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Reduction of Ammonia Volatilization Loss from BRIS Soils Using Controlled Release Urea and Palm Oil Mill Effluent (POME)

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Abstract

This study was conducted to investigate the effect of POME application on reducing ammonia volatilization loss using formulated control release urea (CRU) fertilizers. Ammonia volatilization loss was measured using modified force-draft technique to evaluate its effect via application of palm oil mill effluent (POME). Three type of BRIS soils; Melawi, Rudua, and Rhu Tapai were used under controlled laboratory condition with soil moisture maintained at 40 %. Application of typical urea and three (3) types of formulated control release urea fertilizers; Meister-20, CR Duration type V, and CDU Uber-10 at the rate of 400 µg/g were used *en masse*. Whilst, the application of POME was set at 100 kg/ha of dried POME. Ammonia volatilization loss was recorded on daily basis for a period of two weeks. Results indicated that, the combination of POME and urea shows the best reduction of NH_3 at 83.6 % compared to without POME inclusions. The CRU fertilizers and incorporation of soil with POME in general shows best effect in reducing NH_3 loss.

Keywords: Ammonia volatilization loss, BRIS soils, Controlled release urea, Palm oil mill effluent (POME), Modified force-draft technique.

1. Introduction

Urea is a widely accepted source of nitrogen used in modern agriculture [10]. However, its usage leads to ammonia (NH_3) loss via volatilization especially when applied onto soil surfaces or under redox condition [19] [4]. With the price of urea fertilizer has been skyrockets over the years, these potentially incurred higher cost in plantation sectors [4]. As that, the use of CRU is an excellent alternatives to replace typical urea due to its ability to release N in timely manner. More than 40% of N loss as ammonia (NH_3) when urea applied onto the soil, but only 10 to 14% of N loss using formulated urea fertilizers [16] [11].

In 2004, more than 40 million tons of Palm Oil Mill Effluent (POME) was generated from 372 mills across the Malaysia which numbers gradually increase by years. As that, disposal of POME become one of the critical issues to be managed [14] [24]. At the same time, soil water holding capacity, organic carbon and total N can be improved via incorporation of POME into the soil [15]. Therefore, recycling of POME as soil amendment holds promising prospects for sustainable agricultural practices.

Beach Ridges Interspersed with Swales (BRIS) is a landscape or geomorphology reference of soil contains more than 90% of sand composition, low clay, organic matter and cation exchange capacity (CEC) sites. Therefore, nutrient application on the BRIS soils can be easily leached out, especially during raining season. Suitable land management practices need to be employed in order to improve its BRIS soil properties as well as

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alleviating agriculture productivity.Such practices such asmulching with organic materials potentially to improve CEC values of soil [17]. Since the BRIS soil is less fertile, application of CRUs and POME are suitable options to reduce N loss. Thus, this study was conducted to investigate the effect of POME application on reducing ammonia volatilization loss along with formulated CRUs on the BRIS soils.

2. Material and Methods

Experimental site and design: The experiments were conducted in 2013 at Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia (2.983731, 101.734890). Both of the experiments were designed in completely randomized design (CRD).

Experimental condition: The experiments were divided into 2 parts:- 1) CRUs formulation and, 2) ammonia loss with incorporation of POME and CRUs.

Fertilizers Characterization: Characteristics and appearance of the fertilizers were determined through visual observation and references from manufacturers (Table 3). Whilst, samples of CRUs were examined for the thickness of the coating material. The CRU fertilizers were placed on the slide, treated with ammonia oxalate and sputtered with a very thin layer of gold for 3 min using a sputter coater [20]. The samples were then viewed under scanned electron microscope (SEM) with the magnification ranges from 25x-500x (Plate 1). For the percentage of coating materials, 10 g of fertilizers were weighed in a 250 mL beaker. The fertilizers were crushed until coatings were disintegrated. 100 and 75 mL of distilled water was added and left for 24 hours at room temperature. The insoluble coating materials were washed and placed on the crucibles. Then, the crucibles were transferred to an oven set at 50ºC and dried until constant weight was recorded [5].

$$\textit{Percentage of coating}\ (\%) = [(w_1/w_2) \times 100]\ \text{-------}\ \textit{Equation 1}$$

where,

w_1 = weight of solid (g)

w_2 = weight of coated urea (g)

Ammonia volatilization patterns on BRIS Soils: Three types of BRIS soils were used in this study; Melawi, Rudua and Rhu Tapai Series. Melawi series (*Aquic Dystropept*) was obtained from Bachok, Kelantan, Malaysia. Whilst, the Rudua (*Arenic Tropohumod*) and Rhu Tapai (*Typic Haplotox*) series were obtained from Setiu, Terengganu, Malaysia (Table 1).

Table 1. Selected physical properties of the soils used

Soil Series	Clay	Silt	Sand				Total Sand
			Very fine sand	Fine sand%	Medium sand	Coarse sand	
Melawi(*AquicDystropept*)	--	3.40	16.24	63.03	17.10	0.25	96.62
Rudua(*ArenicTropohumod*)	--	0.50	0.35	6.81	25.59	66.69	99.45
RhuTapai(*TypicHaplotox*)	--	1.00	0.95	8.62	42.54	46.78	98.88

--= not indicated

The soils were air-dried, ground, and sieved through 2-mm size, labelled and kept in a self-adhesive plastic bags for characterization. Particle size distribution for physical properties determination was analyzed [5].The chemical analyses were performed as follows: soil pH (1:2.5), carbon and nitrogen using LECO CNS Analyzer, exchangeable cations potassium (K), calcium (Ca) and magnesium (Mg) was conducted using 1N NH_4OAc at pH 7 [21], and mineral–N (NH_4-N and NO_3-N) by steam distillation method [2].

The incubation study was conducted in completely randomized design (CRD) with three replications for two weeks. The treatments were three control release urea fertilizers (Meister-20, Duration type v, Uber-10), and typical urea (control) applied at the rate of 400 µg/g on the surface. At the same time, another sets of experiment were conducted by mixing dried POME at 100 kg/ha accordingly. Loss of ammonia was determined using the modified force-draft technique [8]. Three hundred grams of soil was weighed and placed into 500 ml Erlenmeyer flask. The NH_3 gas produced was collected in 250 ml flask contained with 10 ml of boric acid containing mixed indicators (bromocresol green and methyl red). The NH_3 loss was determined daily by titration with standard hydrochloric acid (HCl) for a period of two weeks.

The characteristics of POME used as shown in Table 2.

Table 2. Selected chemical properties of POME

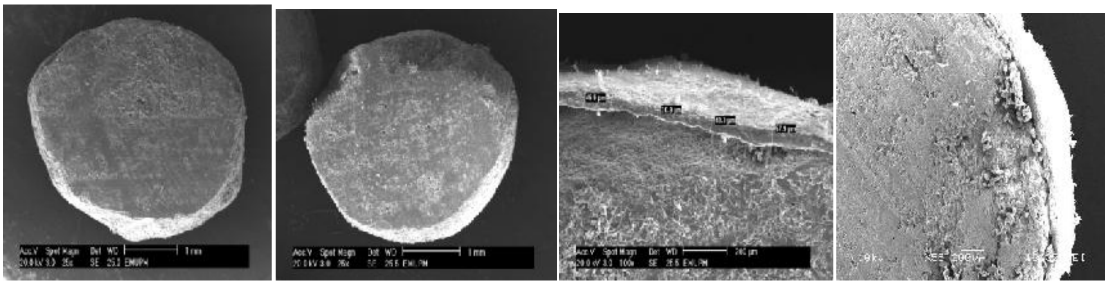
pH (1:2.5)	5.22
Carbon (%)	35.35
Nitrogen (%)	2.51
Phosphorus (%)	1.02
Potassium (%)	2.51
Calcium (%)	1.58
Magnesium (%)	1.22

Statistical analysis: Data analysis was carried out using SAS Statistical package 9.4 (SAS Institute Inc., Cary, NC, USA). When ANOVA for the interaction parameters was significant, means separation was carried out using HSD test.

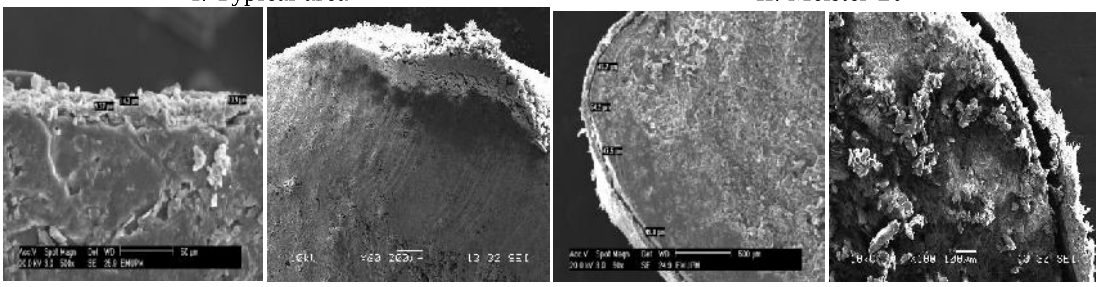
3. Results and Discussion

3.1. CRUs formulation and properties

The description of the typical urea and formulated CRUs were presented in Table 3. The thickness of the coating was indicated by the outer layer of the fertilizer granule according to SEM photograph (Plate 1). Based on the results, the Meister-20 was the thickest (59.8µm) and followed by CR Duration type V (22.3 µm). No coating were found in typical urea and CDU Uber-10.



I: Typical urea II: Meister-20



III: CR Duration Type-V IV: CDU Uber-10

Plate 1: SEM micrograph of typical urea and formulated CRUs

Table 3: Appearance of fertilizers as formulated

Fertilizers	Characteristics
Typical urea, *46% N*	Organic and non-electrolyte solid and produced through the reaction of ammonia and carbon dioxide at high pressure and temperature in between 132ºC-182ºC.
Meister-20, *40% N*	A solid polymer (polyolefin and inorganic powder) coated granulated urea and with a diameter of about 2-4 mm. The coating film is 50-60 µm in thickness and 10% in weight. Release intervals within 200 days.
CR Duration type V, *43% N*	An insoluble polymer coating with release duration approximately150-180 days.
CDU Uber-10, *30% N*	A solid crotonylidene diurea which releases ammonia by microbial and chemical processes for short period after application.Non-hygroscopic and less soluble in water.

Variations in the coating materials recorded were due to the polymerization, inherent properties as well asdifferent structures of each polymer used. As the thicknesses vary, release patterns occur sooner in some granules whilst later for others, resulting in gradual release pattern [7] [9]. For example, Meister-20 was encapsulated in a polymer coating; the thickness can be altered to maximize the release in various environmental conditions [7] [22].

Highest coating percentage was found in Meister-20 (10.53%) followed by CR Duration type V (6.69%) fertilizers. No coatings were found in typical urea and CDU Uber-10 respectively. Usage of coating CRUs should be recommended to improve efficiency of urea utilization [12].

3.2. CRUs and POME on ammonia loss reductions

Typical granular urea produced higher NH_4 loss in percentage than formulated CRUs under 3 different BRIS soil series (Figure 1-3). Nitrogen from CRUscan only be released upon broken sealant or diffusion through coating pores [19] [4]. The CRU fertilizers were lower in NH_4 loss show low nitrification in soil as well as ammonia volatilization.

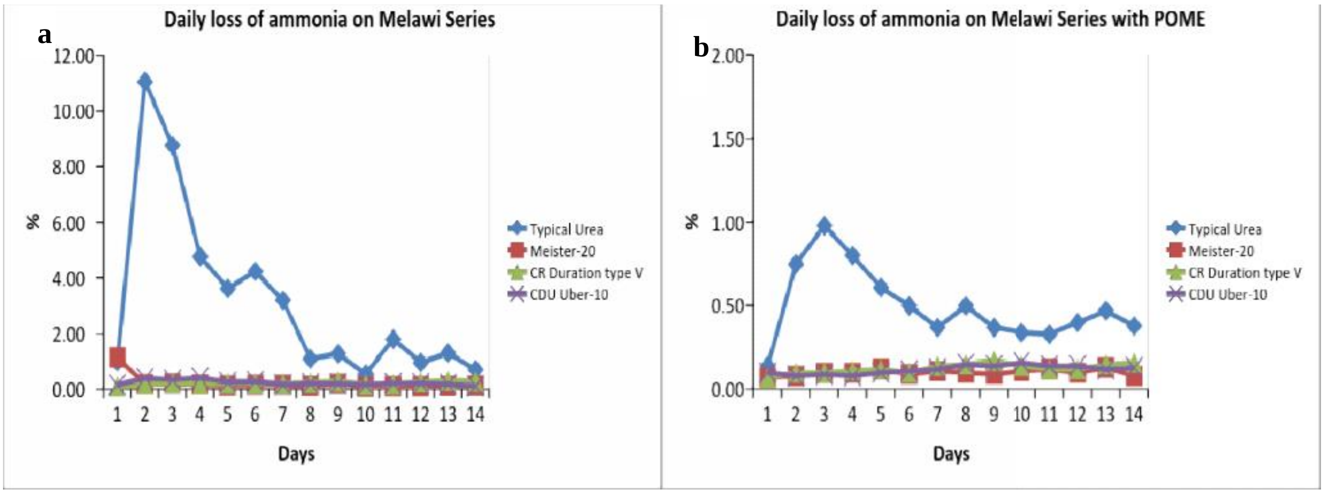


Figure 1: Daily loss of NH_3 in Melawi series BRIS soil: a) without POME and b) with POME

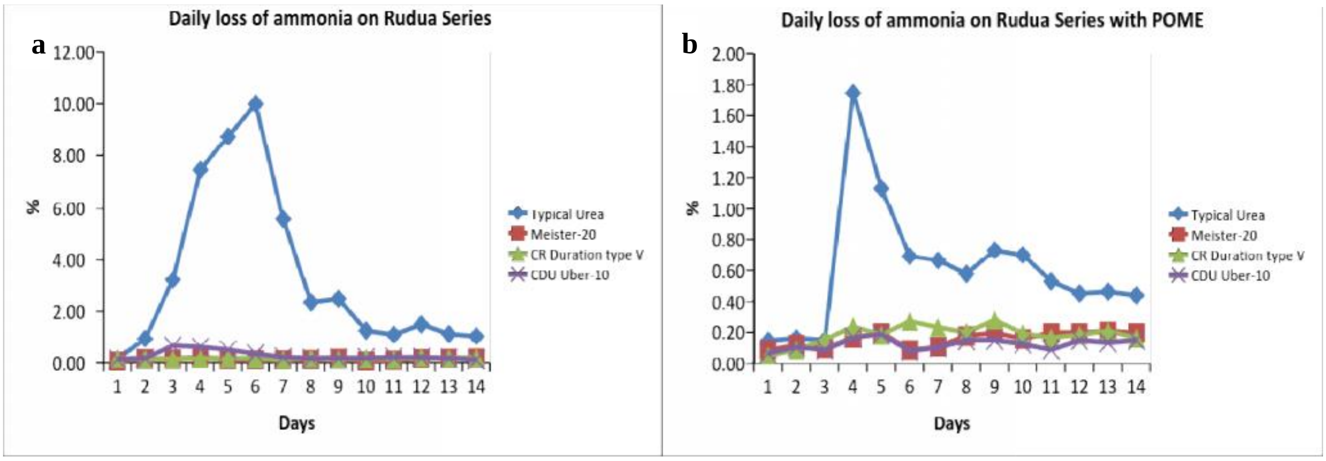


Figure 2: Daily loss of NH_3 in Rudua series BRIS soil: a) without POME and b) with POME

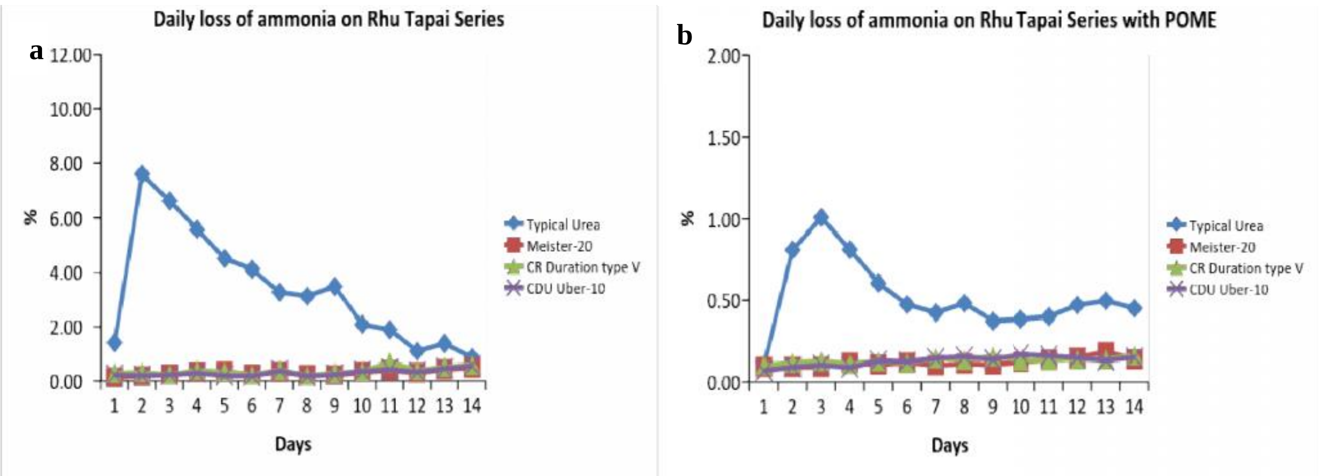


Figure 3: Daily loss of NH_3 in Rhu Tapai series BRIS soil: a) without POME and b) with POME

Daily loss of ammonia after 14 days of incubation were described according to soil series (Figure 1-3). Most of the loss occurred during the first six (6) days of incubation. Typical urea fertilizer had the highest ammonia loss in all soil series whether with or without application of POME as it is easily to be hydrolyzed within days of application [19] [4].

Table 4. Total NH_3 volatilization loss in percentage.

Treatment	Soil: Melawi	Soil: Rudua	Soil: Rhu Tapai	Mean
	NH_3 Loss %			
POME + Urea	6.90	8.60	7.30	7.60b
POME + Meister-20	1.40	2.20	1.70	1.77c
POME + CR Duration type V	1.80	2.70	1.90	2.13c
POME + CDU Uber-10	1.70	1.80	1.80	1.77c
Urea	44.95	46.96	47.04	46.32a
Meister-20	3.00	2.00	4.30	3.10c
CR Duration type V	3.10	2.40	5.40	3.63c
CDU Uber-10	3.30	4.00	4.40	3.90c
Mean	**8.53A**	**8.83A**	**8.97A**	

Means with the same letter are not significantly different according to Tukey's test at $p \leq 0.05$

For the Melawi series, POME application shown maximum volatilization on 3rd day after application at 0.98 %. Without POME inclusion the highest amounts occurred on day 2 at 11.07 %. Similar trends were observed for Rudua series, with POME application highest loss recorded on the 4th day (1.75 %) and 6th day (10.00 %) without POME. Whilst, for Rhu Tapai series typical urea had the maximum loss with POME application at 1.01% on 3rd day but without POME 7.61 % loss were observed on 2nd day. In all BRIS soil series, formulated CRUs fertilizerssignificantly reduced NH_3 loss compared to typical granular urea with and without POME (Table 4).

Formulated CRUs and incorporation of POME significantly affects the NH_3 loss compared with only typical urea application. The inclusions of POME adding extra Ca and Mg micronutrients to the soil, reducing NH_3 volatilization loss with extra cation exchange capacity sites[15] [23]. Higher availability of cation exchange sites stabilized the NH_3 releases. Similarly, elevated soil moisture derived from POME potentially to acts like spongy to retain water in soil as well as nutrients sites [15] [17] [3].

4. Conclusions

The formulated CRUs shows better properties to control the nitrogen releases in compared with typical urea. In addition, inclusions of POME in soil with these formulated CRUs portrayeda better pattern in mitigating NH_3 loss.

5. Acknowledgements

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