EFFECT OF WATER DEFICIENCY TO THE YIELD OF SEVERAL SABAH DRYLAND PADDY

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ABSTRACT

Water deficiency is one of the critical factors affecting rice productivity. The average yields from the major crop plants may be reduced by more than 50 percent as a result of water stress. FAO estimated that by 2025, 1.9 billion people will live in countries or regions with absolute water scarcity, and two-third of world population could be under water stress conditions. Therefore, cultivating crops that are tolerant to water deficiency could be a way to ensure food security. Three cultivars of Sabah dryland paddy namely Kambiring, Purak Bukit and Pulut Tadong was used to investigate the effect of water deficiency to their yields. The objectives of the study were to compare the yields between selected Sabah dryland paddy varieties under water deficient condition and to determine the best Sabah dryland paddy variety in term of yield under water deficiency. The days to fifty (50) percent heading, days to leaf curling, relative water content (%), plant height (cm), culm height (cm), number of tillers per plant, number of panicle per plant, percentage of productive tillers (%), panicle length (cm), 1000 grain weight (g) and extrapolated yield (tonnes ha^{-1}) in plants subjected to the water deficit stressed and controlled-well-watered were recorded. The result was analysed using two-way ANOVA and the mean comparison was compared using Tukey's test. Based upon the results, there were no significant difference in the interaction between varieties and the water stress treatment in all parameters. However, there were significance difference in factors, in term of variety, number of tillers/plant, number of panicle/plant, 1000 grain weight (g), extrapolated yields (tonnes ha^{-1}) and in term of water stress level in extrapolated yields (tonnes ha^{-1}). The Purak Bukit rice cultivar was considered to be the highly drought-tolerant cultivar and Pulut Tadong was considered the least tolerant to drought.

ABSTRAK

KESAN KEKURANGAN AIR PADA HASIL TUAIAN BEBERAPA VARIETI PADI HUMA SABAH

Kekurangan air adalah salah satu faktor penting yang mempengaruhi produktiviti beras, hasil purata daripada tanaman utama boleh dikurangkan sebanyak lebih daripada 50 peratus akibat daripada kekurangan air. FAO menganggarkan bahawa pada tahun 2025, 1.9 bilion orang akan tinggal di negara-negara atau kawasan dengan keaadan tiada keberlangsungan air, dan dua pertiga daripada penduduk dunia boleh berada di bawah keadaan kekurangan air. Oleh itu, penanaman padi yang toleran kepada kekurangan air boleh dijadikan sebagai salah satu alternatif untuk memastikan keberlangsungan makanan. Dengan itu, tiga kultivar padi huma Sabah iaitu Kambiring, Purak Bukit dan Pulut Tadong telah digunakan untuk mengkaji kesan kekurangan air pada hasil tuaian setiap kultivar. Objektif kajian ini adalah untuk membandingkan kadar hasil tuaian antara jenis padi huma Sabah di bawah keadaan kemarau dan untuk menentukan padi huma Sabah yang terbaik dalam hasil tuaian di bawah keadaan kemarau. Hari untuk lima puluh (50) peratus berbunga, hari untuk daun bergulung, kandungan air relatif (%), ketinggian tumbuhan (cm), ketinggian jelaga (cm), bilangan anak padi per pokok, bilangan malai per pokok, peratusan anak padi produktif (%), panjang tangkai (cm), berat 1000 bijirin (g) dan hasil diekstrapolasi (tan ha^{-1}) pada padi dalam keadaan kemarau dan dikawal-diberi air telah direkodkan. Keputusan telah dianalisa menggunakan ANOVA dua hala dan ujian-Tukey telah digunakan untuk membandingkan hasil min eksperimen ini. Berdasarkan keputusan, tidak ada perbezaan yang signifikan dalam interaksi antara kultivar dan rawatan kekurangan air pada semua parameter. Walau bagaimanapun, terdapat perbezaan yang signifikan dalam faktor-faktor eksperimen, dari segi factor varieti, bilangan anak padi per pokok, beberapa malai per pokok, 1000 berat bijirin (g), hasil diekstrapolasi (tan ha^{-1}) dan dari segi tahap kekurangan air di hasil diekstrapolasi (tan ha^{-1}). Daripada eksperimen ini didapati bahawa kultivar Purak Bukit dianggap sebagai kultivar yang paling toleran kepada kekurangan air dan Pulut Tadong dianggap yang paling kurang toleran kepada kemarau.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

Etc	Et cetera
DOA	Department of Agriculture
FAO	Food and Agriculture Organization of the United Nation
NOAA	National Oceanic and Atmospheric Administration
UNEP	United Nations Environment Programmed
mm	millimeter
GISS	Goddard Institute for Space Studies
°N	Degree North
°S	Degree South
°C	Degree Celcius
USA	United State of America
IRRI	International Rice Research Institute
t	tonne
ha	hectare
t ha^{-1}	Tonne per hectare
%	Percentage
USDA	United States Department of Agriculture
Kg	Kilogram
MAFI	Agriculture and Food Industry Ministry
SSL	self-sufficiency levels
MARDI	Malaysian Agricultural Research and Development Institute
ARC	Tuaran Agricultural Research Centre
kg ha^{-1}	Kilogram per hectare
Cm	Centimetre
m^2	Meter square
ml	Millilitre
d^{-1}	Per day
PVC	Polyvinyl chloride
CRD	Completely Randomized Design
g	Gram
MOP	Muriate of Potash

TSP	Triple Superphosphate
NPK	Nitrogen, Phosphorus and Potassium
RTP	Room temperature
DAT	Day of transplanting
No.	Number
SAS	Statistical Analysis Software
RWC	Relative Water Content
ANOVA	Analysis of Variance
/	per

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Water plays a very important function in agriculture. It is a critical necessity in increasing agricultural production, ensuring predictability in the yields and is essential to bring forth the optimum potential of the land and to enable full use of other yield enhancing production factors. It main function is to irrigate agricultural crops which will help optimized the plant metabolic activities that will lead to healthy and productive plant. United Nations Environment Programme reported that agricultural activities account for approximately 75 percent of the global water consumption and in developing countries, 90 percent of water is used for irrigation (UNEP, 2009). Three thousand liters of water is required to grow a daily food needs for a person per day (FAO, 2003). However, competition for water is increasing due to increase pressure from competition in farming, rearing of livestock, urbanization, industrialization, water pollution and climate change which have led to water scarcity.

Water scarcity is one of the biggest threats to the agricultural sector nowadays. One of its biggest threats is water stress towards crop. It is estimated that average yields from the major crop plants may be reduced by more than 50 per cent as a result of water deficiency (Mofizur andHasegawa, 2009). Water stress has a tremendous effect on agriculture that will negatively influencing human activities (NOAA, 2003) - hunger, famine, sickness and war. By 2025, 1.9 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world populations could be under water-stress conditions (FAO, 2015). Since about one-third of potential arable land is facing water scarcity, the yield production in remainder may be adversely affected by periodic drought, and more than half of the world population will be negatively affected by 2025. One of the most affected crop will be the rice crop.

Rice (*Oryza sativa* L.) is the most important staple food in Asia. It is a semi-aquatic species that is typically cultivated under partially flooded condition. It has poor water-deficient tolerant especially the irrigated lowland rice cultures due to its low water adaptability. Rice is a crucial part of everyday Malaysian diet. On average, Malaysian citizen consumes 82.3 kilograms of rice per year. In Malaysia rice is grown either in flooded rice paddies (wet land paddy) or grown in dry soil (dry land paddy). Wet land paddy contributes to 503,184 hectare and dryland paddy contributes to 165,888 hectares (DOA, 2005). However, the production of Malaysia rice is only about 73.5 percent self-sufficient in rice (MARDI, 2015), the remainder is imported mainly from other countries. Therefore, there is a need to increase the production of rice for future needs. However, this is expected to be challenging due to climate change such as drought.

Malaysia is a warm humid tropic country that rich in water resources due to sufficient annual rainfall with an average of 2400 mm. However, Malaysia is often hit by water-related disasters such as droughts and floods due to irregular and unpredictable rainfall in terms of both space and time (Chan, 2002). Recently, intense *El Nino* have brought severe drought to Thailand, Malaysia and Singapore. In Malaysia, the government's meteorological department expects 20 to 60 % less rain due to the *El Nino* phenomenon for 2016 compare to 2015. This phenomenon has led to tonnes of losses to farmers due to deterioration of rice crops, some giving poor yield and some give total loss of no yield. Five thousand one hundred rice farmers were affected hardly by the *El Nino* which causes 8500 hectares of rice fields to dry up. These climatic changes such as drought, heat waves and uneven precipitation pattern have limit water availability for farming (Bates *et al.*, 2008).

Drought have a tremendous threat to rice production of Malaysia. It causes the fields to dry and make it unable to transplant seedling to the fields and cause rice that already transplanted crinkled and died as it was impossible to water them with the water supply being dried up and when watered, the water evaporates so quickly. It was reported that rice farmers in Kerian suffer RM56 million in losses due to the heat wave- drought.

During the intense *El Nino* in mid-2016, it was reported that 8097 hectares of 21108 rice fields in the distinct were affected by the *El Nino* involving 3175 farmers (NST, 2016). Starting from the mid-19th century, the temperature has showed gradual increasement until now. With the temperature risen, more water are loses from lakes, reservoir, ground water etc, which lead to higher water demand for agriculture irrigation. The average global temperature in February 2016 was 2.73℃, 1.35℃ above 1951 and 2.23℃ above 1998(GISS, 2016). Both records were set during strong *El Nino* events. This shown that the effect of drought are greater with times. Therefore, this study is one of the efforts to prepare for the unpredictable future by examining different capabilities/ traits of drought resistant in Sabah traditional dryland paddy varieties.

1.2 Justification of the Study

This experiment was conducted to determine the best Sabah dryland paddy variety grown on water deficit environment. Three (3) Sabah dryland paddy varieties - Pulut Tadong, Purak Bukit and Kambiring were used. It is hoping that this study could assist the farmers on choosing varieties that are better to be grown during water deficient period. Furthermore, farmers may be able to improve the rice yields during water deficient condition or during dry season. More-ever, the water consumption of growing paddy might as well be reduced, as the paddy's water requirement is low. Thus, this will not only reduce the water use on the paddy but indirectly will help to reduce the costs- water bill, labor and also help in conserving water for other necessity which also indirectly helps conserve the world. This will improve the quality of sustainability of the rice production's industry. This experiment also will help in identifying (screening) rice varieties with high levels of water deficient tolerance that can be use as donors in breeding and/or gene discovery. The greater and increasing demand of rice production by the societies justifies the need for a more effective and life-changing planting approaches.

1.3 Objectives of the Study

The objectives of this study were:

1. To compare the yields between selected Sabah dryland paddy varieties under water deficient condition.
2. To determine the best Sabah dryland paddy variety in term of yield under water deficient condition.

1.4 Hypothesis

Hypothesis 1

H_0: There is no significance difference in the yields of the selected Sabah dryland paddy under water deficient condition and normal condition.

H_1: There is significance difference in the yields of the selected Sabah dryland paddy under water deficient condition and normal condition.

Hypothesis 2

H_0: There is no significance difference between the yields of selected Sabah dryland paddy varieties under water deficient condition.

H_1: There is significance difference between the yields of selected Sabah dryland paddy varieties under water deficient condition.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, activities from economic development, urbanization and climate change have caused water shortage issues resulting to limitation of available water for crop irrigation. The limitation will cause a water stress to occur. Water stress is a major limitation to the intensification of rice yields in many regions of the world (Passioura, 2007). Water stress, in its broadest sense, encompasses both drought and flooding stresses and Malaysia is one of the country that is often hit by water-related disasters such as droughts and floods (Chan, 2002). Rice (*Oryza sativa* L.) is one of the most widely consumes cereal crops, providing a staple diet for almost half of the world's population (Song *et al.,* 2003). Water deficiency is a great threat to rice production especially irrigated rice which requires large water consumption. Factors controlling stress conditions alter the normal equilibrium and lead to series of morphological, physiological, biochemical, and molecular changes which adversely affect their growth and productivity. The average yields from the major crop plants may be reduced by more than 50 % as a result of water stress (Bray *et al.* 2000). Therefore, identifying rice varieties with contrasting drought tolerance is a need to bring new insight for the breeding of rice as it can be used as donors in breeding and gene discovery in producing high yielding drought tolerance varieties, and this is one of the main challenges for rice research according to Serraj and Atlin (2008).

2.2 Rice (*Oryza sativa* L.)

Rice is the major staple food for a large proportion of the world's population. It is one of the most widely consumed cereal crops, providing a staple diet for almost half of the world's population (Song *et al.*, 2003). Rice is an annual, monocot, and C_3 plant that belongs to the Poaceae family. The growth duration of the rice plants is three to six months, depending on the variety and the environment under which it grown. Rice plant can be divided into three agronomic phases of development which are vegetative stage (germination to panicle initiation), reproductive stage (panicle initiation to heading), and maturation or ripening stage (grain filling, heading to maturity). Rice is extremely sensitive to water shortage. When soil water content drops below saturation, growth and yield formation are affected, mainly through reduced leaf surface area, photosynthesis rate, and sink size. Rice plants are most sensitive to water stress at the flowering stage. It greatly affects spikelet sterility of the rice plant which results in decreased percentage of filled spikelets. Therefore, grains per panicle and grain weight will also decreased (IRRI, 2016). Water deficiency during this stage has greater grain yield reduction than during other stages (Sarvestani *et al.,* 2008). Flowering stage of rice plants is shown in Figure 2.1.

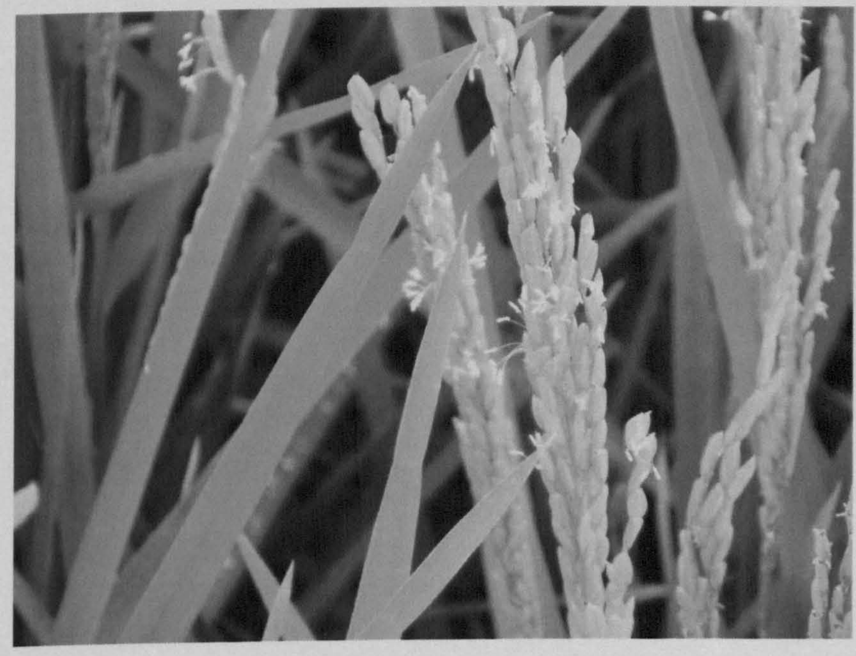

Figure 2.1 Flowering stage of rice

Source: Retrieved from Jerry Wilhm, July 2011

2.3 Rice Production in Worldwide

Rice is grown worldwide on 150 million hectares with total production of about 563 million tons of unmilled rough rice (FOA, 1999). Nearly half of the total population of the world use rice as their staple food and it is the main source of calories for about 40 percent of the world population (Hoffman, 1991). Rice is the second most important crop in the world after wheat (Smith, 1995). It is grown over a considerable geographic range from 45°N to 40°S to elevations of more than 2500 m, but with average temperatures in the range of 20-30°C (Oldeman *et al.*, 1987). The largest rice production is from Asia, which produces about 94 percent of the total world production. In this region, which also contains 59 percent of the global population, rice is the main diet in the routine basis, providing an average of 35 percent of total caloric intake compared to only 2 percent in the USA (Matthews *et al.*, 1995). And, to meet the demands of the rapidly expanding population, an estimation of 70 percent increase in rice production is required over the coming decades (IRRI, 1993). Figure 2.2 shows the world rice acreage from 2008/2009 to 2015/2016. The United States Department of Agriculture (USDA) estimates that the World Rice Production 2016/2017 will be 483.8 million metric tons, rice production last year was 472.1 million tons. This estimation could represent an increase of 11.69 million tons or a 2.48% in rice production around the globe.

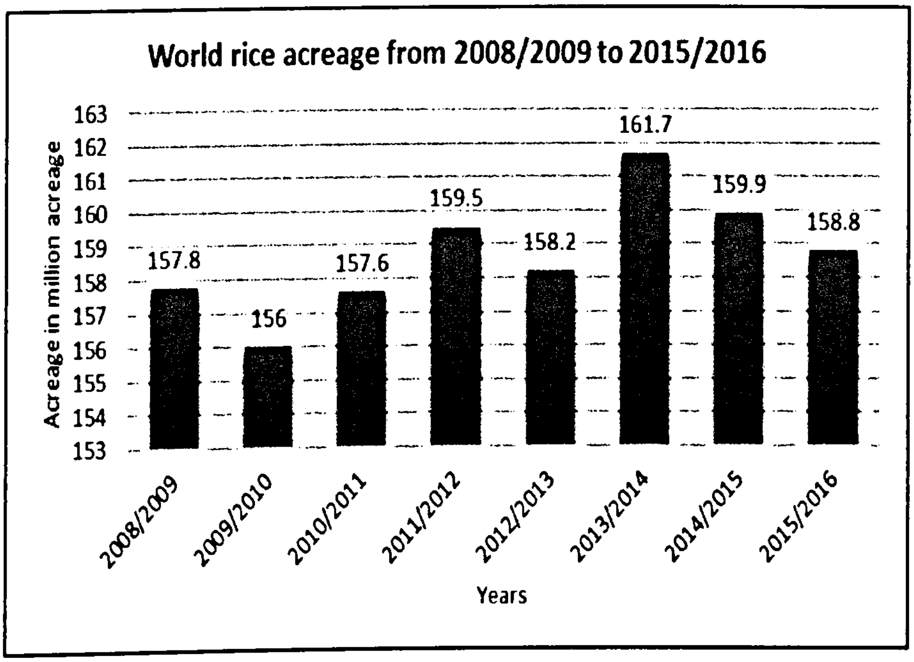

Figure 2.2 World rice acreage from 2008/2009 to 2015/2016 (In million hectares)
Source: Statista, 2016

However, from an El Nino event it was reported that the world rice production is expected to decline for the first time since 2010, as failing rains linked to an El Nino weather pattern cut crop yields in Asia's rice bowl. A heat wave is sweeping top rice exporter India, while the No 2 supplier Thailand is facing a second year of drought. While, Swathes of farmland in Vietnam, the third-biggest supplier, are also parched as irrigation fed by the Mekong river runs dry. The three account for more than 60 per cent of the global rice trade of about 43 million tonnes threatens to cut output and boost prices of a staple for half the world's population (Naveen Thukral, 2016).

2.3.1 Rice Production in Malaysia

Malaysia in the Malay Archipelago is made up of the Malay Peninsula, Sabah, and Sarawak, located between 1° and 7° N latitude and 100° and 120° E longitude. Malaysian population is approximately 31.7 million (Department of statistics Malaysia, 2016), an increase of 0.5 million persons as compared to 31.2 million persons in 2015 with 1.5 per cent population growth rate for the same period. Malaysia is characterized as the warm humid tropics. The climate is govern by the north-east monsoon. In general, Sabah and Sarawak experience greater rainfall than Peninsular Malaysia. Temperature averages a constant high of 26° C with diurnal range of 7° C. Rice have great potential of growing here. Rice is the staple food of Malaysia, with the population rate exceeds 2 percent annually, the national requirement for rice has increase drastically. Malaysia is about 71.6 percent self-sufficient in rice (DOSM, 2015), the remainder is imported mainly from trading partners (Matthews *et al.,* 1995). In Malaysia, rice is the third most important crops after oil palm and rubber in terms of production. Rice is mainly grown under flood irrigation in Malaysia as irrigated lowland rice has low pest and disease incidence as well as high and stable yield. Figure 2.3 shows the total rice area and annual production of rice of Malaysia for the years 2006 until 2015 (FAO, 2015).

REFERENCES

Ahmad Faizal Jamil. Petani Sawah Padi Keningau Tanggung Rugi Akibat Kemarau. http://malaysiaaktif.my/malaysiaaktif2/?p=10561. Access on 5 May 2016. Verified on 7 May 2016

Anjum, S. A, Xie,X. Y., Wang, L. C., Saleem, M. F., Man, C. & Lei, W. (2011). Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research Vol. 6(9), pp. 2026-2032

Anjum, S. A., Xie, X. Y., Wang, L. C., Saleem, M. F., Man, C., & Lei, W. (2011). Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research, 6(9), 2026-2032.

Bakul, M. R. A., Akter, M. S., Islam, M. N., Chowdhury, M. M. A. A., & Amin, M. H. A. (2009). Water stress effect on morphological characters and yield attributes in some mutants T–Aman rice lines. Bangladesh Res. Pub. J, 3(2), 934-944.

Barrs, H. D., & Weatherley, P. E. (1962). A re-examination of the relative turgidity technique for estimating water deficits in leaves. Australian Journal of Biological Sciences, 15(3), 413-428.

Begg, J. E., & Turner, N. C. (1976). Crop water deficits. Advances in agronomy, 28, 161-217.

Bouman, B. A. M., & Tuong, T. P. (2001). Field water management to save water and increase its productivity in irrigated lowland rice. Agricultural water management, 49(1), 11-30.

Bray, E. A., Bailey-Serres, J., & Weretilnyk, E. (2000). Responses to abiotic stresses. Biochemistry and molecular biology of plants, 11581249.

Chan, N. W. (2002). Pembangunan, pembandaran dan peningkatan bahaya dan bencana air di Malaysia: Isu, pengurusan dan cabaran (Abstract in English). *Siri Syarahan Umum*. Penerbit Universiti Sains Malaysia, Pulau Pinang

Department of Agriculture Sabah. (2000). Planted Area, Production and Yields of Wet Paddy, Hilly Paddy and Kenanga Paddy, Sabah in 1991-1996. Department of Agriculture Sabah

Department of statistics Malaysia. (2010). Malaysian Population 2016. Department of statistics Malaysia

DOA. (2005). Agriculture Statistical Handbook. Ministry of Agriculture and Agro-based Industry. pp. 31

Dunand, R. & Saichuk, J. Chapter 4 : Rice Growth and Development. Louisiana Rice Production Handbook

Espino, L. (2014). Rice Yield Components. UC Rice Blog California Rice Production. http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=14826. Access on 23 November 2016. Verified on 28 November 2016

FAO. (1999). FAOSTAT Database, Food and Agriculture Organization

FOA. (2015). Water & Poverty, An Issue of Life & Livelihoods

GISS. (2016). Record Warmth in February: NASA Earth Observatory. Goddard Institute for Space Studies

Harun, R. 2015. Policies and Economic Development of Rice Production in Malaysia. Economic and technology management research centre, MARDI. http://ap.fftc.agnet.org/ap_db.php?id=393. Access on 10 October 2016. Verified on 28 November 2016

Huke, R. E. (1982). Rice area by type of culture: South, Southeast, and East Asia. Int. Rice Res. Inst..
IRRI, (2016). Drought -tolerat rice. IRRI
IRRI. (1993). Rice Almanac 1993. International Rice Research Institute, Los Baños, Philippines, p. 142
IRRI. (2016). Irri. Climate change-ready rice. http://irri.org/our-work/research/better-rice-varieties/climate-change-ready-rice. Access on 21 November 2016. Verified on 28 November 2016
Jaleel, C. A., Manivannan, P. A. R. A. M. A. S. I. V. A. M., Wahid, A., Farooq, M., Al-Juburi, H. J., Somasundaram, R. A. M. A. M. U. R. T. H. Y., & Panneerselvam, R. (2009). Drought stress in plants: a review on morphological characteristics and pigments composition. Int J Agric Biol, 11(1), 100-105.
Kosová, K., Vítámvás, P., Prášil, I. T., & Renaut, J. (2011). Plant proteome changes under abiotic stress—contribution of proteomics studies to understanding plant stress response. Journal of proteomics, 74(8), 1301-1322.
Lilley, J. M., & Fukai, S. (1994). Effect of timing and severity of water deficit on four diverse rice cultivars I. Rooting pattern and soil water extraction. Field Crops Research, 37(3), 205-213.
Lugojan, C., & Ciulca, S. (2011). Evaluation of relative water content in winter wheat. Journal of Horticulture, Forestry and Biotechnology, 15(2), 173-7.
Matthews, R. B. (1995). Modeling the impact of climate change on rice production in Asia. Int. Rice Res. Inst..
McKersie, B. D., & Lesheim, Y. (2013). Stress and stress coping in cultivated plants. Springer Science & Business Media.
NOAA. (2003). All About Drought: National Weather Service. National Oceanic and Atmospheric Administration
NOAA. (2016). Climate Change: National Weather Service. National Oceanic and Atmospheric Administration of United State
Oppenheimer, H. R. (1960). Adaptation to drought: xerophytism. Plant+ water relationships in arid and semi+ arid conditions. Reviews of research. UNESCO: Arid zone research, 15, 105-38.
O'Toole, J. C., & Baldia, E. P. (1982). Water deficits and mineral uptake in rice. Crop Science, 22(6), 1144-1150.
O'Toole, J. C., & Cruz, R. T. (1980). Response of leaf water potential, stomatal resistance, and leaf rolling to water stress. Plant physiology, 65(3), 428-432.
Parker, J. (1968). Drought-resistance mechanisms. Kozlowski, TT Water deficits and plant growth, 1, 195-234.
Passioura, J. (2007). The drought environment: physical, biological and agricultural perspectives. Journal of experimental botany, 58(2), 113-117.
Peyster, E. (2015). University of California agriculture and natural resources. Drought tolerance varieties or crop. http://sonomamg.ucanr.edu/files/183771.pdf. Access on 20 November 2016. Verified on 28 November 2016
Rahman, I. M. and Hasegawa, H. (2009). Water Stress. Edition 2014. Croatia. InTech
Sarvestani, Z. T., Pirdashti, H., Sanavy, S. A. M. M., & Balouchi, H. (2008). Study of water stress effects in different growth stages on yield and yield components of different rice (Oryza sativa L.) cultivars. Pakistan Journal of Biological Sciences, 11(10), 1303-1309.

Sarvestani, Z. T., Pirdashti, H., Sanavy, S. A. M. M., & Balouchi, H. (2008). Study of water stress effects in different growth stages on yield and yield components of different rice (Oryza sativa L.) cultivars. Pakistan Journal of Biological Sciences, 11(10), 1303-1309.
Sarvestani, Z. T., Pirdashti, H., Sanavy, S. A. M. M., & Balouchi, H. (2008). Study of water stress effects in different growth stages on yield and yield components of different rice (Oryza sativa L.) cultivars. Pakistan Journal of Biological Sciences, 11(10), 1303-1309.
Sen, L.N. & Wickham, T. h. (1978). Water management for lowland rice; water requirement and yield responses. In soil and rice. Manilla (Philliphines); IRRI. Pp 649-669

Serraj, R and Atlin, G. (2008). Drought-resistant rice for increased rainfed production and poverty alleviation: a concept note. p 385–400. In: Serraj R, Bennett J and Hardy B eds. Drought Frontiers in Rice: Crop Improvement for Increased Rainfed Production. International Rice Research Institute, Los Baños, Philippines

Shao, H. B., Chu, L. Y., Jaleel, C. A., Manivannan, P., Panneerselvam, R., and Shao, M. A. (2009). Understanding Water Deficit Stress- Induced Changes in the Basic Metabolism of Higher Plants- Biotechnologically and Sustainably Improving Agriculture and the Ecoenvironment in Arid Regions of the Globe. Crit. Rev. Biotechmol., **29**: 131- 151

Singh, S., Amartalingam, R., Harun., W. S. W., and Tarifulislam, M. T. (1996). Simulated Impact of Climate Change on Rice Production in Penisular Malaysia. *Proceeding of the National Conference On Climate Change, Aug. 12-13,* Universiti Putra Malaysia, pp: 41-49

Smart, R. E. And Bingham, G. E. (1974). Rapid Estimates of Relative Water Content. *Plant Physiology.* **53**: 258-260

Smith, W. (1995). Crop Production-Evaluation, History and Terminology. John Wiley and Sons, New York

Song, Z. P., Lu, B. R., Zhung, Y. G. And Chen, J. K. (2003). Gene Flow from the Cultivated Rice to the Wild Species *Oryza rufipogon* Under Experimental Field Conditions. *New phytologist* **157(3)**: 657-665

Statistica. (2016). World rice acreage from 2008/2009 to 2015/2016 (in million hectares). https://www.statista.com/statistics/271969/world-rice-acreage-since-2008/. Access on 20 November 2016. Verified on 28 November 2016

Tabbal, D. F. Bouman, B. A. M., Bhuiyan, S. I., Sibayan, E. B., and Satar, M. A. (2002). On-Farm Strategies for Reducing Water Input in Irrigated Rice: Case Studied in Philippines. *Agriculture Water Management* **56**:93-112

Tabi, F. O., Omoko, M., Boukong, A., Mvondo Ze AD., Bitondo, D., and Fuh, C. C. (2012). Evaluation of Lowland Rice (*Oryza sativa) Production System and Management Recommendations for Logone and Chari Flood Plain - Republic of Cameron. Agricultural Sciece Research Journals* **2(5)**: 261-273

Tuong, T.P., Bouman, B. A. M., and Mortimer, M. (2005). More Rice, Less Water: Integrated Approaches for Increasing Water Productivity in Irrigated Rice-Based System in Asia. *Plant Production Science* **8**: 231-241

Turner, N. C. (1996). Further progress in crop water relations. Advances in Agronomy, 58, 293-338.

UNEP. (2009). Water in the Transition to a Green Economy. UNEP

USDA. (2008). World Rice Production, Consumption and Stocks. USDA

Uzilday, B. Turkan, I., Sekmen, A. H., Ozgur, R., and Karakaya, H. C. (2012). Comparison of ROS Formation and Antioxidant Enzymes in *Cleome Gynandra* (C_4) and *Cleome Spinosa* (C_3) under Drought Stress. *Plant Science* **182**: 59-70

Zeigler R.S., Leong S.A. Teng P.S. (1994). Rice blast disease. IRRI, Manila Philippines. pp. 7-10.

Zubaer, M. A., Chowdhury, A. K. M. M. B., Islam, M. Z., Ahmed, T., & Hasan, M. A. (2007). Effects of water stress on growth and yield attributes of Aman rice genotypes. Int. J. Sustain. Crop Prod, 2(6), 25-30.