Jurnal Perlindungan Tanaman Indonesia, Vol. 23, No. 1, 2019: 6–15
DOI: 10.22146/jpti.32752
Available online at http://jurnal.ugm.ac.id/jpti
ISSN 1410-1637 (print), ISSN 2548-4788 (online)

Research Article

Efficacy of Biopesticide Be-Bas against Sweet Potato Weevils (*Cylas formicarius* Fabricius) in Tidal Land

Yusmani Prayogo[1)]* & Marida Santi Yudha Ika Bayu[1)]

[1)]*Indonesia Legumes and Tuber Crops Research Institute (ILETRI)*
Jln. Raya Kendalpayak, KM 08, PO. BOX 66 Malang, East Java 65101 Indonesia

**Corresponding author. E-mail: yusmani.prayogo@yahoo.com*

Received February 6, 2018; revised September 7, 2018; accepted September 20, 2018

ABSTRACT

In Indonesia tidal land is very wide and quite potential for sweet potatoes, but an obstacle for this cultivation is sweet potato weevil (*Cylas formicarius*) causes loss of 100%. This research aimed to evaluate the efficacy of biopesticide Be-Bas contains *Beauveria bassiana* entomopathogenic conidia to *C. formicarius* mortality at tidal lands. This study was conducted on June-November 2016 in South Kalimantan. The research consisted of five treatments and five replications. Results showed that the application of biopesticide Be-Bas in the planting hole and stem base was effective to cause mortality of 17 and 15 larvae per tuber, respectively. However, the application by soaking cutting was able to kill 3 larvae per tuber. The application of biopesticide Be-Bas in the planting hole and stem base were also effective to suppress the number of eggs laid by *C. formicarius* in the tuber, hence there was no damage found on the tuber. Meanwhile, the application of conventional insecticide was less effective because a total of 17 eggs and 3 larvae of *C. formicarius* were still found in each tuber. It caused tuber damage up to 17%, thus the tuber cannot be consumed. Therefore, the application of biopesticide Be-Bas in the planting hole or stem base was considered capable to suppress tubers damage caused by *C. formicarius* better than that of conventional insecticide.

Keywords: application method, biological control, *Beauveria bassiana*, *Cylas formicarius*, entomopathogenic fungi

INTRODUCTION

Indonesia estimated has 33,393,570 ha tidal land which consists of 20,096,800 ha (60.2%) of tidal land and 13,296,770 ha (39.8%) of non-tidal swamp land (lebak) spread over three islands: Sumatra (32%), Kalimantan (40%), Irian Jaya (20%), and the remaining 5% is in Sulawesi (Wahyunto & Mulyani, 2011; Wahyunto *et al*., 2012). Most of the land has not been fully utilized, thus it is a great opportunity to be advanced considering that productive land on Java becomes limited. Swiadikarta (2012) and Alwi (2014) reported that the type C tidal land in South Kalimantan mostly used for plantation and crops.

Sweet potato is one of the commodities cultivated in tidal land, including in Barito Kuala Regency. Sweet potatoes are local varieties that have potential productivity up to 25 tons/ha (Rina & Syahbudin, 2013; Galib, 2014). One of the obstacles of sweet potato production is tuber borer, *Cylas formicarius*, as reported in various other countries (Reddy *et al*., 2012; Devi *et al*., 2014). Yield loss caused by this pest reaches 100 %, in consequence of infested tuber that is not suitable for human consumption due to toxins that can cause bitter taste (Maingi *et al*., 2002). Control of *C. formicarius* using conventional insecticides has not shown delighted results (Korada *et al*., 2010; Leng & Reddy, 2012). Because of the chemical compound cannot reach the larvae live inside the tuber under the soil. Various efforts yet to develop to manage *C. formicarius* (Reddy *et al*., 2012; Taye & Tadesse, 2014; Hue & Low, 2015), one of which is biological control method using entomopathogenic fungi (Shams *et al*., 2011; Khosravi *et al*., 2015).

Beauveria bassiana is an entomopathogenic fungus to infect almost all orders and various stages of insects, thus it is quite prospective to be used as an alternative for conventional insecticides (Reddy *et al*., 2014). The control of tuber borer using entomopathogenic fungi *B. bassiana* in Indonesia is not yet developed, because there has not been found the right application method to obtain optimal efficacy in the field. Stafford and Allan (2010) studied that *B. bassiana* applicated on the leaf surface is quite effective in controlling pests from mite. Ali *et al*., (2009) indicated that *B. bassiana* applicated on the ground is more effective than other methods. Meanwhile, the efficacy of *B. bassiana* is more determined by the type and behavior of the target pests (Boyle & Cutler, 2012; Rashki & Shirvani, 2013).

B. bassiana isolates had been explored in 2010 from various locations in Java and among those, there were three effective isolates cause adult and larvae mortality up to 100%, and unhatched eggs of *C. formicarius* (Prayogo, 2012; 2013). In advance research, *B. bassiana* was formulated in the form of powder with the product name Be-Bas under patent number P00201605992 (Prayogo, 2016). Powder formulation is expected to make application simple in the field yet effective. Therefore, to verify the consistency of the efficacy of Be-Bas formulation in controlling tuber borer, this biopesticide needs to be validated in various locations, especially at the *C. formicarius* endemic centers of sweet potato plantations. The aim of this study was to validate the efficacy of Be-Bas biopesticide (*B. bassiana*) against sweet potato borer *C. formicarius* in tidal land, South Kalimantan.

MATERIALS AND METHODS

This study was conducted in Sidomulyo Village, Wanaraya District, Barito Kuala Regency, South Kalimantan Province, from June to November 2016. The study was arranged in Randomized Block Design (RBD) with five replications. The treatments were: P1 (Be-Bas applicated in planting hole), P2 (Be-Bas applicated at the base of plant stem), P3 (sweet potato cuttings soaked in Be-Bas for 60 minutes before planting), P4 (full protection using chemical insecticides starting at the age of 30 DAP and 2-week interval), and P5 (non-controlling treatment).

Land Selection

The research location was selected in the center production of sweet potato which is endemic to tuber borer. An observation on *C. formicarius* existence was done prior to research to ensure that the land was truly endemic to tuber borer. Observation *C. formicarius* was conducted by exposing fresh tubers of local varieties on the surface of the land at several points taken diagonally, then the tubers were covered with tilled-soil and left for approximately 30 days. The exposed tuber was taken, observed and calculated the number of egg masses, larvae, and adults of *C. formicarius*. Land indicated as endemic to tuber borer if all of the exposed tubers were infested by *C. formicarius* with damage level of ≥ 50%. If the land was not indicated as tuber borer endemic, then the artificial infestation has to be employed using *C. formicarius* reared in the laboratory.

Land Preparation

The soil was tilled until it was loosened and then made a mound (400 cm in long and 75 cm in wide). The soil then amended with mixed of 2 tons/ha of limestone and 5 tons of manure/ha at the time of tillage. The dosage of fertilizer given was as follows: 100 kg N, 150 SP36, and 100 KCl/ha. All dosages of fertilizer were given during planting time, while 2/3 doses of fertilizer were given at the age of 1 month. Sweet potato cuttings used in this study were local varieties.

Preparation of Be-Bas Biopesticide

Entomopathogenic fungus *B. bassiana* isolate used in this study were obtained from Indonesian Legumes and Tuber Crops Research Institute (ILETRI), Laboratory collection of Biopesticides, formulated in powder under Be-Bas trademark. The efficacy of this product has been tested to kill larvae and adults of *C. formicarius* with mortality level reach 100%. Preparation of Be-Bas formulations was as follows: *B. bassiana* isolate was grown on a medium made from sweet corn plus 5% of chitin flour from clamshells (*Scylla serrata*). Media then put into a plastic bag containing 200 g media and then sterilized in an autoclave at 121^{o} C for 30 minutes. Media then inoculated with *B. bassiana* isolate, and after 21 days post-inoculation (DPI). Each culture bag was put into Erlenmeyer, mixed with 1000 ml of water then shook using a shaker for 60 minutes. Furthermore, the conidia suspension was filtered using gauze to separate conidia from the substrate and then 3 ml/l of Tween 80 was added and shaken so that conidia mixed homogeneously because it is hydrophobic. The conidia suspension was mixed with a carrier material (Kaolin powder), then dried in an aseptic laminar flow cabinet.

The application of the conidium suspension to the planting hole and to the base of the stem was 600 l/ha using conidia density of 10^7/ml by taking 5 g of Be-Bas product put in water and stirring until homogeneous. The application of the conidia *B. bassiana* suspension on sweet potato cuttings was carried out by soaked cuttings in conidia suspension for 60 minutes before planting. Full protection treatment (P4) was used a conventional insecticide with the active ingredient of lambda-cyhalothrin at the age of 30 DAP (day after planting) with an interval of every week. Non-controlling treatment (P5), plants were sprayed only with water since the plant was 30 days old with an interval of every week.

Observation

The variables observed were the number of dead larvae infected by *B. bassiana*, number of live larvae in tubers, number of eggs in each tuber base, tuber damage level (%), and weight tuber of each plant. Observations were made at harvest on tuber of five plants per treatment which were taken randomly.

Data Analysis

The results were analyzed using the Minitab program 14. Any significant differences between treatments will be followed by Duncan Multiple Range Test (DMRT) at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Larval Mortality of C. formicarius

Be-Bas biopesticide was effective in killing sweet potato borer larvae and adults, but the efficacy of the fungi was influenced by the application technique was carried out. This was characterized by the presence of dead larvae and adults infected by *B. bassiana* as bioinsecticide in treatment P1 (application of conidium *B. bassiana* suspension in planting holes), P2 (Be-Bas conidia suspension sprayed to the base of plant stem), and P3 (application through soaking sweet potato cuttings into the conidium *B. bassiana* suspension for 60 minutes before planting). The number of dead larvae and adults of *C. formicarius* infected by *B. bassiana* was higher in P1 (17), then P2 (15) (Table 1). However, P3 (3) was less effective compared to P1 and P2 refer to the larval and adult mortality.

The died larvae or adults of *C. formicarius* infected by *B. bassiana* from the field at P1, P2, and P3 did not show any colonization of *B. bassiana* mycelium. Colonization was seen after the body of the dead insect was incubated in Petri dishes for 98 hours with the presence of white mycelium covering the entire insect body (Figure 1). Colonization of *B. bassiana* mycelium in *C. formicarius* larvae was indicated by mass of white conidia as inoculum or source of infection to host insects. The died instars I and II of Coleoptera order due to *B. bassiana* infection are characterized by colonization of white mycelium covers the entire body of insects in a short time (Ansari & Butt, 2012; Malekan *et al*., 2015; Erler & Ates, 2015). This conidia produced by mycelium colonization is a media to spread the disease in the body of host insects (Gracia-Munguia *et al*., 2011; Lopes *et al*., 2011; Svedese *et al*., 2013).

Referring to the mortality of *C. formicarius*, conidia suspension of *B. bassiana* applied in planting holes or sprayed at the base of plant stems was quite effective to kill *C. formicarius* larvae and adults compared to soaked cuttings and conventional insecticide applications. Because of conidia applied in the planting hole or around the stem of the plant established and colonized plant root area where tubers grow. Thus tubers have been protected by the conidial mycelium *B. bassiana*. According to Du *et al.* (2013), Quesada-Moraga *et al.* (2014), and Swiergiel *et al.* (2015), the conidia suspension of entomopathogenic fungi *B. bassiana* applied to the soil is able to suppress the population of several types of underground pests. *B. bassiana* is an entomopathogenic fungus that is endophytic, parasitic, and saprophytic that establish in the soil hence it can be used for pest control agents in the soil (Lopez *et al*., 2011; Brownbridge

Table 1. The larval and adult mortality of *Cylas formicarius* infected by *Beauveria bassiana* every five clumps of plants

No.	Treatment	Mortality (larvae or adults)
1.	P1 (Be-Bas applicated in planting hole)	17.0a
2.	P2 (Be-Bas applicated at the base of plant stem)	15.0b
3.	P3 (sweet potato cuttings soaked in Be-Bas for 60 minutes before planting)	3.0cd
4.	P4 (chemical insecticide)	4.0c
5.	P5 (non-controling treament)	0.0e

Remarks: Values followed by different letter were not significantly different according to DMRT ($\alpha = 0.05$)

Figure 1. *Cylas formicarius* larvae colonized by *Beauveria bassiana* after 98 hours incubation

et al., 2012; Greenfield *et al*., 2016). This study informed that the pests living around the base of plant stems and soil can be controlled using the biological agent *B. bassiana*.

Number of C. formicarius *Eggs Found in Each Tuber*

C. formicarius eggs found on tuber skin from P1, P2, and P3 were only 5 eggs in each tuber (Table 2). The eggs found on the tuber at harvesting time revealed colonization of *B. bassiana* mycelium after incubation in the petri dish. Furthermore, after 4 days, the incubated eggs failed to hatch, because they had been infected by *B. bassiana* except for the eggs from P3. It was estimated that uninfected eggs by *B. bassiana* from P3 will hatch and the larvae will feed on tubers thus creating damage. Eggs from P1 and P2 were failed to hatch because *B. bassiana* was able to impede eggs (ovicidal) as reported by Nisha *et al*. (2013). Furthermore, Wu *et al*. (2015) and Peter (2015) reported that *B. bassiana* produces metabolites from mycelium and conidium, e.i. bassionalide, oosporin, beauvericin, and beauveriolides which are toxic to aphids (aphicidal), anti-feeding, inhibit egg production and the process of oviposition. Therefore, *B. bassiana* has great potential as a biological agent to suppress the population of pests in the field due to its ability in killing egg (Lord, 2009).

The highest number of the eggs found in P5 (non-controlling treatment) was 23 eggs per tuber, in the conventional insecticide intensively applied every two weeks (P4) found 19 eggs/tubers (Figure 2). *C. formicarius* eggs found in both treatments had a 99% chance of hatching, which triggered the development of larvae and growing inside the tuber. Because of the conventional insecticide used (lambda-cyhalothrin) has no ovicidal ability (Stevenson *et al*., 2009; Kumano *et al*., 2011; Wang *et al*., 2014). Previous research reported that only conventional insecticides with active ingredients of phenylpyrazoles, ethiprole, organophosphates, and carbamate were toxic to Hymenoptera eggs.

Table 2. Number of *Cylas formicarius* eggs and larvae in each tuber applied with Be-Bas and conventional insecticide

No.	Treatment	Number of eggs	Number of larvae
1.	P1 (Be-Bas applicated in planting hole)	5.30c	0.0c
2.	P2 (Be-Bas applicated at the base of plant stem)	5.25c	0.0c
3.	P3 (sweet potato cuttings soaked in Be-Bas for 60 minutes before planting)	5.50c	0.0c
4.	P4 (chemical insecticide)	19.50b	3.0b
5.	P5 (non-controling treatment)	23.50a	7.0a

Remarks: Values followed by different letter were not significantly different according to DMRT (α = 0.05)

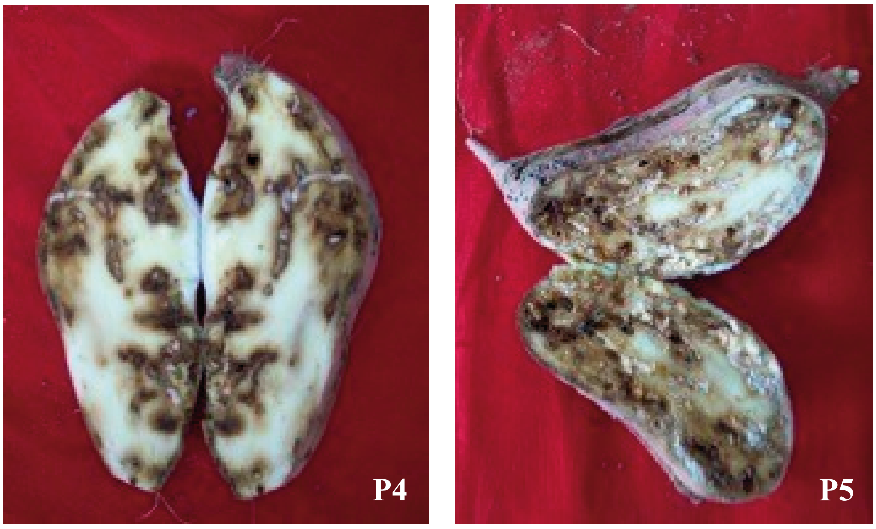

Figure 2. Damaged tuber bored by *Cylas formicarius* larvae from conventional insecticide treatment (P4) and non-controlling treatment (P5)

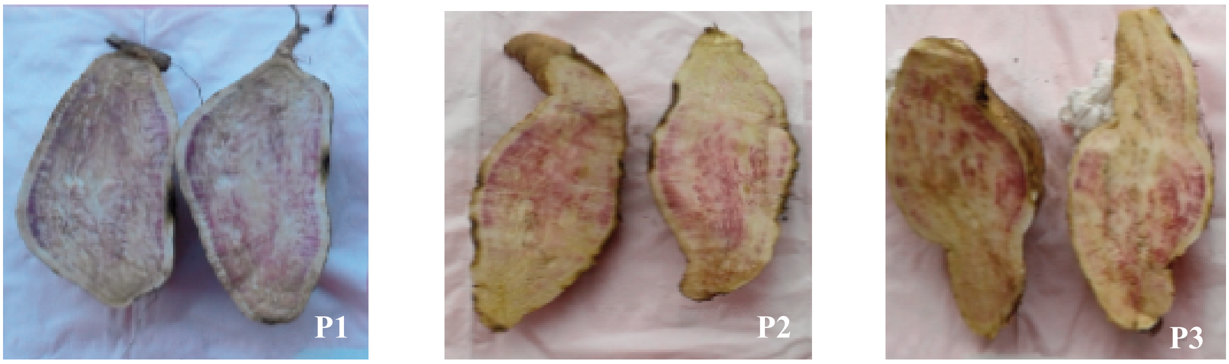

Figure 3. The tuber treated with Be-Bas. P1= (Be-Bas applicated in planting hole), P2 = (Be-Bas applicated at the base of plant stem), P3 = (sweet potato cuttings soaked in Be-Bas for 60 minutes before planting)

Number of* C. formicarius *Larvae

There were no larvae found from P1, P2, and P3 even when the harvested tubers were cut to ascertain the existence of larvae inside the tubers. Because the habitat of *C. formicarius* larvae is inside the tubers under the soil. Observations on the number of eggs indicated that in P3 was found 5 eggs uninfected by *B. bassiana* so that they would become larvae. Furthermore, P3 showed no eggs hatched, which could be influenced by internal and external factors. Therefore, the efficacy of the P3 treatment still needs to be reviewed further to ensure the performance consistency of the Be-Bas biopesticide in protecting cuttings by soaking before planting for 60 minutes.

Larvae found from P4 and P5 were 3 and 7 per plant, respectively (Table 2). That showed that P1, P2, and P3 were quite protected the tubers because there were no larval stages in the tubers hence there was no damage to the tubers (Figure 3). The efficacy of *B. bassiana* in suppressing the development of larvae and eggs is because the fungus is capable of killing various types of pests in all insect stadia (eggs, larvae, and adults) (Hernandez *et al*., 2012; Tangavel *et al*., 2013; Krishna & Bhaskar, 2013; and Zhang *et al*., 2013).

Damage level of the tuber of each plant

P1, P2, and P3 showed there was no tuber damaged by *C. formicarius* larvae (Table 3). From destructive observations, that there were no larvae alive found in each tuber. The destructive observation was carried out by cutting each tuber to examine the existence of larvae inside tuber. This observation informed that the application of *B. bassiana* in P1, P2, and P3 decreased *C. formicarius* population inside tuber. According to Akmal *et al.* (2013), the efficacy of pest control using entomopathogenic *B. bassiana* was related to insect target behavior and habitat. The application of *B. bassiana* into the soil was more able to suppress soil living pests population of Coleoptera order compared to applications on plant canopies. Because of the applied conidium suspension can establish and colonize the root area (Stafford & Allan, 2010). Thus, pests have habitat around the root area will die by fungal infection. In addition, conidia formed from dead insects in the root area become potential inoculum that will transmit the disease to another host pests (Conceschi *et al*., 2016).

Tuber damage was only found in P4 (17.5%) and P5 (60.5%). The infested tuber by *C. formicarius* contained poison because of larval feces, hence unconsumable because it tastes bitter and can cause cancer (Figure 2). Therefore, control of *C. formicarius* on sweet potatoes using conventional insecticides was considered to be less effective, because the attack symptoms on the tuber still occur so that the tuber cannot be consumed. The average tuber damage in P5 reached 60.50% with tubers being severely damaged. Symptoms of tuber borer attack are the presence of *C. formicarius* feces found around the base of the stem (Okonya & Kroschel, 2013; Seow-Mun & Min-Yang, 2015; Zimmerman *et al*., 2016).

Weight and Number of Healthy Tuber of Each Plant

The highest tuber weight was from P1 (575.5 g/plant) (Table 4). Tuber weight of each plant from P2 (565.3 g/plant) and P3 (565.2 g/plant) was also quite high, almost the same as P1. The tuber weight from P4 (495.8 g/plant) was not significantly different from P5 (495.9 g/plant), but in P5, the level of tuber damage was higher than that in P4.

The highest average number of tubers was also from P1 (3.4 tubers/plant). The average number of tubers from P2 and P3 were 3.3 and 3.2 tuber, respectively. P4 only produced 2.2 tubers/plant, and P5 was 2.9 tubers/plant. The number of tubers from P5 (non-controlling treatment) was higher than P4 (conventional insecticide treatment), but the tuber damage on P5 was heavier so it was not possible for consumption. This condition caused by a large number of larvae inside tuber so that the consumable tubers were low. According to Hue & Low (2015), the higher number of *C. formicarius*

Table 3. The damage level on sweet potato tubers by *Cylas formicarius* larvae every five clumps of plants

No.	Treatment	Tuber damage (%)
1.	P1 (Be-Bas applicated in planting hole)	0.0c
2.	P2 (Be-Bas applicated at the base of plant stem)	0.0c
3.	P3 (sweet potato cuttings soaked in Be-Bas for 60 minutes before planting)	0.0c
4.	P4 (chemical insecticide)	17.50 b
5.	P5 (non-controling treament)	60.50a

Remarks: Values followed by different letter were not significantly different according to DMRT (α = 0.05)

Table 4. The weight and number of sweet potato tuber per plant treated with Be-Bas and conventional insecticide (lambda-cyhalothrin)

No.	Treatment	Tuber weight (g)*	Number of tuber/plant
1.	P1 (Be-Bas applicated in planting hole)	575.5a	3.40
2.	P2 (Be-Bas applicated at the base of plant stem)	565.3b	3.30
3.	P3 (sweet potato cuttings soaked in Be-Bas for 60 minutes before planting)	565.2b	3.20
4.	P4 (chemical insecticide)	495.8c	2.20
5.	P5 (non-controling treatment)	495.9c	2.90

Remarks: Values followed by different letter were not significantly different according to DMRT (α = 0.05) larvae inside the tuber, the higher damage level of tuber will obtain and even not suitable for consumption.

According to the weight of the tuber and the tuber damage level, the application of Be-Bas biopesticide in planting holes and at the base of the stem of the plant was an effective and suitable technique to suppress *C. formicarius* population in order to save yield. The method of application required an effort in such manner each planting hole could obtain an adequate initial inoculum so the pests around the planting hole will be infected by this biopesticide. Application method by soaking sweet potato cuttings into *B. bassiana* conidia suspension for 60 minutes before planting can be recommended if there was not enough labor for the application in the planting hole. During soaking, an adhesive must be added to increase the persistence of the conidium attached to the cuttings because the amount of inoculum is quite limited and to ensure the colonization of the inoculum around the stem of the plant can occur. Adhesives will increase the persistence of conidium in the field from less favorable environmental factors, especially on dry land (prevent evaporation) and on the wetland (prevent run off) (Mwamburi *et al*., 2015; Jadhav & Patil, 2016). The application of conventional insecticide with the active ingredient of lambda-cyhalothrin has not been able to suppress the development of *C. formicarius* in tidal land which presumed as endemic area. This finding was concluded from the high larvae population because the insecticide was not able to kill *C. formicarius* eggs, so the tuber damage level was still quite high as well as the treatment without control treatment.

CONCLUSION

Be-Bas (entomopathogenic fungus *B. bassiana*) is more effective in suppressing the development of *C. formicarius*, tuber damage, and maintaining sweet potato yield compared to the efficacy of conventional insecticide. Applicating Be-Bas biopesticide in planting holes and at the base of plant stems are more effective in suppressing the development of *C. formicarius* and thus saving the yield. Soaking cuttings before planting for 60 minutes into Be-Bas biopesticide was recommended for controlling *C. formicarius* although it still needs to be revalidated. Validation of Be-Bas biopesticide in controlling sweet potato borer *C. formicarius* need to be reviewed in various locations of sweet potato production centers and those that have endemic criteria.

ACKNOWLEDGEMENT

We thank to Urip Sembodo, S.P. for helping this research in the field to completion, as well to the Indonesian Agency for Agricultural Research and Development (IAARD) for funding this research.

LITERATURE CITED

Akmal, M., S. Freed, M.N. Malik, & H.T. Gul. 2013. Efficacy of *Beauveria bassiana* (Deuteromycotina: Hyphomycetes) against Different Aphid Species under Laboratory Conditions. *Pakistan Journal of Zoology* 45: 71−78.

Ali, A., H. Sermann, S. Lerche, & C. Buttner. 2009. Soil Application of *Beauveria bassiana* to Control *Ceratitis capitata* in Semi Field Conditions. *Communication in Agricultural and Applied Biological Science* 74: 357−361.

Alwi, M. 2014. Prospek Lahan Rawa Pasang Surut untuk Tanaman Padi, p. 45−59. *In* M. Yasin (ed.), *Prosiding Seminar Nasional "Inovasi Teknologi Pertanian Spesifik Lokasi"*. Banjarbaru, Agustus 6−7, 2014.

Ansari, M.A. & T.M. Butt. 2012. Susceptibility of Different Developmental Stages of Large Pine Weevil *Hylobius abietis* (Coleoptera: Curculionidae) to Entomopathogenic Fungi and Effect of Fungal Infection to Adult Weevils by Formulation and Application Methods. *Journal of Invertebrate Pathology* 111: 33−40.

Boyle, D. & G.C. Cutler. 2012. Effects of Insect Activity, Soil, and Cuticular Factors on Virulence of *Beauveria bassiana* toward *Blissus leucopterus hirtus*. *Journal of Pest Science* 85: 505−512.

Brownbridge, M., S.D. Reay, T.I. Nelson, & T.R. Glare. 2012. Persistance of *Beauveria bassiana* (Ascomycota: Hypocreales) as an Endophyte Following Inoculation of Radiate Pine Seed and Seedlings. *Biological Control* 61: 194−200.

Conceschi, M.R., G.P.D. Alessandro, Rde.A. Moral, C.G.B. Demetria, & I.D. Junior. 2016. Transmission Potential Entomopathogenic Fungi *Isaria fumosoroseus* and *Beauveria bassiana* from Sporulated Cadavers of *Diaphorina citri* and *Toxoptera citricida* to Uninfected *D. citri* Adults. *Biological Control* 24: 1−11.

Devi, M., K.I. Kumar, & R.F. Niranjana. 2014. Biology of Sweet Potato Weevil *Cylas formicarius* on Sweet Potato. *Journal of Entomological Research Society* 38: 53−57.

Du, W.J., P. Jiang, T. Yang, Y.Q. Bu, C.H. Liu, & C.C. Dai. 2013. Effects of *Beauveria bassiana* and Acephate on Enzyme Activities and Microbial in Paddy Soil. *Plant Soil and Environment* 59: 562−567.

Eler, F. & A.O. Ates. 2015. Potential of Two Entomopathogenic Fungi, *Beauveria bassiana* and *Metarhizium anisopliae* (Coleoptera: Scarabidae), as Biological Control Agents against the June Beetle. *Journal of Insect Science* 15: 1−6.

Galib, R. 2014. Pengembangan Komoditas Ubijalar di Lahan Rawa Lebak Kalimantan Selatan sebagai Sumber Pangan (Kasus Di Kecamatan Daha Utara), p. 467−472. *In* M. Yasin (ed.), *Prosiding Seminar Nasional "Inovasi Teknologi Pertanian Spesifik Lokasi"*, Banjarbaru, Agustus 6−7, 2014.

Garcia-Munguia, A.M., J.A. Garza-Hernandez, E.A. Rebollar-Tellez, M.A. Rodriguez-Perez, & F. Reyes-Villaneva. 2011. Transmission of *Beauveria bassiana* Male to Female *Aedes aegypti* Mosquitoes. *Parasites and Vectors* 4: 1−6.

Greenfield, M., M.I. Gomez-Jimenez, & S. Parsa. 2016. *Beauveria bassiana* and *Metarhizium anisopliae* Endophytically Colonize Cassava Roots Following Soil Drench Inoculation. *Biological Control* 95: 40−49.

Hernandez, M.M., E.M. Villar, C. Peau, I. Perez-Morene, & V. Marco. 2012. Compatibility of the Entomopathogenic Fungus *Beauveria bassiana* with Flufenoxuron and Azadirahtin against *Tetranychus urticae*. *Experimental Applied Acarology* 23: 71−80.

Hue, S.H. & M.Y. Low. 2015. An Insight Into Sweet Potato Weevils Management: A Review. *Psyche: A Journal of Entomology* 1: 1−12.

Jadhav, R.S. & S.D. Patil. 2016. Effect of Various Adjuvants on Growth and Development of Entomopathogenic Fungi *Beauveria bassiana* (Balsamo) Vuillemin. *International Journal of Plant Protection* 9: 401−408.

Khosravi, R., J.J. Sendi, A. Zibaee, & M.A. Shokrgozar. 2015. Virulence of Four *Beauveria bassiana* (Balsamo) (Ascomycete: Hypocreales) Isolates on Rose Sawfly, *Arge rosae* under Laboratory Condition. *Journal of King Saudy University Science* 27: 49−53.

Korada, R.R., S.K. Naskar, M.S. Palaniswami, & R.C. Ray. 2010. Management of Sweet Potato Weevil *Cylas formicarius* (Fab.): An Overview. *Journal of Root Crops* 36: 14−26.

Krishna, A.R. & H. Bhaskar. 2013. Ovicidal and Adulficidal Effect of Acaropathogenic Fungi, Neem Oil and New Acaricide Molecules on *Tetranychus urticae* Koch. *Entomology* 38: 177−182.

Kumano, N., T. Kuriwada, K. Shiromoto, D. Haraguchi, & T. Kohama. 2011. Prolongation of the Effective Copulation Period by Fractionated-Dose Irradiation in the Sweet Potato Weevil *Cylas formicarius*. *Entomologia Experimentalis et Applicata* 141: 129–137.

Leng, H. & G.V.P. Reddy. 2012. Bioactive of Selected Eco-Friendly Pesticides against *Cylas formicarius* (Coleoptera: Brentidae). *Florida Entomology* 95: 1040−1047.

Lopes, R.B., M. Michereff-Filho, M.S. Tigano, & P.M. Oliveira. 2011. Virulence and Horizontal Transmission of Selected Brazilian of *Beauveria bassiana* against *Cosmopolites sordidus* under Laboratory Conditions. *Bulletin of Insectology* 64: 201−208.

Lord, J.C. 2009. *Beauveria bassiana* Infection of Eggs of Stored-Product Beetles. *Short Communication* 39: 155−156.

Maingi, D., S. Sivasupramaniam, W. Renee, G. Brown, & F. William. 2002. This Persentation is of Student Competition Ten-Minute Papers, Section B. Physiology, Biochemistry, Toxicology and Molecular Biology.http://esa.confex.com/esa/3002/techprogram/paper_8703.htm, modified 4/9/18.

Malekan, N., B. Hatami, R. Ebadi, A. Akhavan, & R. Radjabi. 2015. Evaluation of Entomopathogenic Fungi *Beauveria bassiana* and *Lecanicillium muscarium* on Different Nymphal Stages of Green House Condition. *Biharean Biologist* 9: 108−112.

Mwamburi, L.A., M.D. Laing, & R.M. Miller. 2015. Effect of Surfactants and Temperature on Germination and Vegetative Growth of *Beauveria bassiana*. *Journal of Microbiology* 46: 67−74.

Nisha, S.M., A. Jebanesan, & C.M. Kumar. 2013. Ovicidal Activity of Entomopathogenic Fungi *Beauveria bassiana* and *Metarhizium anisopliae* against Dengue Vector *Aedes aegypti* (Diptera: Culicidae). *Insect Environment* 19: 195−196.

Okonya, J.S. & J. Kroschel. 2013. Incidence and Damage by the Sweet Potato Butterfly (*Acroea acerata* Hew.) and the African Sweet Potato Weevils (*Cylas* spp.) a Cross an Altitude Gradient in Kabale District, Uganda. *International Journal of Agricultural Science* 3: 814−824.

Peter, C. 2015. *Bioactive Metabolites of an Isolate of the Entomopathogenic Fungus Beauveria bassiana*. Thesis, Lincoln University. 282 p.

Prayogo, Y. 2012. Virulensi Beberapa Isolat Cendawan Entomopatogen *Beauveria bassiana* (Balsamo) Vuill. untuk Mengendalikan Penggerek Ubijalar *Cylas formicarius*, p. 738−754. *In* A. Widjono, Hermanto, N. Nugrahaeni, A.A. Rahmianna, Suharsono, F. Rozi, E. Ginting, A. Taufiq, A. Harsono, Y. Prayogo & E. Yusnawan (eds.), *Prosiding Seminar Nasional Hasil Penelitian Tanaman Aneka Kacang dan Umbi Tahun 2011*. Pusat Penelitian dan Pengembangan Tanaman Pangan, Badan Penelitian dan Pengembangan Pertanian, Malang, November 15, 2011.

Prayogo, Y. 2013. Toksisitas Cendawan *Beauveria bassiana* Vuill. (Balsamo) terhadap Telur dan Larva Penggerek Ubijalar *Cylas formicarius* (Coleoptera: Curculionidae), p. 669−681. *In* N. Saleh, A. Harsono, N. Nugrahaeni, A. A. Rahmianna, Sholihin, M. Yusuf, Heriyanto, I. K. Tastra, M. M. Adie, Hermanto & D. Harnowo (eds.), *Prosiding Seminar Nasional Hasil Penelitian Tanaman Aneka Kacang dan Umbi Tahun 2013*. Pusat Penelitian dan Pengembangan Tanaman Pangan, Badan Penelitian dan Pengembangan Pertanian, Malang, May 22, 2013.

Prayogo, Y. 2016. Proses Pembuatan Biopestisida Berbahan Aktif Cendawan Entomopatogen *Beauveria bassiana* dan Komposisinya. 16 p. Paten No.: P00201605992.

Quesada-Moraga, E., C. Lopez-Diaz, & B.B. Landa. 2014. The Hidden Habitat of the Entomopathogenic Fungus *Beauveria bassiana*: First Demonstration of Vertical Plant Transmission. *Public Library of Science* 9: 1−6.

Rashki, M. & A. Shirvani. 2013. The Effect of Entomopathogenic Fungus *Beauveria bassiana* on Life Table Parameters and Behavioural Response of *Aphis gossypii*. *Bulletin of Insectology* 66: 85−91.

Reddy, G.V.P., N. Gadi, & A.J. Talanao. 2012. Efficient Sex Pheromone Trapping: Catching the Sweetpotato Weevil *Cylas formicarius*. *Journal of Chemical Ecology* 38: 846−853.

Reddy, G.V.P., Z. Zhoo, & R.A. Humber. 2014. Laboratory and Field Efficacy of Entomopathogenic Fungi for the Management of the Sweet Potato Weevil, *Cylas formicarius* (Coleoptera: Brentidae). *Journal of Invertebrate Pathology* 122: 10−15.

Rina, Y. & H. Syahbudin. 2013. Zona Kesesuaian Lahan Rawa Pasang Surut Berbasis Keunggulan Kompetitif Komoditas. *Socio Economic Agribusiness Journal* 10: 103−117.

Seow-Mun, H. & L. Min-Yang. 2015. An Insight into Sweet Potato Weevils Management: A Review. *Psyche: A Journal of Entomology* 13: 83−91.

Shams, G., M.H. Safaralizadeh, S. Imani, M. Shoja, & S. Aramidah. 2011. A laboratory Assessment of the Potential of the Entomopathogenic Fungi *Beauveria bassiana* (*Beauvarin* C) to Control *Callosobruchus maculatus* (F.) (Coleoptera: Brucidae) and *Sitophilus granaries* (L.) (Coleoptera: Curculionidae). *African Journal of Microbiology Research* 10: 1192−1196.

Stafford, K.C. & S.A. Allan. 2010. Field Application of Entomopathogenic Fungi *Beauveria bassiana* and *Metarhizium anisopliae* F52 (Hypocreales: Clavicipitaceae) for the Control of *Ixodes scapularis* (Acari: Ixodidae). *Journal of Medical Entomology* 47: 1107−1115.

Stevenson, P.C., H. Muyinza, & D.R. Hall. 2009. Chemical Basis for Resistance in Sweet Potato *Ipomoea batatas* to the Sweet Potato Weevil *Cylas puncticollis*. *Pure and Applied Chemistry* 81: 141–151.

Svedese, V.M., E.AdeL. Lima, & A.L.F. Porto. 2013. Horizontal Transmission and Effect of the Temperature in Pathogenicity of *Beauveria bassiana* against *Diatraea succharalis* (Lepidoptera: Crambidae). *Brazilian Archives of Biology and Technology* 56: 413−419.

Swiadikarta, D.A. 2012. Teknologi Pengelolaan Lahan Rawa Berkelanjutan: Studi Kasus Kawasan Ex PLG Kalimantan Tengah. *Jurnal Sumberdaya Lahan* 6: 45−54.

Swiergiel, W., N.V. Meyling, M. Porcei, & B. Rament. 2015. Soil Application of *Beauveria bassiana* GHA against Apple Sawly *Haplocampa testudinea* (Hymenoptera: Tenthredinidae): Field Mortality and Fungal Persistence. *Insect Science* 23: 854−868.

Taye, A. & E. Tadesse. 2014. Screening Chemical Pesticides for the Management of Sweet Potato Weevil *Cylas formicarius*. *International Journal of Advance Agricultural Research* 2: 48−57.

Thangavel, B., K. Palaniappan, P. Kim, M. Subbarayalu, & R. Malhalym. 2013. Pathogenicity, Ovicidal Action, and Median Lethal Concentrations (LC 50) of Entomopathogenic Fungi against Exotic Spiraling Whitefly *Aleurodicus disperses* Russel. *Journal of Pathogens* 2013: 1−7.

Wahyunto, R.S, & A. Mulyani. 2011. Sebaran Lahan Gambut di Indonesia, p. 15−26. *In* N.L. Nurida *et al*. (eds.), Balai Penelitian Tanah. Badan Penelitian dan Pengembangan Pertanian. Kementerian Pertanian, Bogor.

Wahyunto, R.S., K. Nugroho, & M. Sarwani. 2012. Inventarisasi dan Pemetaan Lahan Gambut di Indonesia, p. 466. *In* E. Husein, M. Anda, M. Noor, Mamat HS, Maswar, A. Fahmi & Y. Sulaeman (eds.), *Prosiding Seminar Nasional Pengelolaan Lahan Gambut Berkelanjutan*. Badan Penelitian dan Pengembangan Pertanian. Kementerian Pertanian, Bogor, May 4, 2012.

Wang, Y., C. Wu, T. Cang, L. Yang, W. Yu, X. Zhao, O. Wang, & L. Cai. 2014. Toxicity Risk of Insecticides to the Insect Parasitoid *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae). *Pest Management Science* 70: 398−404.

Wu, S., Y. Gao, X. Xu, D. Wang, J. Li, H. Wang, E. Wang, & Z. Lei. 2015. Feeding on *Beauveria bassiana*-Treated *Frankliniella occidentalis* Causes Negative Effects on the Predatory Mite *Neoseiulus barkeri*. *Scientific Reports* 5: 1−12.

Zhang, L., W.B. Shi, M.G. Feng. 2013. Histopathological and Molecular Insights into the Ovicidal Activities of Two Spotted Spider Mites. *Journal of Invertebrate Pathology* 117: 73−78.

Zimmerman, T.W., C. Montilla, & S.M.A. Crossman. 2016. Sweet Potato Cultivar and Harvest Date Influence on Damage. *Acta Horticulturae* (*International Society for Horticultural Science*) 1118: 153−156.