ISSN: 2347-4688, Vol. 9, No.(1) 2021, pg. 54-61

Current Agriculture Research Journal

www.agriculturejournal.org

Virulence of Five Isolates of Indigenous *Beauveria bassiana* Against Eggs and Nymphs of *Bemisiatabaci* Gennadius (Hemiptera: Aleyrodidae)

GITA FLAWERINA, TRIZELIA* and NURBAILIS

Department of Plant Pests and Disease, Faculty of Agriculure, Andalas University Kampuslimau Manis, Padang, West Sumatera, Indonesia.

Abstract

This research aims to study the virulence of five isolates of *Beauveria bassiana* to eggs and nymphs of *Bemisiatabacion* tomato. In the experiment eggs and second instar nymphs of *B. Tabaci* were used. Five isolates of the fungus, i.e.,WS, TD312, PD114, PA221, PB211,were tested. Conidial concentration of *B. bassiana* used were 10^8 conidia/ml. Experimental parameters included mortality of eggs and nymph and percentage of adult emergence. The results showed that all *B. bassiana* isolates tested were able to kill *B. Tabaci* eggs but with very low mortality (2-19%). Mortality of second instar *B. Tabaci* nymphs was dependent on the fungal isolates. Isolate WS had the highest virulence, which caused 70% mortality of 2nd instar nymphs, with aLT50 of 4.87 days. Nymphs of *B. Tabaci* were highly susceptible to *B. bassiana* infection compared with eggs. *B. bassiana* applicated to nymphs of *B. Tabaci* can decrease the percentage of adult emergence.

Article History
Received: 18 March 2020
Accepted: 22 May 2021

Keywords
Bemisia Tabaci;
Eggs;
Entomopathogenic Fungi;
Nymph

Introduction

Bemisia tabaci Gennadius (Hemiptera: Aleyrodidae) is one of the main pests in tomato plants.[1] *B. tabaci* is a polyphagous insect that has many host plants such as ornamental plants, vegetables, fruits, and wild plants (weeds).[2] This insect make damage directly on plants by sucking the liquid, causing a physiological disturbance on plants, chlorosis on leaves, and disturb ripening of tomatoes.[3,4] In addition to direct damages, the pest cause indirect damage by the accumulation of honey dew produced by *B. tabaci* which leads to mold growth on foliage, and as a vector of Tomato yellow leaf curl virus (TYLCV) and more than 100 other begomo viruses.[5,6] The loss of yields due to *B. tabaci* attacks and yellow virus ranges from 20 to100%.[7] This pest was first found in Indonesia in 1938 on a tobacco plant.[8] The reproduction and spread of these pests are very fast, in fact, in a year, is able to produc till 15 generations.[9]

CONTACT Trizelia trizelia@yahoo.com Department of Plant Pests and Disease, Faculty of Agriculure, Andalas University Kampuslimau Manis, Padang, West Sumatera, Indonesia.

Doi: dx.doi.org/10.12944/CARJ.9.1.07

Traditionally, synthetic insecticides have been used for controlling *B. tabaci*, but excessive and irrational use of insecticides has led to adverse effects on the environment. To reduce the use of pesticides, it is important to developing alternative safety control methods such as the entomopathogenic fungus *Beauveria bassiana* (Bals.) Vuill. *B. bassiana* is considered the most effective alternative control method of *B. tabaci*. It is is an entomopathogenic fungus with a wide host range, able to infect various kinds of insects, from pre-adult to adult.[10,11] *B. bassiana* infects insect by digestion, respiration, and particularly through the integuments of insect.[12]

Beauveria bassiana have been used as a biological agent to control several insect pests. In laboratorium condition, *B.bassiana* was able to kill *Crocidolomiapavonanalarvae* till 80%. The mortality of larvae depends on isolates.[13] *B.bassiana* can kill several kinds of vegetable pests such as *Spodopteraexigua*,[14] *S.litura*,[15] *Nezaraviridula,*[16] and *Eurydemapulchrum.*[17] The dose of *B. bassiana* had a significant effect on adult of *Aphis crassivora* and *B.tabaci*. An increase of *B. bassiana* concentration markedly decreased adult longevity, period of reproduction, and fecundity of the two insects.[18] One of the essential criteria in selecting entomopathogenic fungi for commercial development is to have high virulenceto target insects. In order to evaluate the importance of virulent strains for an efficient biological control of *B. tabaci* on tomato, we analyzed under laboratory conditions the effect of five fungal isolates of indigenous *B. bassiana* on eggs andnymphs of *B. tabaci*.

Materials and Methods

Beauveria Bassiana Isolates

Five fungal isolates of *B.bassiana* were obtained from the collection of entomopathogenic fungal culture maintained bythe Biological Control Laboratory, Department of Pests and Plant Diseases, Faculty of Agriculture, Andalas University. (Table 1). *B. bassiana* isolates were obtained from plants and pest insects. Isolates were cultivated on the Sabouraud dextrose agar + yeast extract (SDAY) medium.

Table 1: List of *B. bassiana* isolates used in research

Isolates code	Source	Location
WS	*Leptocorisaoratorius*	Duku (Padang Pariaman), West Sumatra, Indonesia
TD312	Wheat stems endophyte	Koto Laweh (Tanah Datar), West Sumatra, Indonesia
PB211	Chili stems endophyte	Parabek (Agam), West Sumatra, Indonesia
PD114	Chili leaves endophyte	Parabek (Agam), West Sumatra, Indonesia
PA221	Chili roots endophyte	Parabek (Agam), West Sumatra, Indonesia

The conidial suspension of *B. bassiana* was obtained by adding 10 ml of distilled water and 0.1% Tween 80 to Petri dishes containing the fungus culture, and conidia were harvested by scraping the surface of the plate with a steril spatula. The conidial concentration was determined using an improved Neubauer haemocytometer and adjusted to 10^8 conidia / mL.

Insects

Bemisia tabaci adults were collected from chili plants in Padang areas, West Sumatra, Indonesiaand insects mass-reared on tomato plants. The tomato plants were planted in the polybag and put into large screen cages (60 x 75 x 100 cm). A large colony of *B. tabaci* adults was introduced into the screen cages for three days. After that, whitefly adults were removed and tomato plants infested by eggs were transferred to other cages. The eggs laid by female adults of *B. tabaci* were used for *B. bassiana* bioassay on eggs. Other eggs were also kept until nymphs emergence to evaluate the efficacy of the fungus against nymphal stages of *B. tabaci*.

Bioassay of *B. Bassiana* against *B. Tabaci* Eggs

The tomato leaf contained 20 eggs selected and treated with the fungus. Eggs were sprayed by conidial suspension of *B. bassiana*, then eggs were put into Petri dish on a moist filter paper. The assays was repeated five times. As control, the same

number of eggs were treated with distilled water. The eggs were reared till their hatching. Eggs mortality and infection of first instar nymphs were assessed and recorded daily for eight days.

Bioassay of *B. Bassiana* against *B. Tabaci* Nymphs

The second instar nymphs of *B.tabaci* were moved on 30 days old tomato plants using a soft brush. Furthermore, 2 ml of the *B. bassiana* fungal suspensions, for each unit test, were sprayed on the insects using hand sprayer. For the control, theinsects were sprayed with distillate water. The tomato plants were put into a cylindrical tubular-shaped plastic mica cage (high 60 cm, diameter 45 cm) and covered with gauze. The treatments were repeated five times, and every unit of treatment consisted of 10 nymphs. The mortality of nymphs was observed every day by counting the numbers of test insects that died until seven days after application (DAA).

Data Analysis

The data obtained were analyzed by ANOVA and followed by a test of Duncan's New Multiple Range Test (DNMRT) a significant level of 5%.

Table 1: Mortality of *B.tabaci* eggs after the application of *B.bassiana* isolates

Isolates	Eggs mortality±SE
WS	19.00±1.00^{a}
TD312	17.00±2.55^{a}
PB211	5.00±1.58^{b}
PD114	4.00±1.87^{bc}
PA221	2.00±1.22^{bc}
Control	0.00±0.00

Means followed by the same letter are not significantly different (P<0.05) by Duncan's Multiple Range Test.

Results and Discussion

Eggs Mortality

Results of the virulence test of five *B. bassiana* isolates against *B. tabaci* eggs showed that all tested isolates kill *B. tabaci* eggs, but with very low mortality. Statistical analysis showed a significant effect of *B.bassiana* isolate on the mortality of *B. tabaci* eggs (F = 26.15; db = 5, 24; P <0.0001). The mortality of *B. tabaci* eggs after *B. bassiana* application reported in Table 1.

Treatment of WS isolates on *B. tabaci* eggs resulted in the highest egg mortality (19%) compared to other isolates. Treatment with PA221 isolate resulted in the lowest egg mortality, namely 2%. In control, there was no death of the eggs. All the eggs hatched into nymphs. Low mortality of *B. tabaci* eggs after the fungal application is thought to be caused by the eggshell of *B. tabaci* which has a specific layer that can prevent the conidial tube from penetrating to the inside of the egg. The wax coating on insects could inhibit the germination of *B. bassiana* conidia. In addition, the failure of the fungus to infect eggs can be related to the presence of anti-fungal compounds found on the surface of the eggshell, which inhibits the germination process of fungal conidia. Eggs of *Bemisia argentifolii* Bellows & Perring (Homoptera: Aleyrodidae) were resistant to *B. bassiana* infection. Electron microscopy observations showed that only 13.0% of *B. bassiana* conidia germinated on eggs.[11]

The results of this study are similar to the results of Al-Deghairi[19] who observed a mortality of *B. tabaci* eggs after *B. bassiana* application of only 4,49%. Eggs of *B.tabaci* was more tolerant to *B. bassiana* infection and were not easily killed even by the highest conidial concentration. Furthermore, Islam *et al*[20] also reported that applying *B.bassiana* to *B. tabaci* eggs with a concentration of 108 conidia/ml resulted in a mortality of 25.2%. and Trizelia *et al*.[21] reported that *B. bassiana* could not infect *Crocidolomia pavonana* eggs. In eggs of *Blissus antillus* (Leonard) (Hemiptera: Lygaeidae), egg mortality due to *B. bassiana* infection varied between isolates. Isolate CG24 cancause egg infections by 43.3%, while isolates CG04 and ARSEF792 were only 7.8%. The results of observations with fluorescent microscopy showed that the difference in virulence was due to differences in the ability of the fungal conidia to adhere to the surface of the egg and then penetrate the chorion.[22]

Based on macroscopic observations, the fungal mycelial covered the eggs. Fungal mycelia on the surface of the eggs were seen four days after the inoculation of the fungus. Al-Deghairi[19] also reported that infection symptoms on the eggs of *B. tabaci* were observed on the 3rd day of inoculation. Within

four days from the treatment, the eggs that became subsequently infected by the fungal had little color change but appeared slightly shrunk when observed under the microscope. One week after treatment, most of the unhatched eggs became conspicuously shrunk and had fewer fungal out growths on the surface.

Table 2: Mortality of the first-instar nymph of *B. tabaci*

Isolates	Mortality of first nymphs ±SE
WS	7.43±1.27[a]
TD312	5.97±1.87[ab]
PB211	4.16±1.96[abc]
PD114	3.10±1.27[abc]
PA221	2.05±1.26[bc]
Control	0.00±0.00[c]

Means followed by the same letter are not significantly different (P<0.05) by Duncan's Multiple Range Test.

Table 3: Mortality and LT_{50} values of 2nd instar nymphs of *B. tabaci* treated with 10^8 conidia/ml of *B. bassiana* isolates at seven days post-inoculation

Isolates	2nd instar nymph mortality (%) ± SE	LT_{50} (Day)
WS	70.00 ± 4.47[a]	4.87 (4.41-5.46)
TD312	64.00 ± 2.45[a]	5.51 (5.03-6.17)
PB 211	44.00 ± 2.45[b]	7.23 (6.57-8.62)
PD114	44.00 ± 4.00[b]	7.34 (6.59-8.81)
PA221	36.00 ± 2.45[b]	7.80 (6.89-9.82)
Control	00.00 ± 0.00[c]	

Means followed bythe same letter are not significantly different (P<0.05) by Duncan's Multiple Range Test.

Besides beingable to infect the eggs,nymphal mortality also occurs in 1st nymphs upon hatching from eggs contaminated by *B. bassiana* (Table 2). The nymph mortality varied between isolates (F = 3.55; db = 5, 24; P> 0.0152). WS isolates produced the highest nymph mortality, namely 7.43%, while PA221 isolates only produced nymph mortality of 2.05%. In control, there was no mortality in nymphs. The results showed that conidia remained active and can infectnymphs successfully emerging from eggs. Occurrence mortality of 1st instarnymphs is thought due to contact nymphs emerging from eggs with the conidia attached to the surface of the eggshell and on the leaves. Other researchers[23] also reported that *B. tabaci* eggs had low susceptibility to *B.bassiana*, with >91% nymphs successfully emerging from eggs. However, there is significant mortality of 1st and 2nd instar nymphs originating from the treated eggs. These results indicated that newly hatched nymphs probably acquired conidia from the eggs soon after hatching or from the leaf surface as secondary exposure. Trialeurodes vaporariorum eggs treated with entomopathogenic fungus Aschersonia aleyrodis did not become infected, but larvae that hatched from these eggs were infected.[24]

Mortality of *Bemisia Tabaci* Nymphs

The results showed that *B. bassiana* isolate had a significant effect on the mortality of 2nd instar nymph of *B.tabaci*. WS isolates were the most virulent isolates with the highest mortality namely 70.00% after seven days after the fungal application. PA221 isolate had a low virulence with a mortality of 36.0% (Table 3).

The difference in the ability of *B. bassiana* isolates in killing *B. tabaci* nymphs is thought to be due to differences in viability of conidia or the ability to produce enzymes and toxins. The difference in mortality of *C. pavonana* larvae after *B. bassiana* application was caused by differences in physiological and genetic characteristics of the isolates.[25] Several researchers[26,27,28] stated that the germination of conidia and the ability to produce enzymes and mycotoxins during the infection process in insects affects insect mortality by *B. bassiana*.

This research showed that the mortality of nymphs of *B. tabaci* after application *B.bassiana* was influenced by isolate source. *B.bassiana* isolated from insects belonging tothe same taxon of the test insect (WS) was more virulent than that isolated from the plants. Based on the observed values, surveys of *B. bassiana* isolates collected from homopterans seems to be a suitable approach for silver leaf whitefly microbial control programs. Other

researchers also reported that mortality of insect was dependent on the fungal isolates. Isolates or strains of entomopathogenic fungi isolated from the same taxon of the whitefly (Order Hemiptera, suborder Homoptera) were more virulent than the isolates from Lepidoptera, Coleoptera, and Hymenoptera.[23,29,30,31]

There was a difference in LT_{50} between isolates (Table 3) and LT_{50} value related to the virulence isolate. LT_{50} values ranged from 4.87 to 7.80 days. WS isolate has the shortest LT_{50} value compared to other isolates (4.87 days), and this means that the time needed to kill 50% of 2nd instar nymphs of *B. tabaci* is shorter than other isolates.Thre are difference in the LT_{50} value between *B. bassiana* isolates to 2nd instar nymphs of *B. tabaci* bio type B. Estimated LT_{50} values showed that most *B. bassiana* and *I. fumosorosea* isolates killed whiteflies faster (3–5 d) compared with *L. muscarium* isolates.[23]

Mortality of second instar *B. tabaci* nymph due to *B. bassiana* infection began on the second day post-inoculation, and nymph mortality increased after three days. The development of mortality of *B. tabaci* nymphs due to *B. bassiana* infection can be seen in Figure 1.

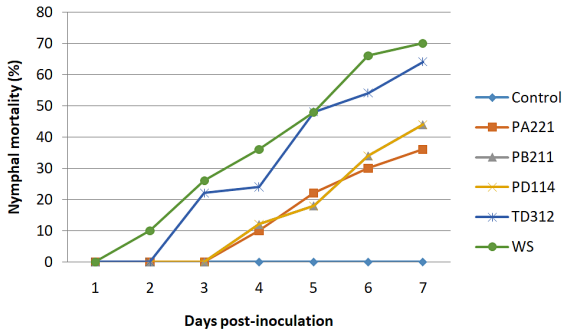

Fig.1: The 2nd instar nymphmortality rate of *B.tabaci* after *B.bassiana* application

Table 4: Percentages of emerged adults of *B.tabaci* after application of *B.bassiana.*

Isolates	Percentage of emerged adults± SE
Control	98.00 ± 9.80[a]
PA221	60.00 ± 3.16[b]
PB 211	52.00 ± 2.00[bc]
PD114	48.00 ± 4.90[c]
TD312	26.00 ± 2.45[d]
WS	22.00 ± 2.00[d]

Means followed bythe same letter are not significantly different (P<0.05) by Duncan's Multiple Range Test.

B. tabaci nymphs that die from *B. bassiana* infection are characterized by the presence of white mycelia or conidia on the surface of the nymph's body. Nymphs of *B. tabaci* treated with *B. bassiana* dried and presented reddish coloration upon death.[29] Mycelia of *B. bassiana* emerged on the cuticles of the immature insects (*B.tabaci, Bactericera cockerelli, Frankliniella occidentalis*) 2-3 days after death, and most conidia were recorded on legs, wings, and thoraces of some adult cadavers.[32] Cherguiet *al*.[33] noted that dead individuals of *Ceratitiscapitata* were covered with a white mycelium characteristic of the fungus *B. bassiana*.

Adults Emergence

The results showed that *B. bassiana* applied to 2nd instar nymphs of *B. tabaci* had a significant effect on the emerged numbers of *B. tabaci* adults. Percentages of emerged adults under five fungal isolates can be seen in Table 4.

The application of fungus *B. bassiana* to the 2nd instar nymph showed a significant effect on adult emergence. In control, the percentage of adult emergence was the highest at 98%, while in the treatment of WS isolates only 22% of nymphs became adult. The low rate of adult emergence was because a lot of some nymphs was killed before becoming an adult. *B. bassiana* applied to *C.capitata* larvae decreased the percentage of pupae formed

and adult emergence.[33] *B.bassiana* can alsoreduce pupation and adult emergence of *S.litura*. Reduction in pupation and adult emergence is due to phago depression and difficulty in molting.[34]

Conclusions

The present study showed that *B. bassiana* can infect *B. tabaci* eggs and nymphs. The mortality of *B. tabaci* eggs is only at 2-19%. Isolate WS had the highest virulence, which caused 70.00% mortality of 2nd instar nymphs, with an LT_{50} of 4.87 days. Isolates of *B. bassiana* have significant effect on the mortality of second instar *B. tabaci*. Nymphs of *B. tabaci* were highly susceptible to *B. bassiana* infection compared with eggs. *B. bassiana* applied to *B.tabaci* nymphs could decrease the percentage of adult emergence.

Acknowledment

We thank the Directorate of Research and Community Service of the Directorate General of Strengthening Research and Development of the Ministry of Research, Technology and Higher Education, under Research Contract 034/SP2H/LT/DRPM/2020 the Fiscal Year 2020, for providing us the finance for this research.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest

The authors do not have any conflict of interest.

References

1. Yuliani, Hidayat, P.,Sartiami, D.Identifikasi kutukebul (Hemiptera:Aleyrodidade) dari beberapa tanaman inang dan perkembangan populasinya. *Jurnal Entomologi Indonesia.* 2006; 3(1):41-49.
2. Hill, D.S. Agriculture insect pests of the tropics and their control. Cambridge University Press., Cambridge. 1987.
3. Van de Ven, W.T., LeVesque, C.S., Perring, T.M., Walling, L.L. Local and systemic changes in squash gene expression in response to silver leaf whitefly feeding. *The Plant Cell.* 2000; 12:1409–1423.
4. Mc Collum, T., Stoffella, P., Powell, C., Cantliffe, D., Khan, H. Effects of silver leaf whitefly feeding on tomato fruit ripening. *Postharvest Biology and Technology.* 2004; 31:183–190.
5. Byrne, D.N., Bellows, T.S. Whitefly biology. *Annual Review of Entomology.* 1991; 36:431-457.
6. Jones, D. Plant viruses transmitted by whiteflies. *European Journal of Plant Pathology.* 2003; 109:195–219 (2003).
7. Setiawati, W., Udiarto, B.K., Gunaeni, N. Preferensi beberapa varietas tomat dan pola infestasi hama kutu kebul serta pengaruhnya terhadap intensitas serangan virus kuning. *Jurnal Hortikultura.* 2007; 17(4): 374-386.
8. Kalshoven, L.G.E. The pests of crops in Indonesia. Jakarta: *Ichtiar Baru-Van Hoeve. Jakarta.* 1981.
9. Brown, J.K. Current status of *Bemisia tabaci* as a plant pest and virus vector in agro-ecosystems worldwide. *FAO Plant Protection Bulletin.* 1994; 42, 3–32.
10. Lord, J.C. Desiccant dusts synergize the effect of *Beauveria bassiana* (Hyphomycetes: Moniliales) on stored-grain beetles. *Journal of Economic Entomology.* 2001; 94: 367-372 (2001).
11. James, R.R, Buckner, J.S., Freeman, T.P. Cuticular lipids and silverleaf whitefly stage affect conidial germination of *Beauveria bassiana* and *Paecilomyces fumosoroseus. Journal of Invertebrate Pathology*. 2003; 84:67-74.
12. Broome, J.R., Sikorowski, P.P., Norment, B.R. A mechanism of pathogenicity of *Beauveria bassiana* on larvae of the imported fire ant. Solenopsis richteri. *Journal of Invertebrate Pathology.* 1976; 28:87-91.
13. Trizelia, Nurdin, F. Virulence of Entomopathogenic Fungus *Beauveria bassiana* isolates to Crocidolomia pavonana F(Lepidoptera: Crambidae). *AGRIVITA Journal of Agricultural Science*. 2010; 32(3): 254-260.
14. Razak, N.A., Nasir, B., Khasanah, N. Efektifitas *Beauveria bassiana* Vuill. terhadap pengendalian Spodoptera exigua Hubner (Lepidoptera: Noctuidae) pada tanaman

bawang merah lokal palu (Allium wakegi). *eJ. Agrotekbis.* 2016; 4 (5) : 565-570.

15. Trizelia, Reflin, Ananda, W. Virulensi beberapa isolat cendawan entomopatogen endofit *Beauveria bassiana* Bals. terhadap Spodoptera litura F. (Lepidoptera: Noctuidae). Prosiding Seminar Nasional BKS PTN Wilayah Barat Bidang Ilmu Pertanian. 2016; 409-415.
16. Prayogo, Y. Patogenisitas cendawan entomopatogen *Beauveria bassiana* (Deuteromycotina: Hyphomycetes) pada berbagai stadia kepik hijau (Nezara viridula l.). *Jurnal Hama dan Penyakit Tumbuhan Tropika.* 2013; 13 (1):75 – 86.
17. Trizelia, Yanti, Y., Suhriani. 2019. Potensi cendawan entomopatogen *Beauveria bassiana* (Bals.) untuk pengendalian kepik kubis Eurydema pulchrum Westw. (Hemiptera: Pentatomidae). Prosiding Seminar Nasional Agroteknologi Jurusan Agroteknologi Universitas Islam Negeri Sunan Gunung Djati Bandung. 2019; 346-352.
18. Zaki, F.N. Efficiency of the entomopathogenic fungus, *Beauveria bassiana* (Bals), against *Aphis crassivora* Koch and Bemesia tabaci Gennandius. *Journal of Applied Entomology.* 1998; 122: 397-399.
19. Al-Deghairi, M.A. Bioassay evaluation of the entomophatogenic fungi, *Beauveria bassiana* Vuellemin against egg and nymphs of *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae). *Pakistan Journal of Biological Sciences.* 2008; 11(12):1551-1560.
20. Islam, Md. T., Castle, S.J., Ren, S. Compatibility of the insect pathogenic fungus *Beauveria bassiana* with neem against sweetpotato whitefly, *Bemisia tabaci*, on eggplant. *Entomologia Experimentalis et Applicata.* 2010; 134: 28–34.
21. Trizelia, Santoso, T., Sosromarsono, S., Rauf, A., Sudirman, L. Patogenisitas jamur entomopatogen *Beauveria bassiana* (Deuteromycotina; Hyphomycetes) terhadap telur Crocidolomia pavonana (Lepidoptera: Pyralidae). Agrin. 2007; 11(1):52-59.
22. Samuels, R.I., Coracini, D.L.A., dos Santos, C.A.M., Gava, C.A.T. Infection of *Blissus antillus* (Hemiptera: Lygaeidae) eggs by entomopathogenic fungi Metarhizium anisopliae and *Beauveria bassiana*. *Biological Control*. 2002; 23:269-273.
23. Mascarin, G.M., Kobori, N.N., Quintela, E.D., Delalibera, I. The virulence of entomopathogenic fungi against *Bemisia tabaci* biotype B (Hemiptera: Aleyrodidae) and their conidial production using solid substrate fermentation. *Biological Control.* 2013; 66: 209–218.
24. Fransen, J.J., Winkelman, K., van Lenteren, J.C. The differential mortality at various life stages of the greenhouse whitefly, Trialeurodes (Homoptera: Aleyrodidae), by infection with the fungus Aschersonia aleyrodis (Deuteromycotina: Coelomycetes). *Journal of Invertebrate Pathology.* 1987; 50: 158-165.
25. Trizelia. Cendawan entomopatogen *Beauveria bassiana* (Bals) Vuil. (Deuteromycotyna: Hypomycetes). keanekaragaman genetik, karekteristik fisiologi, dan virulensinya terhadap Crocidolomia pavonana (F) [Disertasi]. *Institut Pertanian Bogor. Bogor.* 2005.
26. Geden, C.J, Rutz, D.A., Steinkraus, D.C. Virulence of different isolates and formulations of *Beauveria bassiana* for house flies and the parasitoid Muscidifurax raptor. *Biological Control.* 1995; 5:615-621.
27. Sumikarsih, E., Herlinda,S., Pujiastuti, Y. Conidial density and viability of *Beauveria bassiana* isolates from Java and Sumatra and their virulence against Nilaparvata lugens at different temperatures. *AGRIVITA Journal of Agricultural Science*. 2019; 41(2): 335–350.
28. Tanada, Y., Kaya, H.K., Insect pathology. Academic Press, INC. Harcourt Brace Jovanovich, San Diego.1993.
29. Vicentini, S., Faria, M., r.v. de oliveira, M. Screening of *Beauveria bassiana* (Deuteromycotina: Hyphomycetes) isolates against nymphs of *Bemisia tabaci* (Genn.) biotype B (Hemiptera: Aleyrodidae) with description of a new bioassay method. *Neotropical Entomology*. 2001; 30(1): 97-103.
30. James, R.R., Lighthart, B. Susceptibility of the convergent lady beetle (Coleoptera: Coccinellidae) to four entomogenous fungi. *Environmental Entomology.* 1994; 23:190-192.
31. Samuels, R.I, Coracini, D.L.A. Selection

of *Beauveria bassiana* and Metarhizium anisopliae isolates for the control of *Blissus antillus* (Hemiptera: Lygaeidae). Scientia Agricola (Piracicaba. Braz). 2004; 61(3):271-275.

32. Rios-Velasco, C., Pérez-Corral, D.A., Salas-Marina, M.A., Berlanga-Reyes, D.I., Ornelas-Paz,J.J., Acosta Muñiz, C.H., Cambero-Campos, J., Jacobo-Cuellar, J.L.Pathogenicity of the hypocreales fungi *Beauveria bassiana* and Metarhizium anisopliae against insect pests of tomato. *Southwestern Entomologist*. 2014; 39(4):739-750.
33. Chergui, S., Boudjemaa, K., Benzehra, A., Karaca, I. Pathogenicity of indigenous *Beauveria bassiana* (Balsamo) against Ceratitis capitata Wiedemann (Diptera: Tephritidae) under laboratory conditions. *Egyptian Journal of Biological Pest Control.* 2020; 30:128.
34. Malarvannan, S., Murali, P.D., Shanthakumar, S.P., Prabavathy, V.R., Nair, S. Laboratory evaluation of the entomopathogenic fungi, *Beauveria bassiana* against the Tobacco caterpillar, *Spodoptera litura Fabricius* (Noctuidae: Lepidoptera). *Journal of Biopesticides.* 2010; 3: 126 – 131.