EFFECT OF POTASSIUM ON GROWTH, YIELD AND LODGING OF THREE RICE VARIETIES GROWN ON PADDY SOIL

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ABSTRACT

A pot experiment was conducted to evaluate the effect of potassium on growth, yield and lodging of two selected Sabah traditional rice varieties (Padi Wangi and Serendah Merah) and Sri Sabah paddy variety (TR9) as HYV. A 3 x 3 factorial completely randomized design (CRD) with three replications for each treatment combination was used. The treatments for N : P_2O_5 : K_2O used were 60:30:30 kg ha^{-1}, 60:30:60 kg ha^{-1} and 60:30:90 kg ha^{-1} where three split applications of fertilizers were applied to the rice plants, namely basal application before transplanting, topdressing applications at maximum tillering and panicle initiation stages. The results showed that there is significant interaction effect of potassium application rate and rice varieties on the 1000-grain weight, extrapolated yield per season and internode length of two lowest nodes. The rate of 60 kg ha^{-1} produced the lowest plant height (114.67 cm), highest 1,000-grain weight (26.23 g) and the highest extrapolated yield per season (5.25 t ha^{-1}). This application rate also resulted in the lowest culm height (80.11 cm) and highest culm diameter (5.15 mm) that can reduce the lodging susceptibility of rice plants. For the traditional rice varieties, Serendah Merah (V2) produced the highest 1,000-grain weight (26.23 g) and the highest extrapolated yield per season (5.25 t ha^{-1}). This variety also has shorter maturity period of 100-110 days which enables the farmers to cultivate the rice plants for two cycles or even five cycles for every two years. For lodging parameters, Padi Wangi (V1) resulted in the lowest culm height (77.86 cm) and highest culm diameter (5.55 mm) and the lowest internode length between two lowest nodes (3.50 cm). The Sabah local traditional rice varieties had a potential to be cultivated as the potassium fertilizer application contributed to higher rice yields and some of their lodging characteristics were minimized.

KESAN KALIUM TERHADAP TUMBESARAN, PENGHASILAN DAN KEREBAHAN TIGA VARIETI PADI DITANAM PADA TANAH SAWAH

ABSTRACK

Satu kajian telah dijalankan untuk menilai kesan pemberian baja kalium terhadap pertumbuhan, hasil dan kerebahan dua varieti padi tradisional tempatan Sabah (Padi Wangi dan Serendah Merah) dengan satu varieti padi berhasil tinggi (Padi Varieti Sri Sabah, TR9). Kesemua rawatan ini telah disusun dengan menggunakan Rekabentuk Rawak Penuh (CRD), rekabentuk faktoran dua faktor dengan tiga replikasi bagi setiap rawatan. Rawatan-rawatan untuk pengaplikasian N : P_2O_5 : K_2O adalah 60:30:30 kg ha^{-1}, 60:30:60 kg ha^{-1} dan 60:30:90 kg ha^{-1}. Pengaplikasian baja-baja ini telah dijalankan sebanyak tiga peringkat, iaitu pada peringkat sebelum menanam anak benih padi (basal application), *peringkat pembentukan anakan pokok maksimum serta permulaan pembentukan tangkai berbuah. Hasil kajian menunjukkan bahawa faktor pengaplikasian kalium dan varieti padi telah menunjukkan perbezaan beerti terhadap 1,000 butiran padi, unjuran hasil berat bernas setiap tangkai dan panjang ruas tangkai. Pengapklikasian baja kalium pada kadar 60 kg ha^{-1} telah menghasilkan ketinggian pokok yang terendah (114.67 sm), berat 1,000 butiran padi tertinggi (26.23 g) dan unjuran hasil tertinggi (5.25 t ha^{-1}). Kadar pengaplikasian baja kalium ini juga dapat mengurangkan kesan kerebahan pokok padi dengan menghasilkan pokok padi yang mempunyai ketinggian batang padi terendah (80.11 sm) dan diameter batang padi tertinggi (5.15 mm). Dalam aspek penghasilan padi, Serendah Merah telah disyorkan kerana varieti padi ini telah mencatatkan 1,000 butiran padi tertinggi (26.23 g) dan unjuran hasil tertinggi (5.25 t ha^{-1}). Varieti padi ini turut mempunyai tempoh kematangan yang lebih pendek (100-110 HST) yang membolehkan penanaman padi dilakukan dua kali setahun ataupun lima kali dalam tempoh dua tahun. Dalam aspek prestasi kerebahan, Padi Wangi telah menghasilkan ketinggian batang padi terendah (77.86 sm), diameter batang padi tertinggi (5.55 mm), panjang ruas tangkai padi terpendek (3.50 sm). Kesimpulannya, varieti padi tradisional tempatan Sabah mempunyai potensi untuk penanaman kerana pengapklisian baja kalium ini dapat meningkatkan penghasilan padi serta mengurangkan kesan kerebahannya.*

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LIST OF SYMBOLS, UNITS AND ABBREVATIONS

ANAVA	Analisa Variasi
ANOVA	Analysis of Variance
Bu	Bethesda unit
CMS80	Chipper Mulcher Shredder80
CHN	Carbon, Hydrogen, Nitrogen
CRD	Completely Randomized Design
DAS	Days after sowing
DAT	Days after transplanting
FAO	Food and Agriculture Organization
FSA	Faculty of Sustainable Agriculture
HLT	Hari lepas tanam
HYV	High Yielding Variety
IRRI	International Rice Research Institute
ISTA	International Seed Testing Association
LECO	Laboratory Equipment Corporation
MARDI	Malaysian Agricultural Research and Development Institute
MOP	Muriate of Potash
SAS	Statistical Analysis Software
TR9	Paddy Variety Sri Sabah
TSP	Triple Super Phosphate

LIST OF FORMULAE

CHAPTER 1

INTRODUCTION

1.1 Background

Rice, which is scientifically known as *Oryza sativa* L. is a staple food that is being consumed by about half of the world population, including Malaysia (Buresh *et al.*, 2008). In Sabah, traditional rice varieties have been cultivated by the farmers to produce their own food source and generate income by supplying to the local market (Souki, 2015). The adoption of each traditional rice variety is based on the texture, eating quality and availability of seeds in each region (Souki, 2015). In Sabah, Kota Belud is the largest region that is being utilized for rainfed lowland rice production with a land area of approximately 8,502 hectares. The rice grown includes high yielding varieties and traditional rice varieties. The state government of Sabah has set a priority to increase the production of rice which acts as a strategy to enhance the food security of the state (Souki, 2015).

In the rice production sector, poor nutrient and agronomic management leads to the imbalanced use of fertilizers where the farmers give much attention only on nitrogen fertilizer application and often carry out minimal level of phosphorus and potassium fertilization (Manzoor *et al.*, 2008). This causes the rice grain yield reduction due to lodging as well as disease outbreaks that result from low efficiency of nitrogen fertilizer application and use with minimal potassium fertilizer application (Hach and Nam, 2006). Saito *et al.* (2006) reported that some traditional rice varieties may not be suitable to be cultivated under high-input management as the traditional rice plants become more vulnerable to lodging. Amarasinghe *et al.* (2014) also reported that some traditional rice cultivars are not responsive to chemical fertilizer application.

Excessive nitrogen application also potentially leads to increased input cost and environmental pollution (Aishah *et al.*, 2010). Potassium deficiency due to excessive nitrogen application results in the weakening of stem strength due to heavy top on the panicle. Due to this, the tendency of the rice plant to lodge is higher, especially at the beginning of internode elongation and heading stages (Chang, 1964; Slaton *et al.*, 2005). The problems caused by lodging in rice plants include the difficulty in undertaking mechanical harvesting, reduced crop yield due to sprouting and possible moulding, poor grain quality as well as decreased canopy photosynthesis of the plants due to the effects of self-shading and uneven maturity (Umar *et al.*, 2015). In severe potassium deficiencies of rice plants, the visual symptoms include brown spot and premature death of lower leaves. These symptoms typically appear at the booting stage of rice plants, especially in silt and sandy loam soils with the pH's value less than 7.0 (Slaton *et al.*, 2005).

Poor nutrient management and natural disasters such as wind, rain and hail increase susceptibility to lodging in rice crops due to larger bending moments caused by the weakening stalk (Kono and Takahashi, 1964). The uneven land preparation for rice cultivation also tends to affect the growth and yield of rice plants (Anbumozhi *et al.*, 1994). The inefficient water depth management due to uneven land preparation leads to impaired tillering in partially submerged conditions, increased lodging incidence due to increased plant height and inter-node length, poor crop growth and yield due to inhibited tillering as well as reduced leaf area during rooting stage in deep water (Yoshida, 1981; De Datta, 1981; Ohe and Mimoto, 1999). Balanced, integrated and efficient use of fertilizers applied at the correct dose and timing tends to attain sustainable rice production by enhancing the rice productivity, preserving soil health and reduced lodging incidence (Ahmad *et al.*, 2014; Awan *et al.*, 2007).

1.2 Justification

Due to the presence of high yielding varieties (HYV), most of the farmers abandoned the cultivation of traditional rice as the yield produced by the HYV is much higher than that of traditional rice varieties. Souki (2015) reported that some traditional rice varieties only produce average yields less than 2.0 t ha^{-1} per season. However, HYV such as TR9 has a potential yield of 7.0 t ha^{-1} per season (Jabatan Pertanian, 1995).

This leads to the extinction of the traditional rice varieties because HYV have been repeatedly adopted by the local farmers for cultivation, resulting in the occurrence of genetic erosion of rice.

Traditional rice possess tremendous numbers of benefits, but the yield of some varieties is typically low (Ranawake *et al.*, 2013). However, Muhammad *et al.* (2015) suggested that high grain yield of rice can be attained through sustainable rice production practices such as appropriate fertilizer application, maximum desired planting density per unit area for adequate sunlight to the rice plants for photosynthesis. It is also reported that the appropriate use of fertilizers at optimum rate will result in maximum yield of traditional rice with the lowest output cost (Dobermann and Fairhurst, 2000).

Awan *et al.* (2007) reported that the appropriate use of fertilizers can produce higher grain yield, maximum tiller numbers per hill, highest grain weight, and minimum percentage of sterile grains. Potassium plays an important role in enhancing stalk stability and minimizing lodging effect in rice plants (Fathi, 1998). Umar *et al.* (2015) reported that potassium is an essential nutrient element that has a synergistic effect on the uptake of nitrogen by plants to improve plant height by increasing its rate of metabolism and strengthening the stem of plants.

By conducting this study, an evaluation of the response of traditional rice towards different potassium fertilizer rates at a fixed amount of nitrogen fertilizer will be achieved. The high application of nitrogen will increase the yield of the traditional rice and the application of potassium fertilizer will control the lodging of the traditional rice. By obtaining the right combination of potassium and nitrogen to be applied for traditional rice, it is possible to enhance the yield components of the traditional rice such as total number of panicles per plant, total number of grains per panicle, percentage of filled grains per panicle and 1,000-grain weight. Since information on the response of local traditional rice cultivars for fertilizer applications is very limited, hence this study was conducted. The study also provides comparable information HYV and some Sabah traditional rice varieties.

Local farmers use traditional rice varieties for cultivation to produce their own food source as these traditional rice varieties produce low but stable yields even when cultivated under adverse environmental conditions (Saito *et al.*, 2006). The adoption of traditional rice varieties by farmers varies according to their needs such as taste, texture, aroma and availability of the seeds (Souki, 2015). In terms of health benefits, traditional rice is said to be of high nutritional value and possesses medicinal properties for various diseases (Ranawake *et al.*, 2013). In terms of agronomic characteristics, Ranawake *et al.* (2013) reported that most of the traditional rice varieties are more resistant to adverse environmental and soil conditions as well as pest and disease attacks compared to the HYVs.

Due to the long maturity period, less yield and lodging of traditional rice varieties, studies need to be carried out to overcome these problems and to ensure that the farmers will apply the fertilizers at an optimum rate. By addressing the response of traditional rice to potassium fertilizer, it is possible to determine the traditional rice varieties that are responsive to the fertilizers to attain higher yield. This will enable the farmers to commercialize and supply the extra rice produced for generating income.

Moreover, traditional rice varieties also possess superior genetic qualities that can be harnessed to improve the new rice varieties for better growth and yield under limited resources. The genetic materials will be conserved for future breeding programmes (Rabiei *et al.*, 2004). These traditional rice varieties can be alternatives for cultivation when new hybrid rice varieties fail to produce the desired grain yield due to attack by different indigenous pests, infectious diseases and extreme climatic factors. Therefore, it is important to collect and conserve of traditional rice varieties to develop new suitable varieties for sustaining the rice agricultural sector (Mohanty *et al.*, 2011).

1.3 Objectives

The objectives of this study are:

i. to evaluate the effect of potassium fertilizer on growth and yield of selected Sabah traditional and TR9 (HYV) rice varieties.
ii. to evaluate the effect of potassium fertilizer on lodging of selected Sabah traditional and TR9 (HYV) rice varieties.

1.4 Hypothesis

H_o: There is no significance difference between the effect of potassium fertilizer on growth, yield and lodging of selected Sabah traditional and TR9 (HYV) rice varieties.

H_a: There is a significance difference between the effect of potassium fertilizer on growth, yield and lodging of selected Sabah traditional and TR9 (HYV) rice varieties.

CHAPTER 2

LITERATURE REVIEW

2.1 Taxonomy of rice

Rice is being categorized under the family of Poaceae under the genus *Oryza* which has approximately 24 species (Department of Biotechnology, Ministry of Science and Technology, India, 2011). Out of these 24 species, *Oryza sativa* L. and *Oryza glabberima (steud)* are the two major species that have been cultivated worldwide (Morishima, 1984). According to Morishima (1984), *Oryza sativa* L. is the rice species that is widely cultivated in Asian countries, including Malaysia; whereas *Oryza glabberima (steud)* is the rice species which is widely adapted and suitable to be grown under the environmental conditions in Africa. Table 2.1 below indicates the scientific taxonomy of *Oryza sativa* L.

Table 2.1 The scientific taxonomy of *Oryza sativa* (L.)

Kingdom	Plantae
Division	Magnoliophyta
Class	Liliopsida
Order	Poales
Family	Gramineae or Poaceae
Tribe	Oryzeae
Genus	*Oryza*
Species	*sativa*

Source: Department of Biotechnology, Ministry of Science and Technology, India, 2011

Oryza sativa L. species can be further divided into three sub-species due to the differences in morphological and physiological characteristics. These three sub- species of *Oryza sativa* L. are named as *indica, japonica and javanica* (Panda, 2010). Panda (2010) has conducted a study to distinguish these three sub-species of *Oryza sativa* L.

where the different regions of cultivating these three different sub-species is one of the major differences between *indica, japonica and javanica.* The sub-species of *indica* are well adapted to be cultivated under the environmental conditions in the humid tropics and subtropics regions in Asia. Unlike *indica*, the sub-species *japonica* is not widely found in temperate zones and sub-tropics. The *javanica* sub-species are popularly planted in some regions of Indonesia (Panda, 2010).

These three sub-species of *Oryza sativa* L. are also being adopted by farmers based on the different adaption to the niches in terms of climatic factor, soil factor as well as the desired eating quality of people from different regions (Ministry of Science and Technology, India, 2011). It is believed that the traditional rice varieties that are being cultivated in Sabah have been classified under the sub-species of *indica* due to their morphological characteristics such as high tillering numbers per hill, tall plant height and high tendency of lodging occurrence (Souki, 2015). The rice varieties in Malaysia require the optimum photoperiod in order to receive adequate amount of sunlight for producing high grain yield (Muhammad *et al.*, 2015). Moreover, the grain characteristics of the *indica* can be distinguished from the sub-species of *japonica* and *javanica* where the grains of *indica* sub-species can be easily shattered; the grain type is long to medium in length and the grain texture is non-sticky (Panda, 2010).

2.2 Morphology of rice

The rice plant is a monocotyledon that has an annual life cycle. Usually, the rice plant takes up three to six months' time to reach maturity, depending on the rice variety, environmental factors of a particular area and the cultural practices (Ranawake, 2013). There are three main growth stages for rice to complete its life cycle, which include vegetative growth phase, reproductive phase and ripening phase (Moldenhauer *et al.*, 2013). However, there are three factors that potentially influence the yield which include the panicle number per unit land area, the average number of grains per panicle and the average weight of individual grains (Moldenhauer *et al.*, 2013). All these factors are generally affected throughout the season from panicle initiation through head emergence by environmental, nutritional as well as the plant physiological conditions. The vegetation phase, according to Moldenhauer *et al.* (2013), this phase consists of six vegetative stages, namely seed germination, seedling emergence, pre-tillering, tillering, maximum tillering and vegetative lag phase. For the seed germination of rice, the length of time from seed germination to emergence depends on the variety and it takes 7 to 28 days for the seedling to emerge depending on soil temperature and soil-moisture (Moldenhauer *et al.*, 2013).

When the seeds have imbibed water and germination begins, the radicle emerges to anchor it in the soil which subsequently leads to plumule emergence in dry land or soil under optimum temperature of 31°C and this may take between five and 28 days depending on the growing environmental factors (Moldenhauer *et al.*, 2013). The seminal roots or radicle are sparsely branched and persist only for a short time after germination which is until the seventh-leaf stage (Yoshida, 1981). Later, leaf development occurs at regular intervals once the plant emerges from the soil where the development of the primary and secondary leaf up to the fourth leaf leading up to tillering is called pre-tillering phase and this usually requires between 15 and 25 days (Moldenhauer *et al.*, 2013). At the same time, the secondary or lateral root development begins from the emerged radical and seminal roots from soon after germination and this process continues until the permanent flood period. Figure 2.1 illustrates the anatomy of a germinating rice seedling whereas Figure 2.2 displays the growth stages of a rice seed from germination to emergence of prophyll. Figure 2.3 shows one tiller of rice seedling.

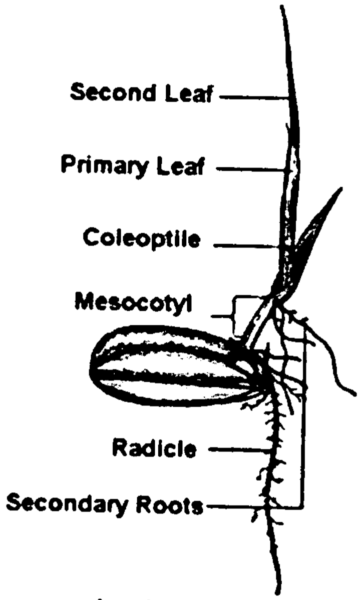


Figure 2.1 The anatomy of a germinating rice seedling
Source: Moldenhauer *et al.*, 2013

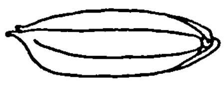
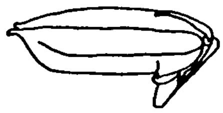
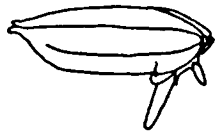
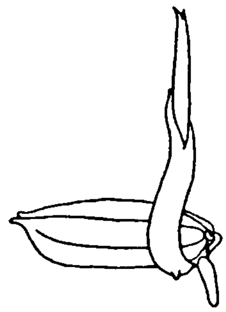
Growth Stage	S0	S1	S2	S3
Morphological Criteria	Dry, unimbibed seed	Emergence of coleoptile	Emergence of radicle	Emergence of prophyll from coleoptile
Illustration				

Figure 2.2 The growth stages of a rice seed from germination to emergence of prophyll

Source: Moldenhauer *et al.*, 2013

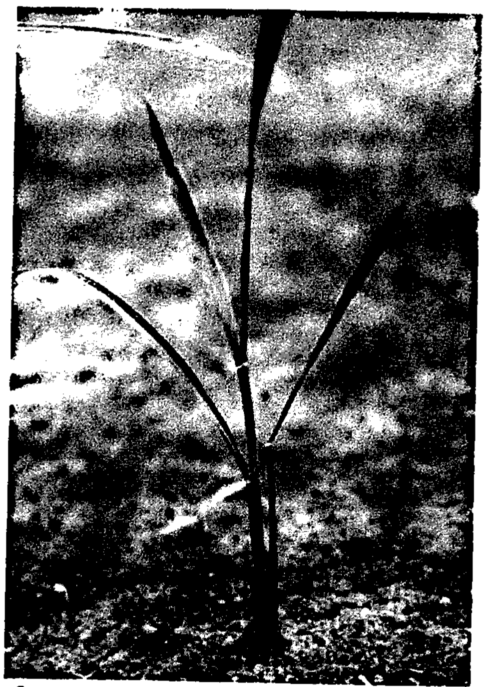


Figure 2.3 One tiller of rice seedling

Source: Dunand and Saichuk, 2014

Tillering occurs when a sprout or stalk is produced from the crown, which forms below the soil surface or from the axils of the lower leaves. Tillering begins usually three weeks after emergence and a rice plant may develop from two to five paniclebearing productive tillers depending on the seeding method. During tillering, the crown roots of each plant continue to develop growing downward and it is only upon flooding that roots begin to develop laterally and vertically in response to the oxygen available on the water surface. Once the tillering process ends, the reproductive phase of the rice plant begins to be expressed by decreasing the number of tillers, while the plant height and stem diameter increases slowly (Moldenhauer *et al.*, 2013). Figure 2.4 illustrates the open floret with floral parts showing.

Figure 2.4 The open floret with floral parts showing
Source: Dunand and Saichuk, 2014

The reproductive phase occurs from panicle initiation to anthesis and is characterized by the panicle primordial beginning to differentiate when a bright green band is being observed just above the top node, followed by the internode elongation until the full plant height is achieved. After that, the panicle begins to expand causing a swelling of the flag leaf sheath where it is completely extended and meiosis occurs in the ovules. Kamalanathan and Arivazhagan (2003) reported that the two equal split of potassium fertilization at the recommended rate tends to produce higher grain yield and straw yield of rice. Heading occurs after the panicle begins to swell in the boot and as the panicle emerges from the boot where it takes another 10 to 14 days depending on the number of tillers on the plant. Once exertion begins, anthesis begins when the floret opens allowing the stamens to extrude, and the pistil becomes visible between the floret lemma and palea. Pollen is then shed from the anthers first while the floret is closed and then shed more once it opens (Moldenhauer *et al.*, 2013).

Flowering proceeds from the tip of the panicle downward to the base of the panicle as it emerges from the boot, which lasts about 6 to 14 days. Ravichandran and

REFERENCES

Ahamd A. I., Ismail, C. H., Wan, Zaki W. M., Muhammad Naim F. A. R. 2014. Pengaruh Baja Nitrogen (N) dan Kalium (K) terhadap Padi Varietu MR269 dan MR284 di Sungai Nibong (PBLS). Jurnal Teknologi (Sciences and Engineering) **70(6)**: 1-4

Aishah, A. W., Zauyah, S., Anuar, A. R. and Fauziah, C. I. 2010. Spatial Variability of Selected Chemical Characteristics of Paddy Soil in Sawah Sempadan, Selangor, Malaysia. *Malaysian Journal of Soil Science* **14**: 27-39

Amarasinghe, U. G. S., Ranawake A. L. and Senanayake S. G. J. N. 2014. Fertilizer Response of some Sri Lankan Traditional Rice Cultivars during Vegetative Growth Phase. *International Journal of Scientific and Research Publications,* **4(7)**: 1-7

Anbumozhi, V., Yamaji, E. and Tabuchi, T. 1994 Variability of Flood Water Depth, Soil Properties and Crop Yield in a Large Sized Paddy Field. *Proceedings of International Agricultural and Engineering Conference and Exhibition*. Bangkok, Thailand. 667-676

Awan, T. H., Z. Manzoor, M. E. Safdar and M. Ahmad. 2007. Yield Response of Rice to Dynamic Use of Potassium in Traditional Rice Growing Area of Punjab. Pakistan, *Journal of Agricultural Science,* **44(1)**: 130-135

Bahmaniar, M.A. and G.A. Ranjbar. 2007. Response of Rice Cultivars to Rates of Nitrogen and Potassium Application in Field and Pot Conditions. *Pakistan Journal of Biological Science* **10**: 1430-1437

Bahmanyar, M. A. and Mashaee, S. 2010. Influences of Nitrogen and Potassium Top Dressing on Yield and Yield Components as well as their Accumulation in Rice (Oryza sativa). *African Journal of Biotechnology* **9(18)**: 2648-2653

Beringer, H. 1980. Nutritional and Environmental Effects on Yield Formation. *Proceedings of 15th Colloquium of the International Potash Institute: Physiological Aspects of Crop Production*. Horgen, Switzerland. 155-173

Berry, P. M., Sterling, M., Spink, Baker, J. H., Sylvester-Bradley, C. J., Mooney, R., Tams, S. J., and Ennos, A. R. 2004. Understanding and Reducing Lodging in Cereal. *Advances in Agronomy* **84**: 217-271

Beser, N. and Genctan, T. 1999. Effects of Different Plantation Methods on Some Agricultural Features and Productivity in the Rice (*Oryza sativa* L.) *Turkey Third Field Crop Congress* **1**: 62-467

Bhuiyan, S. L., Sattar, M. A. and Khan. M. A. K. 1994. Improving Water Use Efficiency in Rice through Wet-seeding. *Irrigation Science* **16**:1-8

Bond, J. A. and Bollich, P. K. 2007. Effects of Pre-harvest Desiccants on Rice Yield and Quality. *Crop Prot.* **26**: 490-494

Borneo Post. 2015. Rice Output Still Below 30% of Self-sustaining level. *Borneo Post,* November 26

Buresh, R. J., Ramesh Reddy K., Chris van Kessel. 2008. Nitrogen Transformation in Submerged Soils. *Nitrogen.indb*: 401-435

Chakmak, I. 2005. The Role of Potassium in Alleviating Detrimental Effects of Abiotic Stress in Plants. *Journal of Plant Nutrition and Soil Science* **168**: 521-523

Chang, T. T. 1964. Varietal Differences in Lodging Resistance. Philippines: International Rice Commission Newsletter **13**: 1-11

Craft, C., Broome, S. and Campbell, C. 2002. Fifteen Years of Vegetation and Soil Development After Brackish-Water Marsh Creation. *Restoration Ecology* **10(2)**: 248-258

De Datta, S. K. 1981. Principles and Practices of Rice Production, New York (Abstract in English). *Le systéme de riziculture intensive malgache, Tropicultura (Brussels)* **11**: 110-114

Department of Agriculture, Malaysia. 2015. *Booklet Statistik Tanaman: Sub-sektor Tanaman Makanan Malaysia*

Department of Biotechnology. 2011. Rice as a Crop Plant. *Biology of Oryza sativa L. (Rice).* Series of Crop Specific Biology Documents: Ministry of Science and Technology, Government of India: 1-2

Dobermann, A., and Fairhurst, T.H. 2000. Rice: Nutrient Disorder and Nutrient Management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191

Dunand, R. and Saichuk, J. 2014. Rice Growth and Development. *Louisana Rice Production Handbook*: 41-53

Fathi, K. H. 1998. Growth and Nutrition of Crops. *Jahad Daneshgahi Mashhad P. In Persian* **372**: 93

Gagandeep, H. N., Sunil, C. and Gopakkali, P. 2016. Growth, Yield and Grain Quality of Traditional Paddy Varieties as Influenced by Nutrient Management Practices. *International Journal of Farm Sciences* **6(1)**: 120-133

Ghosh, M., Mandal, B. K., Mandal, B. B., Lodh, A. K, Dash, A. K., 2004. The Effect of Planting Date of and Nitrogen Management on Tield and Quality of Aromatic Rice (*Oryza sativa*). *Journal of Agricultural Science* **142**: 183-191

Gozubenli, H. 1992. The Effects of Nitrogen Doses and Seeding Rates on Yield and some Yield Components of Rice (*Oryza sativa* L.) *Journal of Science and Engineering* **6(1)**: 39-48

Hach, C. V., Nam, N. T. H. 2006. Response of Some Promising High Yielding Varieties to Nitrogen Fertilizer. *Omonrice* **14**: 78-91

Haefele, S. M., Naklang, K., Harnpichitvitaya, D., Jearakongman, S., Skulkhu, E., Romyen, P., Phasopa, S., Tabtim, S., Suriya-arunroj, D., Khunthasuvon, S., Kraisorakul, D., Youngsuk, P., Amarante, S.T. and wade, L. J. 2006. Factors Affecting Rice Yield and Fertilizer Response in Rainfed Lowlands of Northeast Thailand. *Field Crops Research* **98**: 39-51

Haghighi, H., M. S. Daliri, h. R. Mobaser and A. A. Moosavi. 2011. Effect of Different Nitrogen and Potassium Fertilizer Levels on Quality and Quantity Yield of Flue-cured Tobacco. *World Applied Science Journal* **15**: 941-946

Hitaka, N. 1968. Experimental Studies on the Mechanisms of Lodging and its effect on Yield in Rice Plants. *Bulletin of National Institute of Agricultural Sciences* **15**: 175

Hobbs, P. R., K. D. Sayre and I. Ortiz-Monasterio. 1998. Increasing Wheat Yields through Agronomic Means. Mexico, D. F. Mexico

Inglett, P. W., Reddy, K. R. and Corstanje, R. 2005. Anaerobic Soil. Elsevier: University of Florida, Gainesville

International Seed Testing Association (ISTA). 1993. International Rules for Seed Testing. *Seed Science and Technology* **21**: 25-46

Islam, M. Peng, S. S., Visperas , R. M., Ereful, N., Bhuiya, M. S. U. and Julfiquar, A. W. 2007. Lodging-related Morphological Traits of Hybrid Rice in a Tropical Irrigated Ecosystem. *Field Crops Resources* **101**: 240-248

Jabatan Pertanian Sabah. 1995. Varieti Padi Seri Sabah (TR9). Kementerian Pertanian dan Industri Makanan Negeri Sabah

Jabatan Pertanian. 2015. Booklet statistic Tanaman: Sub-Sektor Tanaman Makanan

Jahan, M. S., Sultana, S. and Ali, M. Y. 2014. Effect of Different Nitrogen Levels on the Yield Performance of Aromatic Rice Varieties. Bull. Inst. Trop. Agriculture, Kyushu University **37**: 47-56

Kamalanathan, J. and Arivazhagan, K. 2003. Effect of Timing of Potassium Application on the Performance of Rice Genotypes. M. Sc.(Agri), Annamalai University, Annamalainagar

Kashiwagi, T., Togawa E., Hirotsu N., and Ishimaru K. 2008. Improvement of Lodging Resistance with QTI S for Stem Diameter in Rice, *Theor. Appl. Genet.*, **117**: 749-757

Kaushal, A. K., Rana, N. S., Singh, A., nerraj, Sachin and Strivastav, A. 2010. Response of Levels and Split Application of Nitrogen of Nitrogen in Green Manure Wetland Rice (*Oryza sativa* L.). *Asian Journal of Agricultural Science* **2(2)**: 42-46

Kawaguchi, K. and Kyuma, K. 1974. Paddy Soils in Tropical Asia. *Southern Asian Studies.* **12(1)**: 3-23.

Kong, L., Sun, M., Wang, F., Liu, J., Feng, B., Si, J., Zhang, B., Li, S. and Li, H. 2014. Effects of High NH_4^+ on K^+ Uptake, Culm Mechanical Strength and Grain Filling in Wheat. *Frontier in Plant Science* **5(703)**

Kono, M. 1995. Physiological Aspects of Lodging. *Science of the Rice Plants: Physiology* **2**: 971-991

Kono, M. and Takahashi, J. 1964. The Effect of Wind Force with Reference to Lodging of Paddy Rice. *Soil Science and Plant Nutrition* **10(6)**: 20-27

Liu, H. J., Rao, Y. C. Yang Y. L., Leng Y. J., Huang, L. C., Zhang, G. H., Hu. J., Guo L. B., Gao Z. Y., Zhu, L., Dong. G. J., Liu, J., Yan, M. X., Qian Q., and Zeng D. L. 2011. Genetic Analysis of Traits Reated to Leaf Sheath in Rice (*Oryza sativa* L.). *Molecular Plant Breeding* **9(3)**: 278-287

Ma, J. F., Y. Miyake and F. Takahashi. 2001. Silicon as a Beneficial Element for Crop Plants. *Silicon in Agriculture.* New York: Elsevier Science Publishing: 17-39

Mackill, D. J., Coffman, W. R. and Garrity, D. P. 1996. Rainfed Lowland Rice Improvement. International Rice Research Institute, Los Banos, Manila, Phillipines. 53

Manzoor, Z. Awan, T. H., Akhter, M. and Faiz, F. A. 2008. Effect of Split Application of Potash on Yield Related Traits of Basmati Rice. *Journal of Animal Plant Science* **18(4)**: 120-124

Marschner, H. 1995. Mineral Nutrition of Higher Plants. Second Edition: 889. Academic Press, San Diego, USA

Md. Razib, R. 2015. Effectiveness of Nitrogen and Potassium Fertilizer Application on Lodging Habit and Yield Attributes of T. Aman Rice in Ganges Tidal Flood Plain. *International Journal of Business, Social and Scientist Research* **3 (2)**: 66-76

Ministry of Science and Technology. 2011. Biology of *Oryza sativa* L. (Rice). Series of Crop Specific Biology Documents. Government of India

Mohanty, R., Tripathy B. K. and Panda, T. 2011. Status, Distribution and Conservation of Some Threatened Indigenous Rice Varieties Cultivated in Odisha, India. *International Journal of Conservation Science* **2(4)**: 269-274

Moldenhauer, K., Wilson C. E., Counce, J. and Hardke, J. 2013. Rice Growth and Development. In Hardke, J. (Eds). *Arkansas Rice Production Handbook.* University of Arkansas System

Morishima, H. 1984. Wild plants and domestication. In: Tsunoda, S. and Takahashi, N. (ed) Biology of rice. Elsevier, Amsterdam: 3-30

Mostafa, K. M., Quazi, K. H. and Ehsanm H. C. 2015. Application of Remote Sensors in Mapping Rice Forecasting its Production: A Review. *Sensor* **15(1)**: 769-791

Mu, P., Li, Z., Li, C., Zhang, H., and Wang, X. 2004. QTL Analysis for Lodging Resistance in Rice using a DH Population under Lowland and Upland Cultural conditions. In Fourth International Crop Science Congress. Brisbane, Australia

Muhammad Naim Fadzil, A R.,Mohad Najib, M. Y., Shahida, H., Elixson, S., Asfaliza, R. 2015. Pengurusan Kesuburan Tanah dan Nutrien untuk Tanaman Padi di Malaysia. *Bulentin Teknologi MARDI* **8**: 37-44

Ohe, M. and Mimoto, H. 1999. Changes in Dry Matter Production of Japonica-type Paddy Rice (*Oryza sativa* L.) due to Deep Water Treatment. *Japanese Journal of Crop Science* **68(4)**: 482-486

Ohnishi, M., Hrie, T., Homma, K., Supapoj, N., Takano, H. and Yamamoto, S. 1999. Nitrogen Management and Cultivar Effects on Rice Yield and Nitrogen Use Efficiency in Northeast Thailand

Panda, S. C., Verma, S. P. and Patra, A. 1978. Maximize the Production of Rice Trough Better Puddling. *Food Fmg Agriculture* **10(2)**: 31-34

Panda, S. C. 2010. *Rice Crop Science.* India: Agrobios Publisher

Pandey, V. R., Singh, P. K., Verma, O. P., Pandey, P. 2012. Inter-relationship and Path Coefficient Estimation in Rice under Salt Stress Environment. *Int. J. Agric. Res.* **7(4)**: 169-184

Pang, S. K., Alidin, M. D., Awang, A., Jalloh, M. B., Itho, K., Mitsui, T. 2015. Effect of Chicken Adding Appropriate Mixture of NPK and Chicken Manure on Growth and Yield of TR-9 Paddy Variety on Beach ridges Interspersed with Swales (BRIS) Soil. *Bulletin of Faculty of Agriculture*, Niigata University, **68**: 43-48

Peng, S., Khush, G. S., Cassman, K. G. 1994. Evolution of New Plant Ideotype for Increased Yield Potential. *Proceedings of a Workshop on Rice Yield Potential in Favourable Environments*: 5-20

Pinthius, M. J. 1973. Lodging in Wheat, Barley and Oat: The Phenomenon, Its causes and Preventive Measures. *Advanced Agronomy* **25**: 209-263

Rabiei, B. M. Valizadeh, B. Ghareyazie and M. Moghaddam. 2004. Evaluation of Selection Indices for Improving Rice Grain Shape. *Field Crops Research* **89**: 359-367

Rajkumara, S. 2008. Lodging in Cereal. *Agricultural Reviews* **29(1)**: 55-60

Rameshkumar, S. C., Reddy, R. S., Shivaprasad, C. R., Harindranath. S., Nandi, L. Srinivas, S. Krishman, P. and Grjabhiye, K. S. 2003. *Reconciling Environment and Economic Executive Summaries of EERC Projects*

Ramos, D. G., Descalsota, J. P. and Sen Valentin G. O. 1999. Efficiency of Foliar Applications of Mono Potassium, Phosphate. *Terminal Report of Funding Agency, ROTEM AMFERT NEGEV by Phil Rice Philippines*

Ranawake, A. L., Amarasingha, U. G. S., and Dahanayake, N. 2013. Agronomic Characters of some Traditional Rice (Oryza sativa L.) cultivars in Sri Lanka. *Journal of University Ruhuna* **1(1)**: 3-9

Ravichandran, M. and Sriramachandrasekaran, M. V. 2011. Optimizing Timing of Potassium Application in Productivity Enhancement of Crop. Karnataka *Journal of Agricultural Science* **24(1)**: 75-80

Reinke, R. F., Lewin, L. G. and Williams, R. L. 1994. Effect of Sowing Time and Nitrogen on Rice Cultivars of Differing Growth Duration in New South Wales. I. Yield and Yield Components. *Australian Journal of Experimental Agriculture* **34(7)**: 933-938

Rahman, S., Sharma, M. P., and Sahai, S. 2006. Nutritional and Medicinal Zalues of Some Indigenous Rice Varieties. *Indian Journal of Traditional Knowledge* **5(4)**: 454-458

Saito K., Linquist, B., Atlin B. N., Phanthaboon K., Shiraiwa, T., Horie, T. 2006. Response of Traditional and Improved Upland Rice Cultivars to N and P fertilizer in Northern Laos. *Field Crops Research* **96**: 216-223

Salam, M. A., Lucy, F., Kabir, M. H. and Khan, A. R. 2011. Effect of different doses of fertilizer on yield and yield components of two varieties of *boro* rice. *Journal Agronomy for Environment* **5(2)**: 53-56

Sarkar, R. K. and Malik, G. C. 2001. Effect of Foliar Spray of KNO_3 and $Ca(NO_3)_2$ on grasspea (*Lathhyrus sativus* L.) grown in Rice Fallows. *Lathyrus Lathyrism Newsletter* **2**: 47-48

Sharma, P. K. and S.K. De Datta. 1986. Physical Properties and Processes of Puddled Rice Soil. *Advanced Soil Science* **5**: 139-178

Sinong, G. F. 2016. Effect of different Rates of NPK Fertilizer Application on Growth and Yield on Several Sabah Local Traditional Paddy Varieties. Bachelor of Agricultural Science Dissertation. University Malaysia Sabah

Selvaraj C. I., Nagarajan, P., Thiyagarajan, K, Bharathi, M., Rabindran, R. 2011. Genetic Parameters of Variability, Correlation and Pathcoefficient Studies for

Grain Yield and Other Yield Attributes among Rice Blast Disease Resistant genotypes of Rice (Oryza sativa L.). *African Journal of Biotechnology* **17**: 3322-3334

Slaton, N., Ross, J., Norman, R., Espinoza, L., Roberts. T., Mozaffari. M., Wilson, C. E., Jr. and Cartwright. 2011. Potassium Requirement and Fertilization of Rice and Irrigated Soybeans. Agriculture and Natural Resource. Division of Agriculture, University of Arkanas

Slaton, N. A., DeLong, R. E., Norman, R. J., Wilson. C. E. and Golden, B. R. 2005. Rice Culture: Rice Response to Phosphorus and Potassium Fertilization. *AAES Research Series* **540**: 333-340

Smith, C. W. and Dilday, R. H. 2003. Rice: Origin, History, Technology and Production. 1st eds. Hoboken, New Jersey: John and Wiley, Inc.

Souki, H. 2015. Performance and Grain Characteristics of Local Rice Varieties Planted on Kota Belud, Sabah. *Buletin Teknologi MARDI* **8**: 57-62

Talpur, M. A., Ji Changying, Junejo S. A., Tagar, A. A. and Ram B. K. 2013. Effect of Different Water Depths on Growth and Yield of Rice Crop. *African Journal of Agricultural Research* **8(37)**: 4654-4659

Tripathi, S. C., Sayre, K. d., Kaul, J. N., and Narang, R, S. 2003. Growth and Morphology of Spring Wheat (*Triticum aestivum* L.) Culms and their Associations with Lodging: Effects of Genotypes, N Level and Ethepton. *Field Crop Research* **84**: 271-290

Uddin, S., M. A. R. Sarkar and M. M. Rahman. 2013. Effect of Nitrogen and Potassium on Yield of Dry Direct Seeded Rice cv. *International Journal Agronomic Plant Production* **4**: 69-75.

Vergara, B. S. 1992. A Farmer's Primer on Growing Rice. International Rice Research Institute, Philippines. ISBN

Vummiti, D. 2015. Determination of Available Nutrients in Soil Using the Agilent 4200 MP-AES: Application Note. India: Agilent Tachnologies

Wakeel, A., Farooq, M., Qadir M. and Schubert, S. 2011. Potassium Substitution by Sodium in Plants. *Critical Review in Plant Science* **30**: 401-413

Wakeel, A. S. Hanstein, B. Pitann, S. Schuber. 2010. Hydrolytic and Pumping Activity of H^+-ATPase from Leaves of Sugar Beet (*Beta vulgaris* L.) as Affected bu Salt Stress. *Journal of Physiology* **167**: 725-731

Widowati, W. U. 2012. The Effect of Biochar on the Growth and Fertilizer Requirement of Maize (Zea mays L.) in Greenhouse Experiment. *Journal of Agriculture Science:* 255-257

Yoshida, S., Forno, D. A., Cock, J. H. and Gomez, K. A. 1976. Laboratory Manual for Physiological Studies of Rice. The International Rice Research Institute, Philippines

Yoshida, S. 1981. Fundamentals of Rice Crop. The International Rice Research Institute, Philippines. 17-30

Zaman, U., Ahmad, Z., Farooq, M., Saeed, S., Ahmad, M and Wakeel, A. 2015. Potassium fertilization may Improve Stem Strength and Yield of Basmati Rice Grown on Nitrogen-Fertilized Soils. *Pakistan J. Agri. Sci.* **52**: 1-7

Zhang, Z. P., 1996. Weed Management in Transplanted Rice. In: Auld, B. A. and Kim, K. U. (Ed.), *Weed Management in Rice*. Food and Agriculture Organisation of the United Nations.