This study was aimed to: (1). Assessing the ability of endophytic fungi in promoting plant growth, (2). Assessing the ability of endophytic fungi in suppressing the growth of pathogenic Fusarium.

MATERIALS AND METHODS

This research was conducted at the Laboratory of Plant Protection and gauze semi-permanent home in the Kebun Kenanga Village, Bengkulu-Indonesia.

Testing Capabilities Endophytic Fungus in Spur Plant Growth

Endophytic fungi obtained from roots, stems, and leaves of pepper plants tested for its ability to stimulate the growth of cucumber plants. Cucumber seeds are used as test plants as cucumber plant age is shorter than pepper plants so that response to treatment faster than chili. Cucumber seeds to be used surface sterilized with sodium hypochlorite 1% and then rinsed with sterile distilled water, then planted in the planting medium. Planting medium used is a mixture of soil and compost that have been sterilized. Endophytic fungi inoculation is done by sprinkling 1 ml of conidial suspension with a density of 105 conidia / ml near the roots of cucumber seedlings beumur 10 days after sowing (HSS). Observation of plant growth plant height, root weight, fresh weight stover 10 days after inoculation of endophytic fungi. Endophytic fungal isolates were able to increase plant height and root length used in the next stage of research.

Pressing Endophytic Fungus Testing Capabilities Pathogen Fusarium

Endophytic fungi suppress Fusarium ability test will be performed with a dual culture on PDA. Endophytic fungi and 5 mm colony diameter of *Fusarium*is placed on PDA medium in a petri dish with a distance of 3 cm between them. Observations development of the colony diameter is calculated at 3, 5, and 7 HSI. The parameters observed variables cucumber plant growth and endophytic fungi suppression capability against *Fusarium*. The data obtained are shown descriptively to compare any data obtained from all observations .

RESULTS AND DISCUSSION

Potential Test Endophytic Fungus against Cucumber Growth

Cucumber plant is used as an indicator plant to test the potential of endophytic fungi on growth because the cucumber plants are very sensitive to inoculation treatments were performed. Endophytic fungi are known to have the ability to induce the plant to produce the growth hormone auxin (Thakuria *et al.*, 2004) and this is in line with the results of testing the potential of endophytic fungi on the growth of cucumber plants . Based on observations of plant height (cm), root length (cm), and plant fresh weight (g) are performed at 10 days after inoculation (DAI) endophytic fungus known positive treatment effect on the growth of cucumber and shown in Figure 1 .

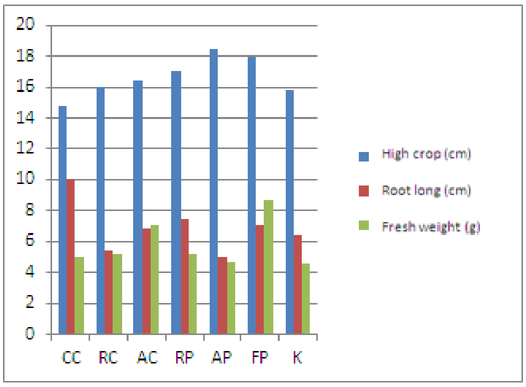

Figure 1. Effect of treatment of endophytic fungi on plant height (cm) , root length (cm) , and plant fresh weight (g) at 10 days after inoculation (DAI)

Description : CC: Curvularia from chili , RC : Rhizopus from Cabe, AC: Aspergillus from chili, RP: Rhizopus from rice, AP: Aspergillus from Rice, FP: Fusarium from rice, K: control

The results showed that the fungus endophyte Aspergillus of Rice showed high growth best of fungal endophyte other, and fungal endophyte Curvularia of chili showed growth of root length highest and fungal endophyte Fusarium of Rice showed fresh weight of most plants either from the fungus endophyte or others. This shows that endophytic fungi can improve plant growth cucumbers.

This is in line with the results Petrini *et al.*, (1992) and Ramdan *et al.*, (2013) that the fungus endophyte can increase the number of hair roots and branching root hairs that can help improve the absorption of nutrients needed by plants for photosynthesis so the optimal result of photosynthesis that can spur the growth of plants. Endophytic fungi' s ability to improve plant growth depends on its ability to produce metabolites, growth promoters such as auxin, gibberellins or cytokinins (Ramdan, 2013) .

Pressing Endophytic Fungus Testing Capabilities Pathogen *Fusarium*

Fusarium is a genus of soil borne pathogens that cause disease in some plants such as plants of the *Solanaceae* group. A disease that is usually caused by *Fusarium i*s Fusarium wilt disease. Test the ability to suppress the growth of endophytic fungus *Fusarium* pathogens carried lab scale with a dual culture method.

Observations on Dual culture test showed that in terms of the growth of the radius of the second colony of mold or fungus known that endophytic fungi grow faster than the pathogen , but could not conclude whether endophytic fungus is able to suppress the growth of pathogenic because there is no zone of inhibition. Colony growth in dual culture test is shown in Figure 2 and the long fingers of both microbes shown in Table 1.

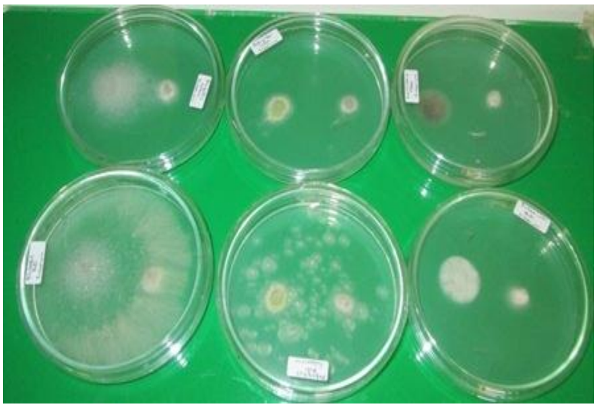

Figure 2. Dual culture of endophytic fungi and pathogens *Fusarium* on 2 DAI

Based on the results obtained known that endophytic fungus has the ability to grow faster than the pathogens tested, it can be seen from most of the length of the fingers fungus longer than the radius of *Fusarium* colonies. However, the results of dual culture no visible inhibition zone, so it can not be known whether the fungus endophyte antagonists have potential as an agent against *Fusarium*. Microbes can be regarded as antagonistic agent if it has the ability to inhibit the growth of pathogens and in a dual culture test usually appear inhibition zone on PDA medium.

This contrasts with the results Asniah *et al.*(2014) who obtained the results that the endophytic fungus is able to compete with endophytic fungi to space and nutrients as indicated by the ability of endophytic fungus that covers the surface of the PDA quickly and inhibit the growth of pathogens in a petri dish. Thus the potential of endophytic fungi in inhibiting pathogenic pertmbuhan need to be re-examined in order to obtain better results. According to a study Tondok *et al.*, (2012) there endophytic fungus capable of suppressing the development of black pod disease and capable of forming a barrier zone to produce antifungal compounds that inhibit the development of pathogens in multiple trials.

Likewise, the results of research Qadri *et al.*, (2013) who obtained results that endophytic fungi tested very active nature inhibit the growth of five of the seven pathogens tested. Thus, future research needs to be carried further by combining several types of endophytic fungi are able to work synergistically in suppressing the development of pathogens which can be one of the recommendations of environmentally friendly control.

Table 1. Long fingers endophytic fungus culture and *Fusarium* on dual culture

Code	No	Fingers long cultures (mm)											
		2 DAI				5 DAI				8 DAI			
		CE		F		CE		F		CE		F	
		r1	r2	r1	r2	r1	r2	r1	r2	r1	r2	r1	r2
CC	1	15	10	8	10	22	25	20	22	24	25	20	28
	2	7	10	12	12	23	24	18	20	23	28	18	28
RC	1	35	25	10	10	60	27	10	22	68	27	15	30
	2	27	27	7	7	60	27	20	23	63	27	20	30
AC	1	11	12	8	10	17	18	21	20	20	20	21	20
	2	10	10	6	6	30	26	10	10	30	27	20	20
RP	1	27	25	2	10	30	25	10	10	21	29	15	28
	2	27	28	2	10	23	25	10	10	30	31	15	27
AP	1	15	10	8	7	15	18	10	7	28	23	10	10
	2	10	10	11	10	10	17	10	10	15	18	20	10
FP	1	10	10	8	8	25	27	15	23	25	28	15	32
	2	13	11	10	10	17	21	25	25	25	28	25	25

Description : r1: Long fingers towards the middle of the petri colony , r2 : long fingers toward the edge of the petri colony. CC: *Curvularia* from chili , RC : *Rhizopus* from Cabe, AC: *Aspergillu*s from chili, RP: *Rhizopus* from rice, AP: *Aspergillus* from Rice, FP: *Fusarium* from rice, K: control

CONCLUSION

Endophytic fungi tested quite able to increase the growth of cucumber plants but has not been able to demonstrate the ability of antagonism against pathogenic fungi, so we need a more intensive exploration in order to be found endophytic fungi that have potential as a biological control agent .

REFERENCES

Asniah, D. Lestari, Mariadi, L. Darliani. 2014. Endophytic fungi pathogenic potential root origin of pepper plants (*Capsicum anuum* L.) as biofungisida pathogen *Fusarium oxysporum*. J. Agripulus. 2 (2):177-183.

Carrol, G. C. 1988. Fungal endophytes in stems and leaves: From latent pathogen to utualistic. symbiont. Ecology 69:2-9.

Petrini, O., T. N. Sieber, L. Toti, and O. Viret. 1992. Ecology, metabolite production, and substrate utilization in endophytic fungi. Natural Toxins 1:185-196.

Qadri, M., S. Johri, B. A. Shah, A. Khajuria, T. Sidiq, S. K. Latto, M .Z. Abdin, and S.R.U. Hassan. 2013. Identification and bioactive potential of endophytic fungi isolated from selected plants of The Western Himalayas. J. Springer Plus.2(8):1-14.

Ramdan, E. P., S. Widodo, S. H. Wiyono, Hidayat. 2013. Nonpathogenic fungal endophytes from chili paper and their potential as growth promoting agent. J. Fitopatologi Indonesia. 9 (5):139-144.

Thakuria, D., N. C. Talukdar, C. Goswami, S. Hazarika, R. C. Boro, and M. R. Khan. 2004. Characterization and screening of bacteria from rhizosphere of rice grown in acidic soils of assam. Current Science. 86 (7): 978-985.

Tondok, ET, M. T. Sinaga, M. T. Suhartono. 2012.Endophytic fungus as a potential agent of biological control *Phytophthora palmivora* (Butl.) Butl. Causes of rotten fruit of the cocoa.. J. Agron. Indonesia. 40 (2):146-152.

Land Suitability Evaluation For Rubber (*Havea Brasiliensis*) Plants in Bengkulu

Nurmegawati, Afrizon, and Dedi Sugandi

Bengkulu Assessment Institute for Agriculture
Jl. Irian Km. 6,5 Kelurahan Semarang Kota Bengkulu
e-mail: nurmegawati_s@yahoo.co.id

ABSTRACT

Rubber (*Havea brasiliensis*) is one of the dominant commodities in the province of Bengkulu and potential for development. For optimal growth and production, it is necessary to evaluate the suitability of the land. This study was aimed to evaluate the suitability for planting rubber tree in Bengkulu. Land suitability evaluation was done by comparing the characteristics of the land with plant growth requirements. Requirements of the crops to be grown in land suitability evaluation criteria. Land characteristics data were collected through field survey and analysis of soil samples in the laboratory. The results showed that the rubber crop land suitability classes of the people of North Bengkulu is quite suitable (S2) with a temperature limiting factors, the availability of water, availability of oxygen, rooting medium and nutrient retention. Rubber crop land suitability class of the farmers' are suitable in marginal Seluma District (S3) with the limiting factor of nutrient retention. Actual land suitability classes for rubber of farmers' in of South Bengkulu is appropriate marginal (S3) by a factor limiting in nutrient retention.

Keywords: Bengkulu, *Havea brasiliensis,* land suitability.

INTRODUCTION

Dry land in Indonesia has a huge potency for agricultural development. But productivity is generally low, except for dry land farming systems with annual crops/ plantation (Syam, 2003). To obtain optimal plant growth is necessary to note the suitability of land with plants growing requirements. Djaenudin *et al*. (2003) reported that the suitability of land is an area of land suitability for particular uses. The land suitability can be assessed for the current state (present) or after improvement. Azis *et al.* (2006) adds that the suitability of land is a land suitability for particular uses, as an example of land suitable for irrigation, pond, perennial crops or agricultural farming seasonal crops.

In assessing the suitability of land there are several ways, one using the minimum law that matchs between land quality and land characteristics as a parameter to the criteria of land suitability classes which have been prepared based on the requirements of growing plants was evaluated. For example, land suitability study ever conducted in southern Sumatra area for rice crops and soybeans (Nurmegawati *et al.*, 2012). Similar research has also been done for the abaca plant in East Kutai Regency (Harijogjo and Sutrisno, 2002) and plant oil palm in Kampar regency of Riau Province (Wigena *et al*., 2009).

One of the dominant commodities in Bengkulu Province, namely rubber. The development of rubber plantations currently is quite rapidly both in large estates, private estates or in smallholdings. The rubber planting was owned by 110 465 farmers with current productivity of 1,261 kg/ha (Department of Plantation Province Bengkulu, 2010). Therefore research on rubber plant land suitability needs to be done keeping in this area has a large area and the potency for the development of plantations. With the expected land suitability class information and management practices appropriate alternatives, it is expected to increase production and the welfare of society. The aim of this study was to evaluate the land suitability for rubber plant (*Havea brasiliensis*) of farmers' in the province of Bengkulu.

MATERIALS AND METHODS

The research was conducted for 11 months. The location of research includes three districts of North Bengkulu, Bengkulu Seluma and South, which are the centers of farmers' rubber plantations. Research using primary data and secondary data including land characteristics, climate and growing requirements of the rubber.

Table 1. Land suitability criteria for rubber (*Havea brasiliensis*)

Terms of use / land characteristics	Land suitability classes			
	S1	S2	S3	N
Temperature (tc)				
The average temperature (°C)	26 – 30	30 – 34 24 – 26	– 22 – 24	> 34 < 22
Water availability (wa)				
Rainfall (mm)	2.500 – 3.000	2.000 – 2.500 3.000 –3.500	2.000 – 2.500 3.500 – 4.000	< 1.500 > 4.000
Number of dry months (month)	1 – 2	2 – 3	3 – 4	> 4
Oxygen availability (OA)				
Drainage	good	medium	slightly cloged	heavily clogged
Rooting condition (rc)				
Texture	fine,bit coarse	-	bit coarse	coarse
Rough material (%)	< 15 > 100	15 – 35	35 – 60	> 60
Soil depth (cm)		75 – 100	50 – 75	< 50
Peat				
Depth (cm)	< 60	60 – 140	140 – 200	> 200
Thickness (cm) of inter mineral layer (if any)	< 140	140 – 200	200 – 400	> 400
Maturity/ripeness	Sapric^{+}	saprck, hemic	hemic, fibric^{+}	Fibric
Nutrient rentention (nr)				
Clay CEC (cmol/kg)	-	-	-	-
Base saturation (%)	< 35	35 – 50	> 50	
pH H_2O	5,0 –6,0	6,0 – 6,5 4,5 – 5,0	> 6,5 < 4,5	
Organic C (%)	> 0,8	≤ 0.8	-	
Toxicity (xc)				
Salinity (dS/m)	< 0,5	0,5 – 1	1 –2	> 2
Sodicity (xn)				
Alcalinity/ESP (%)	-	-	-	-
Sulfidic material (xs)				
Sulphidic depth (cm	> 175	125 – 175	75 – 125	< 75
Erosion hazard (eh)				
Slope (%)	< 8	8 –16	16 – 30 16 – 45	> 30 > 45
Erosion hazard	Very low	Medium low	Heavy	Very heavy
Flood hazard (fh)				
Inundation	F0	-	F1	> F1
Land preparation (lp)				
Surface stoniness (%)	< 5	5 – 15	15 – 40	> 40
Rock outcrops (%	< 5	5 – 15	15 – 25	> 25

Source: Djaenudin *et al.* (2003). Description; FO = without flooding, FI = mild, F2 = moderate, F3 = somewhat heavy, F4 = weight

Primary data is data obtained directly from field survey and secondary data in the form of climatic data (rainfall and humidity) obtained from the climatology station closest to the location of the research. Characteristics of land is the nature of land that can be measured or estimated, which includes rainfall, humidity, drainage, soil texture, coarse material, soil depth and slope obtained from field surveys while, base saturation, pH H2O and organic-C obtained from analysis of soil samples in the laboratory.

Land suitability evaluation in this research comparing the characteristics of the land with the requirements of growing rubber trees that are formulated in the Technical Guidelines for the evaluation of land for Agricultural Commodities (Djaenudin *et al.*, 2003 in Subardja and Sudarsono (2005). Requirements to grow rubber trees become elative in the evaluation of suitability land (Table 1). The process of evaluating the suitability of land through: (1) preparation of land characteristics, (2) the preparation of the growing requirements of plants, (3) evaluation of the suitability of land (matching) between land characteristics and requirements grow crops in order to obtain land suitability classes. Classification of the suitability of land is determined based on the framework of FAO (1976) differentiated according to the level that the Order, Class, Subclass and Unit. At the classroom level, land belonging to the order corresponding (S) are classified into three classes, namely: land very suitable (S1), sufficient appropriate (S2), and the corresponding marginal (S3). The land belonging to the order does not match (N) is not divided into classes.

RESULTS AND DISCUSSION

Land

Seluma has an average temperature of between 21 ° C - 32 ° C with the rainfall for each year between 1500-4500 mm rainfall for each month of 221 mm, the number of rainy days between 110-230 days per year, the highest rainfall in October to December, with the wet months between September to March, the dry months between April to August (BP4K Seluma, 2012). Rainfall South Bengkulu 3,238 mm / year with 212 rainy days, temperatures between 21 ° C -31 ° C with a relative humidity of 80-88% (BP4K South Bengkulu, 2012).

Characteristics of land among the sites that include temperature, rainfall, drainage, texture, coarse material, soil depth and slope, base saturation, pH H2O and C-organic, slopes, puddles, rocks on the surface and outcrop can be seen in Table 1. Climate component data is the average temperature and precipitation in each study site is 23^0C, and 26^0C $26{,}5^0$C. While rainfall is very high ranging between 3000-3250 mm. Rubber good growth requires temperatures between $25\text{-}35^0$C, with an average optimal temperature of 28^0C. While the annual rainfall is suitable for growing rubber trees not less than 2,000 mm. Optimal between 2500-4000 mm / yr, for areas that frequently experience rain on the morning of the production will be less. Ardika *et al*. (2010) reported that the annual rainfall ranges from l.800-2.800 mm. The conditions of considerable potentcy for the development of rubber plantations.

Table 2. Land characteristics in study sites

Land characteristic	Location		
	Northern Bengkulu	Seluma	Southern Bengkulu
Average temperature (^{o}C)	23	26.5	26
Rainfall (mm)	3250	3000	3238
Drainage	Moderate	Moderate	Moderate
Texture	Moderate	fine	Moderate
Coarse material (%)	< 15	< 15	< 15
Soil depth (cm)	> 75	> 75	> 75
Base saturation (%)	19.64	63.55	75.37
pH H_2O	4.9	4.55	4.87
Organic C (%)	3.43	3.11	1.56
Slope (%)	0-3	0-3	0-3
Inundation	FO	FO	FO
Surface stoniness (%)	< 5	< 5	< 5
Surface outcrops (%	< 5	< 5	< 5

Drainage state three study sites was moderate. Drainage affects the availability of oxygen. The relatively smooth texture class to moderate. Soil texture indicates rough or smooth a country which is a relative comparison of sand, silt and clay. Soil containing silt and clay are very difficult to be penetrated by high plant roots so that branching and stunted root development. Texture of land suitable for rubber plant is the percentage of clay loam, sand and dust are almost the same, namely 35% clay, 30% sand and 35% of dust. Ingredients ballpark <15%. The depth of the soil / Effective included in (> 75%).

Base saturation three study sites, respectively 63.55%, 75.37%, 29.83%. Base saturation values reflect the composition of accumulated cations. The higher the value, the higher the content of alkaline soil. Including acidic soil reaction. The content of C-organic in North Bengkulu and Seluma is high while for South Bengkulu is low. Slope relatively flat so as to erosion can be suppressed. No danger of flooding with surface rock and outcrop less than 5%.

Land Suitability

Land suitability evaluation according to FAO (1976) there are two, namely: Land suitability of actual and potential land suitability. The actual land suitability or appropriateness of current land or suitability of land in its natural state, is not considered repair business and management level that can be done to overcome obstacles or factors pembatas.Faktor-limiting factors can be divided into two types, namely: (1) the limiting factor permanent and impossible or uneconomical to repair, and (2) the limiting factors that can be improved and economically still menguntuntungkan by incorporating the right technology.

Land suitability evaluation is intended for the type of land use rubber plants. Results of assessment of land suitability class is based on matching between the characteristics of the land to grow crops mangis requirements, in order to get the level of actual and potential land suitability. The actual land suitability is the land suitability classes based on survey data from the field to the area of research and effort has been no improvement while considering the suitability of potential land is land suitability achieved after the improvement efforts carried out. After the match between land characteristics (Table 1) and a rubber plant land suitability criteria (Table 2) are obtained land suitability class rubber plant in North Bengkulu people as on Table 3.

Table 3. Classes of land suitability for rubber plant of farmers' in North Bengkulu

Land charateristics	Land suitability	
	actual	Potential
Temperature	(S2)	(S2)
Average	S2	S2
Water availability	(S2)	(S2)
Rainfall (mm)	S2	S2
Oxygen availability	(S2)	(S2)
Drainage	S2	S2
Rooting condition	(S2)	(S2)
Texture	S1	S1
Coarse material (%)	S2	S2
Soil depth (cm)	S2	S2
Nutrient retention	(S2)	(S1)
Base saturation (%)	S1	S1
pH H_2O	S2*	S1
Organic C (%)	S1	S1
Erosion hazard	(S1)	(S1)
Slope (%)	S1	S1
Flood hazard	(S1)	(S1)
Inundation	S1	S1
Land preparation	(S1)	(S1)
Surface stoniness (%)	S1	S1
Surface outcrops (%	S1	S1

Description: * improvements can be made, land suitability class up one level

The actual land suitability classes for smallholder rubber plant in North Bengkulu district, namely S2 with temperature limiting factors, availability of water, availability of oxygen, rooting media and nutrient retention. Improvement can only be conducted on nutrient retention/soil fertility from S2 to S1, but the temperature, rainfall, drainage, coarse material and soil depth can not be repaired so that the land suitability classes potential S2 with the limiting factors of temperature, availability of water, availability of oxygen and rooting medium. Factors limiting nutrient retention (soil fertility), namely pH of the soil can be improved by administering lime to raise soil pH. The limiting factor in the S2 class can usually be solved by the farmers themselves. Quite appropriate land suitability class (S2) is a land that has a limiting factor, and this factor will affect the productivity, requires additional inputs (input). The barrier can usually be solved by the farmers themselves. After the match between land characteristics (Table 1) with a rubber plant land suitability criteria (Table 2) the obtained rubber plant land suitability class people Seluma as Table 4.

Table 4. Land suitability classes for rubber in Seluma

Land Charteristic	Land suitability	
	actual	potential
Temperature	(S1)	(S1)
Average	S1	S1
Water availability	(S1)	(S1)
Rainfall (mm)	S1	S1
Oxygen availability	(S2)	(S2)
Drainage	S2	S2
Rooting condition	(S2)	(S2)
Texture	S1	S1
Coarse material (%)	S1	S1
Soil depth (cm)	S2	S2
Nutrient retention	(S3)	(S2)
Base saturation (%)	S3*	S2
pH H_2O	S2*	S1
Organic C (%)	S1	S1
Erosion hazard	(S1)	(S1)
Slope (%)	S1	S1
Flood hazard	(S1)	(S1)
Inundation	S1	S1
Land preparation	(S1)	(S1)
Surface stoniness (%)	S1	S1
Surface outcrops (%	S1	S1

Description: * improvements can be made, land suitability class up one level

The actual land suitability classes for Seluma rubber plant that is appropriate marginal (S3) by a factor limiting of nutrient retention. Repair business can only be conducted on nutrient retention / soil fertility from S3 to S2 so that the land suitability classes potential limiting factor S2 with the availability of oxygen and nutrient retention. Factors limiting nutrient retention (soil fertility) are base saturation. Suitability appropriate class marginal land is land that has a severe limiting factor and these factors will affect the productivity, require additional input more than land classified as S2. To overcome the limiting factor on S3, is required high capital so that the need for assistance or intervention (investment) by government or company.

Subardja (2007) reported that for the corresponding marginal land (S3) with a rather severe limiting factor, namely nutrient retention especially highly acidic soil reaction, extremely low base saturation and high aluminum poisoning hazard. Improved management of land necessary to improve the productivity of the soil are: (1) the addition of soil organic matter to improve soil CEC and the availability of N and P, (2) balanced fertilization, especially P and (3) provision of agricultural lime.

Land suitability classes rubber plant South Bengkulu can be seen in Table 5. The actual land suitability classes for crops of smallholder rubber South Bengkulu is appropriate marginal (S3) by a factor limiting nutrient retention. Repair business can be carried out on nutrient retention / soil fertility from S3 to S2 so that the land suitability classes potential limiting factor S2 with the availability of water, availability of oxygen, rooting media and nutrient retention. Factors limiting nutrient retention (soil fertility) are base saturation. Base saturation values reflect the composition of accumulated cations. The higher the value, the higher the content of alcaline.

Table 5. Classes of land suitability for rubber plant people of South Bengkulu

Land characteristic	Land suitability	
	actual	potential
Temperature	(S1)	(S1)
Average temperatur	S1	S1
Water availability	(S2)	(S2)
Rainfall (mm)	S2	S2
Oxygen availability	(S2)	(S2)
Drainage	S2	S2
Rooting condition	(S2)	(S2)
Texture	S1	S1
Coarse material (%)	S1	S1
Soil depth (cm)	S2	S2
Nutrient retention	(S3)	(S2)
Base saturation (%)	S3*	S2
pH H_2O	S2*	S1
Organic C (%)	S1	S1
Erosion hazard	(S1)	(S1)
Slope (%)	S1	S1
Flood hazard	(S1)	(S1)
Inundation	S1	S1
Land preparation	(S1)	(S1)
Surface stoniness (%)	S1	S1
Surface outcrops (%	S1	S1

Description: * improvements can be made, land suitability class up one level

Suitability appropriate class marginal land is land that has a severe limiting factor and these factors will affect the productivity, require additional input more than land classified as S2. To overcome the limiting factor on S3 require high capital so that the need for assistance or intervention (investment) government or company. Ritung (2011) reported that the topography of the territory was wavy to hilly and the soil fertility is low to very low (pH sour to very sour, CEC is low, NPK low to very low) the suitability of the land more suitable for annual crops (rubber and palm oil) than food plants / season.

CONCLUSION

Rubber plant land suitability class people of North Bengkulu is quite appropriate (S2) with a temperature limiting factors, availability of water, availability of oxygen, rooting media and nutrient retention. Land suitability classes of rubber plants that suit the farmers' in Seluma was marginal (S3) by a factor limiting nutrient retention. The actual land suitability class rubber plant people of South Bengkulu is appropriate marginal (S3) by a factor limiting of nutrient retention.

REFERENCES

Ardika, R, A.N. Cahyo dan Thomas. 2010. Potensi pengembangan perkebunan karet rakyat di Kecamatan Palmatak dan Siantan Kabupaten Natuna, Provinsi Kepulauan Riau. **Warta perkaretan 1(29).**

Azis, A. B.H. Sunarminto, M.D. Renanti. 2006. Evaluasi kesesuaian lahan untuk budidaya tanaman pangan menggunakan jaringan syaraf Tiruan. Berkala MIPA, 16(1) :1-10.

BP4K Kabupaten Seluma. 2012. Programa penyuluhan Kabupaten Seluma tahun 2013.

BP4K Kabupaten Bengkulu Selatan. 2012. Programa penyuluhan Kabupaten Bengkulu Selatan tahun 2013.

Dinas Perkebunan Provinsi Bengkulu. 2010. Statistik Perkebunan Propinsi Bengkulu. Laporan Tahunan.

Djaenudin, D., Marwan, H., Subagyo, H., dan A. Hidayat. 2003. Petunjuk teknis untuk komoditas pertanian. Edisi Pertama tahun 2003, ISBN 979-9474-25-6. Balai Penelitian Tanah, Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, Badan Litbang. Pertanian.

FAO. 1976. A Framework for Land Evaluation. *Soil Resources Management and Conservation Service Land and Water Development Division*. FAO Soil Bulletin No. 32. FAO-UNO, Rome.

Harijogjo dan Sutrisno,U. 2002. Kesesuaian dan potensi lahan untuk tanaman abaka di daerah Sangatta dan sekitarnya Kabupaten Kutai Timur Provinsi Kalimantan Timur. Prosiding seminar nasional sumberdaya lahan. Buku I: 345-356. Cisarua-Bogor: Pusat Penelitian dan Pengembangan Tanah dan Agroklimat.

Nurmegawati, S. Ritung, D. Sugandi, dan W. Wibawa. 2012. Evaluasi Kesesuaian Lahan Padi Irigasi dan Kedelai pada Lahan Terlantar yang Potensial di Kabupaten Lahat Sumatera Selatan. Jurnal Tanah dan Iklim 36 : 13-22

Ritung, S .2011. Identifikasi potensi lahan terlantar di Kalimantan Timur untuk mendukung ketahanan pangan dan pengembangan biofuel. Prosiding seminar nasional sumberdaya lahan pertanian. Banjarbaru, 13-14 Juli 2011. hal 419-436.

Subardja, D. 2007. Karakteristik dan pengelolaan tanah masam dari batuan volkanik untuk pengembangan jagung di Sukabumi, Jawa Barat. Jurnal Tanah dan Iklim. 25: 59-69.

Subardja, D dan Sudarsono .2005. Pengaruh kualitas lahan terhadap produktivitas jagung pada tanah volkanik dan batuan sedimen di Daerah Bogor. Jurnal Tanah dan Iklim. 23:38-47.

Syam, A. 2003. Sistem pengelolaan lahan kering di daerah aliran sungai bagian hulu. Jurnal Litbang Pertanian 22(4): 162-171.

Wigena, I.G.P., Sudradjat., S.R.P. Sitorus, dan Siregar,H. 2009. Karakterisasi Tanah dan Iklim serta Kesesuaiannya untuk Kebun Kelapa Sawit Plasma di Sei Pagar, Kabupaten Kampar, Provinsi Riau. Jurnal Tanah dan Iklim . 30 : 1-16.

Burrowing Activities of the Endogeic Earthworms *Pontoscolex corethrurus* Fr.mull in some Soil Types

Lastrianah [1], Darmi [2] and Rizwar [2]
[1] Biology Student in Faculty of Mathematics and Natural Science, University of Bengkulu
[2] Senior Lecturers of Biology Department In Faculty of Mathematics and Natural Science, University of Bengkulu

* Corresponding author email: darmibuchari@yahoo.co.id
HP.+62-81373244627; Fax. +62-736-20919

ABSTRACT

This study aims to analyze burrowing activities of endogeic earthworms *Pontoscolex corethrurus* on some soil types namely garden soil (mineral soil), peat soil and sandy soil. The earthworm movement *observed* include vertical and horizontal movement. This study was conducted in the laboratory of Ecology, University of Bengkulu from January to March 2015. The parameters observed in this study is a long period of earthworms enter to the media, long period of earthworm reaches a depth of 20 cm and a length of a pore or hole formed by earthworms *P. corethrurus*. The results showed that the ability of earthworms to create pores or holes in the soil through their movement activities varied on three types of soil. Long period of earthworms to enter to three kinds of soil, is not significantly different statistically (at 5.62 minutes on peat soil, at 6.11 minutes on garden soil and 5.62 minutes on peat soil). In all three media, the fastest vertical movement of earthworms to reach the bottom of a glass container (depth 20 cm) is in the garden soil media (14.5 minutes) and significantly different on peat soil (14.75 minutes) and sandy soil (16.24 minutes). The longest vertical pores formed by earthworms is on sandy soil with a pore length of 16.24 cm and is significantly different from lenght of vertical pores on garden soil 13.25 cm and 12.64 cm on peat soil. The longest horizontal pores is on garden soil (7.33 cm) and significantly different from horizontal pores on peat soil (6.14 cm) and on sandy soils (3.61 cm). The vertical pores formed by the earthworms *P. corethrurus* were longer than the horizontal pores.

Key words: earthworm burrowing activities, *Pontoscolex corethrurus*, porous soil

INTRODUCTION

Earthworms are invertebrate animals that are known to have many benefits, for instance, they can improve soil fertility, both physically and chemically. Physically, through their activities, earthworms can make holes or burrows (biopores) in the soil so they contribute in improving soil aeration and drainage. Chemically, earthworms play a role in improving the availability of soil nutrients through decomposition processes of soil organic materials (Gajalaksmi and Abbasi, 2004).

Based on the ecological function, earthworm is divided into three groups: *epigeic*, *endogeic* and *anecic* which known as Bouche's classification system. *Epigeic* earthworm with a small size, darker color, living in litter layers and consume litter (organic material) and rarely consume soil. *Epigeic* earthworms are most found in material organic substrate or in animal manure. In *endogeic* group, species that live in top soil layer of soil until the depth of 20-30 cm from soil surface dig a hole in soil and consume soil (*geophages*) with pale color and size varies. *Anecic* worms tend to have larger body sizes, and live in deeper soil layers. They consume organic material and soil mixture, and rarely appear on surface (Andrade *et al.*, 2010).

Earthworms, especially from groups endogeic and anecic, contribute to improving biopores in soil. The existence of earthworm's biopores also supports the availability of oxygen so microbial activities will increase and ultimately, they improve overall of soil fertility both physics and chemistry (Hanafiah *et al.*, 2005). Results of Ganjari's study (2009) showed that the presence of earthworms can expand the field of groundwater recharge through biopores. Generally, earthworms were able to make 20 holes (biopores) per square meter of land with an average hole size of 4.58 mm.

Pontoscolex corethrurus is one species of earthworms belonging to the endogeic group that is also referred to as the worms of ecosystem engineer. Species of endogeic earthworms is an active to create channels or holes in the soil (Plisko, 2001; Lavelle *et al*., 1987; Amirate et *al*., 2014). When making the holes, earthworm bodies release mucus that serves as the cement in order to make the holes remain stable so that it can be used many times because of the freeway due to blockage. endogeic earthworms in their life cycle can make burrows in the soil by feeding masses of soil and organic matter so that these activities will destroy and prevent soil compaction (Subowo, 2011).

The existence of earthworms in the soil is influenced by several abiotic factors such as, the soil type, soil acidity, soil moisture, soil temperature, soil texture and the availability of organic material (Lee, 1985; Edward and Lofty, 1972). Earthworms have different preferences on habitat. Soil types on earthworm habitat of also affect on their life (Maftuah and Susanti, 2009; Qudratullah *et al*., 2013).

The information of earthworm ability in making burrows in different soil types is still limited so it is necessary to do study the earthworm activities in making holes in different types of soil. This study was conducted in laboratory conditions using three types of soil that are mineral soil, peat soil and sandy soil. Results of this study are expected to provide an overview of earthworm activities in creating holes in three types of soil and can be used as a reference in determining the proper application in using earthworms to improve the soil fertility.

MATERIALS AND METHODS

This study used a transparent glass container with a size of 15cm width, thickness of 3 cm and 20 cm in height. Study was conducted in the Biology laboratory of MIPA Faculty, the University of Bengkulu. The use of glass containers intended to facilitate observation of the earthworms activity in making holes in soil (Whalen et al., 2004). This study was designed by using a completely randomized design (CRD), which consists of 3 treatments (mineral soil, peat soil and sandy soil). Each treatment has eight replications. Mineral soil was taken from top layer of garden soil, while sapric peat and sandy soils were collected from the coastal areas of Bengkulu. Three types of soil media were analyzed their texture, pH and organic content in the Soil Laboratory, Faculty of Agriculture, the University of Bengkulu.

Table 1. Some soil physical and chemical properties of earthworm media

No	Soil types	Physical and chemical properties of soil				
		pH (H_2O)	Organic content (%)	Soil texture		
				Sand (%)	Loam (%)	Clay (%)
1.	Mineral soil	4.6	4.11	35.39	28.71	35.90
2.	Sandy soil	5.7	3.45	90.18	3.47	6.35
3.	Peat soil	4.4	4.35	tt	tt	tt

Description: tt = undefined

Experiment of the earthworm activity in making holes was conducted in the glass containers filled soil media in accordance with the experimental design. Earthworm species used was an adult *Pontoscolex corethrurus* with relatively similar in body size (7-10 cm in length and 3-4 mm in a diameter). Each glass container consists of one individual of earthworm. Observations were made daily from 08:00 to 10:00 pm. The parameters observed in this study include: (1) time duration of earthworm (in minutes) come in soil media, which starts from putting earthworm on the surface of the media until its entire body goes into the media. (2) time duration of earthworm reach depths of 20 cm (base layer of media) which starts from putting a worm in a glass container until the worms reach depths of 20 cm (3) The length of the pores/vertical burrows and (4) The length of the horizontal pores. Data were analyzed by ANOVA of one factor and if the value of F_{ratio}> F_{table}, then continued with Duncan test.

RESULTS AND DISCUSSION

Study results showed that different types of soil media provided various influences on *P. corethrurus* activity in making holes. This can be seen with the variation of time duration of earthworms goes into the media, time duration of worm reach the bottom of the media, pore length vertically and horizontally.

Results of variance analysis showed that the different types of soil media did not significantly affect on time duration of *P. corethrurus* went into the media. It can be seen from the value of F_{ratio} = 0.4 <F_{table} = 3.47 at p = 0.05.

In Figure 1, time duration of *P. corethrurus* coming in soil media was not significantly different among treatments. Time duration in sandy soil was 6.41 minutes, in garden soil 6.11 minutes and in peat soil 5,62 minutes on. Thus the three types of soil were liked by *P. corethrurus* because the insertion of worms into a soil medium is an indicator that they like the media. Time duration of worms entered into three types of soil media was relative similar because this endogeic worms are very sensitive to light (Subowo, 2011). Edwar and Lofty (1972) also stated that generally, the earthworms have a negative response to the light.

Observations on time duration of earthworms in digging holes in three types of soil media showed *P. corethrurus* worms are an able to achieve the basic media in depth of 20 cm. This is the characteristics of *P. corethrurus* as endogeic worms. Andrade *et al.* (2010) stated that the group of endogeic worms is a type of worms that lives from the surface layer to soil depth of 20-30 cm.

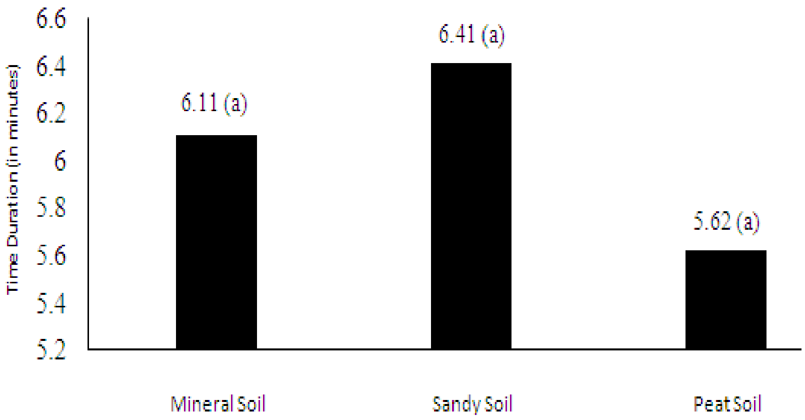

Figure 1. Histogram of time duration (in minute) of endogeic earthworm *Pontoscolex corethrurus* goes into different soil media. Note: Means with the same letter are not significantly different at p=0,05

Results of statistical analysis showed that time duration of *P. corethrurus* to reach the bottom of three types of soil media (20 cm in depth) were significantly different (F_{ratio} = 29.0> F_{table} = 3.47 at p = 0.05). In Figure 2, time duration of worms reach base of the mineral soil (14.5 minutes) and peat soil (14.75 minutes) was much faster (significantly different) than sandy soil (24.98 minutes). *P. corethrurus* were easier and faster to reach base of garden soil media (mineral soil) and peat soil because there was relation to the organic content of both soil types. Soil mineral and peat may have the organic content relatively similar and tend to be higher than sandy soils (Table 1). The organic content in soil is important for earthworms, because *P. corethrurus* are geophage worms also consume soil and create holes in the ground (Suin, 1989; Andrade *et al.*, 2010).

Pontoscolex worms were slower to reach base of sandy media because this soil media consists of the high sand content (Table 1). Sandy soil has a coarse granules that can inhibit the movement of *P. corethrurus* to reach media base in depth of 20 cm. Edwar & Lofty (1972) stated that lands having a high sand fraction are less favored by earthworms.

Experiment on activity P. corethrurus earthworms in burrowing three types of soil indicated that these worms can form pores (biopores) in the ground either vertically or horizontally. The results showed that three types of soil media significantly affected on earthworm activity to burrow vertical and horizontal pores. Results of variance analysis showed that the three types of soil significantly affected on the length of the vertical pores created by P. corethrurus (F_{ratio} = 5.16> F_{table} = 3.47 at p = 0.05). Figure 3 shows that the longest vertical pore is on sandy soil (16.24 cm) and significantly different with vertical pores in the soil minerals (13.25 cm) and peat soil (12.64 cm). Vertical pore length on mineral soil and peat soil were not significantly different. Vertical pore in sandy soil is more length because the soil texture of sandy soil may likely loose soil so that the gravity factor speeds up the movement of earthworms vertically.

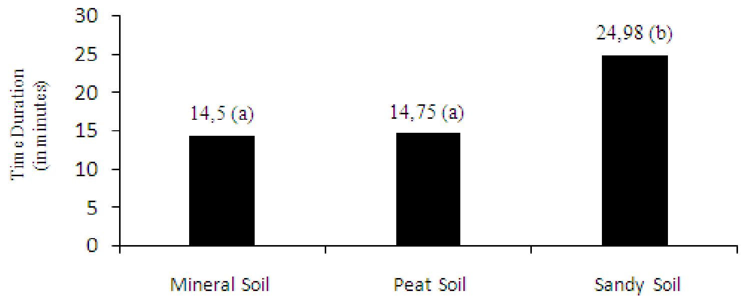

Figure 2. Histogram of time duration (in minute) of earthworms *Pontoscolex corethrurus* to reach bases of three types of soil media in depths of 20 cm. Note: Means with the same letter are not significantly different at p=0,05

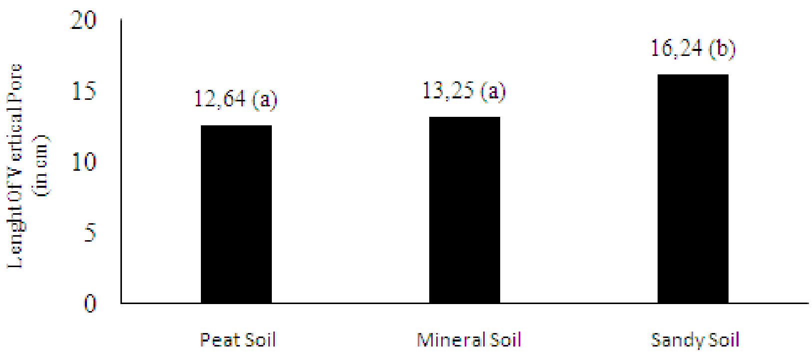

Figure 3. Histogram of length average of vertical Pore (cm) created by endogeic earthworms *Pontoscolex corethrurus* in three types of soils. Note: Means with the same letter are not significantly different at p=0,05

Three types of soil were also significantly affect on the length of the horizontal pores formed by earthworm *P.corethrurus* (F_{ratio} = 13.16> F_{table} = 3.47 at p = 0.05).

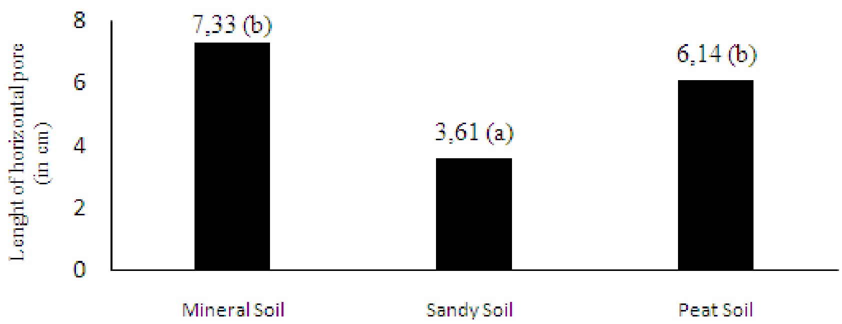

Figure 4. Histogram of length of horizontal pores (cm) created by *Pontoscolex corethrurus* in three soil types. Note: Means with the same letter are not significantly different at p=0,05

Figure 4 shows that the length of the horizontal pores in mineral soil (7.33 cm) and peat (6.14 cm) was much higher and significantly different than length of horizontal pores in sandy soil (3.61 cm). These phenomena are happened because that mineral soil is the original habitat of the P. Corethrurus, while peat soils have a soil pH that is still within the range of tolerance favored P. corethrurus (Table 1). Study results of Darmi et al. (2014) also showed that P. corethrurus in field conditions are many found in peat land planted with oil palms. P. corethrurus can be found on the farm areas, shrubs and field overgrown by grasses and are rarely found on sandy soils (Sayuti, 2001). Comparison of vertical and horizontal pores formed by earthworms P. corethrurus showed that the vertical pores were longer than the horizontal pores on three types of soil. Amirate et al. (2014) also stated that P. corethrurus much more formed vertical pores than horizontal pores.

CONCLUSION

The ability of earthworms to create pores or holes in the soil through their movement activities varied on three types of soil. Time duration of earthworms to go into three kinds of soil, is not significantly different statistically (5.62 minutes on peat soil, 6.11 minutes on mineral soil and 5.62 minutes on peat soil). In three media, the fastest vertical movement of earthworms to reach the bottom of a glass container (depth 20 cm) is in the mineral soil media (14.5 minutes) and significantly different on peat soil (14.75 minutes) and sandy soil (16.24 minutes). The longest vertical pores formed by earthworms is on sandy soil with a pore length of 16.24 cm and is significantly different from lenght of vertical pores on mineral soil 13.25 cm and 12.64 cm on peat soil. The longest horizontal pores is on mineral soil (7.33 cm) and significantly different from horizontal pores on peat soil (6.14 cm) and on sandy soils (3.61 cm). In three types of soil, the vertical pores formed by *P. corethrurus* were longer than the horizontal pores.

REFERENCES

Amirat, F., K. Hairiah, and S. Kurniawan. 2014. Biopore reparation by earthworms (*Pontoscolex corethrurus*). Is the reparation of soil porosity will increase nitrogen leaching? Journal of Soil and Land Resources, 1(2): 28-37.

Andrade, D.P., G.G. Brown, and M.A. Callaham Jr, 2010. Ecological classification of Brazilian earth worm: a first attempt using morphological data. Elaetao 4 13 a15 de outubro, Curitiba, Parana, Brasil.

Darmi, D. Budianta, Sabaruddin, and M. R. Ridho. 2014. Abundance and distribution pattern of earthworm in peatland planted with different age of oil palm plantation in district of Seluma, Bengkulu Province. Asian Academic Research Journal of Multidisciplinary 1(22): 592-503.

Edwards, C.A. and J.R.Lofty, 1972. Biology of Earthworm. Chapman and Hall Ltd. London

Gajalakshmi, S. and S.A. Abbasi, 2004. Earthworm and vermicomposting. Indian Journal of Biotechnology 3: 486-494.

Ganjari, L.E., 2009. Biopore holes of earthworms and their impact on ground water recharge. Widya News 02 (Year XXXIII).

Hanafiah, K. A., A. Napoleon, N. Ghofar, 2010. Soil biology: Ecology and soil macrobiology. Raja Grafindo Persada Ltd.. Jakarta.

Lavelle, P., I. Barois, I. Cruz, C. Fragoso, A. Hernandes, A. Pineda, dan P. Rangel, 1987. Adaptive Strategies of *Pontoscolex corethrurus* (Glossoscolidae, Oligochaeta), A Peregrine Geophagus Earthworm Of The Humid Tropics. Jurnal Bio and Fertil of Soil, 5(2): 188-194.

Lee, K. E., 1985. Earthworm, their ecology and relationships with soils and land use. Academic Press, London.

Maftuah, E. dan M. A. Susanti. 2009. Earthworm communities in some applications of peatland in Central Kalimantan. Biology News, 9(4): 371-378.

Plisko, J. D. 2001. Notes on the occurence of the intruduced earthworm *Pontoscolex corethrurus* (Muller,1857) in South Africa (Oligochaeta: Glossoscolecidae). African Invertebrates, 42: 323-334.

Qudratullah, H., T. R. Setyawati, A.H. Yanti, 2013. Diversity of earthworm (Oligochaeta) on the type of habitat in the district of Pontianak City. Journal of Protobiont, 2(2):56-62.

Sayuti, I. 2001. Time duration of pre-reproduction of earthworm *Pontoscolex corethruru* (Fr.Mull) the various types of feed and its role in the decomposition process. *Thesis.* Graduate Program of Andalas University.

Subowo, G. 2011. The role of endogaesis earthworm group in improving the efficiency of Dryland soil processing to of. Journal of Agricultural Research and development. Vol 30, (4) : 125-131.

Suin, N. M. 1989. Soil Animal Ecology. Bumi Aksara, Bandung.

Whalen, J.K., L. Sampedro, T. Waheed, 2004. Quantifying surface and subsurface cast production by earthworms under controlled laboratory conditions. Biol. Fertil. Soils, 39: 278-291.