

EXPLORATION AND SCREENING FOR ENDOPHYTIC MICROBES OF MAIZE PLANT ROOT AGAINST *Fusarium verticillioides*

Rahmat Jahuddin¹, Jamila¹, Awaluddin¹, & Suriani²

¹Faculty of Agriculture Islamic University of Makassar, Indonesia
Jl. Perintis Kemerdekaan Km 9 No. 29 Makassar South Sulawesi

² Indonesian Cereals Research Institute
Jl. Dr. Ratulangi No. 274 Maros South Sulawesi
E-mail: rahmatjahuddin@yahoo.co.id

ABSTRACT

Exploration and screening for endophytic microbes of maize plant root against *Fusarium verticillioides*. *Fusarium verticillioides* is an important pathogen of maize which can attack cob and stem causing ear rot and stalk rot disease. *Fusarium* ear rot disease needs to get a serious attention because the mycotoxins produced by this pathogen very harmful for consumers. The aim of this study was to screen maize roots endophytic microbes as antagonist to *F. verticillioides*. Endophytes microbial exploration is done by taking samples of local roots of South Sulawesi and hybrid maizes in Soppeng Regency then isolated in Biological Laboratory of Islamic University of Makassar. The endophytes were then tested their effectiveness on inhibiting growth of mycelia pathogenic *F. verticillioides* by using dual culture method and tested the suppressing ability of *F. verticillioides* on maize seed and their influence on seed sprout length. The results showed that there were 8 endophytic microbes consisting of 4 isolates of the fungus group namely HS-01, HS-02, HS-04, LS-01 and 4 isolates from bacterial group namely HS-03, LS-02, LS-03, LS-04. While the results of microbial effectiveness testing on pathogenic *F. verticillioides* showed that HS-04 has the highest percentage of inhibition followed by isolate HS-01, HS-02 and LS-02. HS-04 isolate also showed the ability to suppress *F. verticillioides* attacks on corn seeds at 77.78%. The highest seed sprout length was shown in LS-02 isolate application about 10.57 cm. Thus it can be concluded that there were 3 potentially endophytic microbes to control the *F. verticillioides* namely HS-04, HS-01 and LS-02. The ability to stimulate plant growth became one of considerations to select these three microbes.

Key words: endofit microbes, *Fusarium verticillioides*, maize

ABSTRAK

Eksplorasi dan skrining mikroba endofit perakaran tanaman jagung terhadap *Fusarium verticillioides*. *Fusarium verticillioides* merupakan patogen penting tanaman jagung karena yang menyerang tongkol dan batang menyebabkan penyakit busuk tongkol dan busuk batang. Penyakit busuk tongkol *Fusarium* perlu mendapatkan perhatian serius karena mikotoksin yang diproduksi patogen ini sangat berbahaya bagi konsumen. Penelitian ini bertujuan untuk skrining beberapa mikroba-mikroba endofit perakaran jagung terhadap *F. verticillioides*. Eksplorasi mikroba endofit dilakukan dengan mengambil sampel perakaran jagung Lokal Sulawesi Selatan dan jagung hibrida di Kabupaten Soppeng kemudian diisolasi di Laboratorium Hayati Universitas Islam Makassar. Selanjutnya isolat mikroba endofit diuji efektivitasnya dalam menghambat pertumbuhan miselia patogen *F. verticillioides* dengan menggunakan metode *dual culture*. Pengujian lainnya yakni efektivitas mikroba dalam menekan serangan *F. verticillioides* pada benih jagung dan pengaruhnya terhadap panjang kecambah benih. Hasil eksplorasi didapatkan 8 jenis mikroba endofit yang terdiri dari 4 isolat golongan cendawan (HS-01, HS-02, HS-04, LS-01) dan 4 isolat dari golongan bakteri (HS-03, LS-02, LS-03, LS-04). Hasil pengujian efektivitas mikroba terhadap patogen *F. verticillioides* menunjukkan bahwa HS-04 memiliki persentase penghambatan tertinggi disusul isolat HS-01, HS-02 dan LS-02. Isolat HS-04 juga menunjukkan kemampuan menekan serangan *F. verticillioides* pada benih jagung paling tinggi sebesar 77,78%. Panjang kecambah benih tertinggi ditunjukkan pada aplikasi isolat LS-02 sebesar 10,57 cm. Dengan demikian dapat disimpulkan bahwa terdapat 3 mikroba endofit yang potensi dikembangkan untuk pengendalian *F. verticillioides* yakni HS-04, HS-01 dan LS-02. Kemampuan merangsang pertumbuhan tanaman menjadi pertimbangan lain pemilihan ketiga mikroba tersebut.

Kata kunci: *Fusarium verticillioides*, jagung, mikroba endofit

INTRODUCTION

Occasionally, corn cultivation experiences some main obstacles, including occurrence of plant pests which can reduce plant yields, even produce non-producing plants. Some pathogens cause diseases on maize, they are including *Peronosclerospora* spp., *Bipolaris maydis*, *Fusarium* spp., *Aspergillus* spp., *Puccinia* spp., and *Rhizoctonia solani*. The pathogens infected the maize plants through any mediators, such as water, insects, air and soil. *Fusarium* spp. and *R. solani* were spread through soil, so that they are more recognized as soil borne pathogens (Muis *et al.*, 2015; Suriani *et al.*, 2015). Both pathogens are quite difficult to control because they can life, spread and survive long term in the soil. *F. verticillioides* can life in the soil for years, despite of unfavorable environment conditions and without host plant, by forming persistent spores such as chlamydospores (Sudantha, 2010).

The important thing to be wary about the infection of *F. verticillioides* is its capability to produce a mycotoxin (Djaenuddin & Muis, 2013). Some types of toxins produced by *F. verticillioides* are fusaric acid, fusarin, gibberellin, moniliformin and fumonisin. Especially in maize seeds, it is noticed that the fungi producing fumonisin is correlated to the pathogen biomass. The toxin is produced most at high oxygen pressure and low pH. Therefore, the outbreak of *F. verticillioides* on maize plant must be prevented because it can produce poisons to human and livestock animals. Fumonisin causes necrosis of brain tissues (leucoencephalomalacia= LEM) in horses. Other than that, the fumonisin B1 was also reported as toxic to central nervous system, liver, pancreas, kidney and respiratory tracts in some other species of animals (Widiastuti, 2006).

The production of chlamydospores by *F. verticillioides* can endure long in soil where the dead host plant existed, and it causes difficulty in pathogen controlling. Reduction in chlamydospores population as initial inoculum is one of appropriated methods of controlling. The application of systemic fungicide can reduce the chlamydospore population through improving plant tenacity, and therefore, resulting healthy seeds (Kristiawati *et al.*, 2014). Another controlling method is by using antagonistic microbes which have capabilities to induce plant endurance. The bacteria *Bacillus* spp. and *Pseudomonas* spp. were known to have capabilities in inducing plant tenacity against pathogen outbreak (McMilan, 2007; Djaenuddin, 2016). These microbes can be found from some sites, either in plant rhizosphere or as endophytic microbes in plant.

The endophytic microbes are plant tissue-associating microorganisms without negative impact to the plant. The endophytic microbes can be found in plant root, stem, and leaves. The microbes produce bioactive compound acting as an anti-microbe that is used either in agriculture, industrial or health sector. The microbes were mostly from fungi groups producing secondary metabolite compounds with anti-microbial properties (Strobel, 2003).

The role of endophytic microbes as biological controlling agent of plant has been proved by many researchers. The endophytic microbes have been discovered from particular parts of plant and they have been developed as antagonistic pathogens. Marwan *et al.* (2011) have found 4 endophytic microbial isolates (EAL15, EKK10, EKK20, EKK22) of banana plant root that have capability to suppress blood disease occurrence on banana plantation. Hutabalian *et al.* (2015) reported that the endophytic fungi isolated from *barangan* banana plant root (*Pulluria* sp.) capable to inhibit *F. oxysporum* growth. The other researchers, Saylendra & Firnia (2013) have found two genera of bacteria from maize plant root identified as *Bacillus* sp. and *Pseudomonas* sp. Developing the endophytic microbes as biological control agent is an excellent opportunity. Based on those facts, we are interested to explore the endophytic microbes from maize plant root, to select its effectiveness in inhibiting development of soil borne pathogens of maize plants, especially *F. verticillioides*.

MATERIALS AND METHODS

Research Site. The research was conducted on maize root samples taken from farming fields at Soppeng regency. The research steps from exploration to microbial effectiveness assay was conducted at Laboratory of Biology, Faculty of Agricultural, Universitas Islam Makassar, from April to Oktober 2017.

Exploration of Endophytic Microbes. Samples of hybrid and local maize plant roots of South Sulawesi (*jagung pulut putih*) were obtained from farming field at Soppeng regency. Root samples were taken from healthy, well growing, and pest and pathogen-free plants. The root endophytic microbes were isolated firstly by cutting the root samples in small pieces and sterilizing them by soaking in aquadest for 3-5 minutes. The samples were then removed and soaked in 70% alcohol for 1-3 minutes, and they were finally removed and soaked back in aquadest for 3-5 minutes. The root pieces were grown on PDA (Difco™ *Potato Dekstrose Agar*) and NA (Difco™ *Nutrient agar*), then were incubated

for 3-4 days in room temperature (28-30 °C). The growing fungi inoculum was individually isolated on new PDA media, and the growing bacteria was grown on new NA media, then they were incubated for 7 days.

Preparation of *Fusarium verticilloide* Isolates. The fungi inoculum *F. verticilloides* was isolated from corn cob with indication of cob rot disease. The kernels infected by *F. verticilloides* were sterilized for 1 minute in aquadest, 70% alcohol, then aquadest respectively, and then were grown on PDA media. The growing mycelia of *F. verticilloides* were isolated on new PDA media on petri-dish, then were incubated for 14 days in room temperature (28-30°C). Identification of pure isolates on media was achieved by characterizing morphological properties of *F. verticilloides* by means of the identification keys by Quimio & Hanlin (1999).

Assay for Inhibition Effectiveness of Endophytic Microbes on *F. verticilloides* Mycelial Growth. The endophytic microbes of maize root were examined for their antagonistic properties against *F. verticilloides in vitro* by using dual culture method. The examination was performed by using completely randomized design with 9 treatments and 7 repetitions. Eight isolates of endophytic microbes were obtained, they are consisted of 4 fungi isolates (HS-01, HS-02, HS-04, LS-01) and 4 bacteria isolates (HS-03, LS-02, LS-03, LS-04). The *F. verticilloides* grown on petri-dish without any endophytic microbes was used as control.

The effectiveness test of endophytic fungi was performed on PDA media which is prepared aseptically with standard sterilization by using autoclave at 121°C for 15 minutes. Ten milliliters media were poured on 9 cm diameter petri dish and allowed to solidify. The petri dish was then scaled and divided into two sides. On one side, the endophytic microbe was inoculated and on the other side for *F. verticilloides*. The cultures were

incubated for 7 days in a room with half day illumination (12 hours lightsome and 12 hours dark). On the other side, the assay for endophytic bacteria was completed by using 10 ml NA poured on petri dish and allowed to solidify. Furthermore, the fungi *F. verticilloides* was put on the center of petri dish, and the endophytic bacteria was streaked on 4 points around the *F. verticilloides* inoculum (Figure 1). The cultures were incubated for 7 days in a room with 12 hours lighted and 12 hours dark.

Antagonistic effect of endophytic microbes on *F. verticilloides* was noticed by measuring the PIRG (percentage inhibition of radial growth) (Singh & Vijay 2011)

$$PIGR (\%) = \frac{R1 - R2}{R1} \times 100\%$$

PIRG = Percentage inhibition of radial growth (% inhibition);

R1 = Diameter of pathogen without the antagonistic isolate (control);

R2 = Diameter of pathogen with the antagonistic isolate (dual culture)

The Effectiveness of Endophytic Microbes in Suppressing *F. verticilloides* Outbreak on maize seedling. The assay was performed at UIM Biological Laboratorium by making the maize seedlings grow with ISTA method (2006), i.e. the seedlings were grown on wet paper media with a plastic at base lining. The research was arranged based on a Complete Randomized Design with 9 treatments and 3 replicas. The treatments consisted of 8 seed treatments with individually immersion in endophytic microbe suspension and a control (seed with the only immersion in *F. verticilloides* suspension). Before the test, the endophytic microbe suspensions were prepared by

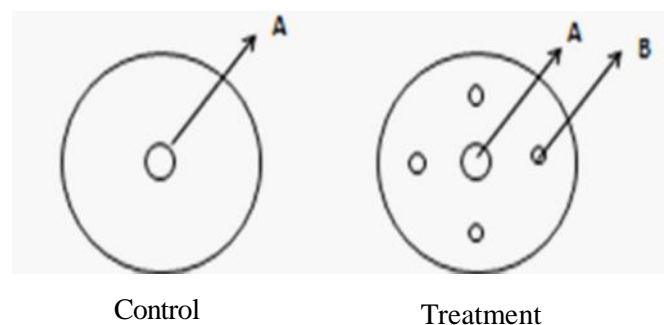


Figure 1. (A) : *F. verticilloides*. (B): Endophytic bacteria.

adding 10 ml aquadest into petri dish containing 15 days growing endophytic microbes. Colonies of each endophytic fungi were counted by using a haemocytometer, by using suspension with 10^6 cfu/ml conidia density. Bacterial suspension, on the other hand, has 10^9 - 10^{10} cfu/ml density, which are counted by using colony counter and the following formula (Waluyo, 2008):

$$\text{CFU's / ml} = \text{colony number} \times \text{dilution factor}$$

The assay using corn seeds from Anoman variety was performed by immersing the seeds in a suspension of *F. verticilloides* for 2 hours. Furthermore, the seeds were left dried and then subjected to each immersion treatment in endophytic microbe suspension for 2 hours. Every 30 seeds from each test unit were grown on paper media and incubated for 7 days.

Observed variables including the percentage of seedlings infected by *F. verticilloides* and the length of sprout (in cm) which is measured on the 7th day after planted. Percentage of *F. verticilloides* infection was measured by using the following formula:

$$I = \frac{A}{B} \times 100\%$$

I = Percentage of *F. verticilloides* infection

A = Number of seeds infected by *F. verticilloides*

B = Number of germinating seeds

Resulted data was analyzed by varian analysis and an advanced test using Duncan's New Multiple Range Test (DNMRT) by 5% level.

RESULTS AND DISCUSSION

Exploration of Endophytic Microbes. The exploration of endophytic microbes on local corn plant (South Sulawesi) and hybrid corn obtained 8 root associated-endophytic microbes (Table 1). They are consisted of 4 endophytic microbes from fungi groups and the rest are from bacteria groups.

Effectiveness of Endophytic Microbe in Suppressing Mycelial Growth of *F. verticilloides*. Results of the effectiveness test of inhibitory properties of the 8 endophytic microbes on mycelial growth of *F. verticilloides* by using dual culture method showed that there is an isolate of endophytic microbe, that is HS-04, that has an effective inhibition with significant difference to all other isolates. The other isolates showed inhibition capability on mycelial growth of *F. verticilloides* more than 30%, they are LS-02, HS-01 and HS-02 with inhibitory percentage 40,2%; 34,88% and 34,16%, respectively (Table 2).

Mechanism of inhibition by endophytic microbes on mycelial growth of *F. verticilloides* was showed in Figure 2. The *F. verticilloides* paired with endophytic microbe LS-02 and HS-01 was noticeably showed imperfect mycelial growth compared to the control (single growth of *F. verticilloides* on petri dish). The controlling mechanism of the endophytic microbes on pathogen growth are occurred through competition and secondary metabolite release. The interaction between the endophytic microbes and pathogens can lead to pathogen hypha cleared up, as a result of utilization of pathogen content as nutrition by endophytic microbes

Table 1. Microbes explored from plant roots of local (South Sulawesi) corn and hybrid corn of Soppeng regency

Isolate code	Origin	Microbe group	Colony color
HS-01	Hybrid corn plant root	Fungi	Nigrescent white
HS-02	Hybrid corn plant root	Fungi	Brownish white
HS-03	Hybrid corn plant root	Bacteria	Clear white
HS-04	Hybrid corn plant root	Fungi	Dark green
LS-01	Local corn plant root	Fungi	Nigrescent white
LS-02	Local corn plant root	Bacteria	Opaque white
LS-03	Local corn plant root	Bacteria	Opaque white
LS-04	Local corn plant root	Bacteria	Opaque white

(Nurzannah *et al.*, 2014). Furthermore, Sunarwati & Yoza (2010) stated that the interaction between pathogen hypha and the antagonistic organisms is characterized with clearing off the pathogen hypha because of the cell content utilization as nutrition by controlling organisms. Furthermore, the endophytic microbes can make the pathogen hypha shrink, as discovered by Kurnia *et al.* (2014).

The differences in inhibitory capability on mycelial growth of *F. verticilloides* indicated differences in bioactive compounds resulted by each endophytic microbe. Therefore, a further research on antibiotic contents of effective microbes is needed to conduct. The larger the inhibitory zones, the larger the antifungal activity. The endophytic microorganisms can produce bioactive compounds other than contained compounds in their host plants (Pratiwi, 2008).

Effectiveness of Endophytic Microbes in Suppressing *F. verticilloides* In Vitro. The results showed that seeds immersed in suspension of endophytic microbe isolate HS-04 has the weakest attacks percentage of 22,22% (Table 3). The other isolates have insignificant difference of attacks percentage from the isolate HS-04, they are the isolate HS-03, LS-02 and LS-04 with onset percentage of 44,44%, 57,78%, and 60%, respectively.

The inhibition effectiveness of endophytic microbes from fungi group on *Fusarium* spp *in vitro* was proved by Orole & Adejumo (2009). Their research indicated that 5 endophytic fungi isolated from maize roots provided inhibition to development of damping off disease on maize plants caused by *Fusarium* spp. and an endophytic fungi, *Alternaria alternate*, showed the highest inhibition, from 53 to 80%. The inhibition

Table 2. Inhibition percentage of the endophytic microbes of maize plant root on mycelial growth of *F. verticilloides*

Endophytic microbes	Inhibition percentage on mycelial growth of <i>F. verticilloides</i>
HS-01	34.88 b
HS-02	34.16 b
HS-03	0 c
HS-04	58.42 a
LS-01	24.25 b
LS-02	40.20 b
LS-03	0 c
LS-04	5.04 c

Number in one column followed by the same letter (s) was not significantly different based on Duncan’s New Multiple Range Test (DNMRT) test at 5% of significant level.

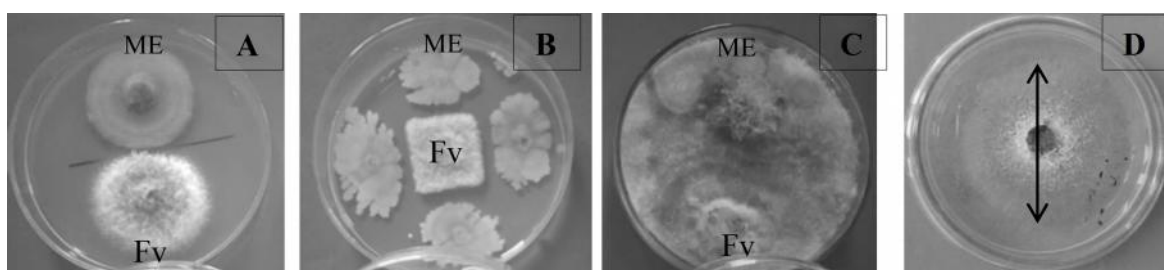


Figure 2. Inhibition test of endophytic microbes on mycelial growth of *F. verticilloides* on the 7th day after inoculation. (A) Endophytic microbe LS-01 on pathogen *F. verticilloides*; (B) Endophytic microbe LS-02 on pathogen *F. verticilloides*; (C) Endophytic microbe HS-01 on pathogen *F. verticilloides*; (D) Single mycelial growth of *F. verticilloides* on petri dish at the 7th day after inoculation.

capability was predicted due to the endophytic microbe's capacity to induce tenacity in maize plant. Tenacity induction in plants is a phenomenon when there is improvement of plant tenacity on pathogen infection as a response to stimulation. The tenacity is a plant protection based on tenacity mechanisms stimulated by metabolic changes. Moreover, competition in the same niche between pathogen and the endophyte can also lowering the infection rate. For example, the endophytic bacteria will be closely related to or influenced by bacterial density, colonization level, and the site of bacteria in relation to pathogen feeding location (Harni *et al.*, 2012).

The effect of endophytic microbes on maize plant growth. Observation on sprout length indicated that the seeds surrounded by endophytic microbe isolate LS-02 has the longest sprout with length 10,57 cm and they

are significantly different to the control (Table 4). However, on the whole, seeds those are immersed in endophytic microbe suspension have longer sprouts compared to the control.

Differences in length of maize sprouts between treated seeds and control demonstrate that the endophytic microbes produce growth inducing-compounds. It is corresponding to the research by Munif *et al.* (2015) that showed that half of 10 endophytic bacterial isolates capable to improve tomato plant height by 30 minutes seed treatment. Additionally, immersion treatment on pepper seedling root with some endophytic bacteria isolated from pepper plant has shown to improve root weight and plant crown on pepper plants (Munif & Harni, 2011; Harni & Ibrahim, 2011). The improvement in plant growth is predicted caused by the endophyt bacteria can produce IAA (Ramadhan *et al.* 2017). And then the endophytic bacteria merging into some

Table 3. Percentage of the *F. verticilloides* attacks on corn seeds on 7 day after plant

Endophytic Microbes	Percentage of the <i>F. verticilloides</i> attacks (%)
HS-01	67.78 ab
HS-02	73.33 ab
HS-03	44.44 bc
HS-04	22.22 c
LS-01	61.11 ab
LS-02	57.78 abc
LS-03	70.00 ab
LS-04	60.00 abc
Kontrol	94.44 a

Number in one column followed by the same letter (s) was not significantly different based on Duncan's New Multiple Range Test (DNMRT) test at 5% of significant level.

Table 4. The length of sprouts grown on plastic rolled-paper on 7 days after plant

Endophytic Microbes	The length of sprouts grown
HS-01	8.07 ab
HS-02	8.25 ab
HS-03	8.28 ab
HS-04	7.17 ab
LS-01	9.15 ab
LS-02	10.57a
LS-03	8.33 ab
LS-04	9.88 a
Kontrol	4.96 b

Number in one column followed by the same letter (s) was not significantly different based on Duncan's New Multiple Range Test (DNMRT) test at 5% of significant level.

physiological processes in plant by means of introducing IAA they produce to the plant, making the plant more sensitive in changing the endogenous IAA concentration with the result that it supports lateral root and adventive root forming and primary root elongation (Leveau & Lindow, 2005).

CONCLUSION

The exploration of endophytic microbes from hybrid and local (South Sulawesi) maize plant roots of Soppeng regency resulted 8 endophytic microbe isolates, consisting of 4 fungi (HS-01, HS-02, HS-04, LS-01) and 4 bacteria (HS-03, LS-02, LS-03, LS-04). The test results showed that there are 3 potential endophytic microbes to develop as biological controlling agents against *F. verticilloides*, they are isolate HS-04, HS-01 and LS-02. Their capability in inducing plant growth also becomes a consideration in selecting the three isolates.

ACKNOWLEDGMENTS

On this occasion the authors would like to thank the part of DP2M Ristekdikti who have funded this research in 2017. And we would like to thank all participant who help our research.

REFERENCES

- Djaenuddin N & Muis A. 2013. Uji patogenitas *Fusarium moniliforme* Sheldon pada jagung. In: Muis A, Pabbage MS, Yasin M, Aqil M, Hermanto, & Pakki S (Eds). *Prosiding Seminar Nasional Serealia, Meningkatkan Peran penelitian Serealia Menuju Pertanian Bioindustri*. Pp. 438–442. Balai Penelitian Tanaman Serealia, Maros. June 18, 2013.
- Djanenuddin N. 2016. Interaksi bakteri antagonis dengan tanaman: ketahanan terinduksi pada tanaman jagung. *Iptek Tanaman Pangan* 11(2): 143–148.
- Harni R & Ibrahim MSD. 2011. Potensi bakteri endofit menginduksi ketahanan tanaman lada terhadap infeksi *Meloidogyne incognita*. *J. Littri* 17(3): 118–123.
- Harni R, Supramana, Sinaga MS, Giyanto, & Supriadi. 2012. Mekanisme bakteri endofit mengendalikan nematoda *Pratylenchus brachyurus* pada tanaman nilam. *Bul. Litro*. 23(1): 102–114.
- Hutabalian M, Pinem MI, & Oemry S. 2015. Uji antagonisme beberapa jamur saprofit dan endofit dari tanaman pisang terhadap *Fusarium oxysporum* f.sp. *cubense* di laboratorium. *J. Agroteknologi* 3(2): 687–695.
- ISTA. 2006. *International Rules for Seed Testing*. International Seed Testing Association, Switzerland.
- Kurnia AT, Pinem MI, & Oemry S. 2014. Penggunaan jamur endofit untuk mengendalikan *Fusarium oxysporum* f.sp. *capsici* dan *Alternaria solani* secara *in vitro*. *J. Agroteknologi* 2 (4): 1596–1606.
- Kristiawati Y, Sumardiyono C, & Wibowo A. 2014. Uji pengendalian penyakit layu *Fusarium* pisang (*Fusarium oxysporum* f.sp. *cubense*) dengan asam fosfit dan aluminium-fosetil. *J. Perlindungan Tanaman Indonesia* 18(2): 103–110.
- Leveau JH & Lindow SE. 2005. Utilization of plant hormone indole-3-acetic acid for growth by *Pseudomonas putida* strain 1290. *Appl. Environ. Microbiol.* 71(5): 2365–2371.
- Marwan H, Sinaga MS, Giyanto, & Nawangsih AA. 2011. Isolasi dan seleksi bakteri endofit untuk pengendalian penyakit darah pada tanaman pisang. *J. HPT Tropika* 11(2): 113–121.
- McMilan S. 2007. Promoting growth with PGPR. The Canadian Organic Grower. Soil Foodweb Canada Ltd. *Soil Biology Lab. & Learning Centre*. Pp. 3–34.
- Muis A, Djaenuddin N, & Nonci N. 2015. Evaluasi lima jenis inner carrier dan formulasi *Bacillus subtilis* untuk pengendalian hawar pelepah jagung (*Rhizoctonia solani* Kuhn). *J. HPT Tropika* 15 (2): 164–169.
- Munif A & Harni A. 2011. Potensi bakteri endofit dan rhizosfer dalam meningkatkan pertumbuhan jagung. In: Makarim K, Zubachtirodin, Yasin HG, Soenartiningih, Dahlan HA, Tandiang J, Arief R, Suarni, Hermanto, & Aqil M (Eds). *Prosiding Seminar Nasional Serealia, Inovasi Teknologi Mendukung Swasembada Jagung dalam Diversifikasi Pangan* : pp 1–8. Balai Penelitian Tanaman Serealia, Maros. October 3-4, 2011.

- Munif A, AR Wibowo, & EN Herliyana. 2015. Bakteri endofit dari tanaman kehutanan sebagai pemicu pertumbuhan tanaman tomat dan agens pengendali *Meloidogyne* sp. *J. Fitopatologi Indonesia* 11(6): 179–186.
- Nurzannah SE, Lisnawita, & Bakti D. 2014. Potensi jamur endofit asal cabai sebagai agens hayati untuk mengendalikan layu *Fusarium* (*Fusarium oxysporum*) pada tanaman cabai dan interaksinya. *J. Agroteknologi* 2(3): 1230–1238.
- Orole OO & Adejumoo TO. 2009. Activity of fungal endophytes against four maize wilt pathogens. *Afr. J. Microbiol. Res.* 3(12): 969–973.
- Pratiwi ST. 2008. *Mikrobiologi Farmasi*. Erlangga, Jakarta.
- Quimio TH & Hanlin RT. 1999. *Illustrated Genera and Species of Plant Pathogenic Fungi in the Tropics*. College of Agriculture Publication Program. Philippines.
- Ramadhan AR, Oedjijono, & Hastuti RD. 2017. Efektivitas bakteri endofit dan penambahan Indole Acetic Acid (IAA) dalam meningkatkan pertumbuhan tanaman padi *Oryza sativa* L. *Scripta Biologica* 4(3): 171–181.
- Saylendra A & Firnia D. 2013. *Bacillus* sp. dan *Pseudomonas* sp. asal endofit akar yang berpotensi sebagai pemacu pertumbuhan tanaman. *J. Ilmu Pertanian dan Perikanan* 2 (1): 19–27.
- Sing PK & Vijay K. 2011. Biological control of *Fusarium* wilt of *Chrysanthemum* with *Trichoderma* and Botanicals. *J. Agric. Techn.* 7(6): 1603–1613.
- Strobel GA. 2003. Endophytes as sources of bioactive products. *J. Microbes Infect* 5(6): 535–544.
- Sudantha IM. 2010. Pengujian beberapa jenis jamur endofit dan saprofit *Trichoderma* spp. terhadap penyakit layu fusarium pada tanaman kedelai. *Agroteksos* 20 (2-3): 90–102.
- Sunarwati D & Yoza R. 2010. Kemampuan *Trichoderma* dan *Penicillium* dalam menghambat pertumbuhan cendawan penyebab penyakit busuk akar durian (*Phytophthora palmivora*) secara in vitro. *Prosiding Seminar Nasional Program dan Strategi Pengembangan Buah Nusantara*. pp 176–189. Balai Penelitian Tanaman Buah, Solok.
- Suriani, Muis A, & Aminah. 2015. Efektivitas 8 formulasi *Bacillus subtilis* dalam menekan pertumbuhan *Fusarium moniliforme* secara in vitro. Pp. 428–435. Dalam: Muis A, Syafruddin, Aqil M, & Bahtiar (Eds). *Prosiding Seminar Nasional Serealia. Maros: Pusat Penelitian dan Pengembangan Tanaman Pangan*.
- Waluyo L. 2008. *Teknik Metode Dasar Mikrobiologi*. Universitas Muhammadiyah Malang Press. Malang.
- Widiastuti R. 2006. Mikotoksin: pengaruh terhadap kesehatan ternak dan residunya dalam produk ternak serta pengendaliannya. *Wartazoa* 16(3): 116–127.