
**UNIVERSITI PUTRA MALAYSIA**

# *AMMONIA VOLATILIZATION AND PHYSIOLOGICAL GROWTH OF MR219 RICE VARIETY UNDER SPLIT UREA FERTILIZATION AND CHICKEN LITTER BIOCHAR AMENDMENT ON TROPICAL ACID SOIL*

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By

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

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Ammonia volatilization from nitrogenous fertilizers such as urea is high especially in paddy fields due to the anaerobic condition. This also leads to inefficient utilization of N in paddy fields thereby increasing the cost of rice production. Approximately, 40% of all soluble N applied to soils are lost *via* ammonification, denitrification, and leaching. The split application of N recommended by Muda Agriculture Development Authority (MADA), Malaysia indicates that N absorption in rice plants at different stages affects the concentration of $NH_4^+$ in the soil solution and this might also affect the amount of $NH_3$ emitted in rice production. Clinoptilolite zeolite, coating urea, and soil organic amendments such as composts and biochars are used to minimize ammonia volatilization and in turn increases N used efficiency in rice production. Because of the surface charges (negative charges due to presence of -OH functional group) of chicken litter biochar, to improve soil CEC, texture, cations, anions and plants N uptake apart from minimizing ammonia loss from split application of urea.

The specific objectives of this study were to determine the effects of split application of urea on: (i) on ammonia volatilization and selected physico-chemical properties of a tropical acid soil amended with chicken litter biochar for 111 days and (ii) on selected growth variables and N uptake up of MR219 cultivation on a tropical acid soil amended with chicken litter biochar. Treatments evaluated were: (i) T1, soil only, (ii) T2, existing recommended fertilization, (iii) T3, biochar alone, and (iv) T4, biochar + existing recommended fertilization in both pot and field trials. Ammonia volatilization were evaluated during incubation period in pot study and field trial for N uptake by plant was observes the changes in plants N uptake and soil N from the split urea application. Three replicates of each treatments in ammonia volatilization was arranged using Complete Randomized Design. In the field study, four replicates of each treatments arranged using Randomized Complete Block Design were evaluated in the field. Selected soil physico-chemical properties and rice plant tissues were analyzed using standard procedures.

The results on ammonia volatilization study revealed that the highest daily release of ammonia released was 8.22% and this emission is lower than the 11% to 10% and losses

reported in the literature. Ammonia emission from the recommended fertilization was higher after third and fourth fertilizations. In this study, the chicken litter biochar reduces ammonia loss from day 70 to day 111 compared with that of the conventioal method. The acidity of the soils with chicken litter biochar were significantly lower than that of soil only. Considering the fertilization schedule of rice, ammonia emissions in rice production could be minimized if acidic soils under paddy cultivation are amended with chicken litter biochar.

A further study into the N uptake and N use efficiency of the split fertilization showed that chicken litter biochar generally increased N uptake as compared with the conventional method. The N uptake increased after first, second, and third fertilizations after which the uptake significantly decreased because the rice plants were at panicle heading stages and most of the N was translocated for grain filling. Application of chicken litter biochar significantly increased Crop Recovery Efficiency and Agronomic Recovery Efficiency of applied N than in the conventional method. The Crop Recovery Efficiency started to decrease 40 days of transplanting of rice seedlings followed by rapid decrease in Crop Recovery Efficiency until 70 days after transplanting. The highest Agronomic Recovery Efficiency occurred on day 70 after which it significantly declined until 90 day. This was because of the translocation of most nutrients into rice grains production. The growth variables and yield of MR219 at harvest showed that plants height, number panicles, and grain yield of T4 were significantly higher than those of T1, T2, and T3 whereas those of T2 and T3 were similar but significantly higher than that of T1. Co-application of chicken litter biochar and chemical fertilizers increased rice grain yield of T4 to approximately 11.04 t $ha^{-1}$ compared with the conventional method (T2) which yielded approximately 5.91 t $ha^{-1}$. This indicates that the split fertilization of N should be increasing with increasing days of rice plants growth.

The findings of this present study suggest that, applying 41.67% and 30.03% of N fertilization after 15 and 35 days of transplanting, respectively is not recommended especially for soils on which the conventional rice cultivation is practiced. Rather, the 41.67%, 30.03%, 14.15%, and 14.15% of total N recommended by MADA to be applied on the 15, 35, 55, and 75 days after transplanting could be modified to 26.67%, 30.03%, 30.15%, and 14.15% of total N on the 10, 30, 50, and 70 days after transplanting respectively, to further increase the rice plants N uptake, Crop Recovery Efficiency, Agronomic Recovery Efficiency, and rice grain yield.

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

**PENGUAPAN AMMONIA DAN FISIOLOGIKAL PERTUMBUHAN BERAS VARIATI MR219 DIBAWAH PEMBAJAAN UREA BERKALA DAN PEMBAIKPULIHAN MENGGUNAKAN BIOCHAR TINJA AYAM PADA TANAH ASID TROPIKAL**

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Penguapan ammonia daripada baja nitrogen seperti urea adalah sangat tinggi terutama dalam ladang padi disebabkan oleh keadaan anaerob. Ini juga membawa kepada penggunaan N di ladang penanaman padi yang tidak cekap dan juga meningkatkan kos pengeluaran bijiran beras. Sekurang-kurangnya, 40% daripada semua larut N yang digunakan di tanah hilang melalui ammonifikasi, denitrifikasi, dan larut lesap. Aplikasi pembajaan N yang disyorkan oleh Lembaga Kemajuan Pertanian Muda (MADA), Malaysia menunjukkan bahawa penyerapan N pada tanaman padi pada peringkat yang berbeza mempengaruhi kepekatan $NH_4^+$ dalam larutan tanah dan ini juga dapat mempengaruhi jumlah $NH_3$ yang dibebaskan dalam jangka masa penghasilan beras. Salutan zeolit klinoptilolit, salutan urea, dan pembaikpulihan organik tanah seperti kompos dan biochar digunakan untuk mengurangkan volatilisasi ammonia dan seterusnya meningkatkan kecekapan penggunaan N dalam penghasilan dan pengeluaran beras. Disebabkan permukaan (cas negatif disebabkan oleh kehadiran kumpulan fungsi -OH) biochar tinja ayam yang mempunyai cas-cas tertentu, penambahbaik organik ini digunakan di dalam kajian, bagi meningkatkan CEC di dalam tanah, tekstur, kation, anion dan penyerapan N pada tumbuhan selain meminimumkan penguapan ammonia daripada peringkat pembajaan urea.

Objektif khusus kajian ini adalah untuk menentukan kesan penguraian urea terhadap: (i) penguraian ammonia dan sifat fizikokimia yang terpilih pada tanah asid tropika yang diletakkan dengan biochar tinja ayam selama 111 hari dan (ii) pemboleh ubah tumbesaran yang terpilih dan penyerapan N pada penanaman MR219 pada tanah asid tropika yang diletak dengan biochar tinja ayam. Rawatan yang dinilai ialah: (i) T1, tanah sahaja, (ii) T2, pembajaan sedia ada yang disyorkan, (iii) T3, biochar sahaja, dan (iv) T4, biochar + pembajaan sedia ada yang disyorkan didalam kedua-dua ujian inkubasi dalam kajian pasu dan lapangan. Penguapan ammonia dinilai semasa tempoh inkubasi dalam percubaan kajian pasu dan lapangan bagi daya serap N oleh tumbuhan dan memerperhatikan perubahan daya serap N pada tumbuhan dan N pada tanah daripada pembajaan urea berkala. Tiga replikasi setiap rawatan pada penguapan ammonia telah disusun dengan menggunakan reka bentuk lengkap rawak (CRD). Dalam kajian

lapangan, terdapat empat replikasi setiap rawatan menggunakan reka bentuk blok lengkap rawak (RCBD) adalah dinilai pada kajian lapangan. Sifat-sifat terpilih fizikokimia tanah dan tisu tanaman padi yang dipilih untuk dianalisis menggunakan prosedur piawai.
Hasil kajian penguapan ammonia menunjukkan bahawa pelepasan ammonia pada harian tertinggi yang dibebaskan ialah 8.22% dan pelepasan ini lebih rendah daripada 11% hingga 10% dari yang dilaporkan dalam literatur. Pelepasan ammonia daripada pembajaan yang disyorkan adalah lebih tinggi setelah pembajaan yang ketiga dan keempat. Dalam kajian ini, biochar tinja ayam mengurangkan kehilangan ammonia dari hari ke 70 hingga ke hari 111 berbanding dengan kaedah konventional. Keasidan pada tanah dengan biochar tinja ayam jauh lebih rendah berbanding dengan tanah sahaja. Dengan mengambil kira jadual pembajaan dalam pengeluaran bijiran beras, penguapan ammonia dalam pengeluaran beras boleh diminimumkan jika keacidan tanah dibawah penanaman padi diletakkan bersama dengan biochar tinja ayam.

Kajian yang lebih lanjut terhadap penyerapan N dan kecekapan penggunaan N dalam pembajaan secara berperingkat menunjukkan bahawa biochar tinja ayam secara amnya meningkatkan daya serapan N pada tumbuhan berbanding dengan kaedah konvensional. Pengambilan N meningkat selepas pembajaan peringkat pertama, kedua dan ketiga selepas penyerapan nutrisi berkurangan dengan ketara kerana tanaman padi berada di peringkat penghasilan panikel dan sebahagian besar N dialihkan untuk penghasilan dan pengisian bijirin. Aplikasi penggunaan biochar tinja ayam meningkat dengan ketara dalam Kecekapan Pemulihan Tanaman dan Pemulihan Agronomi Kecekapan apabila N yang digunakan daripada kaedah konvensional. Kecekapan Pemulihan Tanaman mula menurun pada hari ke 40 selepas pemindahan anak benih padi diikuti dengan penurunan pesat dalam Kecekapan Pemulihan Tanaman sehingga 70 hari selepas pemindahan. Kecekapan Pemulihan Agronomik tertinggi berlaku pada hari 70 selepas itu ketara menurun sehingga 90 hari. Ini adalah kerana kebanyakannya translokasi nutrien ke dalam penghasilan bijiran beras. Pemboleh ubah pertumbuhan dan hasil MR219 pada musim menuai menunjukkan bahawa ketinggian tumbuhan, bilangan panikel, dan hasil bijirin T4 jauh lebih tinggi daripada T1, T2, dan T3 manakala T2 dan T3 adalah sama tetapi lebih tinggi daripada T1. Penggunaan bersama biochar tinja ayam dan baja kimia menaikkan hasil bijirin beras (T4) kepada lebih kurang 11.04 t ha-1 berbanding dengan kaedah konvensional (T2) yang menghasilkan kira-kira 5.91 t ha-1. Ini menunjukkan bahawa pembajaan N perlu ditambah dengan peningkatan hari pertumbuhan pada tumbuhan padi.

Hasil kajian ini menunjukkan bahawa, penggunaan 41.67% dan 30.03% daripada pembajaan N selepas 15 dan 35 hari pemindahan, masing-masing tidak digalakkan terutamanya bagi tanah di mana penanaman padi konvensional dipraktikkan. Sebaliknya, sebanyak 41.67%, 30.03%, 14.15%, dan 14.15% daripada jumlah N yang disyorkan oleh MADA untuk digunakan pada 15, 35, 55 dan 75 hari selepas pemindahan boleh diubah kepada 26.67%, 30.03%, 30.15% dan 14.15% daripada jumlah N pada 10, 30, 50 dan 70 hari selepas pemindahan, untuk meningkatkan lagi kecekapan penyerapan N terhadap tanaman padi, Kecekapan Pemulihan Tanaman, Kecekapan Pemulihan Agronomi dan hasil bijirin beras.

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| | |
|---|---|
| AAS | Atomic Absorption Spectrometry |
| $AE_N$ | Agronomic Efficiency of the applied N |
| Al:Ca | Aluminium per Calcium |
| ANOVA | Analysis of variance |
| C:N | Carbon per Nitrogen |
| CEC | Cation Exchange Capacity |
| CRD | Complete Randomized Design |
| DMY | Dry Matter Yield |
| FAO | Food and Agriculture Organization |
| KCl | Potassium chloride |
| $K_{up}$ | Potassium uptake |
| MADA | Muda Agricultural Development Authority |
| MgO | Magnesium Oxide |
| MOP | Muriate of Potash |
| $NH_4^+$ | Ammonium ions |
| $NO_3^-$ | Nitrate |
| $N_{up}$ | Nitrogen uptake |
| OM | Organic matter |
| $P_{up}$ | Phosphorus uptake |
| RC | Research Complex |
| $RE_N$ | Crop Recovery of applied N |
| TOM | Total Organic Matter |
| UAN | Urea-ammonium nitrate |

# CHAPTER 1

# INTRODUCTION

## 1.1 General introduction

Rice (*Oryza sativa* L.) is one of the most consumed grain crops in the world although it requires significant nitrogen fertilization for optimum yield (Linquist *et al*., 2015). The global nitrogen fertilizer demand increased from 3.7%, 5.4%, 6.9%, and 8.8% in 2014, 2015, 2016, and 2017 respectively, and it was expected to reach 9.5% by the end of 2018 (FAO, 2015; Tei *et al*., 2017). Approximately, 40% of all soluble N applied to soils are lost *via* ammonification, denitrification, and leaching (Liang *et al*., 2011). Although calcium ammonium nitrate and ammonium sulphate are used in crop production, granular urea is the most used N fertilizer in the world (Basosi *et al*., 2014). Inspite of urea being prone to ammonia volatilization, out of the 190 million tons of the yearly production of urea, approximately 80% is used in crop production especially in rice cultivation (Basosi *et al*., 2014). This also leads to inefficient utilization of N in paddy fields thereby increasing the cost of rice production. Althought there is growing concern for ammonia loss in agriculture, the use of urea continues to be a topic of considerable scientific debate as it pollutes the environment.

The agriculture sector accounts for about 17% of the world total ammonia emission and China account for about 36% of the total ammonia emission from agriculture sector (Huang *et al*., 2012; Hou *et al*., 2016; Kang *et al*., 2016). Shan *et al*. (2016) showed that ammonification of applied N fertilizers are the predominant pathways in lowland rice production. However, Ahmed *et al*. (2010) and Palanivell *et al*. (2016) used Clinoptilolite zeolite to mitigate ammonia volatilization from soils applied with urea however, there is limited accessibility of good Clinoptilolite zeolite. The invention of coating urea with humic acids which had been reported by Ahmed *et al*. (2010) to significantly minimize urea loss through ammonia volatilization is expensive innovation for farmers to adopt. Because of the limitations associated with the afore-stated inventions, the use of soil organic amendments such as biochar to mitigate ammonia lost were in this present study employed.

Biochar is produced by the combustion of biomass under no oxygen or oxygen-limited conditions and is useful in agriculture due to conditions under which it is produced. The organic biomass used to produce biochar are heated at a particular temperature to optimize characteristics such as high surface area, ability to persist in soils with very little biological decay, and low amounts of residual resins (Lehmann *et al*., 2006). These charges enable sorption of ammonium ions thereby mitigating the ions from being converted to ammonia (Rondon *et al*., 2006). This observation had been reported by Palanivell *et al*. (2017) where chicken litter biochar was used to minimize ammonia loss from a waterlogged acid soil. However, most of the studies on ammonia volatilization cited previously especially that of Palanivell *et al*. (2017) were conducted within 30 to 42 days and the fertilization which was based on rice MR219 was pooled and applied on the first day of the incubation. These practices might lead to over estimation of the

ammonia volatilized due to escessive N application. In this study, it was assumed that pooling all the four-time N application will lead to over estimation of ammonia loss and the build-up of fertilization effect on ammonia loss cannot be observed. Therefore, need to determine build-up effect of split N application for MR219 following urea application for MR219 (0.55 g, 0.40 g, 0.18 g, and 0.18 g per hill on days 15, 35, 55, and 75, respectively) (MADA, 2015).

Although measuring of ammonia loss using a closed dynamic air flow system is relatively accurate, this system of measurement does not account nutrients uptake by plants. This was because the closed dynamic air flow system cannot support plant growth whilst measuring emitted ammonia from the soil. In this study, the nitrogen uptake of the rice plant and those of the soil were determined in order to relate them to those of ammonia lost throughtout the 111 days growing period of MR219. Plant growth variables such as plant height (Paramasivan and Sreerangaswamy, 1988; Poorter *et al*., 2016), tiller number (Craigmeles *et al.*, 1968; Kim *et al*., 2011), root growth (Sahai and Chaudhary, 1986; Chauhan and Johnson, 2010; Barison and Uphoff, 2011), and dry matter production (Balanco *et al.*,1990; de Melo Carvalho *et al*., 2013) depends on the amount of nutrients especially N absorbed by the rice plants. Improved root growth improves utilization of applied nitrogenous fertilizer and this leads to reduction in the amount of ammonia released during rice growth.

The split application of N recommended by MADA (2015) was because the rice plants have stronger and more active root system although this varies with the age of rice plants. This indicates that N absorption in rice plants at different stages affects the concentration of $NH_4^+$ in the soil solution (Craine *et al*., 2015) such that, the amount of $NH_3$ emitted is affected. The vegetative growth variables such as tillers, panicle weight, panicle length, fertile spikelets, test weight, and harvest index of rice hills directly influence the amount of N uptake (IRRI, 1984; Lokprakash *et al.*, 1992). This might also affect the amount of $NH_3$ emitted in rice production. Recent studies showed that the use of soil organic amendments in the cultivation of hybrid rice significantly increased N use efficiency. Studies by Palanivell *et al*. (2015) and Maru *et al*. (2015) on tropical acid soil using chicken litter biochar significantly increased rice vegetative growth variables and yield of MR219 (Malaysia hybrid rice). However, the study of the afore-cited authors study could not explain the stages at which nutrients especially N are efficiently used: Additionally, it was also assumed that, effective and efficient N uptake of MR219 rice plants would reduce N losses in the form of ammonia gas.

## 1.2 General objectives

The general objectives of this study were to determine:

i. Effects of split urea application on ammonia volatilization from a tropical acid soil amended with chicken litter biochar.
ii. The effects of split urea application on selected growth variables and N uptake up of MR219 cultivation on a tropical acid soil amended with chicken litter biochar.

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