UNIVERSITI PUTRA MALAYSIA

GRAIN-FILLING RATE AND YIELD IN TWO RICE (ORYZA SATIVA L.) VARIETIES BASED ON CRITICAL PERIOD OF WEED CONTROL

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By

LWIN MAR OO

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

April 2014

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DEDICATION

Dedicated to:

(My Beloved Parents)

U Aung Myint and Daw Myint Myint Khin

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

GRAIN-FILLING RATE AND YIELD IN TWO RICE (*ORYZA SATIVA* L.) VARIETIES BASED ON CRITICAL PERIOD OF WEED CONTROL

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April 2014

Chairman : Associate Professor Adam bin Puteh, Ph.D

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Rice (*Oryza sativa* L.) is the staple food crop for more than half of the world population. Weed density, duration of infestation and crop growth stages are critical factors which affect rice yield potential. Little has being studied on crop physiological responses to weed infestation, especially during reproductive growth stage. Therefore, this study was carried out to evaluate the grain filling rate and effective grain filling period during different times of weed free and weedy periods. The glasshouse experiments following normal rice culture techniques were conducted for two trials at Field-2, Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia (UPM). Two rice varieties; MR263 and IR64, were used to determine grain filling rate (GFR) and effective grain filling period (EGFP) during critical period of weed control,. The critical period of weed control was the different between the two varieties. The critical period of weed control for5% yield loss for MR263 and IR64 was observed from 10 to 64 DAS and 5 to 91 DAS for *Trial I* and 13 to 76 DAS and 7 to 65 DAS for *Trial II*, respectively. For yield losses of 10% level, the critical period of weed control was observed from 19 to 52 DAS and 18 to 63 DAS for MR263 and 10 to 75 DAS and 12 to 55 DAS for IR64 for *Trial I*.

The highest grain filling rate was observed when rice plants were free of weeds from sowing to harvest, (T_5), which was in the range of 0.7 to 0.9 mg/seed/day for both varieties in both seasons. The EGFP for both varieties varied between 27 – 29 days for *Trial I* and 24 – 27 days for *Trial II*. Grain filling rate was highly correlated with the final grain yield of MR263 and IR64. However, the effective grain filling period was negatively correlated with the grain yield of both rice varieties.

It was found that GFR (mg/seed/day) and EGFP (days) contributed significantly to the final seed weight of both varieties. Percentage filled grain, panicle numbers and final seed weight and grain yield were highly correlated with grain filling rate for both varieties during two trials. EGFP is inconsistent in contributing to the final grain yield of the two varieties used in this study. There were no correlation of effective grain filling duration and grain filling rate with grain yield based upon varieties. Long duration of weed interference during grain filling can reduce grain filling rate, and lead to reduction in final seed weight. Weed free from sowing to harvest (T_5) increased the grain filling rate and grain yield for both varieties. Therefore, grain filling rate and yield parameters were affected by weeds interference with crop which contributes to reducing grain yield.

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

KADAR PENGISIAN BIJIRIN DAN HASIL TUAIAN PADA DUA (*ORYZA SATIVA* L.) VARITEI PADI YANG BERASASKAN KEPADA JANGKAMASA KRITIKAL MENGAWAL RUMPAI

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Padi (*Oryza sativa* L.) adalah makanan ruji kepada lebih dari setengah populasi penduduk dunia. Densiti rumpai, tempoh infestasi dan peringkat-peringkat pertumbuhan tanaman adalah faktor-faktor kritikal yang memberi kesan kepada potensi hasil padi. Tidak banyak yang telah dikaji berkaitan dengan respons fisiologi tanaman ke atas infestasi rumpai, terutamanya sewasa peringkat pertumbuhan reproduktif. Justeru, kajian ini bertujuan untuk menilai kadar pengisian bijirin dan tempoh efektif pengisian biji dalam tempoh yang berlainan pada keadaan bebas rumpai dan tempoh infestasi rumpai. Eksperimen di rumah kaca dijalankan selama dua percubaan di Ladang-2, Jabatan Sains Tanaman, Fakulti Pertanian, Universiti Putra Malaysia (UPM). Dua varieti padi; MR263 dan IR64 digunakan untuk mengenalpasti tempoh kritikal kawalan rumpai, kadar pertumbuhan biji benih (GFR) dan tempoh efektif pengisian biji (EGFP). Tempoh kritikal kawalan rumpai adalah berbeza bagi dua varieti tersebut. Tempoh kritikal kawalan rumpai untuk kehilangan hasil 5% bagi MR263 dan IR64 di antara 10 hingga 64 DAS dan 5 hingga 91 DAS untuk *Percubaan I*, dan 13 hingga 76 DAS dan 7 hingga 65 DAS untuk *Percubaan II*. Untuk kehilangan hasil 10%, tempoh kritikal kawalan rumpai adalah dari 19 hingga 52 DAS dan 18 hingga 63 DAS untuk MR263 dan 10 hingga 75 DAS dan 12 hingga 55 DAS untuk IR64 bagi dua percubaan.

Kadar pengisian bijirin yang paling tinggi apabila pokok padi bebas rumpai dari penyemaian hingga penuaian, (T_5), dalam lingkungan 0.7 hingga 0.9 mg/biji/hari untuk kedua-dua varieti utuk dua percubaan. EGFP untuk kedua-dua varieti berbeza diantara 27 - 29 hari untuk *Percubaan I* dan 24 - 27 hari untuk *Percubaan II*. Kadar pengisian bijirin mempunyai kolerasi yang tinggi dengan hasil biji untuk MR263 dan IR64. Walau bagaimanapun, tempoh efektif pengisian biji mempunyai kolerasi negatif dengan hasil bagi kedua-dua varieti.

GFR (mg/biji/hari) dan EGFP (hari) dikenalpasti menyumbang secara signifikan kepada berat badan akhir biji benih untuk kedua-dua varieti. Peratusan biji penuh, bilangan panikel dan berat badan biji benih dan hasil mempunyai kolerasi yang tinggi dengan GFR untuk kedua-dua varieti semasa dua percubaan. EGFP adalah tidak konsisten dalam menyumbang kepada hasil akhir biji bagi dua varieti yang digunakan dalam kajian ini. Kolerasi GFR dan EGFP dengan hasil adalah berbeza dan bergantung pada varieti. Tempoh infestasi rumpai ketika pengisian biji boleh mengurangkan GFR dan menyebabkan pengurangan berat badan akhir biji benih. Tempoh bebas rumpai dari penyemaian hingga penuaian (T_5) meningkatkan kadar pengisian bijirin dan hasil untuk kedua-dua varieti. Oleh itu, GFR dan parameter-parameter hasil terkesan oleh rumpai gangguan dengan tanaman yang menyumbang kepada penurunan hasil.

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I certify that a Thesis Examination Committee has met on 10th April 2014 to conduct the final examination of LWIN MAR OO on her thesis entitled "Grain Filling Rate and Yield in Two Rice (*Oryza sativa* L.)Varieties based on Critical Period of Weed Control" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

DAS	Days after Sowing
DAF	Days after Flowering
GFR	Grain Filling Rate
SW	Seed Weight
EGFP	Effective Grain Filling Period
FSW	Final Seed Weight
SAS	Statistical Analysis System
LSD	Least significant difference
cm	Centimeter
mg	Milligram
g	Gram

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the main source of food for more than half of the world population and is a staple food for 3 billion people in the world (IRRI, 2005). It also provides about 35-60% of total calories for human needs (Fageria, 2007). Pinstrup-Anderson *et al*., (1997) estimated that global rice production must increase by 36% in 2025 to supplement the needs of 4 billion people. Khush (2005) predicted that the rice production must be increased by 40% by 2030 without expanding the rice growing areas. This indicates that efficient crop management is important.

It is a widely accepted fact that weeds will compete for light, nutrients and space during crop production. Nowadays, weed infestation is one of the most limiting factors in rice production and can be a threatening factor for continuous increase in yield. A lot of weed species can be found in rice fields and compete for agricultural inputs at all growth stages of rice plants. So, to overcome these issues, the correct time of weeding during crop life cycle while growing in the field is needed to minimize yield loss. The critical time for weed control in rice is well established. Tagour *et al*., (2010) stated that the critical time for weed control is the time period between 4 to 6 weeks from sowing in direct seeded rice. Thus, proper weed management during this period will influence yield. How rice plant responded physiologically to weed infestation during the critical time for weed control is little known.

Rice grain yield is especially influenced by grain filling rate and duration of dry matter accumulation (Egli *et al*, 2004). The grain filling period is the basic mechanism for the reproduction of annual and cereal crops (Sedghi *et al*., 2008; Yang *et al*., 2007) and influenced the final grain yield. Fageria (2007) and Li *et al*., (2011) believed that grain filling process is directly related to increased productivity and quality in rice. Presently, crop production systems to produce higher grain yield focuses on improving the grain filling processes (Zahedi and Jenner, 2003; Kato *et al*., 2007).

Little information is available on the responses of grain filling rate and grain filling period to weeds in some crops (e.g. sunflower) (Sedghi *et al*., 2008). They found that weed infestation influence on grain filling rate in sunflower but, not affecting on the effective grain filling period of crop. In rice, although critical period of weed control well established, but how yield is reduced during this period by affecting grain filling rate and grain filling period of the crops still unknown. Therefore, whether critical period of weed control affect the grain filling rate and grain filling period of rice under direct seeded condition is needed. This will explain rice physiological responses to weed infestation especially during grain filling rate to changes in grain yield potential. Therefore, the glasshouse experiment under controlled environment was carried out to determine the response of grain filling rate and grain filling period during critical period of weed control in two rice varieties under direct seeded condition.

REFERENCES

Abeysekera & Anuruddhika, S.K**. (**2001). Management of *Echinochloa* spp. in rice in Sri Lanka. Paper presented at the FAO workshop on *Echinochloa* spp. control, Beijing, China, 13 pp.

Anaya AL (1999). Allelopathy as a tool in the management of biotic resources in Agroecosystems. *Critical Reviews in Plant Science*, 18 (6): 697-739.

Anwar, P., A.S. Juraimi, A. Samedani, A. Puteh, A. Man (2012). "Critical period of weed control in Aerobic rice". *The Scientific World Journal*. Vol: 2012. Article ID 603043, 10 pages. Doi:10.1100/2012/603043.

Anwar, P., A.S. Juraimi, A. Man, A. Puteh A, A. Selamat, M. Begum (2010). Weed suppressive ability of rice (Oryza *sativa* L.) germplasm under aerobic soil conditions. *Australian J. Crop Sci*. vol : 4. No. 9, pp: 706-717.

Azmi, M (1990). Weed flora in selected rice granary areas in Peninsular Malaysia. Paper presented at the Third Tropical Weed Science Conference, Hilton Hotel, Kualalumpur. P. 16.

Baloch AW, Soomro MA, Javad M, Ahmed M, Bughio HR, Bughio MS, Mastoi NN (2002). Optimum plant density for high yield in rice. *Asian Journal of Plant Science*. 1: 25-27.

Begum, M., Juraimi, A.S., Rajan, A., Syed Omar, S.R. and Azami, M. (2008). Critical Period Competition between Fibristylis miliacea (L.) Vahl and rice (MR 220). *Plant Protection Quarterly*, 23 (4), 153-157.

Begum M, Juraimi AS, Syed Omar SR, Rajan A, Azmi M, (2008). Effect of herbicides for the control of *Fimbristylis miliacea* (L.) Vahl. In *Rice Journal Agronomy*. 7(3): 251-257.

Begum M (2006). Biology and management of *Fimbristylis miliacea* (L.) Vahl. Ph.D. Thesis, Universiti Putra Malaysia, Serdang Darul Ehsan, Malaysia.

Boyd NS, Brennan EB, Smith RF, Yokota R, (2009). Effect of seeding rate and planting arrangement on rye cover crop and weed growth. *Agronomy Journal*. 101: 47-51.

Chang, T.T, and Vergara, B.S. (1972). Ecology and genetic information on adaptability and yielding ability in tropical rice varieties. *In Rice Breeding*, p. 431-453. International Rice Research Institute, Los Banos, Philippines.

Chauhan, B. S., and Johnson, D. E., (2011). "Row spacing and weed control timing affect yield of aerobic rice," Field Crops Research, vol. 121, no. 2, pp. 226–231. View at Publisher · View at Google Scholar · View at Scopus.

Chiang M.Y. and Leu L.S. (1981). Weeds in paddy fields and their control in Taiwan. Weeds and weed control in asia. In *FFTC book series* 20:25-36. ASPEC, Taipei, Taiwan.

Csikasz, T., Z. Alfoldi, S. Jozsa and M. Treitz, (2002). Growth analysis of the grain filling process in sunflower. Act. Bio. Sze., 46 (3-4): 191-193.

Darroch, B.A. and Baker, R.J. (1990). Grain filling in three spring wheat genotypes: Statistical analysis. *Crop Science*, 30: 525-529.

Daugovish, O., Thill, D.C., and Shaft, B., (2003). Modeling competition between wild oat (*Avena fatua*. L) and yellow mustard or canola. Weed Sci., 51: 102-109.

Daynard,T.B., Tanner,J.W., and Duncan,W.G.,(1971). Duration of the grain filling period and its relation to grain yield in corn, *zea mays*L.*Crop Science*,11:45-48.

De Datta, S.K., and Herdt, R.W., (1983). Weed Control Technology in Irrigated Rice. *Proceeding of the Conference on Weed Control in Rice*. International Rice Research Institute. Los Banos, Laguna, Philippines. pp – 90

De Datta, S.K., (1981). Weeds and Weed Control in Rice. *Principles and Practices of Rice Production*. Internatioinal Rice Research Institute. Los Banos, Laguna, Philippines. p - 468.

Dehghanzadeh Jazy, H., and Khajeh Poor, M. R., Sharif Abad, H. H., Soleimani, A., Samieinia, H, and Shayan, M., (2009). Effect of Irrigation regimes on grain growth indices of three winter wheat (Triticum aestivum L.) Cultivars under the Iranian conditions. *Asian Journal of Plant Sciences*, 8 (1): 74-77.

Dillehay, B.L., Curran, W.S., and Mortensen, D.A., (2011). "Critical period for weed control in alfalfa," *Weed Science*, 59 (1): 68 - 75.

Donovan O' JT, Harker K.N, Clayton G.W, Newman J.C, Robinson D, and Hall L.M (2001). Barley seeding rate influence the effects of variable herbicide rates. Weed Sci. 49: 746-754.

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

Egli, D.B., (2004). Seed-fill duration and yield of grain crops. *Advanced Agronomy*. 83, 243–279.

Egli, D.B., Orf ,J.H., and Pfeiffer, T.W. (1984). Genotypic variation for duration of seed size and position on the rate and duration of filling. *Crop Sci*. 24:587-592.

Egli, D.B., (1981). Species differences in seed growth characteristics. *Field Crop Research*, 4: 1-12.

Egli, D.B. and Wardlaw,I.F. (1980) Temperature response of seed growth characteristics of soybeans. *Agron. J* 75, 560-564.

Egli, D.B, (1975). Rate of accumulation of dry weight in seed of soy-beans and its relationship to yield. Can. *J. Plant Sci:* 55 : 215 – 219.

Evans, S.P., S.Z. Knezevic, C. A. Shapiro, and J. L. Lindquist (2003). Critical period for weed control in corn as influenced by nitrogen supply. *Weed Sci*. In press.

Fageria, N.K (2007). Yield Physiology of Rice. *Journal of Plant Nutrients*. 30:843-879.

Fengtong Wei, Hongbin Tao, Shan Lin, B.A.M. Bouman, Limeng Zhang, Pu Wang and Klaus Dittert (2011). Rate and duration of grain filling of aerobic rice HD297 and their influence on grain yield under different growing conditions. *ScienceAsia* 37 (2011): 98-104.

Fernando B. Perez de Vida, Emilio A. Laca, David J. Mackill, Grisel M. Fernandez and Albert J. Fischer (2006). "Relating Rice Traits to Weed Competitiveness and Yield: a path analysis". Weed Science, 54; 1122-1131.

Finlay, K.W and Wilkinson, G.N. (1963).The analysis of adaptation in a plant-breeding programme. *Australia Journal of Agricultural Research*. 14:742-754.

Fischer, R.A. (1983). Wheat. In: Proceeding symposium on potential productivity of field crops under different environments. Pp. 129-154.

Gebeyehou, G., D.R. Knott and R.J. Baker, (1982). Rate and duration of grain in durum wheat cultivars. *Crop Science*, 22: 337-340.

Gesimba, R.M. and M.C. Langat, (2005). A review on weeds and weeds control in oil crops with special reference to soybean (*Glycine max* L.) in Kenya Agricultural Tropical ET Subtropica., 38 (2): 56-61.

Ghosheh, H.Z., Holshouser, D.L. and Chandler, J.M. (1996). The critical period of Johnsongrass (*Sorghum halepense*) control in field corn (*Zea mays*). *Weed Science, 44*, 944 – 947.

Gogoi, A.K.; H. Brown; G.W. Cussans; M.D.Devine; S.O.Duke; Q.C. Fernandez; A. Helweg;R.E. Labrada; M.Landes; P. Kudsk and J.C. Streibig (1996). Integrated weed management of rice in high rainfall region of India. Proce. Of the Second Interactional Weed Control Congress. Copenhagen. Denmark. Vols., 1-4: 715-719.

Grichar WJ, Bessler BA, Brewer KD (2004). Effect of row spacing and herbicide dose on weed control and grain sorghum yield. *Crop Prot*. 23: 263-267.

Grime, J.P. (1979). *Plant strategies and vegetation processes*. J. Wiley and Sons, New York, p.2.

Guendouz, A. and Maamari, K. (2012). Grain-filling, chlorophyll content in relation with grain yield component of durum wheat in a Mediterranean environment. *African Crop Science Journal*, Vol. 20, No. 1, pp. 31-37.

Hakim, M.A., (2011). Rice production and weed management as affected by salinity. Ph.D thesis. Universiti Putra Malaysia.

Halford, C., A.S. Hamill, J. Zhang, and C. Doucet (2001). Critical period of weed control in no-till soybean and corn. Weed Technol. 15:737-744.

Hall, M.R., Swanton, C.J. and Anderson, G.W. (1992). The critical period of weed competition in grain corn (*Zea mays*). *Weed Science, 40*,441 – 447.

Hartzler, B. (2003). Critical periods of competition. *Weed Science*. Iowa State University. *http://www.weeds.iastate.edu/mgmt/2003/critical.shtml*

Ho, N.K. (1996). Weed management in direct seeded rice. *In* B. A. Auld and K. U. Kim (Eds.) weed management in rice. FAO Plant production and Protection paper 139. Food and Agriculture Organization of the United Nations, Rome, Italy.

Holt, J.S. (1988). Ecological and physiological characteristics of weeds. In M.A. Altieri and M.Z.Liebman (Eds.), *Weed management in agroecosystems: Ecological approaches* (pp. 7-14). Boca Raton, FL: CRC Press, Inc.

International Rice Research Institute (IRRI) (2005). *Rice*. International Rice Research Institute. Los Banos, Phillipines.

Iwasaki Y, Mae T, Makino A, Ohira K, Ojima K (1992). Nitrogen accumulation in the inferior spikelet of rice ear during ripening. *Soil Science Plant Nutrition* 38, 517-25.

Johnson. D.E. Wopereis, M.C.S., Mbodj, D., Diallo, S., Haefele, S.M., (2004). Timing of weed management and yield losses due to weeds in irrigated rice in the Shael. *Field Crop Research*. 85, no.1. pp. 31-42.

Jones, D.B., Peterson, M.L., Geng, S., (1979). Association between grain fillingrate and duration and yield components in rice. *Crop Science*. 19, 641–644.

Jones RJ, and Simmons SR (1983). Effect of altered source-sink ratio on growth of maize kernels. Crop Science- 23, 129-4.

Jongkaewwattana, S., Geng, S., (2001). Inter-relationships amongst grain characteristics, grain-filling parameters and rice (Oryza sativa L.) milling quality. *Journal of Agronomy Crop Science*. 187, 223–229.

Juraimi, A.S, Mohamad Najib, M. Y. Begum, M, Anuar, A.R, Azmi, M. and Puteh, A. (2009). "Critical period of weed competition in direct seeded rice under saturated and flooded conditions,"Pertanika Journal of Tropical Agricultural Science, vol. 32, no. 2, pp. 305–316, View at Scopus

Kafi, M., B. Kamkar and A. Mahdavi, (2001). Seed Biology. 1st Edn., Ferdowsi University Press, Iran, ISBN: 964-5782-17-1.

Karim RSM, Azmi BM, Ismail BS (2004). Weed problems and their management in rice fields of Malaysia: An overview. *Weed Biological Management*. 4(4): 177-186.

Kaplan S.L. and Koller H.R. (1974). Variation among soybean cultivars in seed growth rate during the linear phase of growth. *Crop Science*. 14, 613-614.

Kato T, Shinmura D, Taniguchi A. (2007). Activities of enzymes for sucrose-starch conversion in developing endosperm of rice and their association with grain filling in extra-heavy panicle types. *Plant Production Science* 10, 442-450.

Kaya, Y., G. Evci, s. Durak, V. Pekcan and T. Gucer (2007). Determining the relationships between yield and yield attributes in sunflower. *Turkish Journal of Agriculture and Forestry*. 31: 237-244.

Khush, G.S. (2005). What it will take to feed 5.0 billion rice consumers in 2030. *Plant Molecules Biology*. 59: 1-6.

Kim, K. U. (1981). Weeds in paddy field and their control in Korea. *Weeds and Weed Control in Asia*. FFTC Books Series no. 20: 37-50. ASPEC, Taipei, Taiwan.

Knezevic, S.Z., Evans, S.P., Blankenship, E.E., Van Acker, R.C., and Lindquist, J.L., (2002). "Critical period for weed control: the concept and data analysis," Weed Science, vol. 50, no. 6, pp. 773–776. View at Publisher · View at Google Scholar · View at Scopus

Kohli R. K, Batish Daizy R. and Singh H. P. (2006). Weed and Their Management: Rationale and Approaches. *Handbook of Sustainable Weed Management*.P.3-4.

Labrada R. (2006). Weed Management: A Basic Component of Modern Crop Production. Hand book of sustainable weed management. pp. 26-27.

Li Aiguo, Yuesheng Houb, Anthony Trent (2001). Effects of elevated atmospheric CO_2 and drought stress on individual grain filling rates and durations of the main stem in spring wheat. *Agricultural and Forest Meteorology* 106,289–301.

Li JJ, Zhang HL, Wang DP, Tang B, Chen C, Zhang DL, Zhang MH, Duan JZ, Xiong HY, Li ZC (2011). Rice Omics and biotechnology in China. *Plant Omic Journal*. 4(6): 302-317.

Liang JS, Zhang JH, Cao XH (2001). Grain sink strength may be related to the poor grain filling of indica/ japonica rice (*Oryza sativa*) hybrid, Physiol. Plantarum, 112: 470-477.

Liang J S, Cao X Z, Zhang H Y, Song P, Zhu Q S (1994). The changes and affecting factors of stem-sheath reserve contents of rice during grain filling. *Chinese J Rice Science*, 8 (3): 151-156.

Martin, S. G., R. C. Van Acker, and L. F. Friesen. (2001). Critical period of weed control in spring canola. Weed Sci. 49:326–333

McDonald, G.K and Gill, G.S (2009). Improving Crop Competitiveness with Weeds: Adaptations and Trade-offs. Elsevier Inc.

Mercado, B.L. (1979). *Introduction of Weed Science*. Southeast Asia regional Center for Graduate Study and Research in Agriculture (SEARCA), College Laguna, Philippines. 292 p.

Ministry of Agriculture and Agro-based Malaysia (MOA) (2007). Seksyen Industri Padi dan Beras (IPB). *Projek Pembangunan Pertanian Bersepadu* (IADP). Jelapang Padi. http://agrolink.moa.my/moalindex.php?option=com_content&task=view&id=2768Itemid=170.

Ministry of Agriculture and Agro-based Malaysia (MOA) (2003). Paddy Statistics of Malaysia 2001. Department of Agriculture, Peninsular Malaysia. P. 104.

Mohamad Najib M.Y., A, (2009). Critical Period for Weed Control in Saturated and Flooded Field, and Chemical Weed Control in Direct Seeded Rice under Saturated Condition. Master thesis. Universiti Putra Malaysia

Motzo, R., Giunta, F., Deidda, M., (1996). Relationships between grain-filling parameters, fertility, earliness and grain protein of durum wheat in a Mediterranean environment. *Field Crops Research*. 47, 129–142.

Mukhopadhyay, S.S. (1995). Current status and future lines of weeds management in rice crop with particular reference to India. In: *Proceedings of 15th Asia Pacific Weed Science Conference. Tsukuba. Japan*. 14-18 July 1995. Pp. 28-41.

Murata, Y (1969). Physiological responses to nitrogen in plants. Pages 235 – 259 in J. D. Eastin, ed. Physiological aspects of crop yield. American Society of Agronomy, Madison, Wisconsin.

Naderi,A.,A. Hashemidezfuli,A.Majidiharvan, A.Rezaei and G.Nourmohammadi (2000). Study on correlation of traits and components affecting grain weight and determination of effects of some physiological parameters on grain yield in spring wheat genotypes under optimum and drought stress conditions. *J. Sapling Seed*., 16: 374-386.

Norsworthy, J.K. and Oliveira, M.J. (2004). Comparison of the critical period for weed control in wide- and narrow-row corn. Weed Science, 52, 802 – 807.

Ober E S, Setter T L, Madison J T, Thompson J F and Shapiro P S (1991). Influence of water deficit on maize endosperm development. Enzyme activities and RNA transcripts of starch and zein synthesis, abscisic acid, and cell division. Plant Physiology, 97: 154 – 164.

Oerke, E. C., and Dehne, H. W. (2004). Safeguarding production losses in major crops and the role of crop protection. *Crop Protectection*. 23, 275–285.

Pinstrup-Anderson, P., Pandey, L. R., and Rosegrant, M. W. (1997). The world food situation: Recent developments, emerging issues, and long-term prospects. p. 36. International Food Policy Research Institute, Washington, D.C.

Porter, J.R. and Gawith, M. (1999). Temperature and the growth and development of wheat: A review. *European Journal of Agronomy* 10, 23 – 36.

Przulj N and Mladenov N (1999) Inheritance of grain filling duration in spring wheat. Plant Breed 118:517-521.

Qiu HM, Wu JC, Yang GQ, Dong B, Li DH (2004). Changes in the uptake function of the rice root to nitrogen, phosphorus and potassium under brown planthopper, Nilaparvata lugens (Stal) (Homoptera: Delphacidae) and pesticide stresses, and effect of pesticides on rice-grain filling in field. *Crop Protection*. 23: 1041-1048.

Rahman M S and Yoshida S (1985). Effect of water stress on grain filling in rice. Soil Science and Plant Nutrition, 31: 497 - 511

Rao, A.N., Johnson, D.E., Sivaprasad, B., Ladha, J.K., Mortimer, A.M.,(2007). Weed management in direct-seeded rice. *Advanced Agronomy* 93, 153–255.

Riaz, M., M.A. Malik, T.Z. Mahmood and M. Jamil (2006). Effect of various weed control methods on yield and yield components of wheat under different cropping patterns. Int. J. Agric. Biol., 8 (5): 636-640.

Rodenburg J, Johnson DE (2009) Weed Management in Rice-Based Cropping Systems in Africa. *Advanced Agronomy* 103:149-218.

Saini HS and Westgate ME. (2000). Reproductive development in grain crops during drought. *Advances in Agronomy* 68: 59–95.

Sattin, M., A. Berti and G. Zanin (1998). Influence of weed time of emergence and removal on crop. In Report of FAO expert consultation on weed ecology and management (pp. 53-64), Rome, Italy, September 22-24,1997. Rome: Plant Production and Protection Division, FAO.

Sedghi M, Seyed Sharifi R, Namvar A, Khandan-e-Bejandi T and Molaei P. (2008). Responses of sunflower yield and grain filling period to plant density and weed interference. Journal of Biological Sciences 3(9): 1048-1053.

Sharma, S.D., (2010). Domestication and Diaspora of Rice. *Rice Origin, Antiquity and History*. p- 1.

Smith Jr. RJ (1981) Weeds of major economic importance in rice and yield losses due to weed competition. In Proceedings of the Conference on Weed Control in Rice: 31 August-4 September 1981. International Rice Research Institute, Los Baños, Laguna, Philippines. pp: 19-36.

Swanton, C. J. and S. F. Weise. (1991). Integrated weed management: the rationale and approach. Weed Technol. 5:648–656.

Tagour, R.M.H. G.M. Abd EI-Hamed and I. M. EI-Metwally (2010). The critical period of weed competition of direct seeded rice in salinity land. Arab University. *Journal of Agricultural Science*. Cairo, 18 (1), 89-96.

Talbert, L.E., Lanning, S.P., Murphy, R.L., Martin, J.M., (2001). Grain filling duration in twelve hard red spring wheat crosses: genetic variation and association with other agronomic traits. *Crop Science*. 41, 1390–1395.

Tamado T, Milberg P (2000) Weed flora in arable fields of eastern Ethiopia with emphasis on the occurrence of (parthenium hysteroph orus). Weed Res 40: 507-512.

Tang T, Xie H, Wang YX, Lu B, Liang JS (2009). The effect of sucrose and abscisic acid interaction on sucrose synthase and its relationship to grain filling of rice (*Oryza sativa* L.) *J Exp. Bot. 60* 2641-2652.

Teerawatsakul, M. (1981). Weeds in paddy field and their control in Thailand. Weeds and Weeds Control in Asia. FFTC Book Series no. 20: 51 – 56.

Uddin, M.K. and Juraimi, A.S (2013). Salinity tolerance turfgrass: History and Prospects. Review Article. Hindawi Publishing Cooperation. *The Scientific World Journal*. Vol. 2013, Article ID 409413, 6 pages. http://dx.doi.org/10.1155/2013/409413

Van Acker, C. R., C. J. Swanton, and S. F. Weise. (1993). The critical period of weed control in soybean [Glycine max (L.) Merr.]. Weed Sci. 41: 194–200.

Venkateswarlu B and Visperas RM. (1987). Source-sink relationships in crop plants. *International Rice Research Institute Paper Series* 125: 1–19.

Wang, G., Kang, M.S., Moreno, O., (1999). Genetic analyses of grain-filling rate and duration in maize. *Field Crops Research*. 61, 211–222.

Weaver, S.E., and Tan, C.S. (1983). Critical period of weed interference in transplanted tomatoes and its relation to water stress and shading. *Canadian Journal of Plant Science*. 67, 575-83.

Widawsky, D. A., and O'Toole, J. C. (1996). Prioritizing the rice research agenda for Eastern India. In ''Rice Research in Asia: Progress and Priorities'' (R. E. Evenson, R. W. Herdt, and M. Hossain, Eds.), pp. 109–129. International Rice Research Institute, Philippines, and CAB International, Wallingford, UK.

Wiegand, C.L., Cuellar, J.A., (1981). Duration of grain filling and kernel weight of wheat as affected by temperature. *Crop Science*. 21, 95–101.

Williams II, M.M., (2006). "Planting date influences critical period of weed control in sweet corn". *Weed Science*, vol.54, no.5, pp. 928–933. View at Publisher · View at Google Scholar ·View at Scopus

Wolfe, D. W., Henderson, D. W., Hsiao, T. C., and Alvino, A. (1988). Interactive water and nitrogen effects on senescence of maize. II. Photosynthetic decline and longevity of individual leaves. *Agron. J*. 80, 865–870.

Woolley, B.L., Michaels, T.E., Hall, M.R. and Swanton, C.J. (1993). The critical period of weed control in white bean (*Phaseolus vulgaris*). *Weed Sci*. 41: 180 – 184.

Wu C, Shao GJ, Lu WY, Ma LJ, Cui XF, Cao P., Hou XY (2007). Genetic Analysis of Grain Filling Rate in Different Growth Stages of Superior and Inferior Grains in Rice. *Sci Agr Sin*. 40: 1135-1141.

Yang J C, Zhu Q S, Wang Z Q, Liang YZ (1997). Photosynthetic characteristics, dry matter accumulation and its translocation in intersubspecific hybrid rice. *Acta Agron Sin*, 23 (1): 82-88.

Yang J, Zhang J. (2006). Grain filling of cereals under soil drying. *New Phytologist* 169, 223-236.

Yang J, Zhang J. (2010). Grain-filling problem in 'Super' rice. *Journal of Experimental Botany*, Vol. 61, No. 1, pp. 1 - 5.

Yang W, Peng S, Dionisio-Sese ML, Laza RC, Visperas RM.(2008). Grain filling duration, a crucial determinant of genotypic variation of grain yield in field-grown tropical irrigated rice. Field Crops Res. 105: 221–227.

Yoshida, S. (1981). Fundamentals of Rice Crop Science, International Rice Research Institute, Los Banos, Philippines: pp. 59 – 60.

Yoshida, S. (1972). Physiological Aspects of Grain Yield. Ann. Rev. *Plant Physiological*. 23: 437 – 64.

Yoshida, S., Cock, J.H., Parao, F.T. (1972). Physiological Aspects of High Yields. Presented at *Symp. Rice Breed., International Rice Research Institute.*

Zahedi M and Jenner CF. (2003). Analysis of effects in wheat of high temperature on grain filling attributes estimated from mathematical models of grain filling. *Journal of Agricultural Science* 141: 203 –212.

Zhang, Z. P. (2001). Weed management in rice in China. Summary presented at FAO Workshop on *Echinochloa* spp. Control, Beijing, China, 27 May.

Zhang ZX, Li Z, Che J, Li QS, Chen LH, Chen HF, Huang JW, Lin WX (2011). Effects of Nitrogen Management on Protein Expression of Flag Leaves during Grain Filling Period in Large Panicle Rice (*Oryza sativa* L.). *Acta Agron Sin*. 37(5):542-854.

Zhang H, Tan GL, Yang LN, Yang JC, Zhang JH, Zhao BH (2009). Hormones in the grains and roots in relation to post-anthesis development of inferior and

superior spikelets in japonica/ indica hybrid rice. *Plant Physiology Biotechnology*. 47: 195-204.

Zhang Z, Chen J, Li Z, Chen H, Fang C, Huang J, and Lin W, (2012). Differential proteomic expressions between superior and inferior spikelets of rice in response to varied nitrogen treatments. *Australian Journal of Crop Science,* 6 (2): 316-325.

Zhao DL, Atlin GN, Bastiaans L, Spiertz JHJ (2006). Developing selection protocols for weed competitiveness in aerobic rice. Field Crops Res. 97: 272-285.

Zhao Bu-hong, Wang Peng, Zhang Hong-xi, Zhu Aing-sen, Yang Jian-chang (2006). Source-sink and grain filling characteristics of two-line hybrid rice Yangliangyou 6. *Rice science*, 13 (1): 34-42.

Zimdahl, R. L. (1980). Weed-Crop Competition – A Review. Corvallis, OR; International Plant Protection Center, Oregon State University: 195 p.

Zimdahl, R. L. (1993). The Significance of Plant Competition. Fundamentals of Weed Science. p – 153.