2001) reported the effect of mode of exposure to *Beauveria bassiana* on conidia acquisition and the host mortality of Colorado potato beetle. Shekharapha and Kulkarni (2002) tested the two commercial formulation of *Beauveria bassiana* for their bioefficacy against the different instars of sorghum stemborer *Chilo partellus* (Swinhoe). Tefera and Pringle (2003) reported about the effect of different conidial concentration of *B. bassiana* on the second instar larvae of *Chilo partellus*. They observed that *B. bassiana* was highly virulent to neonate stages. Abraham Verghese *et al.* (2003) observed the occurrence of this fungus on mango stone weevil *Stemochus mangiferae* (Fab.). Senthilkumar and Narayanaswamy (2003) reported about the natural mycosis of rice green leaf hopper *Nephotettix virescens* (Distant) due to *B. bassiana* and other pathogens like *Pandora delphalais*, *Metarhizium flavoviride*. Ying *et al.* (2003) investigated the field efficacy of emulsifiable suspension of *B. bassiana* conidia to *Myzus persicae* (Sulz.) population in cabbage. Cotter *et al.* (2004) reported about the density dependent prophylaxis and condition dependent immune function of *Spodoptera litura* treated with *B. bassiana*. Esterase mediated tolerance to a formulation of the organophosphate insecticide monocrotophos with *B. bassiana* was studied by Uma Devi *et al.* (2004). Nahar *et al.* (2004) had evaluated the indigenous fungal isolates of *B. bassiana*, *Metarhizium anisopliae* and *Nomuraea rileyi* for the control of *H.*
arinigera in pigeonpea field. Arun Sharma and Kanaujia (2004) studied the pathogenicity of B. bassiana cultured on sabouraud dextrose agar with and without larval extracts of Spilisoma obliquea Walker against this larva. Pathogenicity of B. bassiana and M. amisopliae on Chrotogomus trachypterus was reported by Mirshekar et al. (2005). Assensio et al. (2005) has evaluated the infection of B. bassiana on the red scale insect Phoemicococcus morlatti

2.3.3. Paecilomyces fumosoroseus (Wize) Brown et Smith

Shelton et al. (1998) isolated Paecilomyces fumosoroseus from Plutella xylostella and observed it’s strong pathogenicity - natural occurrence of this fungus and Paecilomyces amoenoroseus (Hennings). Samson reported about the insect and mites of soybean agroecosystem (Sosa - Gomez and Moscardi, 1994). Wraith et al. (1998) also reported that the P. fumosoroseus was highly pathogenic to silver leaf white fly nymphs. Cantone and Vandenberg (1998) reported the intraspecific diversity of P. fumosoroseus. Relative effectiveness of blastospores and aerial conidia of P. fumosoroseus against the Russian wheat aphid was studied by Vandenberg et al. (1998). Altre et al. (1999) evaluated the pathogenicity of P. fumosoroseus against the diamond, back moth Plutella xylostella (Linn.). Later, Altre and Vandenberg (2001) studied about the factors influencing the infectivity of P. fumosoroseus against diamond back moth Plutella xylostella. Kennedy et al. (2001) had also evaluated the virulence of P. fumosoroseus on P. xylostella. Pell and Vandenberg (2002) had also studied the interaction among the Russian wheat aphid P. fumosoroseus and the convergent ladybird beetle Hippodamia convergens. Genetic variability and phylogenetic relationship of P. fumosoroseus with Beauvaria, Verticillium lecanii and Aschersonia sp. by analyzing the sequence of the divergent domain at the 5′ end of the large subunit RNA gene was undertaken by Miroslav
Obornik et al. (2000, 2001). Feng et al. (2004) has studied the effect of oil based emulsifiable preparation of *P. fumosoroseus* and tested it in the green house white fly *Trialeurodes vaporariorum*. Avery et al. (2004) evaluated the impact of photoperiods on the green house white fly *T. vaporariorum*.

2.3.4. *Verticillium lecanii* (Zimm.) Viegas

*Verticillium lecanii* is a hypomycete soil saprophytic fungi that attacks many insects and is effective in greenhouse against aphids, whitefly and thrips (Hall, 1981; Gillespie, 1987). It was able to survive despite either low or absence of host population. It is best suited for the commercialization because it grows well on all conventional mycological media (Hall, 1981). Most importantly, entomopathogenic *V. lecanii* strains were non-pathogenic to plants (Samson and Rombach, 1985) and humans (Santhanam et al. 1981). Effect of temperature, pH and media on the growth of *V. lecanii* was studied by Easwaramoorthy and Jayaraj (1979). They also studied the pathogenicity of this fungus in ten species of sucking pests. Jayaraj et al. (1978) made a study on the control of coffee green bug with this fungal pathogen. Easwaramoorthy *et al*. (1979) observed the effect of storage time and temperature on the viability of this fungus and also found out the efficacy on insect pests. Kouvelis *et al*. (1999) analysed the mitochondrial DNA by restriction fragment length polymorphisms (RFLPs) that showed 20 different patterns, indicating the considerable genetic variations within the *V. lecanii* species complex. Masada and Kikuchi (1992) isolated *V. lecanii* from *Trialeurodes vaporariorum* (W.) and found to be pathogenic to nymph of *Bemisia tabaci* (Gennadius).
Hazarika and Puzari (2000) conducted the laboratory and small-scale field study to evaluate the efficacy of *V. lecanii* on red spider mite *Oligonychus coffeae* (Nietner). Fournier and Brodeur (2000) studied the effect of *V. lecanii*, azadirachtin and insecticidal soap against aphids. Genetic variability and phylogenetic relationships was extensively studied by Miroslav Obornik *et. al.* (2000). Lakshmi *et al.* (2001) reported the mass culturing methods and the bioefficiency of this fungus against *H. armigera*. The relationship among the genetic diversity virulence and other characteristics of conidia of *V. lecanii* from various hosts and geographical locations has been studied extensively. The effect of submenged cultivation parameters on the production of chitinase by *V. lecanii* in a shake flask and bioreactors has been investigated by Liu *et al.* (2003). Mote *et al.* (2005) had reported the effect of *V. lecanii* with botanicals against sucking pests on Gerbera plant.

2.4. Mass production of entomopathogenic fungi

Uses of cereals as a substrates for the mass production of entomopathogenic fungi was reported by many workers. Hussey and Tinsley (1981) observed wheat bran as a best media for the mass production of *Beauveria bassiana*. Cassava chips mixed with rice bran and urea or fishmeal was used for the mass multiplication of *M. anispliae* (Mohan and Pillai, 1982). Rice grains have found to be suitable media for the mass culture of *B. bassiana* (Ibrahim and Low, 1993). Burges and Hussey (1981); Aregger (1992) reported that in addition to the rice, barley also recorded the highest spore count for *B. bassiana* and *Metarhizium anisopliae*. Shashi Sharma *et al.* (2002) strengthen this finding. Gopalakrishnan *et al.* (1999a) tested various cereals, pulses, vegetables, roots, seeds and synthetic medias for the mass multiplication of *Paecilomyces farinosus*. Lakshmi *et al.*
(2001) evaluated the whole and broken sorghum, pearl millet and maize for mass culturing of *Verticillium lecanii*. Goettel (1984) carried out a simple and inexpensive method for culturing hypomycetes entomopathogenic fungi using pans, bran, for *B. bassiana*, *Verticillium lecanii*, *M. anisopliae* and *Calicinomycetes clavisperus*. Utilization of sugarcane waste products for the mass multiplication of fungal pathogens was reported earlier by Hari and Somasekhar (1998). Mani and Anandam (1991) reported that tobacco tubber and its peels supported moderate spore production of *B. bassiana*. The role of oil cakes as a substrate for the mass production of fungi was also reported. Significantly higher spore production of *Beauveria bassiana* on seasamum cake was reported by Tincilley (2002). Molasses yeast broth medium was suitable for the growth of *B. brongniartiic* and *M. anisopliae* (Sharma et al., 1999a). Similar finding has also been observed by Tincilley et al. (2004) for *Nomuraea rileyi*. Shashi Sharma (2002) evaluated the various synthetic and non-synthetic media for the mass multiplication of *B. bassiana*, *M. anisopliae* and *B. brongniartiic*. Dangar et al. (1991) reported that coconut water was act as an excellent media for the mass production of *M. anisepilae*. Wadyalkor et al. (2002) studied the mass multiplication of *M. anisopliae* using different synthetic and non-synthetic media. Recently Tincilley et al. (2004) evaluated the various agricultural products and their by products for the production of *Nomuraea rileyi*.

2.5. Compatibility of fungi with pesticides and natural enemies

Influence of chemical pesticides on the germination and growth of *M. anisopliae* and *B. bassiana* was studied by Olmert and Kenneth (1974); Li and Holdom (1995). Pathogenicity of *B. bassiana* to silkworm, predators like *Cheilomenes sexmaculatus*, *Coccinella septempunctata* and *Rhynocoris fuscipus* was
reported by Manjula and Padmavathamma, (1996). Haseeb and Murad (1997) reported that C. septempunctata was highly susceptible to B. bassiana while Brumoides suturalis and Syrphids were less susceptible. Compatibility of N. rileyi with plant based pesticides and fungicide was reported by Devi and Prasad (1996). Kulkarni and Lingappa (2001) reported the compatibility of N. rileyi with selected insecticides and fungicide. Gupta et al. (2002) had evaluated some selected systemic and non-systemic pesticides together with organic manures and with B. bassiana and M. anisopliae. Mesquita and Lacey (2001) has studied the interaction among the fungus Paecilomyces fumosoroseus, the parasitoid Aphelinus asychis and their aphid host. Nielsen et al. (2004) studied the compatibility of the pupal parasitoid Spalangia cameroni Perkins with M. anisopliae under the field trails.

2.6. Field efficacy of entomopathogenic fungi

Field efficacy of B. bassiana against various pests was reported elsewhere (Ignoffa et al., 1979; Hajek et al., 1987; Lobo Lima et al., 1992; Hazariaka and Puzari, 1997). Saxena and Ahamad (1997) evaluated the biological control potential of B. bassiana on chickpea against H. armigera leaf roller S. derogata (Fabricius) on cotton (Ramesh et al., 1999), Myzus persicae on cabbage (Ying et al., 2003). Natural epizootics of B. bassiana and N. rileyi on S. litura in groundnut field were also reported (Jayaraj, 2002). Hazariaka and Puzari (2000) reported the efficacy of B. bassiana, V. lecanii and P. fumosoroseus against the tea pests. Kennedy et al. (2001) studied the field evaluation of B. bassiana, P. fumosoroseus and M. anisopliae for the management of Plutella xylostella on cauliflower. Recently Nahar et al. (2004) evaluated the efficacy of B. bassiana, N. rileyi and M. anisopliae for the control of H. armigera in pigeonpea.