UNIVERSITI PUTRA MALAYSIA

CO-APPLICATION OF BIOCHAR AND UREA TO IMPROVE NUTRIENT USE EFFICIENCY AND YIELD OF Oryza sativa L. IN TROPICAL ACID SOIL

ALI MARU

FSPM 2015 4

CO-APPLICATION OF BIOCHAR AND UREA TO IMPROVE NUTRIENTS USE EFFICIENCY AND YIELD OF *Oryza sativa* L. IN TROPICAL ACID SOIL

By

ALI MARU

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

June 2015

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

CO-APPLICATION OF BIOCHAR AND UREA TO IMPROVE NUTRIENTS USE EFFICIENCY AND DRY MATTER YIELD OF *Oryza sativa* L. IN TROPICAL ACID SOIL

By

ALI MARU

June 2015

Chairman : Assoc. Prof. Ahmed Osumanu Haruna, PhD
Faculty : Agriculture and Food Sciences

Excessive use of nitrogen (N) fertilizer in sustaining high rice yields due N dynamics in tropical acid soils has necessitated the exploitation of nutrients addition and retention properties of organic amendment such as chicken litter biochar to increase lowland rice yield and to also reduce N fertilization by improving soil nutrients availability and plant nutrients use efficiency. Biochar (5 t ha^{-1}) and different rates of urea (100%, 75%, 50%, 25% and 0%) only were evaluated in pot and field trials. Selected soil and rice plants physicochemical properties were analyzed using standard procedures. Dielectric response of the soil samples at 20, 40, 55, and 75 days after transplanting of rice plants were determined using an inductance-capacitance-resistance meter HIOKI 3522-50 LCR HiTESTER.

Soil nutrients availability, plants nutrients uptake, nutrients use efficiency, crop recovery and agronomic efficiency of applied N, and dry matter yield in the pot and field trials were significantly increased due to co-application of urea with biochar. This was confirmed by the magnitude, shape, and pattern of spectral response of dielectric conductivity and permitivity. Biochar and N rates stimulated the availability of other nutrients especially available P and K. Grain yield of co-application of biochar with 75% urea of the first and second cycles (7.56 t ha^{-1} and 9.06 t ha^{-1}) were 44.31% and 44.37%, respectively, higher than that of recommended fertilization (4.21 t ha^{-1} and 5.04 t ha^{-1}). However, the grain yield of co-application of biochar with 100% urea and co-application of biochar with 75% urea in the field trials were not significantly different although co-application of biochar with 100% urea had 25% more N fertilization than that of co-application of biochar with 75% urea indicating that, biochar can be used to improve grain yield and as well as reducing N fertilization in rice cultivation on tropical acid soils. Yield of co-application of biochar with 75% urea was higher due to the differences in number of panicles as a result of the effect of biochar on nutrient availability and N use efficiency.

Dielectric conductivity and permitivity of soil samples measured before transplanting rice plants were higher than that of soil samples measured during the cultivation of the rice plants due to low moisture content of the soil samples. Dielectric conductivity of the soil samples was dependent on frequency and nutrients concentration in soil solution. Permitivity of the soil samples was inversely proportional to frequency but directly

proportional to N concentration in soil solution. The conductivity measured at 1000 Hz to 100000 Hz correlated positively with rice grain yield suggesting that dielectric measurement can be used to estimate rice yield and soil nutrients concentration. This study may only be applicable to tropical acid soils and will contribute to improvement in nutrients use efficiency as well as reducing usage of chemical fertilizers. The use of dielectric technology to measure soil nutrients especially N in rice fields contributes to efficient application and utilization of chemical fertilizers, however, further studies are required to establish a stronger correlation between conductivity and N concentration in rice fields.

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

PENGGUNAAN BERSAMA BIOCHAR DAN UREA UNTUK MENINGKATKAN KECEKAPAN PENGGUNAAN NUTRIEN DAN HASIL BERAT KERING *Oryza sativa* L. DI TANAH ASID TROPIKA

Oleh

ALI MARU

Jun 2015

Pengerusi: Prof. Madya. Ahmed Osumanu Haruna, PhD
Fakulti: Fakulti Sains Pertanian dan Makanan

Penggunaan baja nitrogen (N) yang banyak dalam mengekalkan hasil padi yang tinggi disebabkan oleh dinamik N di dalam tanah berasid di kawasan tropika memerlukan eksploitasi penambahan dan ciri-ciri pengekalan nutrien penambahbaik organik seperti biochar tahi ayam untuk meningkatkan hasil padi tanah pamah dan juga mengurangkan pembajaan N dengan meningkatkan ketersediaan nutrien tanah dan kecekapan penggunaan nutrien tanaman. Biochar (5 t ha^{-1}) dan kadar urea yang berbeza (100%, 75%, 50%, 25% dan 0%) sahaja telah dinilai dalam kajian pasu dan lapangan. Sifat-sifat terpilih fizikokimia tanah dan tanaman padi telah dianalisis dengan menggunakan kaedah piawai. Tindakbalas dielektrik sampel tanah pada hari ke 20, 40 , 55, dan 75 selepas pengubahsuaian tanaman padi ditentukan dengan menggunakan meter aruhan - kapasitan - rintangan meter HIOKI 3522-50 LCR HiTESTER.

Ketersediaan nutrien tanah, pengambilan nutrien tanaman, kecekapan penggunaan nutrien, pemulihan tanaman dan kecekapan agronomi N yang dibekalkan dan hasil berat kering dalam kajian pasu dan lapangan telah meningkat secara bererti kerana penggunaan bersama urea dengan biochar. Ini telah disahkan oleh magnitud, bentuk, dan pola tindakbalas spektra kekonduksian dan ketelusan dielektrik. Kadar Biochar dan N telah merangsang kedapatan nutrien lain terutamanya P dan K tersedia. Hasil bijian dari penggunaan bersama biochar dengan 75% urea pada kitaran pertama dan kedua (7.56 t ha^{-1} dan 9.06 t ha^{-1}) adalah 44.31% dan 44.37%, masing-masing, lebih tinggi daripada pembajaan yang disyorkan (4.21 t ha^{-1} dan 5.04 t ha^{-1}). Walau bagaimanapun, hasil bijian penggunaan bersama biochar dengan urea 100% dan penggunaan bersama biochar dengan 75% urea dalam kajian lapangan tidak berbeza secara bererti walaupun penggunaan bersama biochar dengan urea 100% mempunyai kelebihan 25% N berbanding penggunaan bersama biochar dengan urea 75%. Ini menunjukkan bahawa, biochar boleh digunakan untuk meningkatkan hasil padi dan juga mengurangkan pembajaan N bagi tanaman padi di kawasan tanah asid tropika. Hasil penggunaan bersama biochar dengan 75% urea adalah lebih tinggi disebabkan oleh perbezaan dalam jumlah tangkai kesan biochar ke atas ketersediaan nutrien dan kecekapan penggunaan N.

Dielektrik kekonduksian dan ketelusan sampel tanah yang diukur sebelum pengubahsuaian tanaman padi adalah lebih tinggi berbanding dengan sampel tanah yang diukur semasa penanaman tanaman padi disebabkan oleh kandungan kelembapan yang

rendah di dalam sampel tanah. Dielektrik kekonduksian sampel tanah adalah bergantung kepada kekerapan dan kepekatan nutrien di dalam larutan tanah. Ketelusan sampel tanah adalah berkadar songsang terhadap kekerapan tetapi berkadar lansung dengan kepekatan N dalam larutan tanah. Kekonduksian yang diukur pada 1000 Hz hingga 100,000 Hz adalah berkorelasi secara positif dengan hasil bijian beras. Ini menunjukkan bahawa pengukuran dielektrik boleh digunakan untuk menganggarkan hasil padi dan kepekatan nutrien tanah. Kajian ini hanya boleh terpakai bagi tanah asid tropika dan lanya akan dapat menyumbang kepada peningkatan kecekapan penggunaan nutrien serta mengurangkan penggunaan baja kimia. Penggunaan teknologi dielektrik untuk mengukur nutrien tanah terutamanya N di sawah padi menyumbang kepada aplikasi dan penggunaan baja kimia yang berkesan walau bagaimanapun, kajian lanjut adalah diperlukan untuk mewujudkan hubungan yang lebih kukuh antara kekonduksian dan kepekatan N di kawasan sawah padi.

ACKNOWLEDGEMENTS

I thank Almighty Allah for his guidance and mercy on my life throughout my study. I wish to express my sincere and profound gratitude to my supervisor Assoc. Prof. Dr. Ahmed Osumanu Haruna for his help and understanding throughout my study. My deepest gratitude also goes to my co-supervisor Dr. Walter Charles Primus and all the Lecturers of the Department of Crop Science and Department of Basic Science and Engineering who in one way or the other contributed immensely to the success of this dissertation. I appreciate all the indispensable remarks, suggestions, and criticisms to make this thesis a successful one. My final appreciation also goes to the laboratory technicians of Soil Science laboratory and all my friends especially Palanivell Perumal who helped and encouraged me in one way or the other. All I have for you all is may Almighty Allah keep increasing you in knowledge.

I certify that a Thesis Examination Committee has met on 25th June, 2015 to conduct the final Examination of Maru Ali on his thesis entitled "Co-application of Biochar and Urea to Improve Nutrients use Efficiency and Yield of *Oryza sativa* L. in Tropical Acid Soil" in accordance with the Universities and University College 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.

Members of the Thesis Examination Committee were as follows:

Abu Hena Mustafa Kamal, PhD
Senior Lecturer
Faculty of Agriculture and Food Science
Universiti Putra Malaysia
(Chairman)

Susilawati Binti Kasim, PhD
Senior Lecturer
Faculty of Agriculture and Food Science
Universiti Putra Malaysia
(Internal Examiner)

Mohammed Selemat Bin Madom, PhD
Felo Utama
Faculty of Sustainable Agriculture
University Malaysia Sabah
Malaysia
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 August 2015

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

Ahmed Osumanu Haruna, PhD
Associate Professor
Faculty of Agriculture and Food Science
Universiti Putra Malaysia
(Chairman)

Walter Charles Primus, PhD
Senior Lecturer
Faculty of Agriculture and Food Science
Universiti Putra Malaysia
(Member)

BUJANG KIM HUAT, PhD
Professor and Dean
School of graduate studies
University Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other
- degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ________________________ Date: 29 October, 2015

Name and Matric No.: Maru Ali; GS38426

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature:	…………………..………………
Chairman of Supervisory Committee:	Ahmed Osumanu Haruna, PhD

Signature:	……………………………..
Member of Supervisory Committee:	Walter Charles Primus, PhD

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

φ_{atm}	Ionic atmosphere
AAS	Atomic Absorption Spectrometry
AC	Alternating current
AE_N	Agronomic Efficiency of the applied N
Al	Aluminium
Al:Ca	Aluminium per calcium
ANOVA	Analysis of variance
C	Carbon
C:N	Carbon per nitrogen
CEC	Cation exchange capacity
CRD	Complete Randomized Design
DC	Direct current
DMY	Dry matter yield
EPA	Environmental Protection Agency
ID	Internal diameter
K	Potassium
KCl	Potassium chloride
K_{up}	Potassium uptake
LCR	Inductance-capacitance-resistance
MADA	Muda Agricultural Development Authority
MgO	Magnesium oxide
MOP	Muriate of potash
N	Nitrogen
Na	Sodium
NH_4^+	Ammonium ions
NO_3^-	Nitrate
N_{up}	Nitrogen uptake
OM	Organic matter
P	Phosphorous
P_{up}	Phosphorus uptake
RC	Research Complex
RDW	Root dry weight
RE_N	Crop Recovery of applied N
TDR	Time domain reflectometry
TOM	Total organic matter
TSP	Triple superphosphate
UAN	Urea-ammonium nitrate
UNESCO	United Nations Organization for Education, Science and Culture
US	United State

CHAPTER 1

GENERAL INTRODUCTION

The global rice production is expected to increase in a stabilized manner up to 689.8 million tonnes in 2015 and 805.4 million tonnes by 2030 (FAO, 2000). Nitrogen fertilizers use is expected to increase in a stabilized way up to 21.3 million tonnes in 2015 and 23.6 million tonnes by 2030 (FAO, 2000), suggesting that N is an important nutrient in rice cultivation as it plays an essential role in sustaining high yield of crops (Peng *et al*., 2002; Yang *et al*., 2010). Nitrogen is generally applied to soils in large quantity (Murshedul *et al*., 2006; Singh *et al*., 2007; Kong *et al*., 2008) due to several N dynamics such as high demand of N by high yielding rice cultivars to achieve a desirable yield in modern agriculture (Zhu and Chen, 2002), chemical, biochemical, and microbial transformations of N in soils (Zhu and Chen, 2002). Furthermore, there is no residual effect of N in rice fields (Moll *et al*., 1982) because some of the N is immobilized by microbes into soil organic fraction, some is fixed by clay minerals such as illite, vermiculite, and smectite whereas the rest are lost through denitrification, ammonia volatilization, and leaching. However, N use can be efficiently managed through the use of biochar to improve N and other important nutrients uptake in rice cultivation.

Nutrient uptake by rice plants is not different from monocot crops such as wheat and maize but the amount of nutrients uptake varies with rice growth stage. The highest N uptake in rice cultivation is at tillering stage, followed by panicle initiation stage, P uptake is panicle initiation stage is the highest followed by the maturity stage (Guindo *et al*., 1994; Liu *et al*., 2007), and K uptake at tillering stage is highest and little is taken up at maturity stage (Wopereis-Pura *et al*., 2002; Zeng *et al*., 2007; Wang *et al*., 2011; Wu *et al*. 2011). Nutrients uptake of rice plant differs with the type of rice cultivar, fertilizer type, and soil type (Li *et al*., 2005; Liu *et al*., 2005; Zhang *et al*., 2006; Huang *et al*., 2008). Highly weathered tropical soils are dominated with low activity of the clay minerals (Brady, 2002) which result in low soil fertility due high amount of Fe and Al (Brady, 2002). Tropical soils under intensive cultivation cannot maintain fertility due to increasing cost of mineral fertilizers, poor quality of soil organic amendments, and low availability organic amendments and mineral fertilizers (Shisanya *et al*., 2009). Biochar can be used to improve the physical and chemical properties of tropical soils to boost rice yield.

Biochar is pyrolysis biomass under limited or no supply of oxygen (Joseph and Lehmann, 2009). Biochar has an impact on nutrients addition and nutrients retention in soils. Biochar consists mainly of mineral elements such as Ca, Fe, Mg, Na, K, P, Si, and Al (Amonette and Joseph, 2009) with minimum amount of N. During pyrolysis, significant proportions of biomass N are lost by volatilization (Chan and Xu, 2009). The N remaining in the biochar and the fraction of N inside aromatic C structures of biochar tends to be poorly available to plants (Chan and Xu, 2009; Gaskin *et al*., 2010). Biochar has low density and high porosity that makes it possible for microorganisms to live in the soil. Biochar hold moisture up to three times its own weight (McLaughlin *et al*., 2009), thereby preventing nutrient leaching and volatilization. Surface water infiltration in biochar-amended soil improved (Asai *et al*., 2009; Major, 2009; Husk and Major, 2010). Biochar consists largely of amorphous graphene sheets, which gives rise to large amounts of reactive surfaces where a wide variety of organic (both polar and non-polar) molecules and inorganic ions are absorbed (Levine, 2009) and made available for plants uptake. High pH of biochar reduces soil acidity (Brady and Weil, 2008). An increase in pH provides a wide range of benefits in terms of soil quality, notably by improving the chemical availability of plant nutrients, and in some cases it reduces the availability of detrimental elements such as Al and Fe (Brady and Weil, 2008). Hence, there is a need to improve soil nutrient availability, nutrient uptake and nutrient use efficiency of rice cultivation on tropical acid soils using biochar.

However, if biochar can improve soil nutrients availability especially N in rice cultivation on tropical acid soils, then there is a need to measure and monitor N concentration in soil solution during rice growing period using dielectric measurement at low frequency. Fast, easy, and precise knowledge of nutrients concentration in the soil solution during rice cultivation especially N will improve N management and N use efficiency. The traditional sampling and analysis of N are destructive, time consuming, and expensive (Carter and Gregorich, 2007) than dielectric measurement. Recently, new technologies in precision agriculture enable application of fertilizers with high precision in space and time however, there is dearth of information on *in situ* measurement of nutrients concentrations in soils especially N in lowland rice cultivation. Dielectric measurement are mostly used in agriculture to estimate soil moisture content (Andrade-Sanchez *et al*., 2004; Robinson *et al*., 2008) has been adopted by many agronomies to predict crop yield. Time domain reflectometry (TDR) techniques are used to estimate change in nitrate-nitrogen (NO_3-N) concentration in pore water (Das *et al*., 1999; Payero *at al*., 2006; Krishnapillai and Sri Ranjan, 2009) however, this technique is unsuitable for field experiment due to its high cost and inaccurate measurement (Robinson et al., 2003).

Dielectric measurement are affected by measurement frequency, temperature, ion type, and concentrations of the soil solution. Capacitance type probes are used because they are sensitive to change in NO_3^- concentration in soil solution at a lower frequency (Chighladze *et al*., 2010). Bardos *et al*. (2005) showed that, several electrolytes at a frequency range of 1 kHz to 10 MHz depend on frequency of conductance and response of the electrolyte to the concentration and composition of the ion in the soil solution. Additionally, the electrical conductivity of soil on permittivity measurement is negligible at high frequencies (above 50 MHz) but becomes stronger with decreasing frequency measurement (Campbell, 1990; Kizito *et al*., 2008), making capacitance-type sensors insensitive to soil salinity (Campbell, 1990; Kizito *et al*., 2008). This suggests that, there is a potential to measure ionic concentration of soil solution at lower frequency range by analyzing the patterns of the spectral data however, little work has been done in estimating ionic concentration of soil water and to date, no work has been done in estimating ionic concentration of soil water in rice field using a parallel plate capacitor at low frequency.

This study was based on the assumptions that, the chicken litter biochar used in this present study will provide all essential nutrients recommended for rice production except N (due to the properties of biochar) and it will also release and enhance efficient use of N, P, and K in the soil for rice plants growth and developments. Therefore, the specific objectives of this study were as follows to:

1. Increase rice yield by enhancing urea-N efficiency through the use of biochar.
2. Reduce N fertilizer application rate by improving nutrients use efficiency of rice plants.
3. Determine soil nutrients conductivity and permitivity at 20, 40, 55, and 75 days after transplanting using dielectric measurement at low frequency (0.01 Hz to 100 kHz) and correlate conductivity with grain yield at maturity.

REFERENCES

Addiscott, T.M. 2005. Nitrate, agriculture and the environment. CAB International, Wallingford, UK.

Amonette, J. and Joseph, S. 2009. Characteristics of Biochar - Micro-Chemical Properties (Chapter 3), In: Biochar for Environmental Management: Science and Technology, ed. J. Lehmann, and S. Joseph, pp. 33. Earthscan, London, UK.

Andrade-Sanchez, P., Upadhyaya, S.K., Aguera-Vega J. and Jenkins, B.M. 2004. Evaluation of a capacitance-based soil moisture sensor for real-time applications. *American Society of Agricultural Engineers* 47:1281–1287.

Antal Jr, M.J. and Grönli, M. 2003. The art, science, and technology of charcoal production. *Industrial and Engineering Chemistry Research* 42(8): 1619-1640.

Arias, B., Pevida, C., Fermoso, J., Plaza, M.G., Rubiera, F. and Pis, J.J. 2008. Influence of torrefaction on the grindability and reactivity of woody biomass. *Fuel Processing Technology* 89, 169-175.

Asai, H., Samson, B.K., Stephan, H.M., Songyikhangsuthor, K., Homma, K., Kiyono, Y., Inoue, Y., Shiraiwa T. and Horie, T. 2009. Biochar amendment techniques for upland rice production in Northern Laos 1. Soil physical properties, leaf SPAD and grain yield. *Field Crops Research* 111:81-84.

Baldock, J. A. and Smernik, R. J. 2002. Chemical composition and bioavailability of thermally altered *Pinusresinosa* (red pine) wood. *Organic Geochemistry* 33: 1093-1109.

Bardos, A., Zare, R.N. and Markides, K. 2005. Inductive behavior of electrolytes in AC conductance measurements. *Chemical Physics Letters* 402:274-278.

Barrow, G.M. 1996. Physical chemistry. (6th ed.) The McGraw-Hill, pp 134-137. New York, USA

Bollich P.K., R.P. Regan, Romero, G.R. and Walker, D.M. 1998. Influence of tillage and nitrogen on rice variety performance. In: *27th Rice Technology Work*. Group 1998:172-173

Bouyoucos, G.L. 1962. Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal* 53:464-465.

Brady, N.C. and Weil, R.R. 2008. The Nature and Properties of Soils, (14th ed.). ed. V.R. Anthony and S. Kottcamp. Pearson Prentice Hall.

Brady, N.C. and Weil, R.R. 2002. The Nature and Properties of Soils. (11th ed.). ed. V.R. Anthony and S. Kottcamp. Pearson Prentice Hall.

Bremner, J.M. 1965. Total Nitrogen. In *Method of soil analysis part 2*, ed. C.A. Black, D.D. Evan, L.E. Ensminger, J.L. White, F.E. Clark, and R.D. Dinauer, pp. 1149-1178. American Society of Agronomy. Madison, Wisconcin.

Brown, R. 2009. Biochar Production Technology. In: *Biochar for Environmental Management*: *Science and Technology*, ed. J. Lehmann, and S. Joseph, Earthscan.

Bufogle, A. Jr., Kovar, P.K., Lindau, C.W. and Macchivelli, R.E. 1998. Comparisons of ammonium sulfate and urea as nitrogen source in rice production. *Journal of Plant Nutrition* 21:1601-1614.

Bufogle, A. Jr., Kovar, P.K., Lindau, C.W. and Macchivelli, R.E. 1997. Rice plant growth and nitrogen accumulation from midseason application. *Journal of Plant Nutrition* 20:1191-1201.

Carter, M.R. and Gregorich, E.G. (2007). Soil sampling and methods of analysis. 2nd ed. CRC Press, Boca Raton, FL.

Caiyan L., Ma, J., Chen, X., Zhang, X., Shi, Y. and Huang, B. 2010. Effect of nitrogen fertilizer and maize straw incorporation on NH_4^+-15N and NO_3 -15N accumulation in black soil of northeast china among three consecutive cropping cycles

Campbell, J.E. 1990. Dielectric-properties and influence of conductivity in soils at one to 50 megahertz. *Soil Science Society of America Journal* 54:332-341.

Ball, B.C., Watson, C.A., and Crichton I. 2007. Nitrous oxide emissions, cereal growth, N recovery and soil nitrogen status after ploughing organically managed grass/clover swards. In:Soil sampling and methods of analysis, (2nd ed.) ed. M. R. Carter and E. G. Gregorich, Pages 743–761. Boca Raton, FL. CRC Press.

Cetin, E., Moghtaderi, B., Gupta, R. and Wall, T.F., 2004. Influence of pyrolysis conditions on the structure and gasification reactivity of biomass chars. *Fuel* 83: 2139-2150.

Chan, K.Y. and Xu, Z. 2009. Biochar: Nutrient Properties and Their Enhancement. In: *Biochar for Environmental Management: Science and Technology*, ed. J. Lehmann, and S. Joseph, Earthscan.

Chan, K.Y., Van Zwieten, L., Meszaros, I., Downie, A. and Joseph, S. 2007. Agronomic values of green waste biochar as a soil amendment. *Australian Journal of Soil Research* 45(8): 629-634.

Chandra, A. and Bagchi, B. 2000. Frequency dependence of ionic conductivity of electrolyte solutions. *Journal Chemistry and Physics* 112:1876–1886.

Chang, T.T and Luh, B.S. 1991. Overview and prospects of rice production. In *Rice, Vol. 1, Production,* (2nd ed.), ed. B.S. Luh, pp. 1-11. AVI-VanNostrand Reinhold, New York.

Chee-Wan C. and Meng-Chang, C. 2012. Country Report: Malaysia. Asia Pacific Economic Cooperation (APEC). In: *Workshop on Food Security*. Tokyo, Japan.

Cheftez, B., Hatcher, P.G., Hadar, Y. and Chen, Y. 1996. Chemical and biological characterization of organic matter during composting of municipal solid waste. *Journal of Environmental Quality* 25: 776-785.

Chen, C.C, Turner, F.T. and Dioxon, J.B. 1989. Ammonium fixation by high-charged smectite in selected Texas Gulf coast soils. *Soil Science Society of America Journal* 53:2035-1040.

Cheng, C. H., Lehmann, J. and Engelhard, M. 2008. Natural oxidation of black carbon in soils: changes in molecular form and surface charge along a *climosequence. Geochimica et Cosmochimica Acta* 72: 1598-1610.

Chighladze, G., Kaleita, A. and Birrell, S. 2010. Sensitivity of Capacitance Soil Moisture Sensors to Nitrate Ions in Soil Solution. *Soil Science Society of America Journal* 74:1987-1995.

Christopher, T. (2011, June 22). Will Malaysia achieve 100% self-sufficiency in rice by 2015? *Extraordinary minds discuss ideas*. Retrieved 1 October 2013, from christopherteh.com/.../will-malaysia-achieve-100-self-sufficienc.

Cottenie, A. 1980. Soil testing and plant testing as a basis for fertilizer recommendation. *FAO Soil Bull*. 38:70-73.

Das, B.S., Wraith, J.M. and Inskeep, W.P. 1999. Nitrate concentrations in the root zone estimated using time domain reflectometry. *Soil Science Society of America Journal* 63:1561-1570.

Demirbas, A. 2004. Effects of temperature and particle size on bio-char yield from pyrolysis of agricultural residues. *Journal of Analytical and Applied Pyrolysis* 72(2): 243-248.

Dobermann, A.R. 2005. Nitrogen Use Efficiency – *State of the Art. Agronomy - Faculty Publications*. Paper 316. http://digitalcommons.unl.edu/agronomyfacpub/316.

Downie, A., Crosky, A. and Munroe, P. 2009. Physical properties of biochar. In: *Biochar for Environmental Management: Science and Technology*, ed. J. Lehmann, and S. Joseph, Earthscan.

Elmaci, Ö.L., Secer, M., Erdemir, O. and Iqbal, N. 2002. Ammonium fixation properties of some arable soils from the Agean region of Turkey. *European Journal of Agronomy* 17:199-208.

Falkenhagen, H. 1934. Electrolytes. Oxford University Press. Oxford, UK.

Food and Agricultural Organization. 2000. *Fertilizer requirement in 2015 and 2030*, an FAO Perspective, FAO Rome.

Food and Agricultural Organization. 2002. *World Agriculture towards 2015/2030*, an FAO Perspective, FAO Rome.

Food and Agricultural Organization. 2011. *World Agriculture towards 2015/2030*, an FAO Perspective, FAO Rome.

Flach, K.W. and Slusher, D.F. 1978. Soil used for rice culture in the United States. In: *Soil and Rice*, International Rice Research Institute, Manila: The Philippines.

Gaskin, J.W., Speir, R.A., Harris K., Das K.C., Lee R.D., Morris L.A. and Fisher, D.S. 2010. Effect of Peanut Hull and Pine Chip Biochar on Soil Nutrients, Corn Nutrient Status, and Yield. *Agronomy Journal* 102:623-633.

Gavin S. 2006, June 1. Malaysia focused on 2020 vision. *Business reporter, BBC News, Malaysia*. Retrieved 27 September 2013, from *news.bbc.co.uk/2/hi/5020794.stm.*

Guerra, J.D.S., Bassora, L.A, and Eiras, J.A. 2006. Microwave characterization of dielectric materials in the temperature range of 90-450 K. *European Physical Journal-Applied Physics* 36:65-70.

Guindo, D., Wells, B.R. and Norman, R.J. 1994. Cultivars and nitrogen rate influence on nitrogen uptake and partitioning in rice. *Soil Science Society of America Journal* 58(3): 840–849.

Gupta, S.K., Gupta, R.C., Gupta, A.B., Seth, A.K., Bassin, J.K. and Gupta, A. 2000. Recurrent acute respiratory tract infections in areas with high nitrate concentrations in drinking water. *Environmental Health Perspectives* 108:363-366.

Hasted, J.B. 1973. Aqueous dielectrics. Chapman and Hall Ltd. London, UK.

Hilhorst, M.A. 2000. A pore water conductivity sensor. *Soil Science Society of America Journal* 64:1922-1925.

Hill J.E., Roberts, S.R., Brandon, D.M., Scardaci, S.C., Wick, C.M. Williams, J.F., Canevari, W.M. and Weir, B.L. 1992. Rice production in California. Univ. Calif. *Division of Agriculture Natural Resources* Publ. 21498.

Horvath, A.L. 1985. Handbook of aqueous electrolyte solutions: Physical properties, estimation, and correlation methods. Ellis Horwood Ltd. Chichester, UK.

Huang, J.L., He, F., Cui, K.H., Buresh, R.J., Xu, B., Gong, W.H. and Peng, S.B. 2008. Determination of optimal nitrogen rate for rice varieties using a chlorophyll meter. *Field Crops Research* 105: 70–80.

Husk, B. and Major, J. 2010. Commercial scale agricultural biochar field trial in Québec, Canada, over two years: Effects of biochar on soil fertility, biology, crop productivity and quality. Disponible en ligne: http://www.blue-leaf.ca/main.en/files/BlueLeaf%20Biochar%20Field%20Trial%2008-09%20Report-2%20EN.pdf

IRRI, 2006. Bringing hope, improving lives. In: *Strategic Plan 2007–2015*, pp 61. Manila

Ishii, S., Ikeda, S., Minamisawa, K. and Senoo, K. 2011. Nitrogen cycling in rice paddy environments: Past achievements and future challenges. *Microbes and environments* 26(4): 282–292.

Jackson, L.E., Schimel, J.P., and Firestone, M K. 1989. Short-term partitioning of ammonium and nitrate between plants and microbes in an annual grassland. *Soil Biology and Biochemistry* 21(3): 409.

Jones, S.B., Wraith, J.M. and Or. D. 2002. Time domain reflectometry measurement principles and applications. *Hydrological Processes* 16:141-153.

Joseph, S., Peacock, C., Lehmann, J. and Munroe, P. 2009. Developing a Biochar Classification and Test Methods. In: *Biochar for Environmental Management: Science and Technology*, ed. J. Lehmann, and S. Joseph, Earthscan.

Keeney, D.R. and Nelson, D.W. 1982. Nitrogen- Inorganic Forms. In: *Methods of Soil Analysis, Part 2*, (2nd ed.), ed. A.L. Page, D.R. Keeney, D.E. , Baker, R.H. Miller, R. Jr. Ellis, and D.J. Rhoades, Madison: *Agronomy Monograph* 9; ASA and SSSA, Madison, Wisconsin, USA.

Kizito, F., Campbell, C.S., Campbell, G.S., Cobos, D.R., Teare, B.L., Carter, B. and Hopmans, J.W. 2008. Frequency, electrical conductivity and temperature analysis of a low-cost capacitance soil moisture sensor. *Journal of Hydrology* 352:367-378.

Knoll, M.D. and Knight, R. 1994: Relationships between dielectric and hydrogeologic properties of sand-clay mixtures. In: *5th International Conference on Ground Penetrating Radar*. Kitchener, Ontario, Canada: Waterloo Centre for Groundwater Research 1994.

Knudsen, D., Paterson, G.A. and Pratt, P.F. 1982. Lithium sodium and potassium. In: *Methods of soil analysis Part 2,* (2nd ed.), ed. A.L. Page, D.R. Keeney, D.E. , Baker, R.H. Miller, R. Jr. Ellis, and D.J. Rhoades, pp: 225-246. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Kong, W.D., Zhu, Y.G., Fu, B.J., Han, X.Z., Zhang, L. and He, J.Z. 2008. Effect of long-term application of chemical fertilizers on microbial biomass and functional diversity of a black soil. *Pedosphere* 18(6):801-808.

Koryta, J., Dvorak, J., and Kavan, L. 1993. Principles of electrochemistry. 2nd ed. John Wiley and Sons. Chichester, UK.

Krishnapillai, M. and Sri Ranjan R. 2009. Non-destructive monitoring of nitrate concentration in a laboratory flow experiment using time domain reflectometry (TDR). *Environmental Technology* 30:101-109.

Lehmann, J., Da Silva Jr., J. P., Steiner, C., Nehls, T., Zech, W. and Glaser, B. 2003. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol in the Central Amazon basin: Fertilizer, manure and charcoal amendments. *Plant and Soil* 249: 343-357.

Lehmann, J., Gaunt, J. and Rondon, M. 2006. Bio-char sequestration in terrestrial ecosystems - A review. *Mitigation and Adaptation Strategies for Global Change* 11(2): 403-427.

Lehmann, J. and Joseph, S. 2009. Biochar: Environmental Management. Earthscan. United Kingdom and United States. IBSN: 978-9-1-84407-658-1.

Levine, J.E. 2009. US-Focused Biochar Report: Assessment of Biochar's Benefit for the United States of America, USBI - US Biochar Initiative, Colorado, USA.

Li F.M., Fan X.L. and Chen, W.D. 2005. Effects of controlled release fertilizer on rice yield and nitrogen use efficiency. *Plant Nutrition and Fertility Science* 11(4): 494–500.

Liu L.J, Xu, W., Tang, C., Wang, Z.Q. and Yang, J.C. 2005. Effect of indigenous nitrogen supply of soil on the grain yield and fertilizer-N use efficiency in rice. *China Journal of Rice Science* 19(4): 343–349.

Liu, L.J., Xu, W., Wu, C.F. and Yang, J.C. 2007. Characteristics of growth, development and nutrient uptake in rice under site-specific nitrogen management. *China Journal of Rice Science* 21(2): 167–173.

Lu, C.Y., Zhang, X.D., Chen, X., Shi, Y., Ma, J., Zhao, M.Q., Chi, G.Y. and Huang, B. 2010. Fixation of labelled (15NH4)2SO4 and its subsequent release in black soil of Northeast China over consecutive crop cultivation. Soil Tillage Resources. 106, 329-334.

Macdonald, A.J., Poulton, P.R., Stockdale, E.A., Powlson, D.S. and Jenkinson, D.S. 2002. The fate of residua ^{15}N-labelled fertilizer in arable soils: its availability to subsequent crops and retention in soil. *Plant Soil* 246, 123-137.

MADA (1970, June 30). Muda Agricultural Development Authority. Paddy, fertilization. Retrieved September 29, 2013, from http://www.mada.gov.my/semakan-tanaman-padi.

Major, J. 2009. Biochar application to a Colombia Savanna Oxisols: fate and effect on soil fertility, crop production, nutrient leeching and soil hydrology, pp. 841. Ithaca: Department of Crop and Soil Sciences, Cornell University, NY USA.

Malhia, S.S., Grant, C.A., Johnstona, A.M. and Gill, K.S. 2001. Nitrogen fertilization management for no-till cereal production in the Canadian Great Plains: a review. *Soil Tillage Resources* 60: 101-122.

Martínez, M.L., Torres, M.M., Guzmán, C.A. and Maestri, D.M. 2006. Preparation and characteristics of activated carbon from olive stones and walnut shells. *Industrial crops and products* 23: 23-28.

Matsushirna, S. and Tanaka, T. 1960. Analysis of developmental factors determining yields and its application to yield prediction and culture improvement of lowland rice. LV. Early discrimination of non-fertilized rice grains. Proc. *Crop Science Society of Japan* 28:365-366.

Matzner E., Pijpers M., Holland W. and Manderscheid B. 1998. Soil Science. *Soil Science Society of America Journal.* 62: 445–454.

McLaughlin, H., Anderson, P.S., Shields, F.E. and Reed, T.B. 2009. All biochar are Not Created Equal, and How to Tell Them Apart, North American Biochar Conference, Boulder, CO.

Mikkelsen, D.S. 1987. Nitrogen budgets in flooded soils used for rice production. *Plant Soil* 100:71-97.

Moll, R.H., Kamprath, E.J. and Jackson, W.A. 1982. Analysis an interpretation of factors which contribute to efficiency of nitrogen utilization. *Agronony Journal*, 74: 562–564.

Mubarak, A.R., Rosenani, A.B., Zayyah, D.S. and Anuar, A.R. 2001. Nitrogen mineralization in tropical soils amended with crop residues. *Tropical Agriculture* 78: 165-173.

Muchow R.C. 1994. Effect of nitrogen on yield determination in irrigated maize in tropical and subtropical environments. *Field Crops Research* 38: 1–13.

Murphy, J. and Riley, J.P. 1962. A modified single solution method for the determination of phosphate in natural waters. *Analytical Chemistry Acta* 27:31-36.

Murshedul, A.M., Ladha, J.K., Foyjunnessa, R. Z., Rahman, K.S., Harun-Ur-Rashid, Khan, A.H. and Buresh, R.J. 2006. Nutrient management for increased productivity of rice-wheat cropping system in Bangladesh. *Field Crop Research* 96: 374-386.

Norman R.J., Wilson, C.E. Jr. and Slaton, N.A. 2002. Soil Fertilization and Mineral Nutrition in U.S. Mechanized Rice Culture. In *Rice: Origin, History, Technology, and Production*, ed. S.C. Wayney, and R.H. Dilday, pp. 331-410. USA.

Norman R.J., Wilson, C.E. Jr., Bollich, P.K., Gravois, K.A. and Wells, B.R. 1996. Nitrogen uptake of selected rice cultivars. In: *28th Rice Technical Work*. Group 1976:173.

Norman R.J., Wilson, C.E. Jr., Moldenhauer, K.A.K., Bollich, P.K., Slaton, N.A., Ntamatungiro, S. and Beyrouty, C.A. 2000. Influence of nitrogen rate and timing on rice grain and milling yields. In: *28th Rice Technical Work*. Group 2000:114.

Norman R.J., Wilson, C.E. Jr., Moldenhauer, K.A.K., Slaton, N.A. and A.D. Cox. 1999. Grain yield response of new rice cultivars to nitrogen fertilization. In: Rice Research Studies, ed. R.J. Norman, T.H. Johnston, and B.R. Wells (1998), pp. 257-267. Univ. Ark. Agric. Exp. Stn. Res. Ser. 468.

NRCS. 1997. Water quality and agriculture: Status, conditions, and trends. Working Pap. 16. U.S. Gov. Print. Office, Washington, DC.

Okimori, Y., Ogawa, M. and Takahashi, F. 2003. Potential of CO_2 emission reductions by carbonizing biomass waste from industrial tree plantation in south Sumatra, Indonesia. *Mitigation and adaptation strategies for global change* 8: 261-280.

Oldham, K.B. and Myland, J.C. 1994. *Fundamentals of electrochemical science*. Ithaca: Inc. San Diego, CA. Academic Press,

Owens, L.B., Edwards, W.M. and Van Keuren, R.W. 1992. Nitrate levels in shallow groundwater under pastures receiving ammonium nitrate or slow-release nitrogen fertilizer. *Journal of Environmental Quality* 21:607-613.

Paramanathan, S. 2000. Soils of Malaysia: Their characteristics and identification. Academic Science Malaysia, Kuala Lumpur, 1: 1-616.

Patrick, W.H. Jr. 1982. Nitrogen transformations in submerged soils. In *Nitrogen in Agriculture Soils*, ed. F.J. Stevenson, pp.449-466. ASA-CSSA-SSSA, Madison, WI.

Patrick, W.H., Jr. and Mahapatra, I.C. 1976. Fate of nitrogen in flooded rice soil. *Soil Science Society of America Journal* 40:678-681.

Patrick, W.H., Mikkelsen, D.S. and Wells, B.R. 1985. Plant nutrient behavior in flooded soils. In: *Fertilizer Technology and Use*, (3rd ed.), ed. O.P. Engelstad, pp.197-228. Ithaca: Soil Science Society of America, Madison WI.

Payero, J.O., Tarkalson, D.D. and Irmak, S. 2006. Use of time domain reflectometry for continuous monitoring of nitrate-nitrogen in soil and water. *Applied Engineering in Agriculture* 22:689-700.

Peech, H.M. 1965. Hydrogen-ion Activity. In *Method of Soil Analysis*, *Part 2*, ed. C. A. Black, D. D. Evan, L. E. Ensminger, J. L. White, F.E. Clark, and R.C. Dinaue, pp 914 – 926. Ithaca: American society of Agronomy, Madison, Wisconsin.

Peng S.B, Huang, J.L., Zhong, X.H., Yang, J.C., Wang, G.H., Zou, Y.B., Zhang, F.S., Zhu, Q.S., Roland, B. and Christian, W. 2002. Research strategy in improving fertilizer-nitrogen use efficiency of irrigated rice in China. *Science of Agriculture Sin* 35(9): 1095–1103.

Ponnamperuma, F.N. 1972. The chemistry of submerged soils. Advance Agronomy 24:29-96.

Prins, M.J., Ptasinski, K.J. and Janssen, F.J.J.G. 2006. Torrefaction of wood Part 2. Analysis of products. *Journal of Analytical and Applied Pyrolysis* 77: 35-40.

Prodan, C., Mayo, F., Claycomb, J.R., Miller, J.H. and Benedik, M.J. 2004. Low frequency, low-field dielectric spectroscopy of living cell suspensions. *Journal of Applied Physics* 95:3754-3756.

Qiao-Gang Y., Jing Y, Shao-Na Y., Jian-Rong F., Jun-Wei M., Wan-Chun S., Li-Na L., Qiang W. and Jian-Mei W. 2013. Effects of Nitrogen Application Level on Rice Nutrient Uptake and Ammonia Volatilization. *China National Rice Research Institute.* Elsevier BV. 60117-1.

Rhoades, J.D., Raats, P.A.C. and Prather, R.J. 1976. Effects of liquid-phase electrical conductivity, water-content, and surface conductivity on bulk soil electrical conductivity. *Soil Science Society of America Journal* 40:651-655.

Roberts, S.R., Hill, J.E., Brandon, D.M., Miller, B.C., Scardaci, S.C., Wick, C.M. and Williams, J.F. 1993. Biological yield and harvest index in rice: Nitrogen response to tall and semidwarf cultivars. *Journal of Agriculture Production* 6:585-588

Robinson, D.A., Campbell, C.S., Hopmans, J.W., Hornbuckle, B.K., Jones, S.B., Knight, R., Ogden, F., Selker, J. and Wendroth, O. 2008. Soil moisture measurement for ecological and hydrological watershed-scale observatories. *Vadose Zone Journal* 7:358-389.

Robinson, D.A., Jones, S.B., Wraith, J.M., Or., D. and Friedman, S.P. 2003. A Review of Advances in Dielectric and Electrical Conductivity Measurement in Soils Using Time Domain Reflectometry. *Vadose Zone Journal* 2:444-475.

Robinson, R.A., and Stokes, R.H. 1968. Electrolyte solutions: the measurement and interpretation of conductance, chemical potential and diffusion in solutions of simple electrolytes, (2nd ed.), Ithaca: Butterworths Publications Ltd. London, UK.

Roth, K., Schulin, R., Fluhler, H. and Attinger, W. 1990. Calibration of time domain reflectometry for water-content measurement using a composite dielectric approach. *Water Resources Research* 26:2267-2273.

Rowell, D. 1994. Soil Science; Methods and Applications, Department of Soil Science, University of Reading.

Sabri M. A. 2009. FIAM - Fertilizer Industry Association of Malaysia Lot P.T. 200, Persiarang Dagang, Shah Alam 4000 Malaysia.

Santamarina, J.C., Katherine, A.K. and Fam, M.A. 2001. Soil and Waves: particulate material behavior, characterization and process monitoring. John Wiley & Sons, Ltd. Chichester, UK.

SAS, 2011. SAS/STAT Ssoftware. SAS Institute, (2nd ed.) Cary, NC.16.
Cary, NC, USA

Scott, H.D, Miller, D.M. and Renaud, F.G. 2002. Soil Fertilization and Mineral Nutrition in U.S. Mechanized Rice Culture. In *Rice: Origin, History, Technology, and Production*, ed. S.C. Wayney, and R.H. Dilday, pp. 297- 330. USA.

Shisanya, C.A., Mucheru, M.W., Mugendi, D.N. and Kung'u, J.B. 2009. Effect of organic and inorganic nutrient sources on soil mineral nitrogen and maize yields in central highlands of Kenya. *Soil and Tillage Research* 103: 239-246

Shouichi, Y., Douglas, A.F., James, H.C. and Kwanchai, A.G. 1976. Laboratory Manual for Physiological Studies of Rice (3rd ed.). The International Rice Research Institute. Los Baños, Laguna, Philippines.

Singh, S., Nandita, G. and Singh, K.P. 2007. Synchronizing nitrogen availability through application of organic inputs of varying resource quality in a tropical dryland agroecosystem. *Application of Soil Ecology* 36: 164-175.

Smaling, E.M.A. and Oenema, O. 1997. Estimating nutrient balances in agro-ecosystems at different spatial scales. In: Methods for assessment of soil degradation. Advances in Soil Science, ed. R. Lal et al. pp 229-252. CRC press.

Sohi, S., Lopez-Capel, E., Krull, E. and Bol, R., *Biochar, climate change and soil: A review to guide future research.*, CSIRO Land and Water Science Report Rep. No. 05/09, Geln Osmond, Australia. 2009.

Street, J.E and Bollich, P.K. 2002. Rice production. In *Rice: Origin, History, Technology, and Production*, ed. S.C. Wayney, and R.H. Dilday, pp. 271-296. USA.

Sun, Y.F., Liang, J.M., Ye, J. and Zhu, W.Y. 1999. Cultivation of super-high yielding rice plants. China Rice 5:38–39.

Tan, K.H. 2005. Soil Sampling, Preparation and Analysis. (2nd ed.), pp. 154-174 (1-623). Taylor and Francis Group. Boca Raton, Florida, USA, CRC Press,

Tomaszewski, J.E., Werner, D. and Luthy, R.G., 2007. Activated carbon amendment as a treatment for residual DDT in sediment from a superfund site in San Francisco Bay, Richmond, California, USA. *Environmental Toxicology and Chemistry* 10: 2143–2150.

Topp, G.C., Davis, J.L. and Annan, A.P. 1980. Electromagnetic determination of soil water content - measurements in coaxial transmission-lines. *Water Resources Research* 16:574-582.

Wang, W.N., Lu, J.W., He, Y.Q., Li, X.K. and Li, H. 2011. Effects of N, P, K fertilizer application on grain yield, quality, nutrient uptake and utilization of rice. *China Journal of Rice Science* 25(6): 645–653.

Ward, M.H., deKok, T.M., Levallois, P., Brender, J., Gulis, G., Nolan, B.T. and VanDerslice, J. 2005. Drinking-water nitrate and health-recent findings and research needs. *Environmental Health Perspectives* 113:1607-1614.

Wells, B.R. and Faw, W.F. 1978. Short-statured rice response to seeding and N rate. *Agronomy Journal* 70:477-480.

Witt, C., Dobermann, A., Abdulrachman, S., Gines, H.C., Guanghuo, W., Nagarajan, R., Satawatananont, S., Son, T.T., Tan, P.S., Tiem, L.V., Simbahan, G. C. and Olk, D.C. 1999. Internal nutrient efficiencies of irrigated lowland rice in tropical and subtropical Asia. *Field Crops Research* 63: 113-138.

Wopereis-Pura, M.M., Watanabe, H., Moreira, J. and Wopereis, M.C.S. 2002. Effect of late nitrogen application on rice yield, grain quality and profitability in the Senegal River valley. *European Journal of Agronomy* 17: 191–198.

Wraith, J.M. and Das, B.S. 1998. Monitoring soil water and ionic solute distributions using time-domain reflectometry. *Soil & Tillage Research* 47:145-150.

Wu, C.Y., Tang, X., Chen, Y., Yang, S.M. and Ye, S.H. 2011. Effect of fertilization systems on yield and nutrients absorption in japonica rice variety Zhejing 22. *Acta Agriculture Zhejiang* 23(1): 132–137.

Yang, S.N., Yu, Q.G., Ye, J., Jiang, N., Ma, J.W., Wang, Q., Wang, J.M., Sun, W.C. and Fu, J.R. 2010. Effects of nitrogen fertilization on yield and nitrogen use efficiency of hybrid rice. *Plant Nutrition and Fertility Science* 16(5): 1120–1125.

Zeng, J.M., Cui, K.H., Huang, J.L., He, F. and Peng, S.B. 2007. Responses of physio-biochemical properties to N-fertilizer application and its relationship with nitrogen use efficiency in rice (*Oryza sativa* L.). *Acta Agronomy Sin* 33(7): 116–117.

Zhang, Y.H., Zhang, Y.L., Huang, Q.W., Xu, Y.C. and Shen, Q.R. 2006. Effects of different nitrogen application rates on grain yields and nitrogen uptake and utilization by different rice cultivars. *Plant Nutrition and Fertility Sience* 12(5): 616–621.

Zhu, Z.L. and Chen, D.L. 2002. Nitrogen fertilizer use in China-contributions to food production, impacts on the environment and best management strategies. *Nutritional Cycle in Agroecosystem* 63, 117-1.

Zhu, Z.L. 2000. Loss of fertilizer N from plants-soil system and the strategies and techniques for its reduction. Soil Environmental Science 9, 1-6.

BIODATA OF STUDENT

Ali Maru was born on 22nd February, 1982 at Kwamikrom Newtown in the Volta Region of Ghana. He received his primary and junior secondary education from Kwamikrom Newtown Local Authority School. He continued his senior secondary education at Bishop Herman College at Kpando in the Volta Region, Ghana and was awarded a Senior Secondary School Certificate in Agricultural Science in 2004. Afterwards, he was awarded Bachelor of Science in Agriculture (Soil Science) with Second Class Honours (Upper Division) from the University of Ghana in May, 2012. Ali Maru served his country for 1 year as teaching assistant at Soil Science Department, University of Ghana (2012-2013). In September, 2013 he enrolled as a full time Master of Science student at Universiti Putra Malaysia. One of his research paper was submitted to *the Scientific World Journal* and is currently under review and he is about to submit second paper of his work for publication.

PUBLICATIONS

Cited journal.

Ali, M., O.H. Ahmed, and W.C. Primus. Co-application of chicken litter biochar and urea only to improve nutrients use efficiency and yield of *Oryza sativa* L. cultivation on a tropical acid soil. *The Scientific World Journal.* In press.

Ali, M., O.H. Ahmed, and W.C. Primus. Dielectric response determination of soil chemical proporties in rice field co-applied with biochar and urea only. *The Scientific World Journal.* To be submitted.

CONFERENCES

Ali, M., O.H. Ahmed, and W.C. Primus. 2015. Co-application of biochar and urea only to improve nutrients use efficiency and yield of *Oryza sativa* L. cultivation on a tropical acid soil. In: *Proceeding of the 2nd Rice Research colloquium,* pp 62-64. UPM, Serdang, Malaysia.