p ISSN: 2354-5844
e ISSN: 2477-5223

STUDY OF RUBBER GROWTH UNDER CONSTRAINT OF PYRITE IN MUARA SUGIHAN TIDAL SWAMPY AREA

Charlos Togi Stevanus, Umi Hidayati, Thomas Wijaya, and Andi Nur Cahyo

Sembawa Research Institute, Rubber Research Center.

ABSTRACT

A preliminary land suitability survey of tidal swampy area for rubber cultivation located at Muara Sugihan in 2012 described that there were two main problems, the shallow groundwater problem and the low pH (2.87-3.05) at the depth of 40-100 cm that indicates the presence of pyrite layers. Before rubber trees were planted, drainage has been conducted to maintain the water level. However, the drainage was excessive, so that water table reached 66 cm from soil surface hence aerobic condition resulted in oxidation of pyrite layers. This study used survey method that consist of measurement of 2 years old rubber plants girth and sampling of soil, leaves, and water on the trench and the river which indicated the presence of pyrite layers on tidal swamp area, Muara Sugihan. The result showed a significant retardation on rubber growth which were planted in tidal swampy area as the effect of pyrite stresses compared to rubber growth which were planted in dry land. Furthermore, leaf nutrient analysis showed the deficiency of P, K, and Zn, while soil analysis showed a low P content. The pyrite was leached from the soil and accumulated into drainage, hence resulted in a low pH of water. This problem can be solved by water management improvement.

Keywords: rubber plant, pyrite, tidal swamp, girth, water management, Muara Sugihan.

INTRODUCTION

Natural rubber is an export commodity that has a big contribution on national income. Rubber tree can be grown well on dry land. Unfortunately, availability of dry land is becoming limited, so land for rubber cultivation is extended to suboptimal area like tidal low land area. Tidal area is a land that is inundated periodically or continually because of the effect of tidal zone of sea water, rain, or river overflow (Warner and Rubec, 1997).

Based on the inundation pattern, tidal swampy area is categorized into 4 types, i.e. 1) type A, inundated on high and low tide; 2) type B, inundated only on high tide; 3) type C, not inundated but water table at tide time is less than 50 cm; and 4) type D, not inundated at tide time and water table more than 50 cm but the tidal is still can be monitored on tertiary canal (Rina and Syahbuddin, 2013; Najiyati and Muslifat, 2015).

Muara Sugihan is a place with some tidal swampy area that is used as a rubber plantation in South Sumatra. Land suitability for rubber tree survey was conducted at Muara Sugihan tidal swampy area in 2012 before planting activity. This survey was aimed to determine the potency of the land to cultivate rubber. The results showed that there were just two moderate constraint factors of Muara Sugihan to cultivate rubber; hence it was categorized to S2 (suitable) for rubber (Wijaya, 2008). These constraint factors were low water table and pH (<3.0) at the depth of $\geq$ 40 cm. pH below 3.2 indicated the presence of pyrite layer on the area (Turner and Gilbank, 1982). Before rubber was planted in 2013, drainage canal was created in order to decrease water level, but excessive drainage resulted in oxydation of pyrite layer.

Pyrite is one kind of sulfide mineral that is generalli1y developed in cubic crystal form, octahedral, or pyritohedral (Shinya and Bergwall, 2007). Newman (1998) said that relative humidity of minimum 60%, oxygen and water can quicken pyrite oxydation. If pyrite has been oxidized, it will be toxic for plant because solubility of H^{+}, Fe^{3+}, and sulfic acid group is decreasing.

Correspondence: Charlos Togi Stevanus. Sembawa Research Institute, Rubber Research Center, Palembang.
Email: togie_stevanus@yahoo.co.id

p ISSN: 2354-5844
e ISSN: 2477-5223

This paper was aimed to explain the effect of pyrite oxydation on the growth of rubber tree and how to prevent pyrite oxidation by the improvement of water management.

MATERIALS AND METHODS

Study Site

Observation on the effect of oxidation on rubber plant growth was conducted in tidal swampy area located at Muara Sugihan, South Sumatera on February 2015. The soil texture was clay soil (53 % clay; 21 % dust, and 26 % sand). The consecutive dry months was varied between two to three months with the average of rainfall (two years) was adalah 2.375 mm/year. Dry month for rubber tree was months with monthly rainfall < 100 mm (Rao and Vijayakumar, 1992).

Plant and Soil Sampling

Rubber planting at the study area was conducted on January 2013. Soil, girth, and leaf samples were collected compositely as many as 25 trees on pyrite oxidized area (± 80 ha). The rubber tree girths were measured at the height of 100 cm above soil surface. Whereas soil samples were collected at the depth of 0-20 cm using soil auger. The soil samples then were clustered according to the leaf sampling unit (LSU) (Adiwiganda et al., 1994). Soil analyses consist of N, P, K, Ca, Mg, and CEC; whereas leaf analyses consist of N, P, K, Ca, Mg, Cu, Zn, and B. Besides that, pH in the canal was also been measured.

Data analysis

T test was used in this study to differentiate the means between plant growth (stem diameter) of rubber plants grown in Muara Sugihan tidal swampy area (oxidized by pyrite) and in dry land (without pyrite layer). Whereas to determine the nutrient status of rubber plants planted in oxidized pyrite area, the nutrient status data was compared to optimal nutrient status of rubber tree. The criteria of optimal nutrient status for rubber are presented at Table 1 and 2.

Tabel 1. Criteria of nutrient optimal status on rubber tree leaves

Parameter content	Nutrient Content Standard	References
N (%)	3.3*	Adiwiganda et al., 1994
P (%)	0.23*	Adiwiganda et al., 1994
K (%)	1.31*	Adiwiganda et al., 1994
Mg (%)	0.21*	Adiwiganda et al., 1994
Cu (ppm)	10-15**	Suchartgul et al., 2012
Zn (ppm)	21**	Suchartgul et al., 2012
B (ppm)	40-80***	Shorrock, 1983

Tabel 2. Criteria of soil optimal nutrient status for rubber

Parameter	Nutrient Content Standard	Reference
pH	6.6-7.5	Adiwiganda et al., 1994
N (%)	0.21-0.50	
P2O5 (ppm)	16-25	
K (me/100 gram)	0.31-0.50	
Ca (me/100 gram)	1.01-1.75	
Mg (me/100 gram)	0.52-0.80	
KTK (me/100 gram)	17-28	

p ISSN: 2354-5844
e ISSN: 2477-5223

RESULT AND DISCUSSION

Rubber Growth Performance

Based on statistical test, pyrite layer significantly suppressed rubber growth (Figure 1). Furthermore, pyrite also makes rubber trees die with yellowish leaves symptomps. When pyrite is oxidized, Sulfide material under sulfic acid soil forms sulfic acid compound or oxidized sulfide that makes low soil pH (<3) (Newman, 1998; Fitzpatrick et al., 2009). This condition makes solubility of Al, Fe, and SO_4 increase (Shamshuddin et al., 2004) and resulted in plant toxicity. Some researcher showed that plant growth will be inhibited by the presence of oxidized pyrite. Shamshuddin et al. (2004) showed that in sulfic acid soil with pH<3.5, plant height and dry weight of cocoa planting material were inhibited. The high of Al^{3+} solubility and the low soil pH also resulted in the retarded length and root surface area (Azura et al., 2011). Edgardo et al., (1991) also showed that the growth of oil palm root length was retarded at the concentration of Al^{3+} as high as 100 µM.

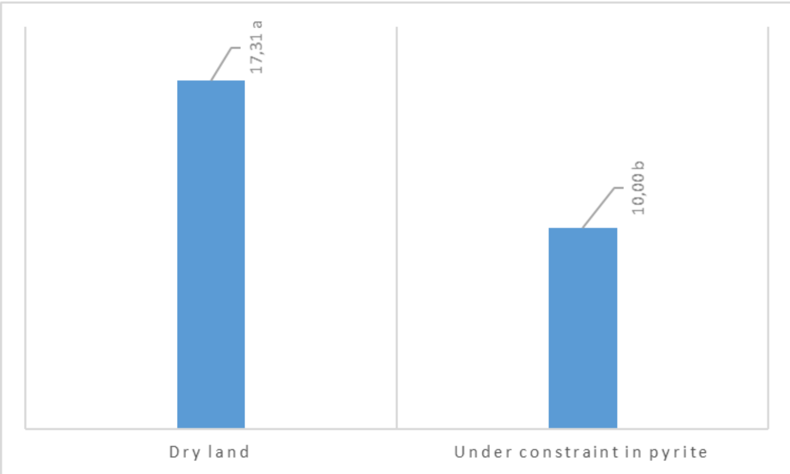

Figure 1. The effect of pyrite on the growth of rubber tree

Leaves and Soil Nutrient Content

The results of leaves and soil nutrient analysis are presented in Table 3 and 4. In general, the stressed plants by pyrite layers were lack of Phosphor, Potassium, and Zinc. Furthermore, the decrease of soil pH at the research site resulted in the increment of Fe and Al concentration in soil solution and also increased P adsorpsion (Bolan et al., 2003). This condition caused P_2O_5 needed by plant is not available. This result was appropriate with previous research by Waniyo et al. (2014). Waniyo et al. (2014) stated that soil P availability decreased significantly with the increment of pyrite concentration. Besides that, although the availability of K^+ was high, K^+ absorption by roots were decreased as the decrease of soil pH (Jacobson et al., 1957).

Tabel 3. Leaves nutrient anlysis result

Parameter	Nutrient content	Nutrient status
N (%)	3,71	High
P (%)	0,20	Deficiency
K (%)	1,06	Deficiency
Mg (%)	0,43	High
Cu (ppm)	15	Optimal
Zn (ppm)	5	deficiency
B (ppm)	72	Optimal

p ISSN: 2354-5844
e ISSN: 2477-5223

Table 4. Soil analysis result in the depth of 0 - 20 cm at research site.

Parameter	Soil nutrient analysis	Nutrient status
pH	3.7	Low
N (%)	0.69	High
P^2O^5 (ppm)	1.8	Low
K (me/100 gram)	0.75	High
Ca (me/100 gram)	3.08	High
Mg (me/100 gram)	10.5	High
KTK (me/100 gram)	23.19	Optimal

Water Quality

Laboratory test on water pH from canal and river showed that the pH are 2.8 and 2.9 respectively. Ravengai et al. (2005) stated that dissolved Fe and SO_4^{2-} through pyrite accumulation leaching resulted in low water pH. At the observation site, water from canal with low pH was used for irrigation of rubber planting material. This condition caused rubber planting material leaves become yellowish and necrosis.

Water Management to Prevent Pyrite Oxydation at Tidal Swampy Area

Water management is a key to prevent pyrite layer from oxydation, that is by keeping pyrite layer inundated by water (anaerob). Emergency water gate can be made from material like board, wood, plastic, and gunny sack filled by soil. Some gunny sack layers were arranged transversal with water canal, then water gates were made in the center of canal until the height of pyrite layer, that is ± 40 cm from soil surface. Gunny sacks were covered by plastic at the bottom, left, and right until the height of pyrite layer surface. Wood was installed up behind plastic and lock the gunny sack from water flow.

Maintenance of emergency water gate was conducted twice a year with a purpose to keep water gate could regulate water level properly (Listijono, 2009). In some points, opened pipes instalation with length of 1.5 m were needed to check water level.

CONCLUSION

Pyrite stresses caused retardation of rubber plant growth in Muara Sugihan tidal swampy area compared to dry land. Furthermore, based on leaves analyses, lack of Phosphor, Potassium, and Zinc in rubber tree was occurred as the effect of oxidized pyrite. In addition, to prevent oxidation of pyrite layer, water table should on above pyrite layer (anaerob). Hence the optimum water table is ± 40 cm below soil surface.

REFERENCES

Adiwiganda YT, Hardjono A, Manurung A, Sihotang UTB, Darmandono, Sudiharto, Goenadi DH, and Sihombing H. 1994. Rubber Fertilization Recommendation Arrangement Technique. Rubber Communication Forum. Medan.

Azura AE, Shamshuddin J, Fauziah CI. 2011. Root elongation, root surface area and organic acid by rice seedling under Al^{3+} and/or H^+ stress. *American journal of Agricultural and Biological Sciences*. 6(93): 324-331.

Bolan NS, Adriano DC, Curtin D. 2003. Soil acidification and liming interaction with nutrient and heavy metal transformation and bioavailability. *Advances in agronomy*. 78: 215 -271.

Edgardo A, Auxtero, Shamshuddin J. 1991. Growth of oil palm (*Elaeis guineensis)* seedling on acid sulfate soils as affected by water regime and aluminum. *Plant and soil*. 137: 243-257

p ISSN: 2354-5844
e ISSN: 2477-5223

Fitzpatrick RW, Grealish G, Shand P, Simpson SL, Merry RH, Raven MD. 2009. Acid Sulfate Soil Assessment in Finniss River, Currency Creek, Black Swamp and Goolwa Channel, South Australia. CSIRO Land and Water Science Report.

Jacobson L, Overstreet R, Carlson RM, Chastain JA. 1957. The effect of pH and temperature on the absorption of Potassium and Bromide by barley roots. *Plant Physiology*. 32(6): 658-662.

Listijono B. 2009. Implementation of water management and fertilization technology on the oil palm plantation establishment of PTPN V in collaboration with The Government of Siak Disitrict, Riau Province. Proceeding of National Seminar on Fertilization and Water Management in Plantation. 5-6 November 2009. Bandung.

Najiyati S, Muslifat L. 2015. Determine the type of peat swamp land. Wetland International-Indonesia Programme. Accessed from http://www.indo-peat.net on 18 March 2015

Newman A. 1998. Pyrite oxidation and museum collections : a review of theory and conservation treatments. *The Geological Curator*. 6(10): 363-371.

Rao PS, Vijayakumar KR. 1992. Climatic requirement. In Natural Rubber : Biology, Cultivation, and Technology. Eds : Sethuraj M.R. and Mathew M. Amsterdam

Ravengai S, Love D, Gratwicke B, Mandingaisa O, Owen RJS. 2005. Impact of iron duke pyrite mine on water chemistry and aquatic life – Mazowe Valley, Zimbabwe. *Water SA*. 31(2): 219-228.

Rina DY, Syahbuddin H. 2013. Suitability zone of tidal swampy land based on commodity competitive superiority. *Agriculture and Agribusiness Socio Economy Journal*. 10(1): 103-117.

Shamshuddin J, Muhrizal S, Fauziah I, Husni MHA. 2004b. Effects of adding organic materials to an acid sulfate soil on the growth of cocoa (*Theobroma cacao* L.) seedlings. *Science of the Total Environment*. 323: 34-45.

Shinya A, Bergwall L. 2007. Pyrite oxidation: review and prevention practices. The Field Museum (p. Poster presentation). Chicago IL: The Field Museum.

Shorrocks MV. 1983. Mineral deficiencies in Hevea and associated cover plants. Rubber Research Institute. Kuala Lumpur. Malaysia

Suchartgul S, Maneepong S, Issarakrisila M. 2012. Establisment of standard values for nutrional diagnosis in soil and leaves of immature rubber tree. *Rubber Thai Journal*. 19 - 31

Turner PD, Gillbanks RA. 1982. Oil palm cultivation and management. The incorporated society of Planters. Kuala Lumpur. p. 672

Waniyo UU, Ngala AL, Sauwa MM, Tekwa IJ, Maryam A, Solomon SO. 2014. Effect of pyrite (FeS2) application rates on sodic soils and performance of Maize (*Zea mays*) plants. *Asian American Soil and Crop Science Research Journal*. 1(1): 1-9.

Warner BG, Rubec CDA. 1997. The Canadian wetland classification system. The Wetlands Reseach Centre, Canada. p. 68.

Wijaya. 2008. Land and Climate Suitability for Rubber. *Rubber News*. 27(2): 33-44