# EFFECT OF SILICON AND HIGH NITROGEN FERTILIZER APPLICATION ON GROWTH AND YIELD OF RICE (VAR.SERENDAH MERAH)

NG HOOI CHIN



CROP PRODUCTION PROGRAMME
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH

2018

PUMS 99:1

# UNIVERSITI MALAYSIA SABAH

## BORANG PENGESAHAN TESIS

JUDUL: Effect of Silicon and High Nitrogen Fertilizer Application on Growth and Yield of Rice (Var. Serendah Merah)

IJAZAH: Ijazah Sarjana Muda Sains Pertanian (Pengeluaran Tanaman)

SAYA: NG HOOI CHIN SESI PENGAJIAN: 2014-2018

(HURUF BESAR)

Mengaku membenarkan tesis *(LPSM/~~Sarjana/Doktor Falsafah~~) ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/)

[ ] SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di AKTA RAHSIA RASMI 1972)

[ ] TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

[/] TIDAK TERHAD

Disahkan oleh:

NURULAIN BINTI ISMAIL
PUSTAKAWAN KANAN
UNIVERSITI MALAYSIA SABAH

(TANDATANGAN PENULIS)

(TANDATANGAN PUSTAKAWAN)

Alamat Tetap: LC 843, Jalan Tokong, 09400 Padang Serai, Kedah.

Dr.Ir.Mohd. Amin Mohd.Soom

(NAMA PENYELIA)

TARIKH: 09/01/2018

TARIKH: 9/1/18

Catatan:
*Potong yang tidak berkenaan.
*Jika tesis ini SULIT dan TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.
*Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana Secara Penyelidikan atau disertai bagi pengajian secara kerja kursus dan Laporan Projek Sarjana Muda (LPSM).

# EFFECT OF SILICON AND HIGH NITROGEN FERTILIZER APPLICATION ON GROWTH AND YIELD OF RICE (VAR.SERENDAH MERAH)

NG HOOI CHIN



DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

CROP PRODUCTION PROGRAMME
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH
2018

## DECLARATION

I hereby declare that this dissertation is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that no part of this dissertation has been previously or concurrently submitted for a degree at this or any other university.

NG HOOI CHIN

BR14110050

22nd NOVEMBER 2017

**VERIFIED BY**

1. Dr. Ir. Mohd. Amin Mohd. Soom
   SUPERVISOR

2. Datuk Hj. Mohd. Dandan @ Ame Hj. Alidin
   CO-SUPERVISOR
   (Retired)

**ACKNOWLEDGEMENT**

I would like to take this opportunity to express my appreciation to my supervisor, Dr Ir. Mohd. Amin Mohd. Soom. I am truly grateful for his support in guiding me to accomplish my dissertation.

Secondly, I also want to express my sincere thanks to my co-supervisor, Datuk Hj. Mohd. Dandan @ Ame Hj. Alidin. I am grateful for his patience, advice and encouragement during the progression of my dissertation writing. Besides that, special thanks to laboratory assistants for helping me to get the materials and apparatus that I needed.

Meanwhile, I also wish to express my appreciation to Mr Borhan Bin Abdul Haya @ Yahya, lecturer of Faculty of Sustainable Agriculture, University Malaysia Sabah for the productive discussions and valuable teaching on the statistical analysis and helpful suggestions for my final year project.

Moreover, I would also like to thanks my friends for their tolerance who have helped me all along the way to complete this dissertation writing and also want to express my appreciation to my parents who always gave me moral support and the financial aid for me to complete this study.

Lastly, I would like to thanks to Mr Allego, Chief Executive Officer of Bloomina AgriLife Sdn.Bhd. for supplying silicon fertilizer for my study.

**ABSTRACT**

Lodging of rice plants in paddy fields can reduce yield and cause economic loss to the farmers. A field experiment was conducted at the Faculty of Sustainable Agriculture (FSA) located at University Malaysia Sabah, Sandakan, Sabah to study the effect of silicon and high nitrogen fertilizer on the growth and yield of Serendah Merah rice variety and to study the effect of silicon in reducing the lodging effect on Serendah Merah rice variety. The experimental design used was Factorial Completely Randomized Design (CRD) by using 60kg/ha, 120kg/ha and 180kg/ha of Nitrogen fertilizer and 0kgha$^{-1}$, 200kgha$^{-1}$ and 400kgha$^{-1}$ of the silicon fertilizer. This experiment had three replications in each treatment. Data were analyzed with two-way analysis of variance (ANOVA) by using Minitab 16 Statistical Analysis Software. The means were compared at $P<0.05$ by using Tukey's test. The results revealed that application of 180kg/ha N contributed to the maximum culm diameter (10.11mm), panicle length (24.2cm), number of grains per panicle (113), number of filled grains per panicle which were 77 (68.14%), number of empty grains per panicle which were 37 (32.74%), leaves dry weight (14.06g) and stem dry weight (10.16g). However, application of nitrogen at the rate of 120kg/ha produced the highest 1,000 grains weight (27.09g), highest root dry weight (33.51g) and also highest extrapolated yield (5.42 tons/ha) but showed no significant effect between nitrogen rates. In the case of silicon, the largest culm diameter (10.29mm) was from 400kg/ha Si. Although there were no significant differences for the interaction between N and Si on all yield parameters, the highest Si rates, 400kg/ha, showed a significant effect on culm diameter in order to reduce lodging incidence. In order to strengthen the culm of the rice plant, application of silicon fertilizer is recommended. Additionally, more studies on growth and yield of Sabah traditional rice varieties need to be carried out to contribute the knowledge about the effect of nitrogen and silicon fertilizer to increase yield and income to the farmers.

***KESAN APLIKASI BAJA SILIKON DAN NITROGEN KADAR TINGGI THERHADAP PERTUMBUHAN DAN HASIL PADI (VAR. SERENDAH MERAH)***


***ABSTRAK***

*Padi rebah di sawah padi boleh menjejaskan hasil dan mengurangkan pulangan kepada para petani. Kajian telah dijalankan di Fakulti Pertanian Lestari (FPL), Universiti Malaysia Sabah, Sandakan, Sabah untuk mengkaji kesan silikon dan baja nitrogen yang tinggi terhadap pertumbuhan dan hasil variti padi Serendah Merah dan juga mengkaji kesan silikon dalam mengurangkan kesan rebah pada variti padi Serendah Merah. Reka bentuk kajian adalah dengan menggunakan Factorial Complete Randomized Design (CRD) dengan mengaplikasikan baja Nitrogen pada kadar 60kgN, 120kgN dan 180 kgN dan 0kg/ha, 200kg/ha dan 400kg/ha bagi baja silikon. Eksperimen ini mempunyai tiga ulangan pada setiap rawatan. Data telah dianalisis dengan dua cara analisis varians (ANOVA) dengan menggunakan perisian Minitab 16 Statistical Analysis. Nilai purata telah dibandingkan pada P<0.05 dengan menggunakan ujian Tukey. Hasil kajian menunjukkan bahawa penggunaan 180kg/ha N menyumbang kepada maksimum garis pusat batang (10.11mm), maksimum panjang tangkai (24.2cm), maksimum jumlah butir setiap tangkai (113), maksimum bilangan butir penuh setiap tangkai (77), maksimum bilangan butir kosong setiap tangkai (37), maksimum berat kering daun (14.06g) dan maksimum berat kering batang (10.16g). Walau bagaimanapun, penggunaan nitrogen pada kadar 120kg/ha menghasilkan berat padi bagi 1,000-butir yang tertinggi (27.09g), berat kering akar yang tertinggi (33.51g) dan anggaran hasil yang tertinggi (5.42 tan/ha) tetapi tidak menunjukkan kesan yang ketara antara kadar nitrogen. Dalam kes silikon, kadar 400kg/ha Si menghasilkan garis pusat batang yang tertinggi (10.29mm). Walaupun tidak terdapat perbezaan yang ketara bagi interaksi antara N dan Si pada semua parameter komponen hasil, kadar Si yang tertinggi, 400kg/ha, menunjukkan kesan yang penting terhadap garis pusat batang untuk mengurangkan masalah rebah. Bagi menguatkan batang padi, penggunaan baja silikon adalah disyorkan. Di samping itu, lebih banyak kajian tentang pertumbuhan dan hasil bagi padi variti tradisional Sabah perlu dijalankan untuk menyumbang ilmu pengetahuan tentang kesan baja nitrogen dan silikon bagi meningkatkan hasil and pendapatan kepada petani.*

## TABLE OF CONTENT

## LIST OF FIGURES

**LIST OF FIGURES**

**LIST OF FIGURES**

## LIST OF FIGURES

## LIST OF TABLES

## LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

| | |
|---|---|
| Al | aluminium |
| CRD | Completely Randomized Design |
| cm | centimeter |
| DAT | Days After Transplanting |
| DAS | Days After Sowing |
| FAOSTAT | Food and Agriculture Organization Corporate Statistical Database |
| Fe | iron |
| $H_4SiO_4$ | monosilicic |
| ha | Hectares |
| IRRI | International Rice Research Institute |
| MARDI | Malaysian Agricultural Research and Development Institute |
| Mn | manganese |
| mm | millimeter |
| N | nitrogen |
| $NO_3^-$ | nitrate |
| $NH_4^+$ | ammonium |
| ppm | parts per million |
| RM | Ringgit Malaysia |
| Si | silicon |

## LIST OF FORMULAE

## CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Rice is the most common grain in Malaysia, not only in production but also in consumption. There were 674,332 hectares planted with rice including those planted twice a year. Rice becomes the third most widely planted crop in Malaysia after oil palm and rubber (Heatwave may see, 2016).The area of rice harvested in Malaysia was 689,732 ha and the production was 2,645,119 tons (Food and Agriculture Organization Corporate Statistical Database, FAOSTAT, 2014). There are two farming seasons done in a year for rice crop which is from March to August and September to February. More than 65% of domestic rice demand has been produced by our country meanwhile Kedah contributing more than 50% of this (Heatwave may see, 2016). The rice production in Sabah is considered low which was only 2.8 tons/ ha compared to the national average production of five tons (The Star Online, 2016).

The genus of rice is *Oryza* and belongs to the family of Poaceae or Gramineae. Meanwhile, the diploid chromosome number for rice crop is 24.There are 23 species of genus *Oryza* and it involves 21 wild species and two cultivated species namely *Oryza sativa* from Asian and *Oryza glaberrima* from African (Siddiq, Saxena, Malik, 2006; Panda, 2010; Mackill, Coffman, Garrity, 1996).

Traditional rice variety can tolerate drought. Meanwhile, it requires less water while planting. This characteristic is important to conserve water in agriculture as water consumption in rice crop is large. Unlike the hybrid rice which the seed cannot be saved since it is sterile and not respond well in organic compost. In addition, traditional rice variety has the characteristic of resistance to pest and disease as their immunity is preserved and it is claimed that traditional rice is healthier and hardier than hybrid rice (Ramoo, 2012). Furthermore, traditional rice present in unique colours, shapes, sizes and distinct flavours based on each variety.

Fertilizers that are supplied to plant are divided into two kinds which are macronutrients and the micronutrients. A macronutrient is a nutrient that the plant needs to complete the life cycle of the plant while the micronutrient is the beneficial nutrients that plant need as an enhancer for the plant in small quantities. Nitrogen, N fertilizer is the example of macronutrient while silicon, Si, is the example of the micronutrient for the growth and development of the plant.

Nitrogen fertilizer has the function to improve root growth and thus enhance the nutrient uptake by the plant. Next, the functions of nitrogen towards rice plant are to increase plant height, tillering, panicles and yield. However, too much of nitrogen application will cause the plant to lodge easily and make the plant susceptible to pest and disease.

Factors like excessive nitrogen application, storm damage, strong wind, soil density, disease, sowing date, overpopulation and seed type contribute to the lodging effect of most of the cereal crops especially in rice crop. This lodging effect will bring down the rice yield, deterioration of rice quality and also increase cost of production as it makes the harvesting process more difficult (Liu *et al.*, 2011; Grant, 2016).

According to Nagata *et al.*, 2002, Zhang *et al.*, 2010 and Takahashi *et al.*, 2005, silicon content in rice plant is one of the factors that influence the rice sheath on yield and lodging resistance (Cited in Liu *et al.*, 2011). Besides that, Liu *et al.* (2011) stated that leaf sheaths can control the lodging effect of the rice plant. Rice crop with thin leaf sheath is easy to lodge compared to thick leaf sheath (Wang *et al.*, 1991, Cited in Liu *et al.*, 2011). According to Wang *et al.*, 1998 and Rao *et al.*, 2009, when there is more stem tightly wrapped with leaf sheaths, the more resistance is the rice crop towards lodging (Cited in Liu *et al.*, 2011). So, silicon plays an important role to increase the lodging resistance as silicon strengthening the stalk strength and improve the wrapping ability of the leaf sheath towards stems and thus reduce lodging effect of rice crop (Liu *et al.,* 2011, and Jones, 2012).

Rice is the crop that will uptake large amount of silica for their growth and development (Srivastave and Mahapatra, 2012). Korea and Japan are the two greatest countries that used silica fertilizer in rice planting as they realized the benefit of the silica fertilizer towards rice plant (Srivastava and Mahapatra, 2012). Research done by Brown, Welsh and Cary (1987) showed that silicon has the function of strengthening the stalk strength of rice crop, providing cellular protection and limit the pest attack on rice plant (cited in Jones, 2012). Rice plants are easy to lodge when there is lack of silicon supply due to the weak stalk strength (Srivastava and Mahapatra, 2012). According to Datta (1970), rice needs the supply of silica to continue its growth (Srivastava and Mahapatra, 2012). Yoshida (1981) also reported that there is an increase of one-tenth of the rice yield in Japan when there is an application of silicon fertilizer on rice crop. This author also mentioned that there is an increase of one-third of rice production in Japan when rice crop was infested with blast disease (cited in Fageria, 2014). This finding is important in term of rice yield when Si is applied while planting rice.

## 1.2 Justification

Farmers do not pay enough attention to silicon as the effect of the silicon deficiency is not so obvious and its universal existence. But research showed that in the group of cereal crops, Si uptake in rice is the highest which is 80mg $g^{-1}$ root dry weight whereas Si uptake in other cereals crops like wheat, sorghum, maize, rye and barley are lesser than 15mg $g^{-1}$ root dry weight (Ma and Takahashi, 2002). This study is to be conducted with the purpose of sharing the information of the appropriate use of the silicon and the nitrogen application rate on the traditional rice variety with the local farmers to increase their rice production.

Traditional rice varieties are tall and their adoption is low as they are susceptible to lodge that reduces the yield. According to Abdullah *et al.* (1991), traditional variety is often low in yield as they are less responsive to nitrogen fertilizer application (Cited in Sinong, 2016). Due to this problem, farmers tend to increase the rate of nitrogen application to get high yield. However, this practice normally makes the physiological structure of rice crop becomes weak and thus easy lodged. Lodging in paddy field will reduce the production and yield of rice crop (Kashiwagi *et al.,* 2008, Cited in Liu *et al.,* 2011).

The presence of silicon in rice will increase culm wall thickness, size of vascular bundle and thus increase the breaking strength when a high rate of nitrogen is used (Takahashi, 1995, cited in Fageria, 2014). Therefore, silicon is capable to alleviate the problem of lodging. By applying the proper amount of fertilizer, it will help to minimize the problem of lodging in paddy field and thus increased the rice yield.

In short, silicon fertilizer will be used to reduce this problem especially in traditional rice variety which is tall, having longer internodes and droopy leaves. Silicon fertilizer can improve rice growth by maintaining more erect leaves and improve the culm strength to support the grain weight (Panda, 2010, Fageria, 2014).

## 1.3 Significance of study

According to Ranawake *et al.* (2013), most traditional rice varieties have advantages like high in nutritional value, excellant eating quality, having medicinal properties and can resist extreme climate as well as resistant to pest and disease (Cited in Sinong, 2016).

Most researchers showed that appropriate use of fertilizer could improve the yield of rice, so it is good news for farmers to plant traditional rice varieties continuously as the traditional varieties have the good taste and aroma. Furthermore, planting of traditional rice is encouraged as it improves the diversity of rice in planting (Sinong, 2016).

The current problem in Malaysia is that farmers are applying excessive N fertilizer on rice crop hoping to increase the yield of rice. But this practice promotes the problem of lodging to occur. Lodging is a big problem that farmers faced at this moment and limits further increase of rice production. Since there is limited information on the response of traditional rice towards fertilizer application, this study wants to figure out whether the application of the high rate of nitrogen and silicon can improve the yield of traditional rice variety by reducing the effect of lodging.

According to the data obtained from World Bank (2017), the price of rice per metric ton is RM 1632.78. Lodging will contribute to a loss of 11 to 52% reduction in grains weight and thus reduce the yield and income of farmers (Panda, 2010). So, the average in grain reduction due to lodging is 31.5%. Average rice production in Sabah is 2.8 tons per hectare, but when lodging happen, farmers can only get the yield of 1.9 tons per hectare (The Star Online, 2016, World Bank, 2017). This will bring the loss of income of RM 1469.50 per hectare to the farmers.

Meanwhile, a supplier of silicon fertilizer said that price of silicon is RM 1.30/kg. It is worth to apply silicon fertilizer when the rice production can increase up to one ton as the cost of silicon fertilizer is RM 520.00/ha when the application rate of silicon is 400kg/ha. The cost of silicon can be covered by the rice production that will be produced.

This study aims that farmers can benefit from this project in term of rice production and farmer's income. Appropriate use of nitrogen fertilizer and with the help of silicon fertilizer in rice planting, farmers may save the cost of nitrogen fertilizer as well as reduce the lodging problem. This action will lead to increase in the income of farmers and thus improve the quality of life of farmers when lodging incidence reduces and rice production increases.

## 1.4 Objectives

The objectives of this study are:

1. To study the effect of silicon and high nitrogen fertilizer on growth and yield of Serendah Merah rice variety.

2. To study the effect of silicon in reducing the lodging effect on Serendah Merah rice variety.

## REFERENCES


Ahmad, A., Afzal, M., Ahmad, A. U. H., Tahir, M. (2013). Effect of foliar application of silicon on yield and quality of rice (*Oryza sativa* L.). *Cercetări Agronomice în Moldova, XLVI , 3 (155).* Retrieved from https://pdfs.semanticscholar.org/76f6/3a90548fb1a1eeb38f231ace7551125624b1.pdf

Arf, O. (1993). Effect of population density and nitrogen fertilization on the behavior of irrigated rice cultivars. Ilha Solteira: UNESP

Asif, M., Aslan, M., Jabar, A., Rafique, K., Babar, M. R., Ehsanullah. (2000) .Panicle structure,kernel quality and yield of fine rice as influenced by NPK rates and split nitrogen application. *International journal of agricultural&biology.*

Barbosa, F. (1987). MP Nutrition and fertilization of rice. Piracicaba: Brazilian Association for Potash and Phosphate Research

Balasubramanian, V., Bell, M. (2012). *Nitrogen.* Retrieved from irri.org/training/fact-sheets/nutrient-management/item/nitrogen?tmpl=component&print=1

Bhiah, K. M., Guppy, P., Lockwood, P., Jessop, R. (2010). Effect of potassium on rice lodging under high nitrogen nutrition. *19th World Congress of Soil Science, Soil Solutions for a Changing World,136-139.* Brisbane, Australia.

Buresh, R., Quilty, J. (2014). *Nitrogen excess.* Retrieved from http://www.knowledgebank.irri.org/index.php?option=com_zoo&task=item&item_id=841&Itemid=782

Carvalho, J. C. (2000). *Analysis of growth and grain yield of rice culture irrigated by spraying as a function of the application of steel slag as a source of silicon.* (Master thesis). Retrieved from http://www.scielo.br/scielo.php?script=sci_nlinks&ref=000077&pid=S0103-90162003000400023000006&lng=en

Chan, L. Y. (2011). *The Effect of Silicon and High Rate of Nitrogen Fertilizers on the Growth and Yield of TQR-2 Paddy Variety,* Bachelor dissertation, University Malaysia Sabah, Sabah.

Chang, S. Q., Chang, T. G., Song, Q. F., Deng, Q. Y. (2016). *Photosynthetic and agronomic traits of an elite hybrid rice Y-Liang-You 900 with a record-high yield.* Retrieved from https://www.researchgate.net/figure/290174038_fig4_Fig-4-The-dry-matter-weight-length-and-diameter-of-different-stem-internodes-

Chaturvedi, I. (2005). Effect of nitrogen fertilizers on growth,yield and quality of hybrid rice(oryza sativa L.). *journal of central european agricultural, 6(4):,*611-618.

Deivaseeno, D., Ismail, M. R., Sinniah, U. R., Tan, K. B. (2017). Influence of silicon on growth, yield, and lodging resistance of MR219, a lowland rice of Malaysia. *Journal of Plant Nutrition, 40 (8), 1111-1124.* doi: 10.1080/01904167.2016.1264420

Deren, C. W., Datnoff, L. E., Snyder, G. H., Martin, F. G. (1994). Silicon concentration, disease response, and yield components of rice genotypes grown on flooded organic histosols. *Crop Science*, 34, 733-737

Dorairaj, D., Ismail, M. R., Sinniah, U. R., Tan, K. B. (2015). Influence of Silicon on Growth, Yield and Lodging Resistance of Mr219, a Lowland Rice of Malaysia. doi:org/10.1080/01904167.2016.1264420

Espino, L. (2014). *Rice Yield Components.* Retrieved from http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=14826

FAOSTAT. (2014). Retrieved from http://www.fao.org/faostat/en/#data/QC

Fageria, N. K. (2014). Nitrogen and Silicon. *Mineral Nutrition of Rice* (pp. 105-535). Boca Raton, Florida: CRC Press.

Fallah, A. (2012).Silicon effect on lodging parameters of rice plants under hydroponic culture. *International Journal of AgriScience, 2(7),* 630-634.

Ghanbari, M. A., Kashani, A., Nourmohammadi, G., Mobasser, H. R., Alavi. S. V. (2011). Evaluation of Silicon and Nitrogen Rates on Yield, Yield Coponents in Rice (*Oryza sativa* L.) In Two Irrigation System. *J.Agric.&Environ.Sci.,10(4),532-543.* Retrieved from https://www.idosi.org/aejaes/jaes10(4)/10.pdf

Google map picture. (2017). Retrieved from https://mapcarta.com/15883680

Grant, B. L. (2016). *Types of Plant Lodging: Treating Plants Affected By Lodging.* Retrieved from https://www.gardeningknowhow.com/edible/vegetables/vgen/plants-affected-by-lodging.htm

Greenland, D. J. (2006). *The Sustainability of Rice Farming.* Manila, Philippines: CABI

Heatwave may see. (2016, March 22). Heatwave may see drop in domestic rice output, says Mardi senior official. *Malaymail online.* Retrieved from http://www.themalaymailonline.com/malaysia/article/heatwave-may-see-drop-in-domestic-rice-output-says-mardi-senior-official

Hirano, K., Ordonia, R. L., Matsuoka, M. picture. (2017). Retrieved from https://www.jstage.jst.go.jp/article/pjab/93/4/93_PJA9304B-05/_html#sec02

Hossain, K. A., Horiuchi, T., Miyagawa, S. (1999). Effects of Powdered Rice Chaff Application on Si and N Absorption, Lodging Resistance and Yield in Rice Plants (Oryza sativa L.) (Plant Production Science, 2:3), 159-164. doi: 10.1626/pps.2.159

Islam, M. S., Peng, S. H., Visperas, R. M., Ereful, N.(2007). Loadging related morphological traits of hybrid rice in a tropical irrigated ecosystem. *Field Crops Res., 104(2), 240-248*

Jawahar, S., Vijayakumar, D., Bommera, R., Jain, N. (2015). Effect of silixol granules on growth and yield of rice. *Int J Curr Res Aca Rev, 3,* 168-174

Jones, B. (2012). Micronutrients Considered Essential to Plants. *Plant Nutrition and Soil Fertility Manual Second Edition* (pp. 98-103). Boca Raton, Florida: CRC Press.

Kosegarten, H., Appel, T. (2001). Further Elements of Importance. In Mengkel, K., Kirkby,E.A. (Ed.), *5th Edition Principles of Plant Nutrition* (pp. 643-649). Netherlands: Kluwer Academic Publishers

Liu, E., Liu, Y., Wu, G., Zeng, S., Thi, T. G. T., Liang, L., Liang, Y., Dong, Z., She, D., Wang, H., Zaid, I. U., Hong, D. (2016). Identification of a Candidate Gene for Panicle Length in Rice (Oryza sativa L.) Via Association and Linkage Analysis. *Front Plant Science, 7,* 596. *doi: 10.3389/fpls.2016.00596*

Liu, H. J., Rao, Y. C., Yang, Y. L., Leng, Y. J., Huang, L. C.,...Zeng, D. L. (2011). Genetic Analysis of Traits Related to Leaf Sheath in Rice (*Oryza sativa L.) Molecular Plant Breeding,* 3,278-287. doi: 10.5376/rgg.2011.02.0003

MARDI Rice Genebank. (2014). *Can The Farmers Expect The Traditional Varieties To Perform The Same As They Did Before?* [Brochure]. MARDI Seberang Perai Station. Kepala Batas, Pulau Pinang: Zuraini.

Ma. J. F., Nishimura. K., Takahashi, E. (1989). *Effect of silicon on growth of rice plant at different growth stages.* Soil Scin Plant Nutr, 35,347-356

Ma, J. F., Takahashi, E. (2002). *Soil, Fertilizer, and Plant Silicon Research in Japan.* Amsterdam :Elsevier.

Ma, J. F., Tamai, K., Yamaji, N., Mitani, N., Konishi, S., Katsuhara, M., Ishiguro, M., Murata, Y., Yano, M. (2006). A silicon transporter in rice. *Nature 440,* 688-691.

Machado, J. R. (1994). *Development of the plant and grain yield of rice (Oryza sativa L.) populations irrigated by flooding due to growing seasons* (Maste's thesis). Retrieved from http://www.scielo.br/scielo.php?script=sci_nlinks&ref=000082&pid=S0103-9016200300040002300011&lng=en

Mackill, D. J., Coffman, W. R., Garrity, D. P.(1996). The cultivars. In Bryant,D., Rola,T. (Ed.), *Rainfed lowland rice improvement* (pp.25-159). Manila, Philippines

Malavolta, E., Vitti, G. S., Oliveira, S. A. (1997). *Evaluation of the nutritional status of plants: principles and applications* (2nd ed.). Piracicaba

Mauad, Munir, Crusciol, Costa, C. A., Filho, G., Hélio, Corrêa, Corulli. J. (2003). Nitrogen and silicon fertilization of upland rice. *Scientia Agricola, 60(4), 761-765.* doi.org/10.1590/S0103-90162003000400023

Mohd, A. (2017). Plant /Crop Rice Botany. University Malaysia Sabah, Sandakan, Malaysia.

Malav, J. K. (2015). *Importance of Silicon in Rice for Yield Enhancement.* Retrieved from http://www.krishisewa.com/articles/miscellaneous/635-silicon-rice.html

Malav, J. K., Ramani, V. P. (2016).Yield and Nutrient Content of Rice as Influenced by Silicon and Nitrogen Application. *Research Journal of Chemical and Environmental Sciences, 4(4),* 46-49.

Malav, J. K., Ramani, V. P., Sajid, M., Kadam, G. L.(2017). Influence of Nitrogen and Silicon Fertilization on Yield and Nitrogen and Silicon uptake by rice (*Oryza sativa* L.) under Lowland Conditions. *Research Journal of Chemical and Environment, 21(8).*45-49.

Moldenhauer, K. A .K., Gibbons, J. H. (2003). Rice Morphology and Development. In Smith, C. W., Dilday, R. H.(Ed.), Rice Origin, History, Technology, and Production (pp. 104-127). Canada, NJ: John Wiley&Sons, Inc.

Miles, M. L., Linquist, B., Mutters, R. (2014) . *Water Management to Mitigate Blanking.* Retrieved from http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=14701

Mu, P., Li, Z., Li, C., Zhang, H., Wang, X. (2004). QTL analysis for lodging resistance in rice using a DH population under lowland and upland cultural conditions. In 4th International Crop Science Congress. Brisbane: Australia

Mulder, E. (1954). Effect of Mineral Nutrition on Lodging of Cereals. *Plant Soil. 5.* 246–306. doi: 10.1007/BF01395900

Nhan, P.P., Dong, N. T. ,Nhan, H. T., Chi, N. T. M. (2012). Effects of OryMax and Siliysol on Growth and Yield of MTL560 Rice. *World Applied Sciences Journal 19* (*5*), 704-709. doi: 10.5829/idosi.wasj.2012.19.05.703

Okayama University picture. (2009). Retrieved from http://www.rib.okayama-u.ac.jp/plant.stress/english/research2.html

Okuno, A., Hirano, K., Asano, K., Takase, W., Masuda, R.,...Matsuoka, M. (2014). New Approach to Increasing Rice Lodging Resistance and Biomass Yield Through the Use of High Gibberellin Producing Varieties. *Journal of PLoSOne, 9.* doi: 10.1371/journal.pone.0086870

Panda, S. C.(2010). Origin and Distribution. Rice Crop Science (pp. 8-23). India: Agrobios

Palato, N. (2007). Retrieved from http://archive.gramene.org/species/oryza/rice_illustrations.html

Pati, S., Pal, B., Badole, S., Hazra, G. C., Mandal, B.(2016). Effect of Silicon Fertilization on Growth, Yield, and Nutrient Uptake of Rice. *Communications in Soil Science and Plant Analysis. 47(3).* 284-290. doi: 10.1080/00103624.2015.1122797

Pereira, H. S., Korndörfer, G.H., Vidal, A. A., Camargo, M. S. (2004). Silicon sources for rice crop. *Sci. Agric.61(5):522-528*

Ramoo. (2012). *Reviving the lost legacy.* Retrieved from http://agrariancrisis.in/2012/12/22/4815/

Redona, E. D. (2013). Standard Evaluation System for Rice (5$^{th}$ ed.). Manila, Philippines: International Rice Research Institute (IRRI)

Roger, P. A. (1996). Major characteristics of the wetland ricefield ecosystem. In Smith, W. H. (Ed.), *Biology and Management of the Floodwater Ecosystem in Ricefields* (pp.3-5). Philippines, Manila: IRRI

Rural Enterprise Network. (n.d.). *Traditional rice.* Retrieved from http://www.rensrilanka.org/tradrice.html

Salman, D. (2012). Application of Nitrogen and Silicon Rates on Morphological and Chemical Lodging Related Characteristics in Rice (*Oryza sativa* L.) at North of Iran. *Journal of Agricultural Science, 4(6). doi:10.5539/jas.v4n6p12*

Siddiq, E. A., Saxena, S., Malik, S. S.(2006). Rice. In Dhillon, B. S., Saxena, S., Agrawal, A., Tyagi, R. K. (Ed.), *Plant Genetic Resources: Foodgrain Crops* (pp. 27-57). New Delhi, India: Narosa Publishing House.

Sinong, G. F. (2016). *Effect of Different Rates of NPK Fertilizer Application on Growth and Yield on Several Sabah Local Traditional Paddy Varieties.* Bachelor dissertation, University Malaysia Sabah, Sandakan, Sabah.

Srivastava, V. C., Mahapatra, I. C. (2012). *Advances In Rice Production Technology Theory and Practice.* India: ARGROBIOS

Stone, L. F., Silveira, P. M., Moreira, J. A. A., Yokoyama, L. P. (1999). Nitrogen fertilizationin rice under additional irrigation by sprinkling. *Pesquisa Agropecuária Brasileira*, 34, 929-932

The Star Online. (2016, March 21). RM381mil to increase Sabah rice production. Retrieved from http://www.thestar.com.my/business/business-news/2016/03/21/rm381mil-to-increase-sabah-rice-production/

Variety trials. (2014). Retrieved from http://www.ricehub.org/RT/varieties/variety-trials/module-3-data-collection/

Vergara, B. S., Lilis, R., Tanaka, A. (1965). Soil Science and Plant Nutrition. *Studies of the internode elongation of the rice plant.* 11:6, 26-30. doi:10.1080/00380768.1965.10431172

Wang. Y., Lu, J., Ren, T., Hussain, S., Guo, C., Wang, S., Cong, R., Li, X. (2017). Effects of nitrogen and tiller type on grain yield and physiological responses in rice. *AoB Plants. 9(2),* doi: 10.1093/aobpla/plx012

World Bank. (2017). Retrieved from http://www.indexmundi.com/commodities/?commodity=rice&months=60&currency=myr

Yao, X. Y., Li, Q., Liu, J., Jiang, S. K., Yang, S. L., Wang, J. Y., *et al.* (2015). Dissection of QTLs for plant height and panicle length traits in rice under different environment. *Sci. Agr. Sin. 48, 407–414.* doi:10.3864/j.issn.0578-1752.2015.03.01

Yogendra, N. D., Kumara, B. H., Changrashekar, N., Prakash, N. B., Anantha, M. S., Jeyadeva,H.M. (2014). Effect of silicon on real time nitrogen management in a rice ecosystem. *African Journal of Agricultural Research,9(9),831-840.* doi: 10.5897/AJAR12.1841

Yoshida, S. (1981). Laboratory Manual for Physiological Studies of Rice. The International Rice Research Institute, Philippines

Yoshida, S., Ohnishi, Y., Kitagishi, K. (1962). Chemical forms, mobility and deposition of silicon in rice plant. *Soil Science and Plant Nutrition, 8,* 15-21

Zhang, W. J., Wu, L. M., Ding, Y. F., Weng, F., Wu, X. R., Li, G. H.,...,Wang ,S. H. (2016). Top-dressing nitrogen fertilizer rate contributes to decrease culm physical strength by reducing structural carbohydrate content in japonica rice. *Journal of Integrative Agriculture,15(5), 992-1004.* doi.org/10.1016/S2095-3119(15)61166-2

Zhang, W. J., Wu, L. W., Wu. X.R., Ding, Y. F., Li, G. H.,...Wang, S. H. (2016). Lodging Resistance of Japonica Rice (Oryza Sativa L.): Morphological and Anatomical Traits due to top-Dressing Nitrogen Application Rates. *Rice (N Y) 9,* 35. doi: 10.1186/s12284-016-0103-8