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EFFECTS OF ACID DEPOSITION ON SOIL CHEMISTRY AND PLANT GROWTH

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By

MOHAMAD HILMI BIN IBRAHIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

EFFECT OF ACID DEPOSITION ON SOIL CHEMISTRY AND PLANT GROWTH

By

MOHAMAD HILMI BIN IBRAHIM

October 2013

Chairman : Susilawati Binti Kasim, PhD

Faculty : Agriculture and Food Sciences (Bintulu)

Emission of pollutant gases mainly SO_2 and NO_X has generated air pollution and acid deposition and the two principal sources of these pollutants are human and natural activities. Acid deposition has adverse effect on plants, soils, water and aquatic organisms. Thus, a study was conducted to determine acid deposition effects on soil properties and plant growth. The preliminary study was conducted by monitoring rainwater chemical characteristics and deposition rate using rainwater sampler. Monitoring was done at the Universiti campus for 104 days and rainwater was collected once every 13 days and analyzed for nutrient concentrations and deposition rate. For the soil study, 54 leaching columns were prepared and arranged in CRD design. A 318 mL of rainwater at different pH was applied up to 4, 7 and 15 applications for 45 days. At day 45, soil and leachate samples were collected and analyzed. Acid deposition effect on plant growth was determined using *Shorea macroptera* and *Sandoricum koetjape* as the test plants. The seedlings were treated with 618 mL of rainwater at different pH for the entire study period and growth parameters were observed once every 30 days up to three months. The amount of ion deposition in the rainfall and through-fall were quantified using resin sampler. Assessment was done in the rehabilitated forest and an open area once in 6 months for a year. Resin was collected and analyzed for nutrient concentration. The amount of ion deposition was calculated using a formulas suggested by EANET. The pH of rainwater ranged from 5.8 to 6.5. Deposition rate was lower for higher volume of rainwater especially for cations and sulfide. For the leaching study, higher pH of rainwater reduced CEC and K concentrations but increased Cu, Fe and SO_4 concentrations in the soil. In the case of leachate, low rainwater pH increased pH, Na, Cu and NO_2 but EC and salinity decreased. The growth of *Shorea macroptera* and *Sandoricum koetjape* was retarded in terms of height, number of leaves and biomass. Chlorosis and necrosis appeared as the rainwater pH decreased from 6.00 ± 0.2 to 3.5. At the same time, it affected P and Ca in *S. macroptera* and N, Ca, Mg, Zn and Fe in *S. koetjape* plant parts. For soil, low SAR pH affected in terms of pH, Fe, Cu, Zn, acidity, H, Al, K and SO_4. The resin sampler recorded higher deposition of Na, Mg, Fe, Zn and NH_4 in the rehabilitated forest compared to the open area. However Ca, Cu, NO_3 and SO_4 deposition was high in the open area compared to the rehabilitated forest. In conclusion, acid rain affects plant growth and soil chemical properties. Higher rainwater pH in the study area indicated that the area is not still affected by acid deposition.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Master Sains

KESAN PEMENDAKAN ASID KEATAS KIMIA TANAH DAN PERTUMBUHAN POKOK

Oleh

MOHAMAD HILMI BIN IBRAHIM

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Pengerusi : Susilawati Binti Kasim, PhD

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Pelepasan gas pencemar terutamanya SO_2 dan NO_X telah menyebabkan pencemaran udara dan pemendakan asid dan dua sumber utama pencemar tersebut adalah aktiviti manusia dan semulajadi. Pemendakan asid mendatangkan kesan buruk ke atas tumbuh-tumbuhan, tanah, air dan organisma akuatik. Oleh itu, kajian telah dijalankan untuk mengenalpasti kesan pemendakan asid keatas ciri-ciri tanah dan pertumbuhan pokok. Kajian awalan telah dijalankan dengan memantau ciri-ciri kimia dan kadar pemendakan dengan menggunakan takungan air hujan. Pemantauan telah dijalankan di kawasan kampus Universiti selama 104 hari dan air hujan dikutip setiap 13 hari dan dianalisa bagi kepekatan nutrien dan kadar pemendakan. Bagi kajian tanah, 54 bekas penyusutan disediakan dan disusun dalam bentuk CRD. 318 mL air hujan pada pH yang berbeza diaplikasikan sehingga 4,7 dan 15 aplikasi selama 45 hari. Pada hari ke 45, tanah dan lechat sampel dikutip dan dianalisa. Kesan pemendakan asid terhadap pertumbuhan pokok ditentukan dengan menggunakan *Shorea macroptera* dan *Sandoricum koetjape* sebagai pokok ujian. Anak pokok telah

dirawat dengan 618 mL air hujan pada pH yang berbeza bagi keseluruhan tempoh kajian dan parameter pertumbuhan telah dipantau sekali setiap 30 hari sehingga tiga bulan. Jumlah pemendakan ion dalam hujan dan tempias diukur menggunakan takungan resin. Pemantauan dijalankan di hutan rehabilitasi dan terbuka setiap 6 bulan selama setahun. Resin dikutip dan dianalisa bagi kepekatan nutrien. Jumlah pemendakan ion dikira dengan menggunakan formula yang dicadangkan oleh EANET. pH air hujan adalah dalam julat 5.8 ke 6.5. Kadar pemendakan adalah rendah bagi isipadu air hujan yang tinggi terutamanya untuk cation dan sulfida. Bagi kajian penyusutan, pH SAR yang tinggi telah mengurangkan CEC dan kepekatan K tetapi meningkatkan kepekatan Cu, Fe dan SO_4 di dalam tanah. Dalam kes lechat, SAR yang rendah telah meningkatkan pH, Na, Cu dan NO_2 tetapi EC dan kemasinan berkurangan. Pertumbuhan *Shorea macroptera* dan *Sandoricum koetjape* terencat dalam bentuk ketinggian, bilangan daun dan biojisim. Klorosis dan nekrosis muncul apabila pH SAR menurun dari 6.00 ± 0.2 ke 3.5. Pada masa yang sama, ia mempengaruhi P dan Ca pada *S. macroptera* dan N, Ca, Mg, Zn dan Fe pada *S. koetjape* bahagian pokok. Bagi tanah, pH SAR yang rendah mempengaruhi pH, Fe, Cu, Zn, keasidan, H, Al, K dan SO_4. Takungan resin merekodkan pemendakan Na, Mg, Fe, Zn dan NH_4 yang tinggi di hutan rehabilitasi berbanding dengan kawasan terbuka. Bagaimanapun, pemendakan Ca, Cu, NO_3 dan SO_4 adalah tinggi di kawasan terbuka berbanding dengan hutan rehabilitasi. Kesimpulannya, hujan asid telah memberi kesan kepada pertumbuhan pokok dan ciri-ciri kimia tanah. pH air hujan yang tinggi di kawasan kajian menunjukkan kawasan tersebut tidak terkesan dengan pemendakan asid.

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I certify that a Thesis Examination Committee has met on 25 October 2013 to conduct the final examination of Mohamad Hilmi bin Ibrahim on his thesis entitled "Effects of Acid Deposition on Soil Chemistry and Plant Growth" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is confirm that:

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
ATP	Adenosine triphosphate
CEC	Cation Exchange Capacity
CRD	Completely Randomized Design
EANET	Acid Deposition Monitoring in East Asia
ICP	Ion Chromatograph
kPa	kilo Pascal
LNG	Liquified Natural Gas
NA	Number application
PVC	Polyvinyl chloride
SAR	Simulated Acid Rain
SCORE	Sarawak Corridor of Renewable Energy
SAS	Statistical Analysis System
UPMKB	Universiti Putra Malaysia Bintulu Campus

CHAPTER 1

INTRODUCTION

Acid deposition is one of the environmental problems plaguing most countries. According to NAPAP (2005), almost all developed countries, and half of the developing countries face this problem. Acid deposition was recognized as a potential environmental problem in England since 1872, followed by Germany in 1982 when forest productivity declined (Bell, 1985; Prinz *et al*., 1985). Switzerland, Austria, France and Italy recorded first acid deposition effect in 1983, while Norway noticed the first effect in 1978 (Tviete, 1985; Bucher, 1985). Rainwater acidity measurement in India, China, and Japan began in 1960, 1970 and 1981, respectively (Zhao and Xiong, 1986; Varma, 1989; JEA, 1990). In the case of Malaysia, the monitoring of acid deposition began in 1976 (MMD, 2008). Acid rain monitoring is important because Malaysia is located in the equatorial region which receives heavy annual rainfall (Ayers *et al*., 2002).

United States Environmental Protection Agency (US-EPA) (1988) categorized air pollution sources into natural and man-made activities. Natural sources include microbial activity, volcanoes, sulfur spring, and weathering processes, while man-made activities include fuel combustion of domestic and industries (Durst *et al*., 1991). Acid deposition is present in dry and wet conditions. Dry deposition refers to the precipitation of air pollutants to the environment in the form of saturated gases or particles. While mixing of acidic pollutants with water vapor in the atmosphere produces wet deposition and falls as rain, snow and fog (Zelles *et al*., 1987). Increasing trend of SO_2 and NO_X were observed in most developed and developing countries. For example, the contribution of SO_2 in The United State increased from 9.5 to 10.2 million tons from 1995 to 2002 (NAPAP, 2005). For China and Thailand, SO_2 emission from 2000 to 2004 exceeded 4.5 parts/billion (ppb). During the same period, Mongolia, Russia, and Japan recorded less than 0.5 ppb of SO_2, while in Korea the value is 2 ppb. At Tanah Rata, Malaysia, the value for SO_2 is 0.752 ppb (EANET, 2006). Similar trend was reported in Malaysia where SO_2 and NO_X increase by about 23 % from 2001 to 2006 (MMD, 2008).

Wet or dry acid deposition may affect trees, soil and water bodies. Exposure of plants to rainwater pH values below 4 may cause adverse effects on growth through its effect on photosynthesis and respiration processes in the plants (Foy, 1984). Acid deposition might also reduce pH and increases the toxic elements such as aluminum (Al) and mercury (Hg) in the water bodies. This is dangerous both to animals and aquatic organisms (Charlson *et al*., 1987).

The absorption of acidic rainwater causes acidification in soil systems due to increase of H ions in soils. Accumulation of free H ions leads to increase of heavy metal solubility and Al mobilization (Michopoulos, 1999). In this case, soils become more acidic and less fertile due to leaching of nutrients. As a result, most of the plants do not get sufficient nutrients for their growth (Seip *et al*., 1999).

According to MMD (2008), from 1994 to 2008, some cities located in west Peninsular Malaysia received rainwater pH of below 5.6 and this has been attributed to industrialization and transportation. In addition, the burning of agricultural wastes and excessive use of ammonia fertilizers also contribute to the problem. Therefore, there is a need to conduct a research on the effect of acid deposition in Malaysia.

The objectives of this research are to: 1) investigate the selected chemical characteristics of the rainwater and deposition rate, 2) determine the effects of Simulated Acid Rain (SAR) on the growth of Meranti melantai (*Shorea macroptera*) and Kelampu (*Sandoricum koetjape*), 3) determine the effect of simulated acid rain (SAR) on the availability of selected nutrients in the soil and 4) quantify the amounts of ions in the different stand age of a rehabilitated forest.

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LIST OF PUBLICATIONS

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