Research Article

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Entomopathogenic fungi – Potential candidates for biocontrol of *Helopeltis antonii* Signoret in cashew

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Abstract

Evaluation of fungal entomopathogens, *viz., Beauveria bassiana, Metarhizium anisopliae* and *Lecanicillium lecanii* against tea mosquito bug (*Helopeltis antonii* Signoret), an insect pest of cashew revealed that these fungi are pathogenic to *H. antonii.* Mortality of *H. antonii* commenced after three days of inoculation, increased gradually with time and became evident at fifth day with 82.5 per cent, 85 per cent and 65 per cent respectively with *B. bassiana, M. anisopliae* and *L. lecanii* @10^9 spores mL^{-1}. *B. bassiana* and *M. anisopliae* shown complete mortality at sixth day, whereas mortality rate with *L. lecanii* was 85 per cent. A field experiment was conducted in randomized block design for two consecutive years with these three entomopathogenic fungi @10^8 spores mL^{-1}. Two rounds of spray were given by targeting flowering and nut set stage in the first year, instead of the routine three spray schedule on flushing, flowering and nut set; while routine three sprays were given in the second year. In the first year of field evaluation, least damage was observed in Kerala Agricultural University package of practices (KAU POP) with quinalphos, targeting both flowering and nut set stage. However, both *B. bassiana and L. lecanii* also recorded less tea mosquito bug damage and were comparable with KAU POP. In the second year, *B. bassiana* was on par with KAU POP and *L. lecanii* was superior to control. Highest nut yield was recorded in trees treated with *B. bassiana* followed by KAU POP.

Keywords: Biocontrol, bio-insecticides, cashew, entomopathogens, nut yield, tea mosquito bug

Introduction

Cashew, an important cash crop of India, is grown in 10.27 million hectare area with an annual production of 7.25 lakh tones (DCCD, 2018). Cashew production is adversely affected by the damage due to the major insect pest- tea mosquito bug, *Helopeltis antonii* Signoret. Many studies have been undertaken to manage tea mosquito bug for the past 5-6 decades and pesticide spray has emerged as the most successful and reliable solution. However, with the increased use of pesticides, the pest incidence may be aggravated and the budget towards pest control may increase continuously. On top of this, restrictions are imposed by developed countries in the import of kernels containing pesticide residues, necessitating an integrated approach to manage the pest.

Utilization of entomopathogens, especially fungi, is one of the options that have distinct advantages in possessing a wide host range and amenability for mass production. They infect the insects through cuticle and therefore they are the principal pathogens among sucking insects. No documental evidences are available on application of entomopathogenic fungi except the reports on the infection on tea mosquito bug by *Aspergillus flavus* and *A. tamarei* by Satapathy (1993) and the report on the isolation of *Beauveria bassiana* Bals. from *H. antonii* infesting guava (Visalakshy and Mani, 2011). Hence, the present investigation was to evaluate the pathogenicity and field efficacy of entomopathogenic fungi on *H. antonii* to develop efficient, economical and eco friendly bio-insecticides.

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Materials and methods

Laboratory bioassay

For the experiment, the fungal pathogens *viz., Beauveria bassiana* (Balsamo) Vuillemin*, Metarhizium anisopliae* (Metsch) Sorokin, and *Lecanicillium lecanii* Zimmerman were obtained from the all India co-ordinated research project on biological control of crop pests and weeds, College of Horticulture, Vellanikkara, Kerala, India. The test insects were field collected and was maintained in the laboratory as per the procedure suggested by Sundararaju and John (1992). Fungal suspensions in two concentrations *viz.*, $1x10^8$ spores mL^{-1} and $1x10^9$spores mL^{-1} were evaluated in the laboratory. The tender shoots of cashew not exposed to insecticides were collected from the field and the specified concentrations of each culture were sprayed on these shoots. Adult bugs of the test insects were released to these sprayed shoots. Fresh shoots were provided daily from second day onwards. Completely randomized design (CRD) was followed for laying out the experiment comprising six treatments and a control as water spray. Each treatment was replicated thrice maintaining 10 insects per replication. Observations on mortality of *H. antonii* were recorded at 24 hours interval for a period of 12 days and per cent mortality was calculated following the formula.

$$\text{Per cent mortality} = \frac{\text{Final population in the treatment}}{\text{Initial population in the treatment}} \times 100$$

Field evaluation

An experiment was laid out in randomized block design (RBD) consecutively for two years in 2015-16 and 2016-17 at Cashew Research Station, Madakkathara, Kerala, India to evaluate the efficacy of mycoentomopathogens under field condition. Pure cultures with a concentration of $1x10^8$ spores mL^{-1} were used in the field experiment. Two sprays were given at first year with the skipping of first spray due to low pest load and three sprays were given sequentially at flushing, flowering and nut set stage in the second year. The treatments were compared with the existing of Kerala Agricultural University package of practices (KAU POP) and a control was maintained by spraying with water alone. Observations on tea mosquito bug damage and population of natural enemies such as red ants and spiders were recorded before as well as 7, 15 and 30 days after each spray.

Statistical analysis

The mortality data was analyzed after arcsine transformation by ANOVA. The data on mean damage score on shoots and panicles at different intervals were subjected to ANOVA after square root transformation with covariance analysis in the cases where pre-count differed statistically and compared by DMRT.

Results and discussion

Laboratory bioassay

Laboratory evaluation of entomopathogenic fungi on *H. antonii* revealed that the mortality of tea mosquito bugs began three days after inoculation and varied from 15 to 32.5 per cent in various treatments which increased gradually thereafter with time and became evident on sixth day by recording complete mortality in both the concentrations of *B. bassiana* and in $1x10^9$ spores mL^{-1} concentration in the case of *M. anisopliae* (Table 1). In case of *L. lecanii* with $1x10^9$ spores mL^{-1} concentration complete mortality was observed on seventh day of inoculation. Less mortality observed on third day may be due to the fact that the conidial germination will occur only after 48-72 hours of penetration into the body of the host. *L. lecanii* at $1x10^8$ spores mL^{-1} has shown least mortality on 6^{th} day of inoculation among the fungi tested. However, all the entomopathogenic fungi were able to induce complete mortality after ninth day of inoculation.

The increased mortality observed at sixth day after treatment was in line with the reports of Patil and Naik (2004), in which they reported 92.5 per cent mortality of *H. antonii* when treated with *B. bassiana* by contact inoculation method. They also reported the pathogenicity of *V. lecanii* and *M. anisopliae* as observed in the present findings. Complete mortality of *B. bassiana* treated red shouldered bugs was reported by Reinert *et al.* (1999). Natural infection of *B. bassiana* on *Helopeltis antonii* was reported by Visalakshy and Mani (2011) in guava and Ambethgar and Bhat (2008) in cashew. Navik *et al*. (2015) reported pathogenicity of *B. bassiana, V. lecanii* and *M. anisopliae* in that order of efficacy.

Table 1. Mortality induced by entomopathogenic fungi on *H. antonii* under laboratory

Treatments	Per cent mortality at different days after inoculation						
	3 DAI	4 DAI	5 DAI	6DAI	7DAI	8DAI	9DAI
Beauveria bassiana	27.50^{ab}	55.00^{ab}	82.50^{ab}	100.00^{a}			
@10^9 spores mL^{-1}	(0.55)	(0.84)	(1.14)	(1.49)			
Beauveria bassiana	22.50^{bc}	42.50^{cd}	77.50^{abc}	100.00^{a}			
@10^8 spores mL^{-1}	(0.49)	(0.71)	(1.08)	(1.49)			
Metarhizium anisopliae	32.50^{a}	62.50^{a}	85.00^{a}	100.00^{a}			
@10^9 spores mL^{-1}	(0.61)	(0.91)	(1.18)	(1.49)			
Metarhizium anisopliae	20.00^{bc}	47.50^{bc}	70.00^{bc}	92.50^{b}	100.00^{a}		
@10^8 spores mL^{-1}	(0.46)	(0.76)	(0.99)	(1.31)	(1.49)		
Lecanicillium lecanii	20.00^{bc}	42.50^{cd}	65.00^{c}	85.00^{c}	100.00^{a}		
@10^9 spores mL^{-1}	(0.46)	(0.71)	(0.95)	(1.18)	(1.49)		
Lecanicillium lecanii	15.00^{c}	35.00^{cd}	37.50^{d}	42.50^{d}	70.00^{b}	75.00^{b}	100.00^{a}
@10^8 spores mL^{-1}	(0.39)	(0.63)	(0.66)	(0.71)	(0.99)	(1.05)	(1.49)
Control	0.00^{d}	0.83^{e}	0.83^{e}	0.83^{e}	0.83^{c}	0.83^{c}	10.00^{b}
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.32)
CV%	14.32	8.89	11.29	5.28	2.80	3.40	0.00
CD	0.094	0.081	0.149	0.081	0.047	0.066	0.015

DAI : Days After Inoculation
Figures are mean of four replications, Figures in parenthesis are arcsine transformed values
Means within a column followed by common alphabets are not significantly different among themselves

Pasaru *et al.* (2014) reported the association of *V. lecanii* on *Helopeltis sp.* infesting cocoa plantation and they proved the pathogenicity and reported 77 per cent mortality after seven days of inoculation. The results from the current study conform to the conclusions of Ghatak *et al*. (2008) in the case of *B. bassiana* but were contradictory in the case with *M. anisopliae* and *L. leacanii.*

Among the nymphs and adult stages of *H. antonii,* only adult stage was found susceptible to *B. bassiana* under laboratory condition. It was observed that when the first instar nymphs were inoculated with *B. bassiana*, the adults, which moulted after completing the nymphal development, got infested, without showing any external symptoms of infection during any stage in nymphal development. The susceptibility of adults in comparison to nymphs is in agreement with Patil and Naik (2004) in the case of *H. antonii* infesting guava and Sudarmadji and Gunwan (1994) but contradictory observations were noticed by Navik *et al*. (2015).

Table 2. Efficacy of entomopathogenic fungi on tea mosquito bug damage in cashew (2015-16)

Treatments	Lateral					Panicle					Nut yield
	Second spray			Third spray		Second spray			Third spray		(kg $plant^{-1}$)
	Pre	15 DAS	30 DAS	15 DAS	30 DAS	Pre	15 DAS	30 DAS	15 DAS	30 DAS	
Beauveria	0.130^{b}	0.054	0.022^{b}	0.044^{b}	0.017	0.159^{ab}	0.104	0.049	0.141	0.005	2.385
bassiana	(0.793)	(0.740)	(0.723)	(0.680)	(0.719)	(0.810)	(0.770)	(0.757)	(0.782)	(0.711)	(1.673)
Metarhizium	0.193^{b}	0.141	0.149^{a}	0.201^{a}	0.018	0.076^{b}	0.038	0.222	0.474	0.008	1.47
anisopliae	(0.830)	(0.797)	(0.803)	(0.833)	(0.719)	(0.758)	(0.732)	(0.866)	(0.964)	(0.713)	(1.403)
Lecanicillium	0.089^{b}	0.077	0.036^{b}	0.030^{b}	0.003	0.351^{ab}	0.057	0.130	0.042	0.002	2.478
lecanii	(0.767)	(0.754)	(0.732)	(0.689)	(0.709)	(0.908)	(0.744)	(0.780)	(0.688)	(0.706)	(1.714)
KAU POP	0.467^{ab}	0.151	0.059^{ab}	0.041^{b}	0.002	0.449^{a}	0.097	0.108	0.008	0.005	3.483
	(0.982)	(0.798)	(0.744)	(0.733)	(0.708)	(0.973)	(0.770)	(0.759)	(0.700)	(0.703)	(1.927)
Control	0.231^{b}	0.029	0.107^{ab}	0.077^{ab}	0.001	0.500^{a}	0.045	0.592	0.198	0.008	3.024
	(0.854)	(0.720)	(0.776)	(0.755)	(0.708)	(0.994)	(0.737)	(0.649)	(0.805)	(0.713)	(1.852)
CV%	6.92	11.97	5.71	7.9	1.81	13.25	8.82	25.87	16.46	1.13	22.22
CD	0.084	0.138	0.069	0.084	0.015	0.182	0.097	0.330	0.201	0.015	NS

DAS: Days after spray, Figures are mean of four replicates, Figures in parenthesis are $\sqrt{x+0.5}$ values
Means followed by common alphabets are not significantly different among themselves

Field evaluation

First season trial

Two sprays were given skipping the first spray due to low pest load at flushing stage. In post treatment observations, 15^{th} day after second spray, no statistical difference was observed, with respect to damage on laterals, among treatments. However, at 30^{th} day, damage was comparatively less in *B. bassiana* and *L. lecanii* compared to control (Table 2). The same trend was observed on 15^{th} day observations after third spray. On panicles, there was no significant difference among treatments after spray imposition except for 15^{th} day after third spray in which *L. lecanii* was on par with KAU POP and these two were significantly superior. Highest nut yield noticed in KAU POP and the lowest nut yield in *M. anisopliae* was not significant.

Second season trial

Three sprays were given sequentially at flushing, flowering and nut set stages of the crop. After the first spray, no fresh attack was observed up to 30 days in KAU POP, in which lambda cyhalothrin was sprayed, in spite of damage before spray application. However at 15^{th} day, fresh attack was visible in both *B. bassiana* and *M. anisopliae* and all the treatments including control were on par among each other. Same trend was observed at 30^{th} day also. The treatments were not statistically different in damage score on panicles both at seventh and 15^{th} day after spray. At 30^{th} day, fresh attack was not recorded in KAU POP and *L. lecanii* and both *B. bassiana* and *M. anisopliae* (Table 3a) had shown comparatively less damage. However, all the treatments were significantly superior to control.

On seventh day after the second spray, least damage was observed in KAU POP and it was superior to control. In bio-agent treated trees, though damage was comparatively low and comparable with KAU POP, (Table 3b) they were on par with control. At 15^{th} day, no fresh attack was noticed in KAU POP. At the same time both *B. bassiana* and *L. lecanii* were on par with KAU POP. On panicle, at seventh day after spraying, all the treatments except KAU POP were statistically on par. At 15^{th} day after spraying, KAU POP recorded least damage and *B. bassiana* was on par with KAU POP followed with *L. lecaniii* and these three were significantly different from control.

At seventh day after third spray, there was no significant difference observed among treatments including control. However, at 15^{th} day, all the treatments were superior to control. No fresh attack was observed in case of KAU POP. All the treatments were significantly superior to control with respect to damage on panicles at seventh and 15^{th} day after third spray. Comparatively high nut yield was recorded in *B. bassiana* followed with KAU POP and these two were on par with each other. Nut yield was least in *M. anisopliae*.

Table 3a. Efficacy of entomopathogenic fungi on tea mosquito bug damage in cashew (2016-17)

Treatments	Mean damage score for 52 leader shoots (0-4 scale) - pre treatment and first spray							
	Laterals				Panicle			
	Pre	7 DAS	15 DAS	30 DAS	Pre	7 DAS	15 DAS	30 DAS
Beauveria	0.000	0.000	0.026	0.101	0.000	0.000	0.007	0.080
bassiana	(0.707)^{a}	(0.707)^{b}	(0.725)	(0.771)	(0.707)^{b}	(0.707)	(0.712)	(0.760)^{b}
Metarhizium	0.000	0.000	0.015	0.131	0.000	0.000	0.011	0.072
anisopliae	(0.707)^{a}	(0.707)^{b}	(0.717)	(0.791)	(0.707)^{b}	(0.707)	(0.715)	(0.756)^{b}
Lecanicillium	0.000	0.000	0.000	0.003	0.000	0.000	0.021	0.000
lecanii	(0.707)^{a}	(0.707)^{b}	(0.707)	(0.709)	(0.707)^{b}	(0.707)	(0.722)	(0.707)^{c}
KAU POP	0.015	0.000	0.000	0.000	0.072	0.003	0.011	0.000
(λ-cyhalothrin)	(0.717)^{a}	(0.707)^{b}	(0.707)	(0.707)	(0.755)^{a}	(0.709)	(0.715)	(0.707)^{c}
Control	0.000	0.032	0.053	0.096	0.000	0.000	0.000	0.179
CD	0.015	0.015	NS	NS	0.015	0.015	0.015	0.049
CV(%)	0.60	2.39	4.00	9.99	3.08	0.28	1.78	4.93

DAS: Days after spray, Figures are mean of four replicates, Figures in parenthesis are $\sqrt{x+0.5}$ values.
Means followed by common alphabets are not significantly different among themselves

Table 3b. Efficacy of entomopathogenic fungi on tea mosquito bug damage in cashew

Treatments	Mean damage score for 52 leader shoots (0-4 scale) at different days after spray										Nut yield ($kg\ plant^{-1}$)
	Lateral					Panicle					
	Second spray			Third spray		Second spray			Third spray		
	7 DAS	15 DAS	30 DAS	7DAS	15 DAS	7 DAS	15 DAS	30 DAS	7 DAS	15 DAS	
B. bassiana	0.113 (0.780)^{ab}	0.039 (0.734)^{c}	0.148 (0.805)	0.158 (0.810)	0.038 (0.732)^{b}	0.299 (0.892)^{a}	0.092 (0.768)^{bc}	0.662 (1.060)^{ab}	0.389 (0.943)^{b}	0.110 (0.779)^{b}	4.69^{a}
M. anisopliae	0.107 (0.779)^{ab}	0.247 (0.860)^{ab}	0.290 (0.878)	0.053 (0.743)	0.020 (0.720)^{b}	0.347 (0.912)^{a}	0.474 (0.983)^{a}	0.991 (1.209)^{a}	0.216 (0.843)^{bc}	0.105 (0.770)^{b}	2.34^{c}
L. lecanii	0.076 (0.755)^{ab}	0.074 (0.755)^{bc}	0.076 (0.754)	0.118 (0.783)	0.018 (0.720)^{b}	0.336 (0.907)^{a}	0.232 (0.855)^{b}	0.481 (0.984)^{ab}	0.074 (0.757)^{c}	0.298 (0.883)^{ab}	3.23^{bc}
KAUPOP	0.010 (0.714)^{b}	0.000 (0.707)^{c}	0.071 (0.755)	0.047 (0.740)	0.000 (0.707)^{b}	0.033 (0.730)^{b}	0.000 (0.707)^{c}	0.109 (0.779)^{b}	0.033 (0.730)^{c}	0.000 (0.707)^{b}	4.33^{ab}
Control	0.164 (0.814)^{a}	0.341 (0.913)^{a}	0.258 (0.866)	0.286 (0.876)	0.311 (0.901)^{a}	0.406 (0.945)^{a}	0.486 (0.988)^{a}	0.562 (1.018)^{ab}	0.859 (1.153)^{a}	0.539 (1.011)^{a}	2.33^{c}
CD	0.084	0.119	NS	NS	0.049	0.109	0.109	0.288	0.146	0.182	1.22
CV(%)	6.75	10.10	11.22	10.64	3.01	8.33	8.44	18.58	10.69	14.47	23.48

DAS: Days after spray, Figures are mean of four replicates, Figures in parenthesis are $\sqrt{x+0.5}$ values.
Means followed by common alphabets are not significantly different among themselves

Influence on natural enemies

No much significant difference in population of natural enemies was observed (Table 4) after spray with different bio-agents during the first season and the population was comparable with control plots. The natural enemy population was negligible during the second season trial and hence not provided.

Pooled analysis

a) Damage on laterals

The result on pooled analysis of the data for two years is given in Table 5**.** At 15th day of second spray, the treatments remained statistically on par. At 30th day after second spray, damage was significantly less in *L. lecanii* and KAU POP and these two were on par with each other. This was followed by *B. bassiana*. The damage was less in *B. bassiana* and in control.

At 15th day after third spray, *L. lecanii* treated trees had shown least damage and *B. bassiana*, KAU POP and *M. anisopliae* followed next in increasing order of damage score. However, all the treatments were superior to control.

Table 4. Influence of entomopathogenic fungi on natural enemies in cashew ecosystem

Treatments	Mean number of natural enemies in 52 inflorescence								
	Black ants			Red ants			Spiders		
	Pre-spray	Second spray	Third spray	Pre-spray	Second spray	Third spray	Pre-spray	Second spray	Third spray
Beauveria	0.00^{b}	0.36	0.84^{a}	2.50^{ab}	11.91	14.19	0.00	0.13	0.00
bassiana	(0.71)	(0.88)	(1.08)	(1.34)	(2.52)	(2.58)	(0.71)	(0.78)	(0.71)
Metarhizium	0.50^{a}	0.05	0.50	0.13^{b}	6.77	1.40	0.13	0.00	0.00
anisopliae	(0.99)	(0.73)	^{ab}(0.99)	(0.78)	(1.76)	(1.11)	(0.78)	(0.71)	(0.71)
Lecanicillium	0.00^{b}	0.49	0.03^{b}	1.88^{ab}	19.08	1.12	0.00	0.00	0.00
lecanii	(0.71)	(0.96)	(0.69)	(1.24)	(3.85)	(0.95)	(0.71)	(0.71)	(0.71)
KAU POP	0.00^{b}	0.01	0.03^{b}	36.88^{a}	3.49	8.03	0.00	0.13	0.00
	(0.71)	(0.70)	(0.69)	(5.25)	(0.84)	(1.63)	(0.71)	(0.78)	(0.71)
Control	0.00^{b}	0.11	0.22^{ab}	31.25^{ab}	4.01	25.39	0.13	0.00	0.13
	(0.71)	(0.78)	(0.83)	(4.27)	(1.78)	(4.85)	(0.78)	(0.71)	(0.78)
CV%	17.63	29.53	26.82	100.24	90.33	96.04	13.10	13.10	9.08
CD	0.207	0.351	0.355	4.003	2.990	3.290	0.146	0.146	0.097

DAS: Days after spray, Figures in parenthesis are $\sqrt{x+0.5}$ values
Means followed by common alphabets are not significantly different among themselves

Table 5. Effect of different entomopathogenic fungi on tea mosquito bug damage in cashew (pooled mean)

Treatments	Mean damage score due to tea mosquito bug							
	Laterals				Panicle			
	Second spray			Third spray	Second spray			Third spray
	Pre-spray	15 DAS	30 DAS	15 DAS	Pre-spray	15 DAS	30 DAS	15 DAS
Beauveria bassiana	0.116 (0.782)^{ab}	0.043 (0.735)	0.087 (0.765)^{ab}	0.021 (0.721)^{b}	0.119 (0.785)^{b}	0.098 (0.769)^{b}	0.382 (0.921)^{ab}	0.116 (0.773)^{ab}
Metarhizium anisopliae	0.162 (0.811)^{a}	0.187 (0.824)	00.220 (0.841)^{a}	0.075 (0.754)^{b}	0.074 (0.757)^{b}	0.256 (0.857)^{a}	0.651 (1.060)^{a}	0.281 (0.858)^{ab}
Lecanicillium lecanii	0.046 (0.738)^{b}	0.084 (0.759)	0.059 (0.745)^{b}	0.017 (0.718)^{b}	0.176 (0.807)^{b}	0.145 (0.800)^{ab}	0.308 (0.889)^{ab}	0.159 (0.805)^{ab}
KAUPOP (quinalphos)	0.234 (0.844)^{a}	0.081 (0.755)	0.060 (0.747)^{b}	0.024 (0.723)^{b}	0.224 (0.840)^{ab}	0.049 (0.739)^{b}	0.092 (0.764)^{b}	0.029 (0.726)^{b}
Untreated contro	l0.164 (0.811)^{a}	0.181 (0.817)	0.182 (0.821)^{ab}	0.178 (0.818)^{a}	0.339 (0.908)^{a}	0.265 (0.863)^{a}	0.520 (0.953)^{a}	0.322 (0.882)
CD	0.065	0.086	0.073	0.056	0.086	0.073	0.198	0.134
CV	8.16	10.67	9.13	6.91	10.31	8.40	20.98	15.88

DAS: Days after spray, Figures are mean of four replicates, Figures in parenthesis are $\sqrt{x+0.5}$ values
Means followed by common alphabets are not significantly different among themselves

b) Damage on panicles

At 15th day after second spray, least damage was observed in KAU POP followed by *B. bassiana and L. lecanii.* At the same time, *L. lecanii* was not significantly differed from control. Both *B. bassiana* and *L. lecanii* were statistically on par with KAU POP. Same trend was observed at 30th day after second spray. However, the damage in *B. bassiana* and *L. lecanii* was statistically not differed from control. At 15th day after third spray, KAU POP was significantly superior with least damage and the bio-agents were on par with KAU POP. But, the bio-agents did not differ statistically from control.

The field efficacy of these three fungal entomopathogens on *H. theivora* damaging tea plantation was there in the ealier record by Ghatak *et al*. (2008) in which, they reported 57 per cent reduction in leaf damage in fields treated with these bio-agents at concentration of 2.5 gL^{-1} compared to 89 per cent reduction in chemical treatment. The report on field efficacy of *B. bassiana* on *H. antonii* was also there in the record by Indriyanti (2017), but in cocoa plantation.

Summary and conclusion

The bio-agents were effective under laboratory conditions. Complete mortality of tea mosquito bugs was observed within six days after inoculation with *B. bassiana* and *M. anisopliae* and 85 per cent in *L. lecanii*. Among the different stages of *H. antonii,* adults were vulnerable to the tested fungal entomopathogens and the treated nymphs were not affected.

Considering the laboratory and field results, the entomopathogens, *B. bassiana, M. anisopliae* and *L. lecanii* were pathogenic and effective on *H. antonii. B. bassiana* and *M. anisopliae* induced a higher mortality within six days of inoculation followed with *L. lecanii* under laboratory. In the field condition, both *B. bassiana* and *L. lecanii* performed better to *M. anisopliae* and even comparable with KAU POP at different intervals of observation. These two fungi have the potential to manage the tea mosquito bug, *H. antonii* in cashew.

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